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Full Length Research Article

ASSESSMENT OF HEALTH RISK EXPOSURE OF PUPILS TO CLASSROOM DUST IN SOME PRIMARY SCHOOLS IN CALABAR METROPOLIS, CROSS RIVER STATE, NIGERIA

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ABSTRACT
This study examined the health risk exposure of pupils to classroom dust in some primary schools in Calabar Metropolis, Cross River State, Nigeria. Dust samples were collected from chosen primary schools by the sweeping method. The samples were analyzed using Ultra -Violet Spectrophotometer Palintest model 7500. The data were analyzed using ingestion, inhalation and dermal contact models. The findings of the study revealed that classrooms in the study area are heavily polluted with Ni, Cu, Cr, Cd and Co with exception of a few schools and this may pose health risks to the pupils. The mean concentration of heavy metals was in this order: Co>Fe>Cu>Mn>Cr>Ni>Zn>Cd>Pb. The calculated values of the hazard quotient (HQ) and the hazard index (HI) were greater than 1. The total carcinogenic risk was in this order: Cr>Cd>Ni>Pb and were all greater than the acceptable range of $1 \times 10^{-6} - 1 \times 10^{-4}$ indicating a significant risk indicators of cancer. The implication of this is that there is the likelihood of cancer risk. It was therefore recommended that the State Universal Basic Education Board (SUBEB) should sponsor research to routinely monitor the classrooms to ensure that they are pollution – free of heavy metals such as Ni, Cu, Cd and Co. There should be an awareness campaign among teachers and pupils on good sanitation and hygiene in the classrooms and school environment. Also, environmentally – free remediation techniques should be used by experts to clean off heavy metals in classrooms.

Keywords: Health risk; classroom dust; pupils, primary schools; heavy metals; Calabar metropolis.

INTRODUCTION

Dust is one of the global environmental problems facing the world today especially in developing countries. Dust also known as particulate matter can be in the form of fine powder, lying on the ground or the surface objects or blown about by the wind (International Standardization Organization (ISO) 4225 - ISO, 1994). They are generated naturally in sandstorms, volcanoes, wind or anthropogenic activities such as bagging, sweeping, grinding etc.

Dust particles released into the air will slowly settle due to the earth's gravitational force. The sizes of dust particles vary; some may be less than $l\mu m$ and up to about $100\mu m$ in diameter (USEPA, 2020). Dust particles can be found indoors and outdoors. Different types of dust are generated from environmental processes due to their different sources. Therefore, the chemical constituents of dust particles vary and the chemical components of dust are metals. Human exposure to high levels of some metals leads to adverse health effects. If dust is laden with heavy metals, it provides a critical link in the exposure pathway for young children; contaminated classroom dust can pose a potential risk to the health of young school children (Ugwu & Ofomatah, 2021).

In many tropical and developing countries like Nigeria, dust particles are usually seen on most surfaces due to several uncontrolled human activities and natural factors. It is worrisome to notice the amount of settled indoor dust in some public school classrooms in Nigeria. The health effects of toxic metals in dust inhaled can inflame, sensitize and even scar the lungs and tissue. The pollutants may enter the numerous tiny air sacs deep inside the lungs and also blood stream thereby affecting several other organs and lungs (Gbadebo and Bankole, 2002). Dust makes a significant contribution to pollution in the urban area and consists of vehicle exhaust, sinking particles in air, house dust, soil dust and aerosols that are carried by air and water.

Dust pollution has a significant impact on our health, environment and economy. The sources of indoor environment dust pollution include two types namely, internal and external pollution sources (USEPA, 2020). The internal sources include cooking, smoking, sweeping, wall erosion, rubber carpet products, painting and other indoor activities (Wong et al, 2006 and Tan et al, 2016). The external pollution sources include vehicular emissions, auto repair, welding, waste burning, playground dust etc. (USEPA, 2020). Dust is a source of heavy metals and organic pollutants since it has fine particles and can easily enter the human body through three pathways, which are inhalation, ingestion and dermal contact, causing health risks to humans in the long- term (Bradham et al, 2014 and Praveena et al, 2015).

Many studies found that exposure to some heavy metals can lead to various disease conditions such as asthma, cardiovascular, neural, blood, and bone diseases, as well as gingivitis and kidney failure (Shi et al, 2011).

Biose et al (2020) carried out a study on heavy metal contents in topsoil of selected primary school playgrounds in Benin Metropolis, Nigeria. From the result, heavy metal concentrations were low when compared to the values obtained elsewhere in the world. However, long-term accumulation constitutes health hazards.

Ugwu and Ofomatah (2021) investigated the health risk of student's exposure to some toxic metals in classroom dusts in South East, Nigeria. The findings of the study showed that all the dust samples were polluted with Fe and Cr with few exemptions.

Aguilera et al (2020) used microwave – assistedacid digestion and ICP-OES in the determination of heavy metal concentration in street dust inMexico City, the contamination on factor and the geoaccumulation index showed that the streetdust in Mexico City is moderately contaminated by Pb, Zn and Cu. They also found that Cr and nickel together were part of the polluting lead of street

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dust which indicated that more than 90% of Mexico City was contaminated (polluting load index higher than one).

Radhi et al(2021) evaluated the level of pollution with heavy metals (Cd, Cr, Cu, Ni, Pb, Zn) and their potential sources in schools in Ramadi City, Iraq. The results showed that the pollution levels of schools' dust ranged from unpolluted for Cu, Cr, Ni, and Zn, unpolluted to moderately polluted for Pb, and heavily polluted for Cd. The pollution load of all heavy metals in the schools indicates no moderate pollution. The origin of Cd and Cu is anthropogenic (traffic emissions and exhaust emissions released from the electrical generators spread in the study area). The high Pb concentrations come from mixed sources (anthropogenic and geogenic sources). The concentrations of Cr, Ni, and Zn are of geogenic origin.

Agbaire et al (2019) conducted a study on heavy metals in indoor dust from primary schools in Delta State, Nigeria. The findings of the study showed that school placement and open windows for ventilation may be potential sources of heavy metal contamination in classroom dust.

Popoola et al. (2012) carried out a study on heavy metal concentrations in Nigerian primary schools, in Lagos. The concentration of metals found in classroom dust was less than that found in the street dust of several other cities worldwide. To assess risk and study contamination, Huang et al. (2014) looked into the concentration of several metals in indoor and outdoor dust particles discovered in Guangzhou cities. The levels of metal in Kumasi, Ghanaian school classrooms were studied by Nkansah et al. (2015). Wheng et al. (2010) and Al-Khashman (2007) examined the levels of heavy metals in the streets of Huludao, China, and Amman, Jordan, respectively, while Taiwo et al. (2017) evaluated road dust in classrooms, streets or offices within Abeokuta, Nigeria.

When compared to adults, the children are more vulnerable to the risks of heavy metals in the dust, because of their habits of crawling, randomly inserting materials into the mouth, sucking fingers, and high respiratory rates that increase the risk of the intake of heavy metals.

This study is aimed at evaluating the health risk associated with the exposure risk of pupils to classroom dust in Primary Schools in Calabar Metropolis, Cross River State, Nigeria.

Health risk assessment indicators

Human health risk assessment is a procedure employed to appraise the adverse health effects that could come from people's exposure to non-carcinogenic and carcinogenic heavy metals. The potential exposure routes for heavy metals in consummated dust according to United States Environmental Protection Agency (US EPA, 1989) can be evaluated using the following:

Exposure dose

Exposure through ingestion of the Mean Daily Dose (MDD) mg/d

$$MDDing = \frac{C \times IngR \times CF \times EF \times ED}{BW \times AT} \quad 1$$

Exposure through Inhalation of dust

$$MDDinh = \frac{C \times InhR \times EF \times ED}{PEF \times BW \times AT} \quad 2$$

Exposure through dermal contact dust

$$MDDder = \frac{C \times SA \times CF \times SL \times EF \times ED}{BW \times AT} \quad 3$$

All the parameters in the equations with their numerical values are represented in Table 1.

Table 1 Health risk parameters ((Ferreira-Batista and De Miguel, 2005[a], Lim *et al*, 2008[b], US EPA,2002[c], Li et al, 2013[d])

Parameter	Unit	Child	Adult
Concentration of heavy metals in the dust, C	mg/kg		
Ingestion Rate (IngR) (mg/d)		200[a]	100[a]
Conversion Factor (CF)		1×10^{-6}[b]	1×10^{-6}[b]
Exposure Frequency (EF) (d/a)		365[c]	365[c]
Exposure Duration (ED) (Years)		6[c]	24[c]
Body Weight (BW) (kg)		15[c]	70[c]

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Average Time (AT)	Non-Carcinogenic	Carcinogenic	
	ED x 365d[c]	70 x 365d[c]	
inhR-Inhalation Rate (Cm^3/day)		7.6[c]	20[c]
Particle Emission Factor (PEF) (m^3/kg)		1.36×10^{9}[d]	1.36×10^{9}[d]
Skin Area (SA) exposed to dust (cm2)		2800[c]	5700[c]
Skin Adherence factor (SL) (cm-1/d		0.2[c]	0.2[c]
Dermal Absorption factor (ASB)		0.001[d]	0.001[d]

Evaluation of non-carcinogenic risk: A hazard quotient (HQ) is a dimensionless quantity normally used when dealing with non-carcinogenic risk. It is the probability that a person may be exposed to effects of heavy metals. It is the ratio of the mean daily dose divided by the toxicity threshold value also known as chronic reference dose (RfD) in mg/kg – day.

$$HQ = \frac{MDD}{RfD} \qquad 4$$

Table 2 Oral reference dose for ingestion, inhalation and dermal contact(mg/kg/day) (US EPA, 2002)

Heavy metals	RfD_{ing}	RfD_{inh}	RfD_{der}
Cu	4.00×10^{-2}	4.02×10^{-2}	1.20×10^{-2}
Zn	3.00×10^{-1}	3.00×10^{-2}	6.00×10^{-2}
Fe	7.00×10^{-1}	3.00×10^{-2}	6.00×10^{-2}
Mn	4.60×10^{-2}	1.43×10^{-5}	1.84×10^{-3}
Co	2.00×10^{-2}	5.76×10^{-6}	5.76×10^{-6}
Ni	2.00×10^{-2}	2.06×10^{-2}	5.40×10^{-3}
Cr	3.20×10^{-3}	2.86×10^{-5}	6.00×10^{-5}
Cd	1.20×10^{-3}	5.70×10^{-5}	5.00×10^{-4}
Pb	3.52×10^{-3}	3.52×10^{-3}	5.25×10^{-2}

For n number of heavy metals, the non-carcinogenic influence on people is the total of all the HQs due to particular heavy metals. This total is known as the Hazard Index (HI), and is given by (5), (6) and (7)(USEPA, 1989):

$$HI = \sum_{i=1}^{n} HQ_i = \sum_{i=1}^{n} \frac{MDD}{RfD_i} \qquad 5$$

$$HI = \left(\frac{MDD}{RfD}\right)ing + \left(\frac{MDD}{RfD}\right)inh + \left(\frac{MDD}{RfD}\right)derm \qquad 6$$

$$HI = HQ_{ing} + HQ_{inh} + HQ_{derm} \qquad 7$$

Where: $HQ_{ing} = \left(\frac{MDD}{RfD}\right)ing$, $HQ_{inh} = \left(\frac{MDD}{RfD}\right)inh$, $HQ_{derm} = \left(\frac{MDD}{RfD}\right)der$ 8

If HI < I, then people exposed to heavy metals are unlikely to suffer the adverse effects, while HI > I, then people exposed to heavy metals may suffer the adverse effects (US EPA, 1989).

Evaluation of carcinogenic risk: The probability of cancer risk from dust can be calculated as the incremented possibility of a person developing cancer over a life time due to exposure to carcinogenic heavy metals (Enuneku *et al*, 2018; Ukah *et al*, 2019; Egburi and Mgbenu, 2020). The risk can be calculated using (9):

$$CR_{Route} = MDD \times CSF_i \qquad 9$$

Where SF_i = the slope factor (mg/kg/day).
The total extra lifetime cancer risk for a person can be computed from the mean contribution of a given heavy metal for the routes as follows:

$$LCR = \sum CR_i = (MDD \times CSF)_{ing} + (MDD \times CSF)_{inh} + (MDD \times CSF)_{der} \qquad 10$$

$$= (Risk)_{ing} + (Risk)_{inh} + (Risk)_{der} \qquad 11$$

The acceptable value of CR lies between 1×10^{-6} and 1×10^{-4} (US EPA, 2023; Ukah *et al,* 2019, Egburi and Mgbenu, 2020).

Geology and hydrogeology of the study area

Calabar is characterized by two maxima rainfall that climaxes in the months of July and September. Calabar South records the mean annual rainfall amount of 3000 mm and relative humidity of above 85%
(Eni and Effiong, 2011). The climatic data indicate that the monthly temperature varies between 23.1°C and 28.7°C and the monthly precipitation varies from a low of 28.7 mm (February) to a high of 459.1 mm (July) (Edet and Okereke, 2002). The study area belongs to the lowland and swampland of South-eastern Nigeria (Iloeje, 1991). Elevations in this area are generally less than 100 m above the mean sea level. Three main rivers dominate the landscape of the study area. These are the Calabar River, Great Kwa and Akpayafe Rivers – flowing southwards into the Cross River.

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Geologically, the study area is made up of Tertiary to Recent, continental fluvialite sands and clays, called the Coastal Plain Sands. This formation is characterized by alternating sequences of loose gravel, sand, silt, clay, lignite and alluvium (Short and Stauble, 1967). It is underlain mostly by rocks of the Cretaceous Calabar Flank and Pre-Cambrian Oban Massif (Fig.1).

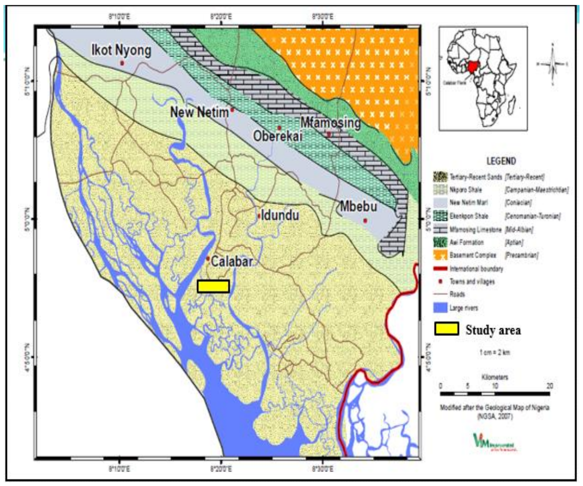

Figure.1 Geologic map of the study area (Modified from Amah *et al*., 2012)

MATERIALS AND METHODS

Dust particles were collected from eighteen (18) primary schools (Fig.2). Sampleswere collected using the sweeping method with the help of a broom and a packer. For every portion of the composite sample that was collected in each school, a fresh broom, and fresh polythene were used to ensure that that dust from one school was not transferred to another. After the samples were collected from the eighteen (18) schools, they were packaged together and transported to the laboratory for further preparations and analyses. The mesh was used to sieve the unwanted particles from the dust samples and placed in an airtight container to avoid infiltration from the surroundings.

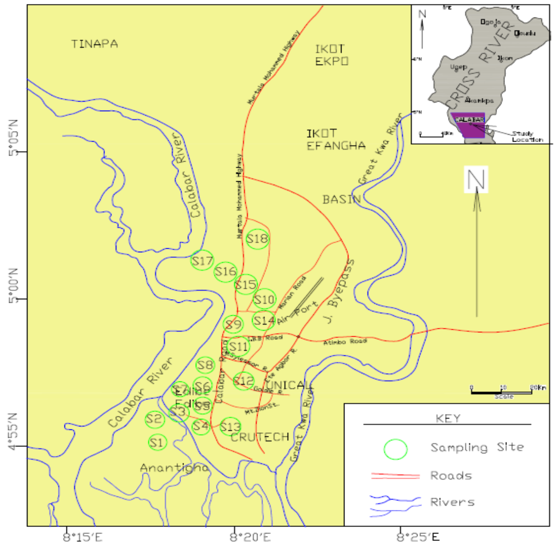

Figure. 2 Location map of the study area

Digestion of Soil Samples:

Quantitative chemical analysis was employed and this method has been used by many researchers (Ganiyu et al, 2021; Ugwu and Ofomatah, 2021; Ojiogo et al, 2022). Soil samples were kept in the oven to make it dry. It was then grinded into powder form using mortar and pestle. 1.0g of the grounded soil samples were weighed using an electric weigh balance. The weighed sample was then transferred into a conical flask and 30mls of concentrated Nitric acid and 10 mls of perchloric acid was also added to the solution. The solution was kept in an oven to heat for 30minutes. After the heating was done, the solution was removed from the oven and 60 mls of distilled water was added to the solution to dilute the acid. This process was done simultaneously for all the 18 dust samples. The solutions were then labelled. A syringe was used to extract 5ml of digested soil sample which was placed in a test tube. 0.5ml of reagent for each heavy metal (Ni, Zn, Cu, Cr, Cd, Fe, Co, Pb and Mn) to be checked was added to the test tube and mixed. Five (5) minutes of reaction time was allowed. Later on, blanking was done for calibration and accurate reading by placing a test tube filled with distilled water on the spectrophotometer before determining the concentration of heavy metals. The digested samples were analyzed for concentration of nickel (Ni), copper (Cu), Zinc (Zn), iron (Fe), manganese (Mn), chromium (Cr), cadmium (Cd), cobalt (Co) and lead (Pb)in triplicate using Ultra -Violet Spectrophotometer Palintest model 7500. The equipment was calibrated with standard solutions of the metals to be determined.

RESULTS AND DISCUSSION

The results of the study are presented in Table 3 and Table 4, and Fig.3 and Fig.6.

Table 3 Concentrations of heavy metals (mg/kg) in the study area

S/N	Primary schools	Label	Ni	Cu	Zn	Fe	Mn	Cr	Cd	Co	Pb
1	A	S1	240	550	90	6100	230	5	9	21000	50
2	B	S2	19	420	50	3120	150	3	5	16000	60
3	C	S3	22	330	20	2500	190	2	2	14000	30
4	D	S4	10	320	70	4100	200	4	4	18000	40
5	E	S5	80	330	30	2600	160	2	6	13000	30

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6	F	S6	100	280	10	2300	120	1	1	12000	20
7	G	S7	130	300	40	2800	110	3	3	14000	10
8	H	S8	110	210	10	2100	100	2	4	10000	20
9	I	S9	170	410	120	690	230	310	106	87	84
10	J	S10	130	370	90	590	150	290	115	71	90
11	K	S11	100	330	80	720	190	280	110	81	50
12	L	S12	160	400	100	580	200	280	110	63	30
13	M	S13	210	510	140	710	260	330	119	86	60
14	N	S14	230	480	100	660	160	210	117	65	50
15	O	S15	100	360	70	650	130	160	101	83	30
16	P	S16	120	330	80	590	150	190	112	64	50
17	Q	S17	90	320	50	700	190	180	112	61	60
18	R	S18	180	400	110	720	200	220	113	59	50
	Mean		122.28	369.44	70.00	1790.56	173.33	137.33	63.83	6595.56	45.22
	SD		67.78	84.05	38.19	1552.84	44.06	131.30	54.99	7832.92	21.34
	WHO /NESREA /FAO		**70.0**	**100.0**	**421.0**	**50000.0**	**200.0**	**100.0**	**3.0**	**50.0**	**164.0**

SD = Standard Deviation

Table 3 shows the concentrations of heavy metals in the study area. It indicates that for all the schools, the concentrations of Cu and Co were above the World Health Organization (WHO)/National Environmental Standards and Regulations Enforcement Agency (NESREA)/Food and Agriculture Organisation (FAO) standard (2021). Also, the concentrations of Zn, Fe and Pb in all the chosen schools were within the permissible limit of WHO/NESREA/FAO standards. The concentration of Ni in schools A, E, F to R were above the standard, while school B, C and D were below the standard limit.

The concentration of Cr in schools A to H was within the permissible limit while schools I to R were above the standard limit. In addition, the concentration of Cd in schools C, F and G were within the standard limit while schools A - B, D – E and H – R were above the standard limit. The distribution is shown in Table 3. The mean concentration was in this order: Co>Fe>Cu>Mn>Cr>Ni>Zn>Cd>Pb. Hence, the schools in the study area are polluted with Ni, Cu, Cr, Cd and Co with exception of few schools and this may pose health risks to the pupils.

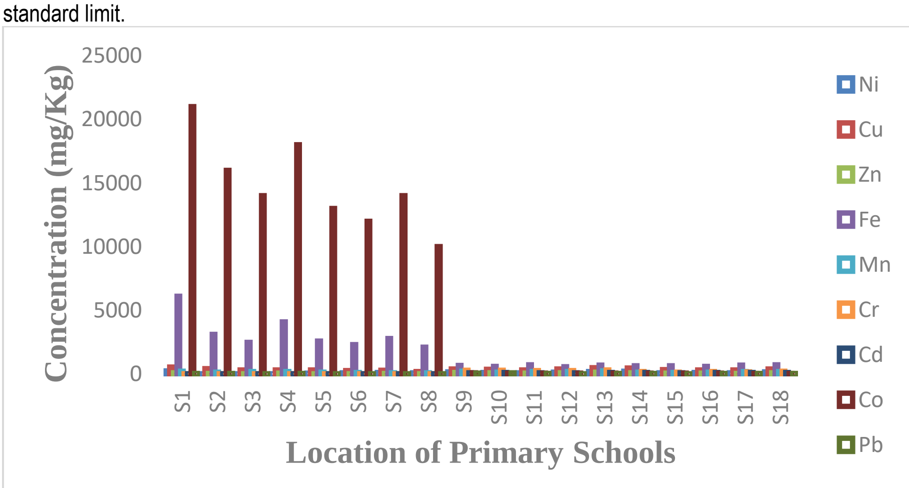

Figure.3 Bar chart showing the concentration of heavy metals in the classroom

Table 4 Mean daily dose, reference dose and hazard quotient of heavy metals in the study area

Heavy Metals	MDD_{ing}	HQ_{ing}	MDD_{inh}	HQ_{inh}	MDD_{der}	HQ_{derm}
Cu	5.28×10^{-4}	1.32×10^{-1}	7.77×10^{-8}	1.93×10^{-6}	6.02×10^{-6}	5.02×10^{-4}
Zn	1.00×10^{-4}	3.34×10^{-4}	1.47×10^{-8}	4.91×10^{-8}	1.14×10^{-6}	1.90×10^{-5}
Fe	2.56×10^{-3}	3.66×10^{-3}	3.77×10^{-7}	1.26×10^{-6}	2.92×10^{-5}	4.87×10^{-4}
Mn	2.48×10^{-4}	5.39×10^{-3}	3.65×10^{-8}	2.55×10^{-3}	2.83×10^{-6}	1.54×10^{-3}

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Co	9.43×10^{-3}	4.72×10^{-1}	1.39×10^{-6}	2.41×10^{-1}	1.08×10^{-4}	1.87×10^{1}
Ni	5.99×10^{-5}	2.99×10^{-3}	1.20×10^{1}	5.81×10^{2}	6.83×10^{-7}	1.26×10^{-4}
Cr	6.73×10^{-5}	2.24×10^{-2}	13.4527	4.19×10^{5}	7.67×10^{-7}	1.28×10^{-2}
Cd	3.13×10^{-5}	3.13×10^{-2}	0.625×10^{-1}	1.10×10^{5}	3.56×10^{-7}	7.13×10^{-4}
Pb	2.21×10^{-5}	6.33×10^{-3}	0.443×10^{-1}	1.26×10^{3}	2.52×10^{-7}	4.81×10^{-4}
		6.76 $\times 10^{-1}$		**5.30** $\times 10^{5}$		**1.87** $\times 10^{1}$
HI = 5.30 x 10^5						

Table 4 shows the calculated Mean Daily Dose (MDD), Hazard Quotient and Hazard Index (HI) for ingestion, inhalation and dermal contact. The calculated values of HQ for all the heavy metals for ingestion were less than one (<1) meaning no risk indicator; HQ for inhalation Ni, Cr, Cd and Pb were greater than 1 indicating a significant risk indicator and Zn, Cu, Fe, Mn, and Ni were less than 1 indicating no risk indicator. For dermal contact, all the heavy metals in the study have HQ<1 except Co indicating no risk indicator. This implies that HQ in the classroom dust is in this order: HQ_{inh}>HQ_{derm} > HQ_{ing} and the hazard index (HI) is greater than 1. The distribution is shown in Fig 4.

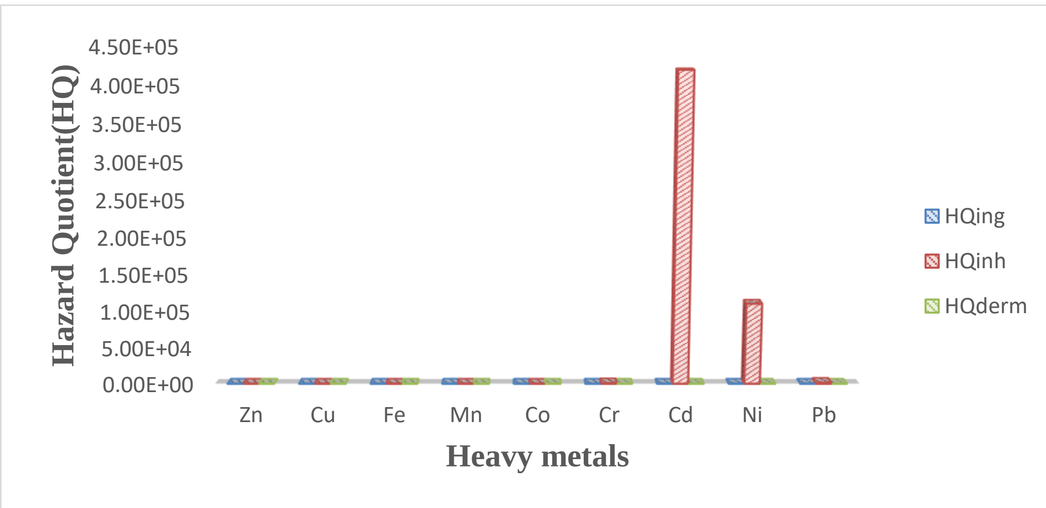

Figure. 5 Bar chart showing the hazard quotient (HQ) of heavy metals in the study area

Table 4 Carcinogenic risk for ingestion, inhalation and dermal contact of heavy metals in the study area

Heavy Metals	CR_{ing}	CR_{inh}	CR_{derm}	CR_{total}	Acceptable range	Status
Ni	3.36×10^{-5}	5.03×10^{-1}	1.54×10^{7}	5.030982357		SR
Cr	1.19×10^{-5}	3.939×10^{1}	2.17×10^{6}	39.39224263	1×10^{-6} –1×10^{-4}	SR
Cd	1.257×10^{-3}	1.006×10^{1}	3.82 10^{9}	10.06315488		SR
Pb	1.88×10^{-7}	1.86×10^{-1}	2.15×10^{-12}	0.186048188		SR

SR = Significant Risk indicator.

Table 4 shows the carcinogenic risk for ingestion, inhalation and dermal contact of heavy metals in the study area. The total carcinogenic risk was in this order: Cr>Cd>Ni>Pb. The four heavy metals were all greater than the acceptable range of 1×10^{-6} – 1×10^{-4} indicating a significant risk indicator of cancer (US EPA, 2023; Ukah *et al,* 2019, Egburi and Mgbenu, 2020). The results obtained in this study are also in consonance with the findings of Ushie et al (2023), Radhi et al(2021) and Ugwu and Ofomatah (2021).
. Cr had the highest value of 3.94×10^{1} and Pb had the least value of 1.86×10^{-1}. The distribution of the carcinogenic cancer risk is shown in Fig.6.

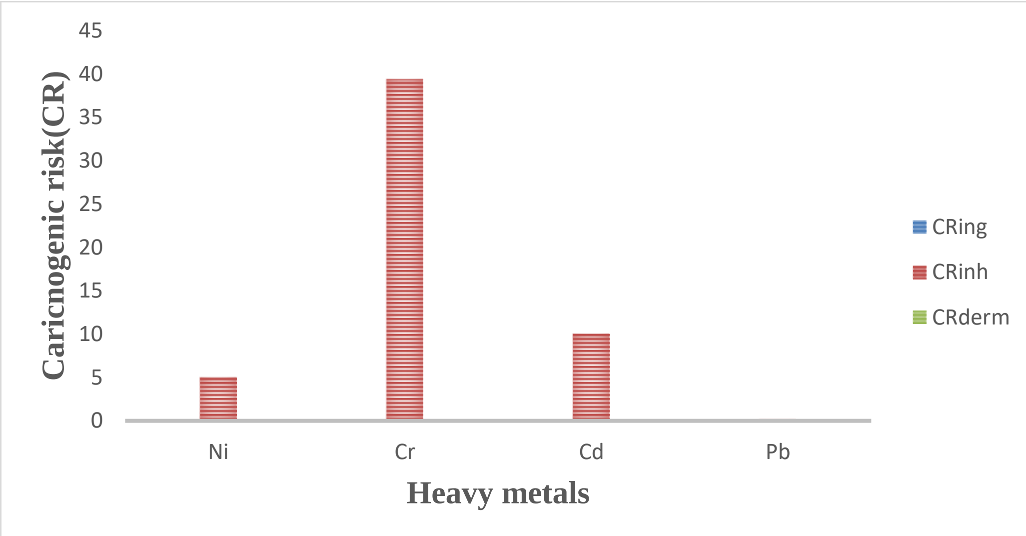

Figure. 6 Bar chart showing the carcinogenic risk in the study area

Conclusion

This study was aimed at evaluating the health risk associated with exposure of pupils to classroom dust in Primary Schools in Calabar Metropolis, Cross River State, Nigeria. From the findings of this study, it was found that the classrooms in the study area are heavily polluted with Ni, Cu, Cr, Cd and Co with exception of few schools and this may pose health risks to the pupils. It was therefore recommended that the State Universal Basic Education Board (SUBEB) should sponsor research to routinely monitor the classrooms where teaching and learning take place to ensure that they are pollution – free of heavy metals such as Ni, Cu, Cd and Co. There should be an awareness campaign among teachers and pupils on good sanitation and hygiene in the classrooms and school environment. Also, environmentally – friendly remediation techniques such as in situ flushing, biowall, in situ chemical reduction etc. should be used by expert to clean off heavy metals in classrooms.

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