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Metal Speciation and Pollution Status of Trace Metals in Roadside Dusts in High Traffic Density Areas of Akwa Ibom State, Nigeria

G. A. Ebong* and E. A. Moses

Chemistry Department, Unversity of Uyo, P. M. B 1017, Uyo, Nigeria

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Roadside dusts from high traffic density areas in Uyo, Ikot Ekpene, Eket, Ibeno, Abak and Itu local government areas of Akwa Ibom State, Nigeria were analyzed for concentrations of total cadmium, chromium, copper, nickel, zinc and lead. Optimized Bureau Community of Reference (BCR) speciation method was used for determination of metals forms. Results indicated that, mean concentrations of Cd and Cu were higher while concentrations of Cr, Ni, Zn and Pb were lower than their standards. Cd and Cr existed predominantly in acid extractable form, Cu and Zn in residual fraction while Ni and Pb mostly in reducible form. Cd and Pb were in the high risk class while Cu, Ni and Zn were within the low risk zone. Ibeno as the most contaminated area studied, closely followed by Uyo while Abak was the least contaminated area. Correlation analysis indicated strong positive association and common source for the metals evaluated in this study.

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INTRODUCTION

Waste generation has been a component of human existence but improper management of these wastes (solid, gaseous or liquid) is becoming a serious problem mostly in developing countries of the world. In Nigeria, management of wastes associated with land transportation such as gaseous emissions, metal parts and discarded tires has not been given much attention as it deserved. Solid particles that accumulate on outdoor ground surfaces in urban areas are collectively referred to as "street dust". Metals accumulate in roadside dust, surface soil and water and influence the ecosystem in the world especially in developing countries like Nigeria where data on environmental contamination are grossly inadequate [1]. The existence of metals is useful indicator for contamination in surface soil, sediment and dust environments [2]. However, the continuous accumulation of these toxic metals in urban environment owing to their non-biodegradability and long residence time is considered to be ''chemical time bombs'' [3]. Studies have shown that, most research works on roadside dust were carried out in developed countries of the world, but only limited information is available on trace metals of roadside dust for developing countries [4, 5, 6, 7]. Thus, the adverse effects of poor environmental conditions on human health are seriously manifested in urban environments, especially in developing countries where urbanization, industrialization and rapid population growth are taking place in an extraordinary scale. Metal contamination of roadside dust is based on three major sources namely: road traffic (automobiles), industrial/commercial activities, and weathered materials [8, 9]. These metals are bio-accumulative and there are possibilities that these metals can reach a critical value and threatened human health [10, 11]. Ghrefat and Yusuf [12] reported that, traffic congestion has negative effects as the emissions from combustion engines emit toxic metals so that surface soils, plants and even residents along the roadsides are subjected to elevated levels of contamination with trace metals. Reports have shown that there is high incidence of respiratory tract infections, digestion, and skin irritation among the traffic police officers and considerable number of them turns out to be victim of lungs disorder [13]. The effects of long term inhalation of toxic metals are mostly seen in developing countries such as the study area where diseases such as diabetes, renal failure, hypertension, nervous disorder

* Corresponding author: G. A. Ebong
E-mail: g_ebong@yahoo.com; Tel: +234 -8069342419

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and skin irritation are on the increase. Other consequences of metals in roadside dust include respiratory system disorders, nervous system interruptions, endocrine system malfunction, immune system suppression and cancer [14]. The common trace metals introduced to the environment by overland transportation are lead, zinc, cadmium and copper [4, 15, 16]. Use of leaded petroleum products is mainly responsible for the Pb contamination in roadside dust whereas, tire wear and corrosion of roadside safety fences contribute to Zn pollution [17, 18]. Cu is mainly released from the wear of brake linings, which is also an important source of Pb and Zn. Nickel and chromium in roadside dust may be attributed to the corrosion of vehicular parts [19]. The assessment of metal contamination level in roadside dusts within Akwa Ibom State was necessary because much has not been done in this area to ascertain the environmental and health implications associated with metal contamination in roadside dust. The few research works done on metal contamination of roadside dust were based mainly on total metal whereas, it has been established that it is only speciation that can indicate level of metal toxicity, mobility and bioavailability [20]. Besides environmental pollution has been created by dusts in high traffic density areas; fuel and energy consumption would be the additional side effect of toxic metal pollution. Eliminating roadside dust not only preserved our environment, but it would save fuel and reduce energy consumption.

Material and Methods

Study Area

This study was conducted in some local government areas within Akwa Ibom State, Niger Delta of Nigeria. Akwa Ibom is named after Qua Iboe River. It is situated in the coastal south-south part of Nigeria, lying between latitudes 4 32 and 5 33 North and longitudes 7 25 and 8 25 East (Fig. 1). Principally, the state has two separate seasons namely wet and dry. This research work was carried out during the dry season of the area and roadside dusts were collected at the following locations: Uyo (007. 56 E and 05.17 N); Ikot Ekpene (007.39 E and 05. 09 N); Eket (007. 53 E and 04. 36 N); Ibeno (007.98 E and 04.56 N); Abak (007 59 E and 04.56 N); Itu (007.59 E and 05. 09 N) (see Figure 1).

Sample Collection and Treatment

Six (6) locations were chosen in Akwa Ibom State based on traffic density to collect roadside dust. These locations as shown in Figure 1 were Uyo (UY) which is the capital city of Akwa Ibom State, Ikot Ekpene (IK) the city between Uyo and Aba, Eket (EK) the town between Uyo and Qua Iboe terminal, Ibeno (IB) where intensive oil and oil related activities are carried out, Abak (AK) the town linking Uyo and Port Harcourt (Rivers State) and Itu (IT) which links Uyo and Calabar (Cross River State). At each location, road side dusts were collected using soft touch brush and plastic dust pan according to the methods of Atiemo *et al*. [21]. Three (3) sub-samples were obtained at each location at a frequency of once a week for one month in February, 2016 when there was no rain in the study area. A total of seventy two (72) sub-samples and six (6) composite samples were obtained for this study. These samples were dried under the sun for three (3) days, ground and sieved through a 0.5mm sieve. These sieved samples were stored in well-labeled polyethylene containers for further treatment and analysis.

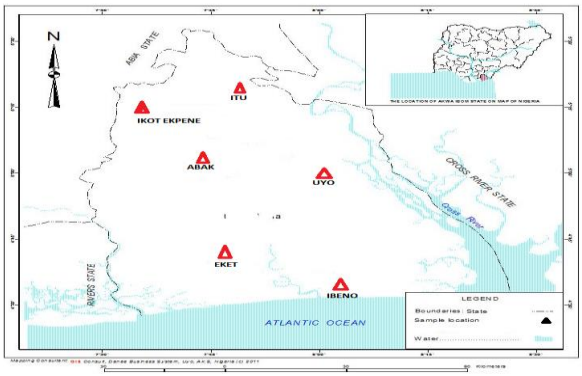

Figure 1. Map of Akwa Ibom State showing the study area.

Determination of total metal concentration

1g of sieved roadside dust sample was digested with a mixture of 5ml 16M HNO_3 and 15 ml 12M HCl on a hot plate. At the end of digestion, the mixtures was cooled, the digest filtered into a 100 ml volumetric flask and filled to mark with distilled water. Concentrations of Cd, Cr, Cu, Ni, Pb and Zn in the extracts from sequential extraction and total metal extracts were analyzed using air acetylene flame atomic absorption spectrophotometer (Unicam model 939/959) following the procedures of Ebong *et al*. [20].

Optimized BCR sequential extraction procedures

Sequential extraction of trace metals in roadside dusts was done using optimized BCR procedures as reported by Rauret *et al.* [22]. Fraction 1: Acid extractable (Aex) (weak acid extractable, exchangeable and carbonate bound fraction): To 1g of homogenized roadside dust sample, 40ml of 0.11M acetic acid solution was added. The mixture shaken with a mechanical shaker at room temperature for 16h and extract separated by centrifugation at 3000rpm for 20min collected and stored in polyethylene bottles. Fraction 2: Reducible (Red) (Metal fraction bound to Fe-Mn oxides): 40ml of 0.50M hydroxylammonium chloride solution was added to the residue from step 1 above, shaken for 16h at room temperature and centrifuged as in step 1 to separate the supernatant from the residue. Fraction 3: Oxidisable (Ox) (Metal fraction bound to sulphide and organic matters):

Residue from step 2 was treated with 10ml 8.8M hydrogen peroxide and allowed to digest for 1h. The mixture was evaporated to dryness and 50ml of 11M ammonium acetate added, shaken for 16h at room temperature and centrifuged to separate the extract from residue. Fraction 4: Residual (Res) (Metal fraction bound to crystalline silicates in soil): To the residue from step 3, a mixture of 5ml 16M trioxonitric acid and 15ml 12M hydrochloric acid was added and placed on hot plate for 2h. The mixture was cooled and filtered through Whatman No. 50 filter paper into a volumetric flask for analysis.

Identification of pollution status of trace metals in roadside dusts.

Mobility Factor (MF) was determined using equation (1):

$$MF = \frac{F1}{F1+F2+F3+F4} \quad (1)$$

Whereas, bioavailability factor (BF) in roadside dust sample was calculation using equation (2) below:

$$BF = \frac{F1}{F1+F2+F3+F4} \times 100 \quad (2)$$

where F1, F2, F3 and F4 are acid extractable, reducible, oxidisable and residual fractions respectively in optimized BCR speciation procedures. The percentage recovery of metals in samples evaluated was determined using equation 3 below:

$$\%Recovery = \frac{\sum n\ Sequential\ Extraction\ \ Procedure}{Single\ Digestion\ with\ Strong\ Acids} \times 100 \quad (3)$$

where n is the concentration of a particular metal and the single digestion with strong acids used for digestion of residual fraction [23]. I_{poll} Index proposed by Karbassi *et al*. [24] for the assessment of metal pollution in aquatic and terrestrial environments was employed for the evaluation of metal pollution in roadside dust.

$$I_{poll} = \log_2 (Bc/Lp) \quad (4)$$

where I_{poll} is the pollution intensity, Bc is the bulk concentration and Lp the lithogenous portion from results of sequential extraction procedures.

The degree of metal contamination in roadside dust was assessed using geoaccumulation index (Igeo) was calculated by applying the formula

$$Log_2(C_n/1.5B_n) \quad (5)$$

where Cn is the measured concentration of trace metal in roadside dust and B_n is the geochemical background concentration of trace metal (crustal average) [25]. Geoaccumulation indices are multiplied each time by a constant 1.5 to allow content fluctuations of a given element in the environment as well as small anthropogenic influences [26]. The different classifications of geoaccumulation index as proposed by Huu *et al*. [27] are given in Table 1 below:

TABLE 1. Classes of Geoaccumulation Indices

Igeo value	Igeo class	Designation of sample quality
>5	6	Extremely contaminated
4 – 5	5	Strongly to extremely contaminated
3-4	4	Strongly contaminated
2- 3	3	Moderately to strongly contaminated
1-2	2	Moderately contaminated
0- 1	1	Uncontaminated to moderately contaminated
0	0	Uncontaminated

Contamination level of roadside dust was established using contamination factor (CF) by applying the formula

$$CF = \frac{Cm\ sample}{Cm\ background} \quad (6)$$

where Cm sample is the mean of a metal in roadside dust and Cm background is the global average shale data of individual element [25]. The degree of site to site contamination of roadside dusts by trace metals was also evaluated using degree of contamination (Cdeg) as shown in the equation

$$Cdeg = \sum C^i_f \quad (7)$$

where $\sum C^i_f$ is the sum of the contamination factors for all the elements at a particular site. The classes of contamination factors (CF) as proposed by Hakanson [28] are CF < 1 = low contamination, 1 < CF < 3 = moderate contamination, 3 < CF < 6 = considerable contamination and 6 < CF = very high contamination while the degree of contamination (C_{deg}) are categorized as $C_{deg} < 8$ = low degree of contamination, $8 < C_{deg} < 16$ = moderate degree of contamination, $16 < C_{deg} < 32$ = considerable degree of contamination and $32 < C_{deg}$ = very high degree of contamination.

RESULTS AND DISCUSSION

Distribution of total and species of trace metals in roadside dust samples.

Results in Table 2 indicate that, total cadmium (Cd) concentrations ranged between 1.23mg.kg^{-1} obtained in samples from Abak during week 2 and 2.29mg.kg^{-1}in samples from Uyo by week 4. The high concentrations of

cadmium in dust samples from Uyo may be attributed to high volume of traffic and commercial activities in the State capital as observed by Adedeji *et al*. [29]. Cadmium recorded a mean concentration of 1.72±0.35mg.kg^{-1}which is lower than 1.00mg.kg^{-1} reported in roadside dust from Edinburgh, Scotland by Sudip *et al*. [30] but higher than 2.60mg.kg^{-1} obtained by Al-Fatlawi and Al-wani [31] in roadside dust from Hilla city, Iraq. However, the mean Cd concentration recorded (1.72±0.35mg.kg^{-1}) is higher than 0.8mg.kg^{-1} recommended limit by FEPA. Thus, cadmium may pose serious environmental and health risk in areas studied as studies have shown the metal to be highly toxic [32, 33]. This alarming mean concentration of Cd may be attributed to anthropogenic sources of the metal and mostly motor vehicle emissions as reported by Balasubramanian *et al*. [34]. The distribution of cadmium in roadside dusts from the different locations studied was symmetrical as confirmed by the values of mean, median and skewness in Table 2. Results for sequential extraction of metals in Table 3 show that, cadmium existed mainly in acid extractable form (Aex) with 50.91% of the total fractions while residual (Res) fraction with 9.09% was the least form of the element obtained. Generally, the different forms of cadmium in samples investigated followed the order Aex>Red> Ox> Res with 50.91, 22.42, 17.58 and 9.09%, respectively. This high availability of Cd in acid extractable form may have resulted in the high mobility factor and high bioavailability exhibited by the metal. It may also be an indicative of anthropogenic sources of the metal in samples assessed. The dominant fraction of Cd in acid extractable fraction obtained in this study is similar to that reported by Tokalioglu and kartal [35] but different from principal fraction of Cd in reducible fraction recorded by Li *et al*. [36]. The high mobility of Cd in roadside dust indicated in Table 3 is similar to that obtained by Salmanzadeh *et al*. [37]. Speciation result of Cd has confirmed the toxic and high bioavailability of the metal in areas studied as indicated by the total cadmium result. Result in Table 2 has also shown that cadmium recorded highest values for mobility and bioavailability factors amongst the metals assessed.

The distribution of total chromium (Cr) in roadside dust from different locations studied varied from 1.27mg.kg^{-1} to 2.76mg.kg^{-1}. The highest Cr concentration was recorded at Uyo during week 2 while the lowest concentration was reported in Itu during week 1. This range is in agreement with that reported by Mafuyai *et al*. [38] in roadside dust from Jos metropolis, Nigeria but lower than the value recorded in roadside dust from Accra, Ghana by Atiemo *et al*. [21]. The mean concentration of Cr (1.78±0.47 mg.kg^{-1}) obtained in this study is lower than the recommended limit of 100mg.kg^{-1} for Nigerian soil by FEPA [39]. Concentrations of Cr in samples assessed indicated positively skewed distribution as affirmed by the mean being higher than the median in Table 2. Result obtained from speciation of Cr in dust samples studied indicated that, the element existed mainly in the acid extractable form while residual fraction was the least fraction. The general results followed the trend: Aex>Red>Ox>Res with percentage composition of 42.53, 27.01, 21.26 and 9.20, respectively. The existence of Cr predominantly in residual fraction is in agreement with the speciation results reported by Alomary *et al*. [40]. This study has shown that despite the lower mean Cr level obtained, the element can be highly bioavailable and toxic as indicated in Table 3. The result obtained has also shown that, Cr may have been available in areas studied mainly from anthropogenic source. The high mobility of chromium is indicated in the high mobility factor of 43%.

Concentrations of total copper ranged between 31.42mg.kg^{-1} obtained at Abak in week 3 and 78.14mg.kg^{-1} recorded at Ibeno during week 2 of this study. This range is higher than that reported by Abah *et al*. [41] in Namibia but lower than the one obtained by Shinggu *et al*. [42] in Adamawa, Nigeria. The high concentrations of copper in dust samples from Ibeno may be attributed to high industrial emissions in the area and overland transportation as reported by Thorpe and Harrison [43] and Han *et al*. [44]. The mean concentration of copper obtained in this work (59.10±16.56mg.kg^{-1}) is higher than 10.1ppm recommended limit by FEPA [39]. Hence, excessive inhalation of roadside dust from these locations may cause copper toxicity and its attendant's effects in human. Based on this finding, removal of roadside dust and the use of safety gadgets by environmental workers in these areas are encouraged. Results in Table 2 have also shown that, the distribution of copper in areas studied skewed to the left (negatively skewed) as the mean is lower than the median. Sequential extraction of copper in samples studied revealed that, the metal existed mostly in the silicate form (residual) and closely followed by copper bound to organic matter and sulphide (oxidisable) (see Table 3). Speciation of copper showed the following trend: Res>Ox>Red>Aex with 38.80, 30.08, 17.68 and 14.44%, respectively. The predominant availability of copper in residual fraction is similar to the report by Pickering [45] but different from result obtained by Banerjee [15] who reported major fraction of copper in oxidisable phase. Thus, the mean copper being higher than recommended limit may not really pose serious health threat since the metal existed more in the non-available fractions. The existence of more copper in the non-available fractions may have resulted in the low mobility and bioavailability factors of the metal recorded in this study.

Concentrations of total nickel (Ni) varied between 1.36mg.kg^{-1}at Itu during week 1 and 8.18mg.kg^{-1} obtained sample from Uyo in week 3 (see Table 2). This Ni range is higher than that reported by Bada and

Oyegbami [46] in roadside dust from Abeokuta, Nigeria but lower than Ni range recorded in samples from Edinburg, Scotland by Sudip *et al*. [30]. The high level of Ni in samples from Uyo may be attributed to the elevated number of vehicles in the city since Lu *et al*. [19] opined that, the major sources of nickel in roadside dust are corrosion of vehicular parts, fossil fuel combustion and vehicle oils. However, the mean concentration of Ni ($4.38\pm2.96 mg.kg^{-1}$) is lower than the recommended limit in Nigerian soil ($35.00 mg.kg^{-1}$) by FEPA [39]. Consequently, Ni may not pose serious health implications on the people inhaling dust from these locations but bioaccumulation of the metal and the associated effects should be avoided. The distribution of Ni in locations studied was symmetrical as the values of mean and median are close (Table 2). This is also affirmed by the value of skewness being close to zero. Speciation of nickel in dust samples collected revealed that the metal existed mainly in reducible fraction. This is different from the highest proportion of nickel in residual fraction obtained in dust samples by Salmanzadeh *et al*. [37]. Result recorded indicated the following trend: Red > Res > Ox > Aex. These different fractions showed compositions of 37.53, 33.07, 20.21 and 9.19%, respectively. This study has confirmed the strong association of Ni with Fe-Mn oxides reported by Tessier *et al*. [47]. Nickel result has also shown a combination of natural and anthropogenic sources of the metal in areas investigated. However, results obtained from total and sequential extraction of Ni indicated predominant natural source of the metal in areas examined. Results in Table 3 also corroborated the non-availability of nickel in the study area with bioavailability and mobility factor values of 09 and 0.09, respectively. These values were the lowest recorded in this research work thereby confirming the low bioavailability and mobility of the metal in areas studied.

A range of $38.14 – 148.27 mg.kg^{-1}$ was obtained for total zinc (Zn) in this work (Table 2). The highest level of Zn was recorded in samples from Ibeno in week 3 while the lowest concentration was reported in samples from Abak in week 4. This range is higher than that obtained by El-Sayed *et al*. [48] in Zagazig city, Egypt but lower than the range obtained by Shinggu *et al*. [42] in Adamawa, Nigeria. The high levels of zinc in Ibeno may be attributed to high vehicular movement that may result in tire and brake linings wear [4, 16, 17]. The mean concentration of Zn ($107\pm38.41 mg.kg^{-1}$) obtained is lower than $140 mg.kg^{-1}$stipulated for Nigerian soil by FEPA [39]. Thus, zinc may not pose a problem to those inhaling these roadside dusts based on results from total zinc and speciation. Distribution of zinc in roadside dust samples indicated that its concentrations shifted to the left (negatively skewed) as indicated by the values of mean and median in Table 2. Sequential extraction of zinc in dust samples revealed the existence of the metal principally in residual form; this is similar to that reported by Isen *et al*. [49]. Thus, the low bioavailability and predominant natural source of zinc in areas assessed were confirmed in this study. Speciation results recorded the following trend: Res>Ox>Red>Aex with 47.64, 26.73, 15.86 and 9.77, respect to percentage composition (Table 3). Notwithstanding, the essential nature of zinc for plants, animals and human excessive accumulation in living organism may be highly toxic [50]. Thus, prolong exposure to these roadside dusts should be avoided to forestall zinc toxicity and attendants' effects due to bioaccumulation with long exposure.

Total lead (Pb) concentrations ranged between $11.83 mg.kg^{-1}$ recorded in samples from Itu in week 3 and $93.52 mg.kg^{-1}$obtained at Ibeno during week 4 (Table 2). This range is higher than that reported by Mafuyai *et al*. [38] in roadside dust from Jos metropolis, Nigeria but lower than the range reported by Atiemo *et al*. [21] in dust samples from Accra, Ghana. The high lead concentrations in samples from Ibeno may be attributed primarily to the use of leaded gasoline in vehicles, wear of vehicle parts and intense oil activities in the area [18]. Nevertheless, the mean concentration of total Pb (54.87 ± 32.78 $mg.kg^{-1}$) is lower than 85 $mg.kg^{-1}$recommended limit for Nigerian soil by FEPA [39]. Thus, removal of dust at roadsides should be encouraged as speciation analysis has shown that Pb existed mostly in the readily available fraction. Results obtained also showed that, distribution of lead in areas studied skewed to the left with the median being higher than the mean (Table 2). Speciation of lead in roadside dusts obtained showed that the metal associated predominantly with Fe-Mn oxide (reducible fraction), this is in agreement with the reports by Alomary *et al*. [40] and Li *et al*. [36] from analyses of street dusts. Studies have shown that, Fe-Mn oxides are efficient scavenger for lead in soil thus, the predominant existence of this metal in reducible form may be due to Pb adsorption onto colloids of Fe-Mn [15, 51]. Speciation of Pb indicated the following trend: Red>Ox>Aex>Res with the following percentage composition 45.77, 27.06, 16.88 and 10.30 respectively (Table 3). The existence of high proportion of Pb in reducible fraction is an indicator of anthropogenic and natural sources of the metal in street dust.

Pollution intensity and risk assessment of trace metals in roadside dusts according to I_{poll} values.

Results of metal pollution intensity according to I_{poll} are shown in Table 4. Results obtained revealed that, cadmium, chromium and lead showed high level of risk while copper; nickel and zinc indicated low risk level. Thus, those exposed to these dust particles may be prone to having Cd, Cr and Pb toxicities and their associated health implications in the study areas.

Validation of Analytical Results.

In the absence of standard reference material (SRM), the analytical procedures employed and results obtained were validated using the percentage recovery of elements assessed. Percentage recovery was determined using the equation 3 above. Results obtained for percentage recovery as shown in Table 3 are as follows: Cd (96%); Cr (98%); Cu (96%); Ni (87%); Pb (95%) and Zn (96%). These results generally agreed with acceptable values stipulated by Gaithersburg *et al*. [52].

Pollution status of trace metals and locations studied.

The contamination level of trace metals in roadside dusts and degree of contamination in locations studied were assessed using contamination factor and degree of contamination were employed respectively as reported

by Rastmanesh *et al*. [53]. Contamination factor (CF) for metals analyzed for and degree of contamination (Cdeg) for locations studied are shown in Table 5. Results obtained indicated that, cadmium recorded CF values ranging from 5.24 in samples AK with class 3 (considerable contamination) to 8.56 recorded in samples UY which is in class 4 (very high contamination). The mean contamination factor of cadmium obtained (6.91) belongs to class 4 (very high contamination). Chromium indicated CF values ranging from 0.01(low contamination) in samples IT to 0.03 (low contamination) in samples UY. The mean CF value of Cr (0.02) is within the low contamination class. The CF values of copper ranged between 0.37 (low contamination) in sample AK and 1.41 (moderate contamination) recorded in samples IB. Cu indicated a mean CF value of 1.03 which is in class 2 (moderate contamination). Contamination factors recorded by nickel varied between 0.02 (low contamination) reported in samples IK, Ak and IT and 0.10 (low contamination) in samples UY and IB. Nickel recorded a mean CF value of 0.06 which is in class 1 (low contamination). This study recorded contamination factors of lead ranging from 0.88 (low contamination) in samples IK to 3.92 (considerable contamination) reported in samples UY. Lead recorded a mean CF value of 2.75 which is in class 2 (moderate contamination). Contamination factors of zinc varied between 0.65 (low contamination) in samples IK and 2.12 (moderate contamination) recorded in samples IB. Zinc indicated a mean CF value of 1.53 in class 2 (moderate contamination). Contamination factor of the different metals studied followed a trend: Cd>Pb>Zn>Cu>Ni>Cr indicating that, cadmium recorded the highest contamination level while chromium indicated the lowest contamination in areas studied. The high contamination exhibited by cadmium in this study is similar to findings reported in roadside dusts by Awadh [54] in Karkh district of Baghdad. Results obtained for Cdeg revealed that, all the locations studied were within moderate degree of contamination as proposed by Hakanson [28] except Ibeno with considerable degree of contamination. Degree of contamination obtained followed the trend: IB > UY > EK > IK> IT> AK revealing Ibeno as the location with highest level of contamination while Abak showed the lowest degree of contamination. As shown in Table 5, the high degree of contamination in Ibeno was closely followed by that in Uyo. The high contamination level in samples from these areas may be attributed to the intensive oil exploration and exploitation activities and Uyo being the state capital respectively. These have resulted in elevated number of vehicles, high population, intensive commercial and oil related activities and contamination from these activities at the two locations.

TABLE 2. Statistical distribution of trace metals in roadside dust within Akwa Ibom State.

	Cd	Cr	Cu	Ni	Pb	Zn
SUM	41.38	42.78	1418.70	105.06	1316.88	2572.14
MIN	1.23	1.27	31.42	1.36	11.83	38.14
MAX	2.29	2.76	78.14	8.18	93.52	148.27
MEAN	1.72	1.78	59.10	4.38	54.87	107.17
SD	0.35	0.47	16.56	2.96	32.78	38.41
MEDIAN	1.73	1.62	66.34	4.11	58.24	110.19
SKEWNESS	0.05	1.09	-0.61	0.04	-0.07	-0.65

TABLE 3. Mean concentration (mg.kg^{-1}) and percentage of the different forms of trace metals in roadside dust.

	AEX F1	%	RED F2	%	OX F3	%	RES F4	%	TF	TM	% REC	MF	BF
Cd	0.84	50.91	0.37	22.42	0.29	17.58	0.15	9.09	1.65	1.72	96	51	0.51
Cr	0.74	42.53	0.47	27.01	0.37	21.26	0.16	9.20	1.74	1.78	98	43	0.43
Cu	7.61	14.44	10.01	17.68	17.03	30.08	21.97	38.80	56.62	59.10	96	13	0.13
Ni	0.35	9.19	1.43	37.53	0.77	20.21	1.26	33.07	3.81	4.38	87	09	0.09
Pb	8.77	16.88	23.78	45.77	14.06	27.06	5.35	10.30	51.96	54.87	95	17	0.17
Zn	10.09	9.77	16.37	15.86	27.60	26.73	49.18	47.64	103.24	107.17	96	10	0.10

TF = Total fraction; TM = Total metal; % Rec. = Percentage recovery; MF = Mobility Factor; BF = Bioavailability Factor.

TABLE 4. Contamination classes according to I_{poll} index (Karbassi *et al*., 2008)

Level of pollution	Pollution intensity class	Element	I_{poll}	Risk Assessment
Extremely polluted	> 5	Cd	3.5	Highly polluted
Strongly polluted	4 – 5	Cr	3.5	Highly polluted
High polluted	3 – 4	Cu	1.4	Low polluted
Moderately polluted	2 - 3	Ni	1.8	Low polluted
Low polluted	1 – 2	Pb	3.4	Highly polluted
Unpolluted	< 0 – 1	Zn	1.1	Low polluted

TABLE 5. Contamination factor (CF) of Trace metals in roadside dusts.

	Cd	Cr	Cu	Ni	Pb	Zn	C_{deg}
UY	8.56	0.03	1.28	0.10	3.92	2.05	15.94
IK	7.56	0.02	1.16	0.02	0.88	0.65	10.29
EK	6.24	0.02	1.26	0.10	4.35	1.80	13.77
IB	8.36	0.02	1.41	0.10	4.63	2.12	16.64
AK	5.24	0.02	0.37	0.02	1.41	1.19	8.25
IT	5.48	0.01	0.68	0.02	1.28	1.39	8.86
Mean	6.91	0.02	1.03	0.06	2.75	1.53	12.30

TABLE 6. Results of geoaccumulation index (Igeo) of Trace metals in roadside dusts.

	Cd	Cr	Cu	Ni	Pb	Zn
UY	2.51	-5.88	-0.24	-3.94	1.39	0.45
IK	2.33	-6.51	-0.36	-6.06	-0.78	-1.22
EK	2.06	-6.66	-0.25	-3.97	1.54	0.26
IB	2.48	-6.21	-0.09	-3.97	1.63	0.50
AK	1.80	-6.69	-1.15	-6.27	-0.09	-3.34
IT	1.87	-6.78	-1.15	-6.27	-0.24	-0.11
Mean	2.18	-6.46	-0.54	-5.08	0.58	-0.58

Geoaccumulation index (Igeo) is one of the recent models used for the examination of pollution indices in an environment. Results obtained as shown in Table 6 indicate that, cadmium recorded Igeo values ranging from 1.80 (class 2) in samples AK to 2.51 (class 3) in samples UY. The mean Igeo value recorded for Cd (2.18) is in moderate to strongly contaminated class. Chromium, copper and nickel recorded negative Igeo values in all the samples indicating the unpolluted nature of these elements in areas studied. This is similar to the negative Igeo indices for these elements in road dust samples in Bolgatanga municipality, Ghana reported by Adugyamfi *et al*. [55]. Lead indicated negative Igeo values in samples IK, AK and IT while samples UY, EK and IB showed positive values of 1.39, 1.54 and 1.63 respectively. Consequently, samples IK, AK and IT may not have been contaminated by Pb however, Igeo values of the metal were in class 2(moderately contaminated) in samples UY, EK and IB. The mean Igeo index of lead (0.58) is in the contaminated to moderately contaminated class. This has shown that, lead may have contaminated samples obtained from Uyo, Eket and Ibeno as indicated by their degree of contamination in Table 5. Zinc also indicated negative Igeo indices in samples IK, AK and IT but positive Igeo values in samples UY, EK and IB. This has shown that, zinc may have been one of the major contributors to the high degree of contamination reported at these three locations.

TABLE 7. Correlation Coefficient of trace metals in roadside dusts.

	Cd	Cr	Cu	Ni	Pb	Zn
Cd	1.000					
Cr	0.865	1.000				
Cu	0.857	0.624	1.000			
Ni	0.639	0.628	0.829	1.000		
Pb	0.536	0.513	0.764	0.981	1.000	
Zn	0.422	0.539	0.513	0.876	0.912	1.000

Metal – metal relationship

Pearson correlation analysis was employed to assess the interrelationship between trace metals evaluated and possible identify the ones from common source as indicated by Romic and Romic [56]. Results in Table 7 indicated that, cadmium showed strong positive relationship with chromium and copper at 99% confidence with r values of 0.865 and 0.857, respectively. Cadmium also indicated a significant positive correlation with nickel but at 90% confidence limit with r = 0.639. Thus, cadmium may have originated from the same source with chromium, copper and nickel which may be a consequence of land transportation [16]. However, cadmium showed positive but insignificant correlation with lead and zinc (r = 0.536 and 0.422, respectively). Consequently, source of cadmium in roadside dust may not have supplied substantial quantity of lead and zinc. Chromium correlated positively and significantly with copper and nickel at 90% confidence limit with r values of 0.624 and 0.628 respectively. Accordingly, these metals may have originated from the same source which could be corrosion of vehicular parts as reported by Lu *et al*. [19]. Nevertheless, chromium showed insignificant positive relationship with lead and zinc with r values of 0.513 and 0.539, respectively. Thus, the source of chromium in roadside dust assessed may not have supplied adequate quantities of Pb and Zn. The relationship between copper and nickel indicated a strong positive one at 98% confidence limit with r = 0.829. Copper also correlated positively and significantly with lead but at 95% confidence limit with r = 0.764. This indicated that, the source of copper in roadside dust assessed may have been similar to those of nickel and lead, this common source could have been wear of brake linings and other vehicle parts [43]. However, copper correlated positively with zinc but insignificantly with value of 0.513. Thus, the source of copper in dust samples

examined may not have contributed substantial amount of zinc to these samples. Nickel showed strong positive association with lead and zinc at 99% confidence limit with r values of 0.981 and 0.876, respectively. Consequently, corrosion of vehicular parts, combustion of fossil fuel and vehicle oils which are the major sources of nickel in roadside dust may have supplied appreciable quantities of Pb and Zn to dust samples assessed. Lead correlated positively and significantly with zinc at 99% confidence limit with r = 0.912. This corroborates the report by Han *et al*. [44] that, the wear of brake linings is a common source for lead and zinc in roadside dust.

CONCLUSION

This study has shown that inhalation of dust particles from the different locations studied may cause metal and their attendants health implications in human. it has also been identified in this research work that, cadmium, chromium, nickel and lead were in available forms while copper and zinc were in the non-available form. Samples obtained from Ibeno and Uyo showed very high degree of contamination whereas, samples from Abak indicated the lowest degree of contamination. Based on models employed in this study, cadmium and lead were confirmed as metals in high risk class. Common associations and sources were reported for metals evaluated based on Pearson correlation analysis. The outcome of this study has shown that, environmental workers, traffic police officers and those residing by roadside should be properly educated on the health implications of what they are exposed to and some preventive measures provided.

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.

Persian Abstract

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چکیده

گرد و غبار کنار جاده ای در یک جاده پر رفت و آمد در منطقه ای از نیجریه جهت تعیین مقادیر کادمیوم، کروم، مس، نیکل، روی و سرب مورد ارزیابی قرار گرفت. نتایج حاکی از آن است که مقادیر متوسط کادمیوم و مس بیشتر از بقیه فلزات مورد بررسی و همچنین سطح غلظت کروم، نیکل، روی و سرب کمتر از مقدار استاندارد است. کادمیوم و سرب خطرناک ترین موارد در میان موارد مورد ارزیابی است. نتایج نشان از مقدار بالای کادمیوم در گرد و غبار کنار جاده ای در این منطقه دارد..