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MULTIVARIATE STATISTICAL ANALYSIS OF HEAVY METALS IN STREET DUST OF OWERRI METROPOLIS, NIGERIA

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ABSTRACT

Samples of urban dusts collected from five locations in Owerri metropolis in May and July were investigated for heavy metal levels. Results revealed mean concentrations per dry weight of 3.00µg/g, 43.59 µg/g, 15032.00 µg/g, 43.22 µg/g, 78.64 µg/g and 312.29 µg/g of Cr, Cu, Fe, Ni, Pb and Zn respectively. Significant positive correlation was established between pH and metals while Cr/Cu and Zn/pH in all sites was unity. Using principal component analyses two components were extracted, the most important having the following percentage variances: Site I: 76.99%; Site II: 6.98%; Site III: 70.70%; Site IV: 55.90% and Site V: 65.57%; with high contributions for five variables Pb, Cu, Zn, Fe,Ni, and Cr in Site I; Pb, Fe, Zn, Cr and Cu in Site II and Pb, Fe, Zn, Cu and Cr in Site III; were deemed to be technogenic/anthropogenic. The second principal component, had high loadings for Ni in Sites II, III and IV. Some metals (Cu, Fe, Pb and Zn) were always clustered together in the same group for each study location implying a similarity in behaviour and common origin. Their cycling was also pH dependent. Generally, the metals occurred in levels that are below regulatory intervention limits.

KEYWORDS: street dust, technogenic, lithogenic, correlation, clusters.

INTRODUCTION

Heavy metal in roadside dust is increasingly becoming an issue of global concern as it constitutes a crucial component of urban environment and an ecological crossroad in the environment (Thuy et al, 2000). Important heavy metals in street dust are As, Cd, Cr, Hg, Pb and Zn which may be derived from sources such as weathering of natural background rocks, metal deposits and anthropogenic activities like industrial, foundries, vehicular exhaust emissions and wear and tear of vehicle tyres (Alloway, 1995). They have been found to exist in street dust in high concentrations and in soils along heavily travelled highways and foundries. These dusts are composed of particles of various sizes, some of which can penetrate the pulmonary region of the human respiratory system, if inhaled, causing adverse health effects (Harrison and Wilson, 1983; WHO, 2000; CONCAWE, 1992; De Miquel et al, 1997). Storm runoff could propel contaminated street dust into adjourning water bodies, thus making them to be adversely impacted. The biota in the water bodies may also be subjected to uptake which could be transferred via many trophic levels impacting on man as the ultimate consumer. Owerri metropolis hosts high economic activities and is vulnerable to pollution from various heavy metal sources. It is also vulnerable to pollution from vehicular emissions. The need to evaluate the extent of pollution of the environment, possible impacts of the observed levels on man who is the ultimate consumer in the food chain and also the assessment of the input sources necessitated this study. Unfortunately, information regarding the levels of these metals in road/street dust in Owerri metropolis is limited. This study determines the levels and distribution of heavy metals in the study area as well as assesses the contribution of street dust to heavy metal pollution in Owerri metropolis.

METHODOLOGY

Study Area

Owerri metropolis has a humid tropical climate characterized by the hot and wet conditions, which is associated with the movement of the inter-tropical convergence zone (ITCZ) north and south of the equator and has two major seasons, the dry and wet seasons. It is located within latitudes 5^o 29' to 7^o 15' and longitude 6^o 50' E and 7^o 25'E The geological material in the study area is of coastal plain sands (Benin formation) of the Oligocene – Miocene era. The soil characteristics are laterite material under s superficial layer of fine grained sand. It also has impermeable layer occurring near the surface. The formation, which is of late tertiary age, is rather deep, porous, infertile and highly leached. The geography is on low-land (Onyeagocha, 1980).

The population density of the study area was estimated to be over 5.5 million in 2007 and is expected to be over 6 million by the year 2012. Vital resources of life such as air, water and land are increasingly contaminated in the wake of population growth, agricultural activities, industrialization and other anthropogenic activities in the area.

Owerri has an average rainfall ranging from 2250 – 2500mm, average relative humidity of 75% which is the highest during the rainy season, when it rises to about 90%. It has a mean annual temperature range of 27 – 29^{o}C. Since temperature varies only slightly, rainfall

distribution becomes a single most important factor (Abu and Egeronu, 2004).
The vegetation in the study area is highly altered by anthropogenic activities such as farming, sand mining, deforestation for fuel wood and operation of automobile services.

Sampling
Five sites in Owerri metropolis were selected in order to capture the effect of traffic density and other sources of heavy metals in roadside dust as follows:

Sampling Site	Location	Coordinates	Activities in the Location
I	Wetheral Road	05^o 28. 751', 007^o 02.396'	Foundries, furniture/woodwork workshop and less traffic
II	Naze Road	05^o 28. 306', 007^o 02.224'	Car wash, discarded vehicles, petrol station, intense vehicular activities, auto mechanic workshop village, municipal open solid waste dump site Various transport garages, less traffic density
III	Egbu Road	5^o 28. 733', 007^o 02.584'	Heavy traffic and motor park activities Very heavy traffic and many power generating
IV	Okigwe Road	5^o 29. 431', 007^o 01.907'	sets due to high level of commercial activities here
V	Douglas Road	5^o 29. 265', 007^o 01.804'	

Samples consisted of loose materials (dust, sand, earth, etc) which were collected by sweeping the roadsides. They were packed using clean plastic tools and stored in polyethylene bags (Akther and Mandany, 1993). A total of 15 samples were collected from the five sites during three consecutive sampling times in the months of May, June and July. Standard sample collection, preservation and analytical procedures were followed (Akhionbare, 2009).

Sample Pre-treatment and Analysis
The dust samples were air dried and sieved using 850µm sieve and pulverized using a shatter-box grinding mill and further sieved using a 250µm. 2g of each sample was digested using $HClO_4$ and concentrated HNO_3 with gentle heating. The mixture was heated to dryness, allowed to cool and 50ml of distilled water added. It was filtered, transferred to a 100ml standard flask and made up to the mark.
Portions of each filtrate was analyzed for Pb, Cr, Cu, Fe, Ni and Zn using a BUCK SCIENTIFIC MODEL 200A Atomic Absorption Spectrophotometer with air/acetylene flame.
Sample pH was carried out using a 1:2.5 (w/v) sample/water suspension.
Analytical data on the concentrations of the heavy metals in samples were subjected to one way analysis of variance (ANOVA) to test significance of differences between site means. The relationship between pairs of continuous variables were tested using Pearson product moment correlation. Principal component analysis (PCA) was used to assess input source. All statistical analyses were done using SPSS 10.00 and Analysis Tool pack software, with significance based on an α of 0.05.

RESULTS AND DISCUSSION
Table 1 shows the levels of heavy metals obtained in samples of street dust collected from the five sampling points in Owerri metropolis. Table 2 shows the result of the analysis of variance (ANOVA) for the data while Tables 3 -8 show the results of the Pearson Product Moment Correlation Coefficient and PCA factor loadings for the heavy metals studied at the various sampling sites.

pH
The mean level of 7.79 recorded in this study is within permissible limits (DPR, 2002). There was no significant difference between site pH means at P>0.5. pH also correlated positively with a considerable number of the heavy metals at the locations. This indicates that the immobilization of these metals in street dusts is pH dependent (Al-Khashman, 2004).

Cr, Cu, Fe, Ni, Pb and Zn
Levels of these heavy metals recorded in this study (Cr: 3.0, Cu 43.59, 15032, 43.22, 78.64 and 312.29 µg/g dry weight) were below intervention limit (DPR, 2002). There were also no significant difference in values at the various sites. Levels also correlated with each other in most of the sites implying that the cycling of these metals is related (Akhter and Madany, 1993). Levels of Cr in street dusts may be from chemicals, manufacturing and trading on textiles, metal alloys, paints, cement, paper, rubber and other materials in use in the study sites. Cu and Zn may have been derived from mechanical abrasion of brake linings, oil leak sumps, etc. Fe, however, has no limit to its concentration in street dust because it is a geochemical component. It may have been largely lithogenic in source in this study. Pb may have originated from vehicular emissions (Al-Khashman, 2004).

Results of Principal Component Analysis (PCA)
Two principal components or groups of metals (PC1 and PC2) were extracted from the street dusts in site I (Wetheral Road) and accounted for 76.99% and 23.01% of the total variance. The first principal component (PC1) had significant positive loadings in Pb, Fe, Zn, Cu, Cr and Ni while the second (PC2) had positive loadings in Cr and Pb implying that the likely input sources of the metals on Wetheral Road are from anthropogenic/technogenic activities. Similarly, for Site II, PC1, expressing about 67.98% includes metals that are from anthropogenic activities (Pb, Fe, Zn, Cu and Cr) while group 2 (32.02%) includes Fe and Ni. PC1 for Site III with a variance of

70.70% includes Pb, Fe, Cu and Cr while PC2 (29.30%) includes Pb, Ni and Zn. For Site IV, group 1 (55.90% of the total variance) consists mainly of Ni and Zn which are mainly of anthropogenic origin while group 2 (44.10%) includes Fe which is a geochemical component as suggested by its persistent levels. Ni could also come from bush fires, weathering of soils and geological materials (Knox et al, 1999) and Zn could originate from smelting, bio-solids, sewage, mining and refining. For Site V, two principal components were extracted, which was contributed by most of the heavy metals except Cr and Ni, which were mainly anthropogenic in origin. This, therefore indicates that the source of Cu, Pb, Fe and Zn was different from that of the other metals. However, Cr may originate from sludge, solid waste, tanneries while Ni may come from furniture works, automobile body materials, deteriorating paint and building materials, landfills amongst other sources (De Miquel et al, 1997).

TABLE 1. Ranges and Means of Heavy Metals in Street Dust Samples in Owerri Metropolis Sampling Sites

Quality Parameters	I	II	III	IV	V
pH	7.71 – 7.36 (7.52 ± 0.18)	8.02 - 7.72 (7.89 ± 0.16)	8.20 – 7.65 (7.90 ± 0.28)	7.95 – 7.72 (7.83 ± 0.12)	7.92 – 7.74 (7.84 ± 0.09)
Pb (µg/g)	160.65 – 115.27 (144.96 ± 25.72)	64.18 – 32.63 (46.61 ± 16.06)	32.98 - 27.01 (29.85 ± 2.99)	79.66 – 76.46 (78.26 ± 1.62)	102.01 – 83.23 (93.51 ± 9.52)
Cr (µg/g)	3.01 – 2.99 (3.00 ± 0.01)	3.00 – 2.98 (2.99 ± 0.01)	3.01 – 2.98 (2.99 ± 0.01)	3.02 – 2.99 (3.00 ± 0.01)	2.99 – 2.98 (2.98 ± 0.00)
Zn (µg/g)	307.89 – 288.74 (297.07 ± 9.82)	324.63 – 307.91 (317.36 ± 8.57)	334.51 – 304.53 (318.12 ± 15.18)	320.98 – 308.18 (314.16 ± 6.44)	319.02 – 315.75 (314.77 ± 4.82)
Fe (µg/g)	16745.99 – 14624.32 (14755.49 ± 185.51)	16028.26-14526.92 (14612 ± 121.17)	15677.28 – 14974.44 (15325.86 ± 496.98)	16236.87 – 15758.08 (15638.16 ± 846.71)	16352.06 – 14585.10 (14832.52 ± 349.86)
Cu (µg/g)	63.32 – 36.27 (53.56 ± 15.03)	50.93 – 25.84 (40.65 ± 13.15)	62.38 – 34.96 (45.35 ± 14.87)	68.79 – 39.72 (50.97 ± 15.61)	32.67 – 21.71 (27.39 ± 5.44)
Ni (µg/g)	52.71 – 38.39 (43.69 ± 7.85)	46.77 – 39.76 (43.16 ± 3.51)	45.33 – 40.16 (43.43 ± 2.85)	43.73 – 38.71 (41.81 ± 2.71)	49.95 – 36.42 (43.99 ± 6.91)

TABLE 2: Results of one-way ANOVA for the Samples at the Various Sites

Quality Parameter	P – Value
Cr	0.20583
Pb	1.64343E-05
Ni	0.9871879
Zn	0.116563029
Fe	0.9191159
Cu	0.20583
pH	0.116563029

TABLE 3.1. Results of Pearson Correlation for Heavy Metals in Wetheral Road

	Pb	Zn	Cu	Fe	Ni	Cr	pH
Pb	1						
Zn	0.711887	1					
Cu	0.994424	0.781979	1				
Fe	0.568029	0.982366	0.651653	1			
Ni	0.380083	0.920165	0.475506	0.977142	1		
Cr	0.994424	0.781979	1	0.651653	0.475506	1	
pH	0.711887	1	0.781979	0.982366	0.920165	0.781979	1

TABLE 3. 2. Results of Pearson Correlation for Heavy Metals in Naze Road

	Pb	Zn	Cu	Fe	Ni	Cr	pH
Pb	1						
Zn	0.520495	1					
Cu	0.876895	0.866857	1				
Fe	0.975633	0.320468	0.750063	1			
Ni	-0.62145	0.345502	-0.16835	-0.77820	1		
Cr	0.876895	0.866857	1	0.750063	-0.16835	1	
pH	0.520495	1	0.866857	0.320468	0.345502	0.866857	1

TABLE 3.3. Results of Pearson Correlation for Heavy Metals in Egbu Road

	Pb	Zn	Cu	Fe	Ni	Cr	pH
Pb	1						
Zn	0.692031	1					
Cu	-0.20595	-0.84892	1				
Fe	0.9171	0.922439	-0. 57899	1			
Ni	0.8772543	0.251167	0.298365	0.605451	1		
Cr	-0.20595	-0.84892	1	-0.57899	0.298365	1	
pH	0.692031	1	-0.84892	0.922439	0.251167	0.84892	1

TABLE 3.4. Results of Pearson Correlation for Heavy Metals in Okigwe Road

	Pb	Zn	Cu	Fe	Ni	Cr	pH
Pb	1						
Zn	-0.74459	1					
Cu	0.639911	0.036489	1				
Fe	-0.42261	-0.29031	-0.96689	1			
Ni	-0.06115	0.711808	0.727879	-0.87877	1		
Cr	0.639911	0.036489	1	-0.96689	0.727879	1	
pH	-0.74459	1	0.036489	-0.29031	0.711808	0.036489	1

TABLE 3.5. Results of Pearson Correlation for Heavy Metals in Douglas Road

	Pb	Zn	Cu	Fe	Ni	Cr	pH
Pb	1						
Zn	0.999893	1					
Cu	0.672506	0.683267	1				
Fe	0.423803	0.437016	0.955351	1			
Ni	-0.46356	-0.47648	-0.96752	-0.99902	1		
Cr	0.672506	0.683267	1	0.955351	-0.96752	1	
pH	0.999893	1	0.683267	0.437016	-0.47648	0.683267	1

TABLE 4: PCA Factor Loadings for Heavy Metals in Sampling Site I (Wetheral Road)

Quality Parameter	Factor 1	Factor 2
Pb	0.859	0.513
pH	0.971	-0.238
Fe	0.971	-0.238
Zn	0.908	0.415
Cu	0.910	-0.415
Cr	0.688	0.726
Ni	0.801	-0599
Var.%	76.99	23.01

TABLE 5. PCA Factor Loadings for Heavy Metals in Sampling Site II (Naze Road**)**

Quality Parameter	Factor 1	Factor 2
Pb	0.977	-0.215
pH	0.692	0.722
Fe	0.692	0.722
Zn	0.960	0.281
Cu	0.906	-0.424
Cr	0.956	-0.294
Ni	-0.439	0.899
Var.%	67.98	32.02

TABLE 6. PCA Factor Loadings for Heavy Metals in Sampling Site III (Egbu Road)

Quality Parameter	Factor 1	Factor 2
Pb	0.754	0.657
pH	0.996	-9.00E-02
Fe	0.996	-9.00E-02
Zn	-0.798	0.603
Cu	0.953	0.302
Cr	0.859	-0.513
Ni	0.337	0.941
Var.%	70.70	29.30

TABLE 7: PCA Factor Loadings for Heavy Metals in Sampling Site IV (Okigwe Road)

Quality Parameter	Factor 1	Factor 2
Pb	0.426	-0.905
pH	0.287	0.958
Fe	0.287	0.958
`Zn	0.968	-0.251
Cu	-1.000	-3.89E-03
Cr	-0.928	0.372
Ni	0.877	0.481
Var.%	55.90	44.10

TABLE 8. PCA Factor Loadings for Heavy Metals in Sampling Site V (Douglas Road)

Quality Parameter	Factor 1	Factor 2
Pb	0.857	0.527
pH	0.857	0.515
Fe	0.857	0.515
Zn	0.962	-0.274
Cu	0.838	-0.546
Cr	-0.174	0.985
Ni	-0.861	0.509
Var.%	65.57	34.43

Principal component analyses revealed two components extracted in each sampling site. The most important components had the following percentages of the total variance: Site I: 76.99%; Site II: 6.98%; Site III: 70.70%; Site IV: 55.90% and Site V: 65.57%. These had high contributions for five variables Pb, Cu, Zn, Fe,Ni, and Cr in Site I; Pb, Fe, Zn, Cr and Cu in Site II and Pb, Fe, Zn, Cu and Cr in Site III and are deemed to be technogenic and anthropogenic in origin. The second principal component, with high loadings Ni in Sites II, III and IV are considered as technogenic alone as a result of deteriorating building materials, old motor scraps in automechanic workshops found in these sites, in addition to lithogenic factors.

The levels of Pb in the various sampling sites are in the order of decreasing magnitude as follows: Wetheral Road (144.96)>Douglas Road (93.52) > Okigwe Road Road (78.26) > Naze Road (46.61) > Egbu Road (29.85). This indicates that there is significant difference between site means ($P<0.5$). Pb also correlates with Cu and Cr in Okigwe Road, Zn, Cu and Cr in Douglas Road, Zn, Cu, Fe and Cr in Naze in Wetheral Roads and with Zn and Ni in Egbu Road. The implication of this is that the cycling of the correlated metals in the environment is related (Akhther and Madany, 1993). It further imples that Pb in the street dust may have originated from vehicular emissions (Al-Khashman, 2004). Generally also, the correlation coefficient for Cr/Cu and Zn/pH in all sites was unity (1.0000) throughout the study period.

Generally, certain metals were always clustered together in the same group for each site studied. These metals may be potentially bio-available and /or toxic especially as their cycling in the environment is pH dependent. The presence of some metals in the same group(s) reflects a similar behaviour and also suggests common sources.

SUMMARY

Principal component analyses revealed two components extracted in each sampling site. The most important components had the following percentages of the total variance: Site I: 76.99%; Site II: 6.98%; Site III: 70.70%; Site IV: 55.90% and Site V: 65.57%; with high contributions for five variables Pb, Cu, Zn, Fe,Ni, and Cr in Site I; Pb, Fe, Zn, Cr and Cu in Site II and Pb, Fe, Zn, Cu and Cr in Site III; were deemed to be technogenic and anthropogenic. The second principal component, with high loadings Ni in Sites II, III and IV are considered as technogenic alone as a result of deteriorating building

materials, old motor scraps in automechanic workshops in addition to lithogenic factors.

pH correlated significantly with the levels of some heavy metals namely: Ni and Zn in Okigwe Road, Cu, Cr, Pb and Zn in Doudglas Road, Cr, Cu, Pb and Zn in Naze Road, Cu, Cr, Fe, Pb Ni, Zn in Wetheral Road, and Cr, Pb, Fe and Zn in Egbu Road. Ni and Zn are from a common source in Okigwe Road; Pb, Fe, Zn, Cr, Ni and Cu are from a common source in Douglas Road. The cycling of Pb, Fe, Zn, Cr and Cu are pH dependent; Pb, Fe, Zn, Cu, Cr and Ni are from a common source on Wetheral Road. Pb, Fe, Zn, Cu and Cr are from a common sources in Naze Road; Pb, Fe, Cu, Cr

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