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Toxicological Profiling of Dusts from Selected Public Schools in Rivers State, Nigeria

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Abstract

The potential toxicity effects and health risk of exposure to heavy metals in dust samples from selected primary schools' windows in Rivers State was studied. Twenty-seven samples from nine Public Primary Schools were collected from selected Local Government Areas based on factors such as proximity to urban industrialization, and high traffic ways. Dusts from window corners were analysed for Pb, Cd, Cr and As using Atomic Absorption Spectrophotometer (AAS, GF, Flame HVG, model: S4=71096). Results showed mean maximum levels for Pb (21.26±0.12 $mgkg^{-1}$) and Cd (2.36±0.00 $mgkg^{-1}$) in Schools B_2 and A_1 while mean maximum levels for Cr (42.46±0.12 $mgkg^{-1}$) and As (0.94±0.1 $mgkg^{-1}$) was seen in school C_2. Heavy metal pollution profiling revealed high Cd load in all samples except in B_3. Multiple Pollution Index (MPI) decreased in the order $A_1 > A_2 > B_2 > B_1 > A_3 > C_2 > C_3 > C_1 > B_3$. Chronic daily intake dose ($CDI_{ingestion,\ dermal}$ and $_{inhalation}$) were below the recommended reference doses with ingestion contributing more to exposure than dermal or inhalation. Target Hazard Quotients (THQ) and Hazard Index (HI) were below 1. Furthermore, Life cancer Risks (TLCR) indicated that children population in the study areas may be more vulnerable to carcinogenic risk and may pose a public health concern.

Key words: Heavy Metals, Dusts, Public Primary School, Health Risk Assessment, Carcinogenic Risks.
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1. Introduction

Anthropogenic activities around the Niger Delta region of Nigeria has largely contributed to environmental pollution. These intensive oil and gas exploration and exploitation activities are majorly responsible for the release of contaminants such as heavy metals, organic and inorganic substances into the environment. Consequently, dusts from urban and industrial wastes in this region are usually made up of a complex mixture of particles. Heavy metals in dust may arise from various sources such as vehicular emission, industrial wastes, road surface wear, atmospheric deposition and particulate emission (López et al., 2005; Al-Khashman & Shawabkeh, 2006; Popoola et al., 2012; and Olua, Patrick-Iwuanyanwu, & Nwaichi, 2018). Human beings are generally exposed to lots of these contaminants, environmental hazards and potential toxicant. Studies have shown that these contaminated dusts are found around our homes, offices, classrooms (Popoola et al., 2012 and Olua et. al., 2018), etc.

The Niger Delta region of Nigeria and in particular Rivers State has witnessed a long term exposure to illegal crude refining, open air burning (Babayemi et al. 2009; Ighariemu et al. 2023), high traffic congestion, gas flare etc all of which contribute to air pollution. This no doubt settles together with suspended dust particles both indoors and outdoors and are thereby been exposed to humans.

These enter into the human system either by oral ingestion, dermal contact, and inhalation or through these three (3) exposure means (Tong, and Lam, 1998; Latif et al. 2014; Olujimi et. al. 2015 & Olua et. al., 2018). Several studies have revealed presence of contaminants such as heavy metals in dusts seen in offices and class rooms (Popoola et al., 2012; Addo, 2012, and Olua et. al., 2018). Heavy metals can cause adverse health effects on humans (Sanborn et al. 2002; Faiz et al. 2009; Sarda et al. 2013; Ighariemu et al. 2023; Olua et al. 2021; Nyimone et al. 2024; Olua et al. 2024). Lead (Pb) on entering the body system could limit water imbalance, enzyme activities and change in hormonal status. It could also alter the permeability of membranes; high concentrations could restrain cell activities leading to cell death (Seregin, and Ivaniov, 2001; Nyimone et al. 2024). Cadmium causes bone disorders on chronic exposure (Asia et al. 2008). It could have toxic effect even on low absorption via ingestion. No known beneficial effect of Cd is known yet (Gough, et al. 1979 and Aydinalp, and Marinova, 2009). Chromium produces pulmonary defects or symptoms on exposure to humans, on inhalation it could cause ulceration of the

nasal mucosa (Dayan, and Paine, 2001; Lindberg, E. and Vesterberg, 1983). Arsenic has the ability of disrupting ATP production, it as well inhibits lipoic acid in tricarboxylic acid cycle (Klaassen, C. and Watkins, 2003). As arsenate it can uncouple oxidative phosphorylation, thus stalling reduction of NAD^+. Some of these metabolic meddling could however lead to death (Sabina, 2005). This study however examined the presence of heavy metals in dusts obtained around classroom window corners in selected public schools in Rivers State.

Materials and Methods

Materials

Solar thermo elemental Atomic Absorption Spectrophotometer (Flame AAS) model: S4=71096, Analytical balance: Capable of weighing 0.1 mg. Stock metal solution, Aluminum nitrate solution, Hydrogen tetraoxosulphate (vi) acid (H_2SO_4), Trioxonitrate (v) acid (HNO_3), Perchloric acid ($HClO_4$).

Study Area

The study area covers selected public primary schools within Rivers State.

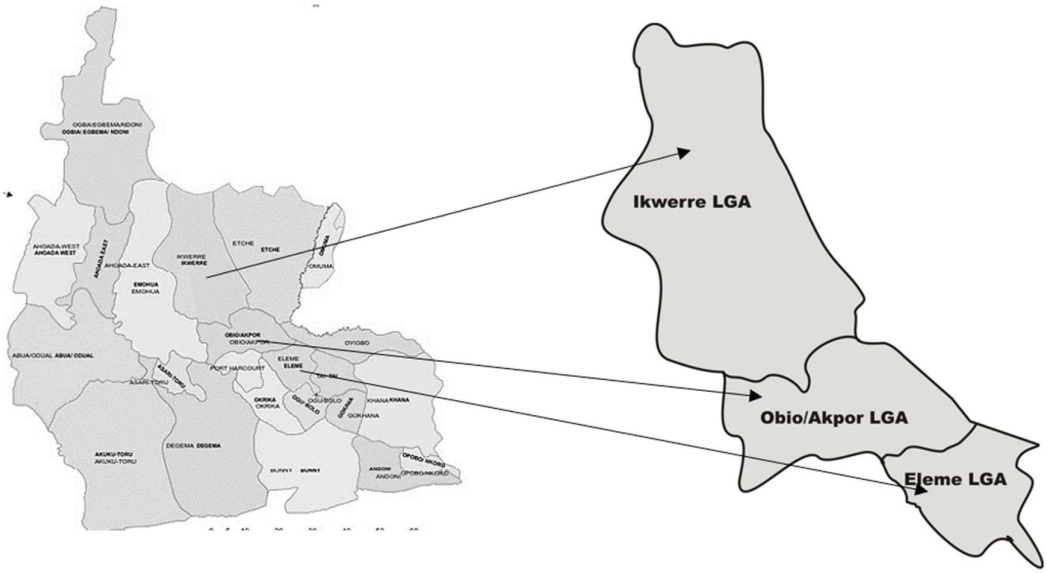

Fig. 1 Map of Rivers State showing sampled LGAs

Sample Collection Preparation and Analysis

Dust samples were collected from the sample sites using hard brush and foil:
At each sampling point, 50g of dust samples were collected from classroom window corners. The collected samples were put into sterile bottles and labelled appropriately before taking them to the laboratory for digestion (Acid digestion) and analysis.
Each sample was analysed for heavy metals (Pb, As, Cd, Cr and Ni) using Atomic Absorption Spectrophotometry using the method described by Olua *et al*. (2018)

Quality assurance and control (QA/QC)

Trace elements in indoor dust, from NIST, USA was used as the certified reference elements (CRM) NIST® 2584 and was evaluated using same experimental procedure in other to authenticate integrity/accuracy of procedure and results obtained. About 95% accuracy was recorded. Cross contamination and interferences were put on check using spiked Standard sample and procedural blank. All readings were taken in triplicate (n=3). Blank values for sampled metals were below the limit of detection (LOD- this measures concentration of analyte that gives 3 times the baseline's noise level i.e signal to noise ratio). Obtained LOD was 0.079mgkg^{-1} for Pb, Cr and As while that of Cd was 0.01mgkg^{-1}. Limit of quantification (LOQ), (given as the concentration which gives 10 times the baseline's noise level) was 0.25mgkg^{-1} for Pb, Cr and As while that of Cd was 0.03mgkg^{-1}.

Contamination/pollution index (C/PI): The C/PI was calculated using (Lacatusu, 1998)

$$C/PI = \frac{\text{Concentration of metal in dust}}{\text{Reference value}} \quad (1)$$

The reference value was taken from the crusta abundance value of respective sampled metals (Turekian & Wedepohl, 1961). A C/PI value >1 shows pollution range while values <1 shows contamination range. Multiple pollution index (MPI) was calculated from the sum of respective metal from sampled dust's C/PI values greater than 1.

Index of geo-accumulation (I_{geo}): The I_{geo} values as proposed by Muller (1969) was used to evaluate degree of metal contamination in the sampled dusts.
This was calculated using;

$$I_{geo} = \log_2 \frac{C_n}{1.5B_n} \quad (2)$$

where C_n denotes concentration of individual heavy metal in collected dust sample while B_n is background level of same metal as obtained from their crustal abundance value respectively (Turekian & Wedepohl, 1961). The factor 1.5 normalizes the likely lithological differences which exists between test and background samples (Rogan, et al. 2010).

Table 1. Significance of indices for contamination/pollution, and Index of geo-accumulation.

C/PI	Significance	I_{geo}	Class	Significance
<0.1	Very slight contamination	<0	Class 1	Practically unpolluted
0.10–0.25	Slight contamination	0-1	Class 2	Unpolluted to moderately Polluted
0.26–0.5	Moderate contamination	1-2	Class 3	Moderately polluted
0.51–0.75	Severe contamination	2-3	Class 4	Moderately to strongly polluted
0.76–1.0	Very severe contamination	3-4	Class 5	Strongly polluted
1.1–2.0	Slight pollution	4-5	Class 6	Strongly polluted to very polluted
2.1–4.0	Moderate pollution	>5	Class 7	Extremely polluted
4.1–8.0	Severe pollution			
8.1–16.0	Very severe pollution			
>16.0	Excessive pollution			

(Lacatusu, 1998)

Health Risk Assessment

Health risk assessment is a risk characterization of the potential adverse health effects that could occur on human exposure to contaminants (Luo et al. 2012). The International Agency for Research on Cancer has classified As, Cd, Cr and Pb as potential non-carcinogenic and carcinogenic elements. According to the Exposure Factors Handbook (USEPA. 2002), the Chronic daily intake, CDI $mgkg^{-1}day^{-1}$ of heavy metals via ingestion, dermal contact and inhalation was estimated using the following equations, respectively:

$$CDI_{ingest} = C \times IngR \times EF \times ED \times CF / BW \times AT \quad (3)$$

$$CDI_{dermal} = C \times SA \times AF \times FE \text{ x } ABS \times EF \times ED \times CF / BW \times AT, \quad (4)$$

$$CDI_{inhale} = C \times InhR \times EF \times ED / PEF \times BW \times AT, \quad (5)$$

where C is the concentration of heavy metals (mg/kg); IngR = the ingestion rate ($mgday^{-1}$); SA = the surface area of the skin exposed to heavy metal (cm^2); AF = the skin adherence factor (mg/cm^2day^{-1}); ABS = the dermal absorption factor (mg/cm^2); InhR = the inhalation rate (m^3day^{-1}); PEF, the particle emission factor (m^3/kg); EF, the exposure frequency (days/year); ED=the exposure duration (year); BW= the body weight (kg); AT= the averaging time (days); FE=Dermal exposure ratio and CF= the conversion factor.

The parameters of the CDI, reference dose (RfD) and cancer slope factor (CSF), which were obtained from the Exposure Factors Handbook(USEPA. 2002; USDOE. 2011), Integrated Risk Information System (USEPA. 2007, 2011) are shown in Tables 2a and b. Furthermore, these risks can be grouped into non-carcinogenic and carcinogenic risks. Both risks exposure for children and adult population were estimated using Hazard Quotient (HQ) and Life Cancer Risk (LCR), respectively.

For non-carcinogenic risk, the HQ for children and adult population during a lifetime was estimated by dividing the CDI from each exposure pathway by a specific RfD as shown, whereas CDI is the chronic daily intake and RfD is the estimated maximum permissible risk posed to humans through daily exposure. Afterward, the estimated

HQ from the three (3) exposure pathways (dermal contact, ingestion and inhalation) was summed to obtain the Hazard Index (HI). If it is less than 1 (HI ≤1), then adverse health effects would be unlikely to occur. Nevertheless, potential non-carcinogenic effects would occur when HI >1 as this indicates significant non-carcinogenic risk posed to human health.

The formula used for calculation of HQ

$$HQ = ADD/RfD, \quad (6)$$

$$HI = HQ_{ingest} + HQ_{dermal} + HQ_{inhale}. \quad (7)$$

For carcinogenic risk, the LCR of children caused by potential carcinogen exposure over a lifetime can be calculated as shown below, for CDI and CSF is the slope factor for cancer. Total Life Cancer Risk (TLCR) adds up all LCRs calculated for ingestion, dermal contact and inhalation. The acceptable range of TLCR for carcinogenic risk is in the range of $1\times10^{-6} – 1\times10^{-4}$. If the risk exceeds the range, this implies that carcinogenic risks exist, and the potential carcinogenic effect would likely occur.

$$LCR=CDI\times CSF, \quad (8)$$

$$TLCR=LCR_{ingest}+LCRdermal+LCR_{inhale.} \quad (9)$$

Table 2a. Recommended Standard Values for Dusts Health Risk Assessment

Parameters	Pb	Cd	Cr	As
RFD_{ing}	0.0035	0.001	0.003	3.00E-04
RFD_{inh}	3.50E-02	0.001	0.0001	1.00E-03
RFD_{dermal}	5.25E-04	0.00001	0.00006	1.00E-05
CSF_{ing}	0.0085	6.3	0.5	1.5
CSF_{inh}	4.20E-02	6.3	4.10E-01	1.50E+01
CSF_{dermal}	-	-	2.0E+1	1.5

(USEPA. 1989, 2002, 2007, 2011; USDOE. 2011 and MEP. 2014)

Table 2b Recommended Standard Values for Dusts Health Risk Assessment Contd

Parameter	Symbol	Value	
		ADULT	CHILD
Ingestion rate	IngR	100 mg	200 mg
Exposure duration	ED	24 years	6 years
Exposure frequency	EF	350 days	350 days
Average body weight	BW	70	15 kg
Averaging time (AT)	ATnon-carcinogenic	ED × 365 days	ED × 365 days
	ATcarcinogenic	70 × 365 days	70 × 365 days
Conversion factor	CF	1×10^{-6} kg/mg	1×10^{-6} kg/mg
Surface area of skin	SA children	5800 cm^2	2800 cm^2
Skin adherence factor	AFdust	0.07 mg/cm^2/day	0.2 mg/cm2/day
Dermal absorption factor	ABS non-carcinogenic	0.001 mg/cm^2	0.001 mg/cm^2
	ABS carcinogenic	0.03 mg/cm^2	0.03 mg/cm^2
Inhalation rate	InhR	20	10 m^3/day
Particle emission factor	PEF	1.36×10^9 m^3/kg	1.36×10^9 m^3/kg
Dermal exposure ratio	FE	0.61	0.61

(USEPA. 1989, 2002, 2011; Rogan. et al. 2010 20USDOE. 2011)

Statistical Analysis

The significant difference of heavy metal mean values obtained were subjected to Analysis of variance (ANOVA) using SPSS version 20.

Results and Discussion

Profiling of Heavy metals contamination and pollution

Heavy Metal contamination and pollution profiling of sampled dusts from window corners of selected Public Primary Schools in Obio/Akpor, Eeleme and Ikwerre Local Government Areas (LGAs) of Rivers State was evaluated using individual metals C/PI, MPI and $I_{geo.}$ The respective values are shown in Tables 3 and 4. C/PI values were shown to vary from one metal to the other and one location to the other with highest level 17.295 seen in Cd in school $A_{1,}$ this shows that the window corner dust at A_1 is heavily polluted with Cd. Cadmium pollution (1.0125 – 17.2893) was notable in all sampled schools except at B_3 (0.586) which however shows severe contamination. Most analysed heavy metals were within the range of slight contamination to slight pollution; however, Arsenic shows no contamination in all sampled school in Ikwerre LGA, $B_{1\&3}$ in Eleme LGA and A_1 in Obio/Akpor LGA. The MPI showed that schools B_3 and C_1 were devoid of pollution (on multiple pollution index). However, other sampled schools showed multiple pollution index from slight pollution to heavily polluted in the order $A_1>A_2>B_2>B_1>C_2>C_3$.

The degree of metal contamination as measured with I_{geo} revealed A1 to be strongly polluted with Cd (3.53) while other schools showed degree of pollution from practically unpolluted to moderately polluted with various sampled heavy metals.

Table 3: Contamination/Pollution Index (C/PI) of Heavy Metals from sampled Public Primary Schools Window Corner Dusts

	C/PI				MPI
SAMPLE	Pb (mg/kg)	Cd(mg/kg	Cr(mg/kg)	As(mg/kg)	
A_1	0.664045	17.28938	0.197779	0.019022	17.28938
A_2	1.019663	10.18315	0.151442	0.19837	11.20281
A_3	0.953933	5.934066	0.148985	0.105978	5.934066
B_1	0.889888	6.007326	0.106776	0.07337	6.007326
B_2	1.194382	6.886447	0.204609	0.220109	8.080829
B_3	0.471348	0.586081	0.080094	0.005435	0
C_1	0.122941	0.9875	0.2851	0.001724	0
C_2	0.236471	1.425	0.4246	0.032414	1.425
C_3	0.186353	1.0125	0.2173	0.00931	1.0125

Table 4: I_{geo} of Heavy Metals from sampled Public Primary Schools Window Corner Dusts

I_{geo}				
SAMPLE	Pb (mg/kg)	Cd(mg/kg)	Cr(mg/kg)	As(mg/kg)
A_1	-1.17561	3.526852	-2.923	-6.30117
A_2	-0.55687	2.76315	-3.30812	-2.9187
A_3	-0.653	1.984058	-3.33172	-3.82312
B_1	-0.75327	2.00176	-3.8123	-4.35364
B_2	-0.3287	2.198797	-2.87402	-2.76867
B_3	-1.6701	-1.35579	-4.22712	-8.10852
C_1	-1.35334	1.947989	-3.42052	-6.7866
C_2	-0.40964	2.477098	-2.84589	-2.55394

Heavy Metal Contents

Table 5 shows heavy metal levels as seen from collected dust samples from classroom window corners of nine (9) public primary schools. The study showed in $mgKg^{-1}$ Pb mean level of 21.26±0.12 and Cd 2.36±0.00, from School B_2 and A_1 respectively, these schools are located within Eleme and Obio/Akpor LGAs respectively of Rivers State Nigeria. These LGAs are within the urban and industrialised region of Rivers State. This could however account for the high level of the heavy metals seen. Cr and As maximum mean levels were seen as 42.46±0.12 and 0.94±0.1,

as seen from School C_2 located at a major junction in Ikwerre Local government within Port Harcourt metropolis Rivers State. However, it is notable that the level of these metals on estimation of their chronic daily intake were below the respective reference doses for oral, inhalation and dermal contact in both adults and children populations (Tables 6 to 8). The non-carcinogenic risk assessment using hazard quotient and hazard index as the toxicological indices gave values below the bench mark of 1, which implies that these heavy metals at the level found in the sampled sites were potentially free of non-carcinogenic risks.

Popoola *et al*., 2012; Addo *et al*., 2012 and Olua et al., 2018, have previously reported the presence of Pb with values within the range as seen in this study. Pb is known for its ability to restrain water imbalance, alter enzyme activities and hormonal status with lots more potential adverse effects to human (Sanborn et al. 2002, Seregin & Ivanjoy, 2001; Asia et al. 2008; Uaboi – Egbenni et al. 2010 & Ademoroti, 1996).

It has been reported that Cd is toxic even at low absorption by ingestion and chronic exposure to high levels of cadmium in food could lead to osteoporosis, osteomalacia etc (Asia et al. 2008). However no known beneficial effect due to Cd exposure have been reported (Gough et al. 1979; Aydinalp, and Marinova, 2009).

Exposure to Cr(III) has been associated with respiratory diseases and substantiated with coughing, wheezing, tracheobronchitis, chronic rhinitis, asthma polyps of the upper respiratory tract, etc (Dayan, and Paine, 2001; Lindberg, E. and Vesterberg, 1983; Novey, HS., and Habib, 1983). Lewis, and several other authors (Lewis, 2004, Bruynzeel, and Hennipman, 1988; Polak, 1983) also reported that dermal exposure to chromium elicits irritation and allergic responses, localized erythematous or vesicular lesions at points of contact or generalized eczematous dermatitis.

Several adverse health effects could be associated with long-term ingestion of inorganic arsenic some of which are developmental effects, neurotoxicity, diabetes, pulmonary disease and cardiovascular disease(WHO. 2016). Excessive mortality has been shown in previous studies (Rose et al. 2007).

Table 5: Heavy Metal Content of Window Corner Dusts in Public Primary Schools

SAMPLE SITE	Pb (mg/kg)	Cd(mg/kg)	Cr(mg/kg)	As(mg/kg)
A_1	11.82±0.01 ^{a}	2.36±0.00 ^{a}	40.25±0.12^a	0.07±0.01 ^{a}
A_2	18.15±0.03 ^{a}	1.39±0.17 ^{a}	30.82±0.01^a	0.73±0.00 ^{b}
A_3	16.98±0.00 ^{a}	0.81±0.01 ^{a}	30.32±0.01^a	0.39±0.12 ^{a}
B_1	15.84±0.02 ^{a}	0.82±0.06 ^{a}	21.73±0.03^a	0.27±0.12^a
B_2	21.26±0.12 ^{a}	0.94±0.02 ^{a}	41.64±0.01^a	0.81±0.01 ^{c}
B_3	8.39±0.17 ^{a}	0.08±0.03 ^{a}	16.30±0.17^a	0.02±0.01 ^{a}
C_1	10.45±0.01 ^{a}	0.79±0.06 ^{a}	28.51±0.01^a	0.05±0.03 ^{a}
C_2	20.10±0.03 ^{a}	1.14±0.07 ^{a}	42.46±0.12^a	0.94±0.1 ^{a}
C_3	15.84±0.02 ^{a}	0.81±0.01 ^{a}	21.73±0.11^a	0.27±0.06 ^{a}
Ketu Ghana	22.89	-	744.02	-
Lagos Nigeria	23.33	0.09	8.35	-

Values are Mean±SEM Means in the same column with same superscript alphabet are significantly different at $p \leq 0.05$. $A_{1,2,3}$ = Sampled public primary schools in Obio/Akpor, $B_{1,2,3}$ =sampled public primary schools in Eleme, $C_{1,2,3}$= sampled public primary schools in Ikwerre. (Addo et al. 2012; (López et al. 2005).

Table 6 Chronic Daily Intake Dose (CDI_{ingest})

SAMPLE	Pb ($mgkg^{-1}day^{-1}$)		Cd($mgkg^{-1}day^{-1}$)		Cr($mgkg^{-1}day^{-1}$)		As($mgkg^{-1}day^{-1}$)	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child
A_1	1.69E-05	1.58E-04	3.37E-06	3.15E-05	3.45E-06	5.37E-04	1.00E-07	9.33E-07
A_2	2.59E-05	2.42E-04	1.99E-06	1.85E-05	2.64E-06	4.11E-04	1.04E-06	9.73E-06
A_3	2.43E-05	2.26E-04	1.16E-06	1.08E-05	2.60E-06	4.04E-04	5.57E-07	5.20E-06
B_1	2.26E-05	2.11E-04	1.16E-06	1.08E-05	1.86E-06	2.90E-04	3.86E-07	3.60E-06
B_2	3.04E-05	2.83E-04	1.34E-06	1.25E-05	3.57E-06	5.55E-04	1.16E-06	1.08E-05
B_3	1.20E-05	1.12E-04	1.14E-07	1.07E-06	1.40E-06	2.17E-04	2.86E-08	2.67E-07
C_1	1.49E-05	1.39E-04	1.13E-06	1.05E-05	2.44E-06	3.80E-04	7.14E-08	6.67E-07
C_2	2.87E-05	2.68E-04	1.63E-06	1.52E-05	3.64E-06	5.66E-04	1.34E-06	1.25E-05
C_3	1.90E-05	1.77E-04	1.87E-06	1.75E-05	2.24E-06	3.48E-04	1.86E-07	1.73E-06

E=exponential, $A_{1,2,3}$ = Sampled public primary schools in Obio/Akpor, $B_{1,2,3}$ =sampled public primary schools in Eleme, $C_{1,2,3}$= sampled public primary schools in Ikwerre.

Table 7 Chronic Daily Intake Dose ($CDI_{inhalation}$)

SAMPLE	Pb ($mgkg^{-1}day^{-1}$)		Cd($mgkg^{-1}day^{-1}$)		Cr($mgkg^{-1}day^{-1}$)		As($mgkg^{-1}day^{-1}$)	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child
A_1	2.48E-09	5.79E-09	4.96E-10	1.16E-09	2.54E-09	1.97E-08	1.47E-11	3.43E-11
A_2	3.81E-09	8.90E-09	2.92E-10	6.81E-10	1.94E-09	1.51E-08	1.53E-10	3.58E-10
A_3	3.57E-09	8.32E-09	1.70E-10	3.97E-10	1.91E-09	1.49E-08	8.19E-11	1.91E-10
B_1	3.33E-09	7.76E-09	1.70E-10	3.97E-10	1.37E-09	1.07E-08	5.67E-11	1.32E-10
B_2	4.47E-09	1.04E-08	1.97E-10	4.61E-10	2.62E-09	2.04E-08	1.70E-10	3.97E-10
B_3	1.76E-09	4.11E-09	1.68E-11	3.92E-11	1.03E-09	7.99E-09	4.20E-12	9.80E-12
C_1	2.20E-09	5.12E-09	1.66E-10	3.87E-10	1.80E-09	1.40E-08	1.05E-11	2.45E-11
C_2	4.22E-09	9.85E-09	2.39E-10	5.59E-10	2.68E-09	2.08E-08	1.97E-10	4.61E-10
C_3	2.79E-09	6.50E-09	2.75E-10	6.42E-10	1.65E-09	1.28E-08	2.73E-11	6.37E-11

E = exponential

Table 8 Chronic Daily Intake Dose (CDI_{dermal})

SAMPLE	Pb ($mgkg^{-1}day^{-1}$)		Cd($mgkg^{-1}day^{-1}$)		Cr($mgkg^{-1}day^{-1}$)		As($mgkg^{-1}day^{-1}$)	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child
A_1	4.18E-08	2.69E-07	8.35E-09	5.37E-08	1.42E-07	9.17E-07	2.48E-10	1.59E-09
A_2	6.42E-08	4.13E-07	4.92E-09	3.17E-08	1.09E-07	7.02E-07	2.58E-09	1.66E-08
A_3	6.01E-08	3.87E-07	2.87E-09	1.84E-08	1.07E-07	6.90E-07	1.38E-09	8.88E-09
B_1	5.60E-08	3.61E-07	2.87E-09	1.84E-08	7.69E-08	4.95E-07	9.55E-10	6.15E-09
B_2	7.52E-08	4.84E-07	3.33E-09	2.14E-08	1.47E-07	9.48E-07	2.87E-09	1.84E-08
B_3	2.97E-08	1.91E-07	2.83E-10	1.82E-09	5.77E-08	3.71E-07	7.08E-11	4.55E-10
C_1	3.70E-08	2.38E-07	2.80E-09	1.80E-08	1.01E-07	6.49E-07	1.77E-10	1.14E-09
C_2	7.11E-08	4.58E-07	4.03E-09	2.60E-08	1.50E-07	9.67E-07	3.33E-09	2.14E-08
C_3	4.69E-08	3.02E-07	4.63E-09	2.98E-08	9.24E-08	5.95E-07	4.60E-10	2.96E-09

E = exponential

Table 9 Hazard Quotient (HQ_{ingest})

SAMPLE	Pb		Cd		Cr		As	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child
A_1	0.005	0.045	0.003	3.15E-02	1.15E-03	1.79E-01	3.33E-04	3.11E-03
A_2	0.007	0.069	0.002	1.85E-02	8.81E-04	1.37E-01	3.48E-03	3.24E-02
A_3	0.007	0.065	0.001	1.08E-02	8.66E-04	1.35E-01	1.86E-03	1.73E-02
B_1	0.006	0.060	0.001	1.08E-02	6.21E-04	9.66E-02	1.29E-03	1.20E-02
B_2	0.009	0.081	0.001	1.25E-02	1.19E-03	1.85E-01	3.86E-03	3.60E-02
B_3	0.003	0.031	0.0001	1.07E-03	4.66E-04	7.24E-02	9.52E-05	8.89E-04
C_1	0.004	0.040	0.0011	1.05E-02	8.15E-04	1.27E-01	2.38E-04	2.22E-03
C_2	0.008	0.077	0.0016	1.52E-02	1.21E-03	1.89E-01	4.48E-03	4.18E-02
C_3	0.005	0.051	0.0019	1.75E-02	7.46E-04	1.16E-01	6.19E-04	5.78E-03

Table 10 Hazard Quotient ($HQ_{inhalation}$)

SAMPLE	Pb		Cd		Cr		As	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child
A_1	7.09E-07	1.66E-06	4.96E-07	1.16E-06	2.54E-05	1.97E-04	4.90E-08	1.14E-07
A_2	1.09E-06	2.54E-06	2.92E-07	6.81E-07	1.94E-05	1.51E-04	5.11E-07	1.19E-06
A_3	1.02E-06	2.38E-06	1.7E-07	3.97E-07	1.91E-05	1.49E-04	2.73E-07	6.37E-07
B_1	9.51E-07	2.22E-06	1.7E-07	3.97E-07	1.37E-05	1.07E-04	1.89E-07	4.41E-07
B_2	1.28E-06	2.98E-06	1.97E-07	4.61E-07	2.62E-05	2.04E-04	5.67E-07	1.32E-06
B_3	5.04E-07	1.18E-06	1.68E-08	3.92E-08	1.03E-05	7.99E-05	1.40E-08	3.27E-08
C_1	6.27E-07	1.46E-06	1.66E-07	3.87E-07	1.80E-05	1.40E-04	3.50E-08	8.17E-08
C_2	1.21E-06	2.82E-06	2.39E-07	5.59E-07	2.68E-05	2.08E-04	6.58E-07	1.54E-06
C_3	7.97E-07	1.86E-06	2.75E-07	6.42E-07	1.65E-05	1.28E-04	9.10E-08	2.12E-07

Table 11 Hazard Quotient (HQ_{dermal})

SAMPLE	Pb		Cd		Cr		As	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child
A_1	7.97E-05	5.13E-04	8.35 E-04	5.37E-03	2.37E-03	1.53E-02	2.48E-05	1.59E-04
A_2	1.22E-04	7.87E-04	4.92 E-04	3.17E-03	1.82E-03	1.17E-02	2.58E-04	1.66E-03
A_3	1.14E-04	7.37E-04	2.87 E-04	1.84E-03	1.79E-03	1.15E-02	1.38E-04	8.88E-04
B_1	1.07E-04	6.87E-04	2.87 E-04	1.84E-03	1.28E-03	8.25E-03	9.55E-05	6.15E-04
B_2	1.43E-04	9.22E-04	3.33 E-04	2.14E-03	2.46E-03	1.58E-02	2.87E-04	1.84E-03
B_3	5.65E-05	3.64E-04	2.83E-05	1.82E-04	9.61E-04	6.19E-03	7.08E-06	4.55E-05
C_1	7.04E-05	4.53E-04	2.8 E-04	1.80E-03	1.68E-03	1.08E-02	1.77E-05	1.14E-04
C_2	1.35E-04	8.72E-04	4.03 E-04	2.60E-03	2.50E-03	1.61E-02	3.33E-04	2.14E-03
C_3	8.94E-05	5.76E-04	4.63 E-04	2.98E-03	1.54E-03	9.91E-03	4.60E-05	2.96E-04

Table 12 Hazard Index (HI)

SAMPLE	Pb		Cd		Cr		As		ΣHI	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
A_1	4.90E-03	4.55E-02	4.21E-03	3.69E-02	3.55E-03	1.94E-01	3.58E-04	3.27E-03	1.30E-02	2.80E-01
A_2	7.53E-03	6.99E-02	2.48E-03	2.17E-02	2.72E-03	1.49E-01	3.74E-03	3.41E-02	1.65E-02	2.75E-01
A_3	7.05E-03	6.54E-02	1.44E-03	1.26E-02	2.68E-03	1.47E-01	2.00E-03	1.82E-02	1.32E-02	2.43E-01
B_1	6.57E-03	6.10E-02	1.44E-03	1.26E-02	1.91E-03	1.05E-01	1.39E-03	1.26E-02	1.13E-02	1.91E-01
B_2	8.82E-03	8.19E-02	1.68E-03	1.46E-02	3.68E-03	2.01E-01	4.15E-03	3.78E-02	1.83E-02	3.35E-01
B_3	3.48E-03	3.23E-02	1.42E-04	1.25E-03	1.44E-03	7.87E-02	1.02E-04	9.35E-04	5.16E-03	1.13E-01
C_1	4.34E-03	4.03E-02	1.41E-03	1.23E-02	2.51E-03	1.38E-01	2.56E-04	2.33E-03	8.51E-03	1.93E-01
C_2	8.34E-03	7.74E-02	2.03E-03	1.78E-02	3.74E-03	2.05E-01	4.81E-03	4.39E-02	1.89E-02	3.44E-01
C_3	5.51E-03	5.11E-02	2.33E-03	2.05E-02	2.30E-03	1.26E-01	6.65E-04	6.08E-03	1.08E-02	2.04E-01

CARCINOGENIC RISKS

The carcinogenic risk factor was estimated using Life cancer risk (LCR) and Total life cancer risk (TLCR). Results from this study revealed that the exposure population of pupil and adults are to a higher extent prone to cancer risks. The values (2.08E-06 to 2.45E-05) obtained for adult population are within the upper tolerable limit 10^{-6} to 10^{-4} within which it is seen as been potentially risk free. While the pupils showed value (8.49E-05 to 2.54E-04) which is higher than the upper tolerable unit except at school B_3 which showed values below 10^{-4}.

Studies by International Agency for Research on Cancer (IARC) have shown Pb, Cd, Cr, and As, as potential carcinogens(IARC. 1987), this is also in agreement with the recognition of these heavy metals as carcinogenic agents by World Health Organization (WHO) and Agency for Toxic Substances and Disease Registry (ATSDR)**,(**WHO. 2016, ATSDR. 2015). This study has revealed that exposure to these metals by inhalation could be associated with increased risk of cancer of the respiratory system (ATSDR. 2000), lung cancer risk, lung cancer death (Katz, and Salem, 1993).

Table 13 LIFE CANCER RISK (LCR_{ingest})

SAMPLE	Pb		Cd		Cr		As	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child
A_1	1.44E-07	3.35E-07	2.12E-05	4.96E-05	1.73E-06	6.71E-05	1.50E-07	3.50E-07
A_2	2.20E-07	5.14E-07	1.25E-05	2.92E-05	1.32E-06	5.14E-05	1.56E-06	3.65E-06
A_3	2.06E-07	4.81E-07	7.29E-06	1.70E-05	1.30E-06	5.05E-05	8.36E-07	1.95E-06
B_1	1.92E-07	4.49E-07	7.29E-06	1.70E-05	9.31E-07	3.62E-05	5.79E-07	1.35E-06
B_2	2.58E-07	6.02E-07	8.46E-06	1.97E-05	1.78E-06	6.94E-05	1.74E-06	4.05E-06
B_3	1.02E-07	2.38E-07	7.20E-07	1.68E-06	6.99E-07	2.72E-05	4.29E-08	1.00E-07
C_1	1.27E-07	2.96E-07	7.11E-06	1.66E-05	1.22E-06	4.75E-05	1.07E-07	2.50E-07
C_2	2.44E-07	5.70E-07	1.03E-05	2.39E-05	1.82E-06	7.08E-05	2.01E-06	4.70E-06
C_3	1.61E-07	3.76E-07	1.18E-05	2.75E-05	1.12E-06	4.35E-05	2.79E-07	6.50E-07

Table 14 Life Cancer Risk ($LCR_{inhalation}$)

SAMPLE	Pb		Cd		Cr		As	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child
A_1	1.04E-10	6.08E-11	3.12E-09	1.82E-09	1.04E-09	2.02E-09	2.21E-10	1.29E-10
A_2	1.60E-10	9.34E-11	1.84E-09	1.07E-09	7.96E-10	1.55E-09	2.30E-09	1.34E-09
A_3	1.50E-10	8.74E-11	1.07E-09	6.25E-10	7.83E-10	1.52E-09	1.23E-09	7.17E-10
B_1	1.40E-10	8.15E-11	1.07E-09	6.25E-10	5.62E-10	1.09E-09	8.51E-10	4.96E-10
B_2	1.88E-10	1.09E-10	1.24E-09	7.26E-10	1.08E-09	2.09E-09	2.55E-09	1.49E-09
B_3	7.40E-11	4.32E-11	1.06E-10	6.18E-11	4.21E-10	8.19E-10	6.30E-11	3.68E-11
C_1	9.22E-11	5.38E-11	1.05E-09	6.10E-10	7.37E-10	1.43E-09	1.58E-10	9.19E-11
C_2	1.77E-10	1.03E-10	1.51E-09	8.80E-10	1.10E-09	2.13E-09	2.96E-09	1.73E-09
C_3	1.17E-10	6.83E-11	1.73E-09	1.01E-09	6.75E-10	1.31E-09	4.10E-10	2.39E-10

Table 15 Life Cancer Risk (LCR_{dermal})

SAMPLE	Pb		Cd		Cr		As	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child
A_1	-	-	-	-	1.26E-06	1.37E-04	1.11E-08	1.79E-08
A_2	-	-	-	-	9.67E-07	1.05E-04	1.16E-07	1.87E-07
A_3	-	-	-	-	9.51E-07	1.04E-04	6.21E-08	9.99E-08
B_1	-	-	-	-	6.82E-07	7.42E-05	4.30E-08	6.92E-08
B_2	-	-	-	-	1.31E-06	1.42E-04	1.29E-07	2.08E-07
B_3	-	-	-	-	5.11E-07	5.57E-05	3.18E-09	5.12E-09
C_1	-	-	-	-	8.94E-07	9.74E-05	7.96E-09	1.28E-08
C_2	-	-	-	-	1.33E-06	1.45E-04	1.50E-07	2.41E-07
C_3	-	-	-	-	8.19E-07	8.92E-05	2.07E-08	3.33E-08

Table 16 Total Life Cancer Risk (TLCR)

SAMPLE	Pb		Cd		Cr		As		ΣTLCR	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
A_1	1.44E-07	3.35E-07	2.12E-05	4.96E-05	2.99E-06	2.04E-04	1.61E-07	3.68E-07	2.45E-05	2.54E-04
A_2	2.20E-07	5.14E-07	1.25E-05	2.92E-05	2.29E-06	1.56E-04	1.68E-06	3.84E-06	1.67E-05	1.90E-04
A_3	2.06E-07	4.81E-07	7.29E-06	1.70E-05	2.25E-06	1.55E-04	8.99E-07	2.05E-06	1.06E-05	1.74E-04
B_1	1.92E-07	4.49E-07	7.29E-06	1.70E-05	1.61E-06	1.10E-04	6.23E-07	1.42E-06	9.72E-06	1.29E-04
B_2	2.58E-07	6.02E-07	8.46E-06	1.97E-05	3.09E-06	2.11E-04	1.87E-06	4.26E-06	1.37E-05	2.36E-04
B_3	1.02E-07	2.38E-07	7.20E-07	1.68E-06	1.21E-06	8.29E-05	4.61E-08	1.05E-07	2.08E-06	8.49E-05
C_1	1.27E-07	2.96E-07	7.11E-06	1.66E-05	2.11E-06	1.45E-04	1.15E-07	2.63E-07	9.47E-06	1.62E-04
C_2	2.44E-07	5.70E-07	1.03E-05	2.39E-05	3.15E-06	2.16E-04	2.16E-06	4.94E-06	1.59E-05	2.45E-04

Conclusion

This study investigated the concentration of heavy metals in dust samples from classroom windows of selected public primary schools in Rivers State. Data from the study showed that the concentration of Pb detected in classroom dust was lower while the Cd load was higher than those previously reported in Ketu (Ghana) and Lagos (Nigeria). Health risk assessment revealed that children population may be more susceptible to both non-carcinogenic and carcinogenic risks. Generally, results from the study suggests that exposure to dusts contaminated by heavy metals may pose serious health concerns considering the hand to mouth attitude of children leading to high heavy metals exposure and ingestion rate.

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