PRINT ISSN 1119-8362
Electronic ISSN 2659-1502

Full-text Available Online at
https://www.ajol.info/index.php/jasem
http://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 27 (9) 1977-1984 September 2023

Evaluation of Pollution Indices of Heavy Metals in Ceiling Fan Dust in Lecture Halls of a Tertiary Institution, Calabar, Nigeria

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ABSTRACT: This study evaluated heavy metals in ceiling fan dust in five (5) lecture halls of a tertiary institution in Cross Rivers State, Calabar, Nigeria using appropriate standard techniques. Data obtained reveal that contamination factor for Zn, Cu, Fe, Mn, Cr, Ni and Pb were all < 0.10 indicating very slight contamination, while the geoaccumulation index for Zn, Cu. Fe, Mn, Cr, Ni and Pb were ≤ 0 indicating non – contamination. Nemerow integrated pollution index (NIPI) for Zn, Cu, Fe, Mn, Cr, Ni and Pb were all ≤ 0.7 which indicates non – pollution, while Cd showed high level of pollution with values NIPI > 3 in all sampled sites. Enrichment factor for Zn, Cu, Mn, Cr, Cd, Ni and Pb in all the sites were >1000 which indicates that all the heavy metals were from artificial source. Generally, the findings of the study revealed that the lecture halls are polluted with cadmium (Cd) mainly from artificial source while other heavy metals such as Zn, Cu, Fe, Mn, Cr, Ni and Pb were within the permissible limits of the indices. It was recommended that ceiling fans should be regularly and thoroughly cleaned to prevent pollution by heavy metals. Also, there should be awareness campaign for users of lecture halls on the health risk associated with ceiling fan dust.

DOI: https://dx.doi.org/10.4314/jasem.v27i9.12

Cite this paper as: USHIE, C. A; ABONG, A. A; OBI, E. O. (2023). Evaluation of Pollution Indices of Heavy Metals in Ceiling Fan Dust in Lecture Halls of a Tertiary Institution, Calabar, Nigeria. *J. Appl. Sci. Environ. Manage.* 27 (9) 1977-1984

Dates: Received: 16 August 2023; Revised: 10 September 2023; Accepted: 25 September 2023 Published: 30 September 2023

Keywords: Ceiling fan; dust pollution; heavy metals; classroom air pollution

Dust is one of the global environmental problems facing mankind today. Due to urbanisation, population growth, increased in transportation facilities, industries, mining, agricultural practices etc. the quantity of dust and metal pollutants have tremendously increased. Dust particle is made up of air particles, soil, wastes from industrial activities, vehicles, building materials and heavy metals (Moradi *et al*, 2018). Apart from the dust particles polluting the air, Khadem and Golchin (2019) observed that they also have effect on the soil by contaminating the grains, vegetables and groundwater due to migration of heavy metals from contaminated soil to the water. Heavy metals in dust can be deposited on the ground and easily be suspended by wind into the atmosphere (Sharma *et al*, 2008 and Amato *et al*, 2009). Heavy metals in dust constitute the main environmental issue; they are toxic, non-biodegradable and spread pollution (Ogundele *et al*, 2017 and Malakootian *et al*, 2021). Heavy metals commonly found in dust include zinc (Zn), lead (Pb), cadmium (Cd), chromium (Cr) and nickel (Ni) (Du *et al*., 2013; Alharbi, Pasha and Al-Shamsi, 2019). Also Liu *et al* (2018) observed that pollution with heavy metals originate from vehicular emission, coal burning, mining, agricultural practices, waste water disposal, surface run off, agro-chemical industries, furniture making and refineries. Heavy metals which formed fine and light compounds stay suspended in the ambient air and when rain falls, part of these pollutants are dissolved in the rain and get back to the earth's surface. However, the heavy metals in the air or dust increase the concentration of these

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compounds in the residential settlement through respiration, ingestion and absorption (Hawley, 1985 and Murgueytio *et al*, 1998). Moreover, heavy metals have disastrous impacts on the health of man. Exposure to air/dust pollutants gives rise to chronic and acute poisoning and various diseases like asthma, anaemia, infertility, hair loss, insomnia, cancer, osteoporosis, premature aging, gene disorder, abortion, obesity, hormonal imbalances, deficiency in nutrition, neurological abnormalities, weak immune system, cardiac and respiratory abnormalities, liver and kidney destruction, allergy and death (Farahmandkia *et al*, 2010). Ceiling fans are fans placed on the ceiling of a room or space. They are electrically powered and use a hub-mounted rotating blade to circulate air. They cool people by increasing the air speed. It has been observed that ceiling fans in a tertiary institution are dirty and dusty. Cleaners concentrate their sweeping on the floors and desks without paying attention to the ceiling fans. Students receive lectures; write examinations in these halls and ceiling fans are usually switched on to provide cooling to the students and lecturers. Dust deposited on ceiling fans contains heavy metals some of which are dangerous to human health and the environment. Little literature exists on the exposure risk of students and lecturers to ceiling fan dust in Nigeria in general and Cross River State in particular. Most of the literatures are foreign with foreign cultural background. This has aroused the interest of the researcher to evaluate heavy metals and exposure risk to ceiling fans in a tertiary institution in Southern Nigeria. Hence, the objective of this work was to evaluate the pollution indices of heavy metals in ceiling fan dust in five (5) lecture halls of a tertiary institution in Cross River State, Calabar, Nigeria.

MATERIALS AND METHODS

The major equipment used in this was Ultra Visible Spectrophotometer (UV-VIS) model CE 1101 with other accessories such as a ladder, five (5) plastic brushes, five (5) polythene bags, five (5) plastic pans, global positioning system (GPS) Garmin 72 model and a large bag. Dust particles were collected from five (5) lecture halls in the study area (Table 1 and Fig 1). Samples were collected from the lecture halls with dusty ceiling fans with the help of a plastic brush and a plastic pan. For every portion of the composite sample that was collected in each site, a fresh plastic brush, a fresh plastic pan and fresh polythene was used to scoop the deposited dust particles from the ceiling fans. After the samples were collected from five (5) different sites, there were packaged together and transported to the laboratory for further preparations and analyses.

Laboratory analysis: 0.1g of samples of dust were dissolved in 100ml of distilled water in a 250 ml beaker, stirring with glass rod and transferred to different separating funnels (1litre) and shaken for a period of 5 minutes respectively. After addition of 50ml of xylene in each flask, each flask was kept for layer separation and collected lower layers of xylene for five (5) separating funnels with further centrifuge. The aqueous layer of xylene layers volume of dust samples was measured with Ultra violet visible (UV-VIS) spectrophotometer CE 1011. The absorbance of each sample was recorded and the following heavy metals were detected: Zn, Cu, Fe, Mn, Cr, Cd, Ni and Pb.

Location and geology of the area: The tertiary institution is situated close to the highway linking Cross River State and Ebonyi State. The study area is associated with two seasons viz; wet season from April – October and dry season from November - March with yearly rainfall average value of 1750 mm – 2000 mm. According to Akpanidiok (2010) and Edet *et al* (2011), the area is characterised with high temperature with mean annual temperature value from 27^0C - 29^0C. The geology of the study area consist of shale, siltstone, sandstone/limestone and clay with granites and gneisses which have been weathered due to high tropical climatic factors (Fig. 1).

Pollution indices: There are many pollution indices used in environmental studies. Some of which include the following:

Contamination Factor/Pollution Indices (CF/PI): This is the ratio of the concentration of heavy metals in dust sample to the same heavy metal in reference value or earth's crust. The expression is given by Kianpor *et al* (2019) as:

$$CF / PI = \frac{C_n}{B_n} \qquad 1$$

Where B_n = reference value in the earth crust; C_n = concentration of heavy metals in dust samples

Table 6 Midpoint coordinates of sampling sites

S/N	Tertiary institution	Label	Latitude	Longitude	Elevation(m)
1	Lecture Hall A	L1	N06^{0}42'22.2''	E008^{0}45'54.7''	133.0
2	Lecture Hall B	L2	N06^{0}42'23.5''	E008^{0}45'54.3''	124.0
3	Lecture Hall C	L3	N06^{0}42'23.8''	E008^{0}45'53.2''	111.0
4	Lecture Hall D	L4	N06^{0}42'11.6''	E008^{0}45'47.6''	125.0
5	Lecture Hall E	L5	N06^{0}42'12.0''	E008^{0}45'48.2''	122.0

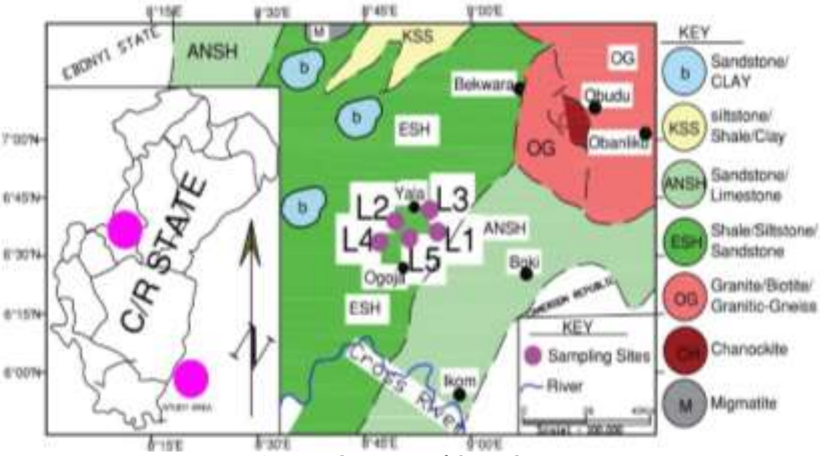

Fig.1. Geologic map of the study area

Table 1 Background or average continental crust *Taylor (1964*[a] *Dineley et al. (1976*[b]*; Arhin et al. (2017*[c]*; Turakran and Wedepohi (1961) in Ebong et al, 2020*[d]*)*

Heavy metals	Background or average continental crust (mg/kg)		
Zn	60[a]	70[b]	60[c]
Fe			4600[b]
Mn	1000[b]	1000[b]	1000[b]
Cr	100[a]	122[b]	100[a]
Cd	0.15[b]	0.15[b]	0.15[b]
Ni	80[b]	80[b]	80[b]
Pb	16[a,b]	16[b]	16[b]

The degree of contamination/pollution of this index can be categorised as in Table 2.

Table 2. Classification of degree of contamination/pollution of CF/PI (Boisa and Odagwe, 2019; Brown and Peake, 2006)

S/N	Index	Degree of contamination/pollution
1	< 0.10	Very slight contamination
2	0.10 – 0.025	Slight contamination
3	0.26 – 0.50	Moderate contamination
4	0.51 – 0.75	Severe contamination
5	0.76 – 1.00	Very severe contamination
6	1.10 – 2.00	Slight pollution
7	2.10 – 4.00	Moderate pollution
8	4.10 – 8.00	Severe pollution
9	8.10 – 16.00	Very severe pollution
10	> 16.00	Excessive pollution

Geological Accumulation Index (Igeo): This is the index that measures the degree of geogenic or anthropogenic accumulated loads in the soil (Bello *et al*, 2016). It is given by.

$$I_{geo} = Log_2\left(1.5\frac{C_n}{B_n}\right) \qquad 2$$

Where: C_n and B_n are the concentration of heavy metals in the dust sample and background. The constant 1.5 indicates the likely changes in anthropogenic of the contaminants in the background.

Table 3 Categorisation of geo-accumulation Index (Hakanson, 1980)

S/N	KK	Igeo	Contamination
1	0	Igeo ≤ 0	Non-contamination
2	1	0 < Igeo ≤ 1	Light to moderate
3	2	1 < Igeo ≤ 2	Moderate
4	3	2 < Igeo ≤ 3	Moderate to strong
5	4	3 < Igeo ≤ 4	Strong
6	5	4 < Igeo ≤ 5	Strong to extremely serious
7	6	5 ≤ Igeo ≤ 10	Extremely serious

KK = Categorisation; Igeo = Geo-accumulation index

Nemerow integrated pollution index (NIPI): This is an index used to examine the overall soil quality and dust environments. It is given by Kianpor *et al* (2019) as:

$$NIPI = \sqrt{\frac{\frac{1}{n}\left(\sum_{n=1}^{n} PI_{av}\right)^2 + PI_{mac}^2}{2}} \qquad 3$$

Where: PI_{imax} = the maximum of the pollution index for each heavy metal; PI_{iav} = the mean value of the pollution index for each heavy metal

The major advantage of this index over other indexes is that it creates room for evaluation of pollution risk of all the heavy metal in a given location (Yang *et al*, 2011).

Table 4 Classification of Nemerow Integrated Pollution Index (Kianpor *et al*, 2019)

S/N	Index	Interpretation
1	NIPI ≤ 0.7	Non-pollution
2	0.7 < NIPI ≤ 1	Warning line of pollution
3	1 < NIPI ≤ 2	Lowly level of pollution
4	2 < NIPI ≤ 3	Moderate level of pollution
5	NIFI > 3	High level of pollution

Enrichment factor (EF): This is the factor that differentiates natural levels of heavy metals from non-natural (or artificial) levels of heavy metals (Loska *et al*, 2005). It is given by:

$$EF = \frac{\left(\frac{Ci}{Fe(s)}\right)sample}{\left(\frac{Ci}{Fe(b)}\right)reference} \qquad 4$$

C_i = Concentration of heavy metal in the sample, Fe(s) is the concentration of Fe in sample and Fe(b) is the concentration of Fe is the earth's crust or reference background or baseline.

Table 5. Enrichment values and enrichment degree of heavy metals in the dust (Xiong *et al*, 2017)

S/N	EF value	Level	Rank	Source
1	EF ≤ 1	Rarely enriched	1	Soil and crust source
2	1 < EF ≤ 10	Mildly enriched	2	Natural and artificial sources
3	10 < EF < 10	Moderately enriched	3	Artificial source
4	100 < EF ≤ 1000	Highly enriched	4	Artificial source
5	EF > 1000	Extremely enriched	5	Artificial source

RESULTS AND DISCUSSION

Contamination factor/pollution index (CF/PI): Table 7 shows that the contamination factor for Zn, Cu, Fe, Mn, Cr, Ni and Pb were all < 0.10 in site S_1 to S_5 indicating very slight contamination. For Cd the pollution index for S_1, S_3 and S_5 were within the range 8.10 – 16.00 indicating very severe pollution status, while S_2 and S_4 were >16.00 indicating excessive pollution (Boisa and Odagwe, 2019). It also shows that S_4 has the highest level of Cd pollution. Fig.2 shows the distribution of the contamination factor/pollution index.

Table 7 Contamination factor/pollution index of heavy metals

Site	Zn	Cu	Fe	Mn	Cr	Cd	Ni	Pb
S_1	0.00429	0.00383	$6.53 x10^{-6}$	0.00006	0.00024	14.0667	0.00005	0.00625
S_2	0.00700	0.00683	1.12×10^{-6}	0.00005	0.00039	17.0667	0.000163	0.00875
S_3	0.00529	0.00417	$7.46 x10^{-6}$	0.00205	0.00020	14.6000	6.25×10^{-5}	0.008125
S_4	0.00943	0.00800	2.8×10^{-5}	0.00300	0.00071	37.3333	0.00035	0.011875
S_5	0.00443	0.00467	7.46×10^{-6}	0.00070	0.00020	14.5333	6.25×10^{-5}	0.0075

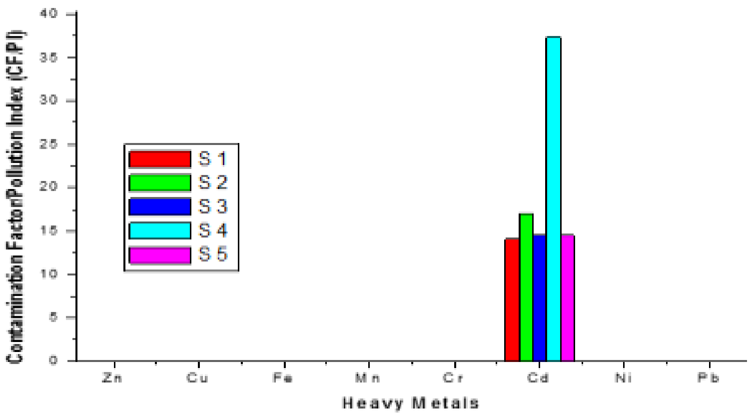

Fig.2. Bar chart showing contamination factor/pollution index in the study area

Geoaccumulation index (I_{geo}): Table 8 indicates that the geoaccumulation index for Zn, Cu. Fe, Mn, Cr, Ni and Pb were ≤ 0 indicating non – contamination. But for Cd, the I_{geo} for S_1, S_2, S_3 and S_5 fall within moderate to strong level of contamination with 2<Igeo ≤3, while S_4 belongs to strong level of contamination with 3<Igeo ≤ 4(Hakanson, 1980). Again S_4 has the highest level of Cd contamination. Fig.3 shows the distribution of geoaccumulation index in the study area.

Table 8. Geoaccumulation index of heavy metals

Location	Zn	Cu	Fe	Mn	Cr	Cd	Ni	Pb
S_1	-5.85295	-5.9645	-12.3396	-10.1216	-8.73535	2.2433	-10.304	-5.4757
S_2	-5.36232	-5.38642	-11.8006	-10.3040	-8.24984	2.4367	-9.1253	-5.1392
S_3	-5.64323	-5.88112	-12.2061	-6.59039	-8.91767	2.2805	-10.081	-5.2133
S_4	-5.06449	-5.22879	-10.8843	-6.20962	-7.65072	3.2194	-8.3581	-4.8338
S_5	-5.82016	-5.76779	-12.2061	-7.66491	-8.91767	2.2760	-10.081	-5.2933

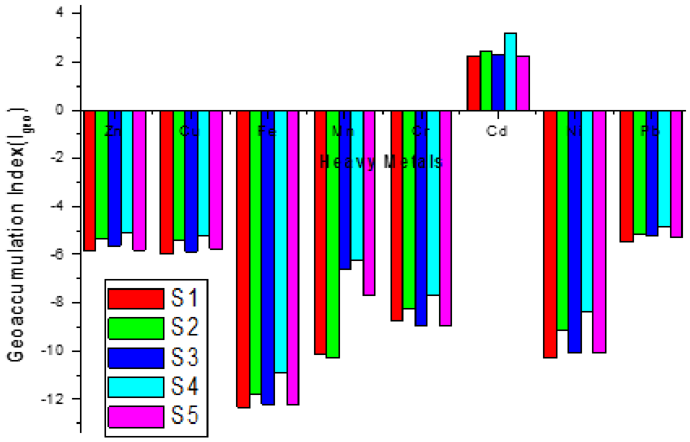

Fig.3. Bar chart showing geoaccumulation index in the study area

Nemerow Integrated Pollution Index (NIPI): Table 9 shows that Nemerow integrated pollution index (NIPI) for Zn, Cu, Fe, Mn, Cr, Ni and Pb were all ≤ 0.7 which indicates non – pollution, while Cd shows high level of pollution with values NIPI >3 in all sampled sites (Kianpor *et al*, 2019). Fig.4 shows the distribution of Nemerow integrated pollution index in the study area.

Table 9. Nemerow integrated pollution index for heavy metals

Site	Zn	Cu	Fe	Mn	Cr	Cd	Ni	Pb
S_1	0.004286	0.0038	6.53×10^{-6}	0.00006	0.00024	14.067	0.00005	0.006
S_2	0.007000	0.0068	1.119×10^{-5}	0.00005	0.00039	17.067	0.000163	0.009
S_3	0.005286	0.0042	7.463×10^{-6}	0.00200	0.00020	14.600	6.25×10^{-5}	0.008
S_4	0.009429	0.0080	2.799×10^{-5}	0.00300	0.00071	37.333	0.00035	0.012
S_5	0.004429	0.0047	7.463×10^{-6}	0.0010	0.00020	14.533	6.25×10^{-5}	0.008
Average	0.0061	0.0055	0.00001	0.0012	0.00030	19.520	0.0001	0.0085
NIPI	0.00928	0.0097	0.0000297	0.003	0.00077	42.128	0.000363	0.015

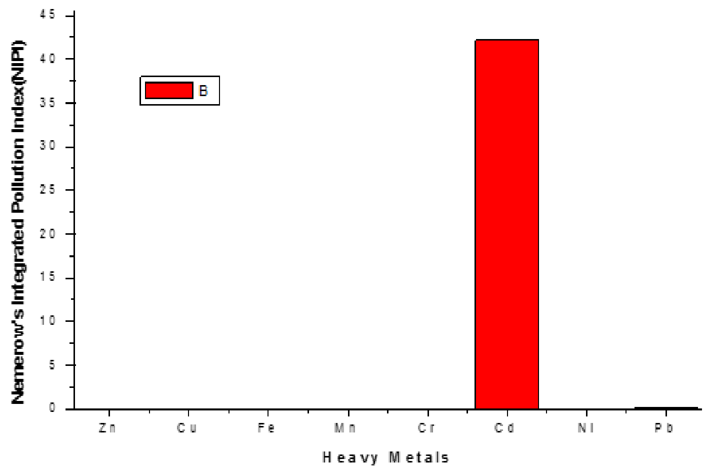

Fig.4. Bar chart showing Nemerow integrated pollution index (NIPI) in the study area

Enrichment factor (EF): Table 10 shows that enrichment factor for Zn, Cu, Mn, Cr, Cd, Ni and Pb in all the sites were >1000 which indicates that all the heavy metals were from artificial source (Xiong *et al*, 2017). Fig.5 shows the distribution of enrichment factors in the study area.

Table 10. Enrichment for heavy metals

Location	Zn	Cu	Fe	Mn	Cr	Cd	Ni	Pb
S_1	153142.9	153142.9	153142.9	153142.9	153142.9	153142.9	153142.9	153142.9
S_2	89333.33	134000	134000	134000	134000	134000	134000	1340000
S_3	134000	134000	134000	134000	134000	134000	134000	1340000
S_4	35733.33	35733.33	35733.33	35733.33	35733.33	35733.33	35733.33	35733.33
S_5	134000	134000	134000	134000	134000	134000	134000	134000

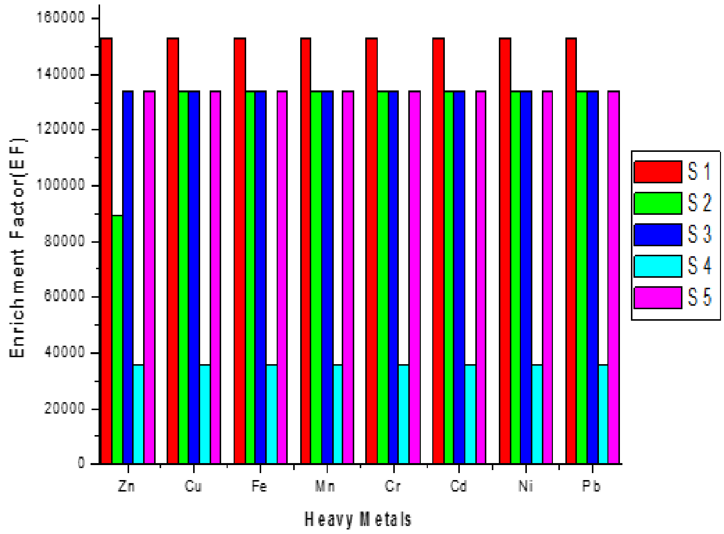

Fig. 5. Bar chart showing enrichment factor in the study area

Table 11 Correlation matrix of heavy metals in the study area

		Zn	Cu	Fe	Mn	Cr	Cd	Ni	Pb
Zn	Pearson Correlation	1							
	Sig. (2-tailed)								
Cu	Pearson Correlation	.955*	1						
	Sig. (2-tailed)	.011							
Fe	Pearson Correlation	.944*	.877	1					
	Sig. (2-tailed)	.016	.051						
Mn	Pearson Correlation	.635	.436	.727	1				
	Sig. (2-tailed)	.250	.463	.164					
Cr	Pearson Correlation	.964**	.924*	.979**	.595	1			
	Sig. (2-tailed)	.008	.025	.004	.290				
Cd	Pearson Correlation	.916*	.836	.997**	.752	.965**	1		
	Sig. (2-tailed)	.029	.078	.000	.143	.008			
Ni	Pearson Correlation	.979**	.942*	.986**	.643	.993**	.969**	1	
	Sig. (2-tailed)	.004	.017	.002	.242	.001	.006		
Pb	Pearson Correlation	.966**	.905*	.951*	.777	.921*	.933*	.958*	
	Sig. (2-tailed)	.008	.035	.013	.122	.026	.021	.010	1

**Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed). c. List wise N=5*

Table 11 indicates that a significant and strong positive correlation exists between the pairs Cu/Zn, Fe /Zn, Cd/Zn, Cr/Cu, Ni/ Cu, Pb/Cu, Pb/ Fe, Pb/Cr, Pb/ Cd, Pb/Ni with $p < 0.05$. This implies that Cu, Zn, Fe, Cd, Cr, Ni, Pb are from the same origin or source. Also, a significant and strong positive correlation exists between the pairs Cr/Zn, Ni/Zn, Pb/Zn, Cr/Fe, Cd/Fe, Ni/Fe, Cd/Cr, Ni/Cr, Ni/Cd with $p<0.01$. This indicates that Cr, Zn, Ni, Pb, Fe, Cd are from the same source or origin. Strong correlation also exists between the pairs Fe/Cu, Cd/Cu, Mn/Fe, Cd/Mn, Pb/Mn and moderate correlation between Fe/Zn, Cr/Mn and Ni/Mn but not significant at 0.01 and 0.05. Other heavy metals have poor positive correlations. The results obtained in this study are in line with Laxman *et al* (2016), Mohamed *et al* (2019) and Ukwu and Ofomatah (2021) who reported that concentration of heavy metals such as Cd, Fe, Ni, Cu, Zn and Pb could be as result of man's activities like vehicular emission, waste incineration, traffic volume etc. Similar studies carried out in different parts of the world by Victor *et al*(2018), Ahmed *et al* (2019), Alghamdi *et al* (2019), Abdulraheed *et al* (2022) obtained moderate to heavy contamination of Cd, Pb, Cr.

Conclusion: The importance of ceiling fans in lecture halls cannot be overemphasized. They cool people by increasing the air speed. Lectures and examinations cannot take place conveniently in the absence of ceiling fans especially during hot season. Based on the findings of this study, it was found that ceiling fans in the chosen lecture halls in a tertiary institution are heavily polluted with cadmium and the source is mainly from man's activities. It was recommended that ceiling fans should be regularly and thoroughly cleaned and washed in order to dispose them of dust.

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