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Evaluation of Heavy Metal Contents in Road Dust of Jalingo, Taraba State, Nigeria

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Abstract

The investigation of the anthropogenic contamination by heavy metals on road surface is very necessary for environmental planning and monitoring in urban towns. In the presentstudy, the concentration of five heavy metals (Fe, Pb, Cd, Cu and Zn) in dust samples, from two major township roads -Hammaruwa Way (HW) and Palace Way (PW) in Jalingo metropolis, were analyzed using Atomic Absorption Spectrophotometer. The pollution status was assessed using Sediment Quality Guidelines (SQG), Geo-accumulation index (Igeo), Degree of Contamination (CD), Pollution Load Index (PLI) and Enrichment Factor (EF). Results of SQG, Igeo, CD and PLI show that these urban roads are not polluted. Analysis of the Enrichment Factor shows that apart from Pb, all other metals analyzed are enriched and the enrichment comes from anthropogenic activities. This implies that the soils are contaminated to some degree but not polluted. It is evident that the concentration of these heavy metals may increase and pose health hazards at the long run if proactive steps are not taken to check vehicular pollution.

Keywords: heavy metals, pollution, road dusts, anthropogenic, contamination

1. Introduction

Heavy metals occur either naturally in the soil through a pedogenic process of weathering of parent materials or by anthropogenic activities. However, naturally occurring heavy metals are rarely toxic and pose little or no threat to the soil ecosystem. Increased concentrations of heavy metals are caused by anthropogenic activities and may lead to high risks to human health, plants and animals, among others. Anthropogenic heavy metals pollution may occur through different diffuse and point sources (El-Hassan *et. al.*, 2006). Traffic activities are examples of diffuse sources, while industrial emissions (e.g., from power plants, coal combustion, chemical plants, etc.) are examples of point sources. Traffic activities on roads can lead to elevated levels of heavy metals in the environment through vehicular exhaust and non-exhaust emissions. Exhaust emissions are produced during incomplete combustion of vehicle fuel which is a mixture of hydrocarbons and compounds that improve combustion properties. Several types of pollutants such as Carbon monoxide, Nitrogen dioxide, polycyclic aromatic hydrocarbons (PAHs) and particulate matter are generated during this process. Non-exhaust emissions are generated through mechanical (e.g., braking, clutch usage, tire wear and road abrasion) and chemical processes (e.g., corrosion of vehicle elements). It was reported that topsoil and road side soils near heavy traffic in urban areas are indicators of heavy metal contamination from atmospheric deposition (Arowolo *et. al.*, 2000). Metals such as Cd, Cu, Pb and Zn are good indicators of contamination in soils because they appear in gasoline, car component, oil lubricants and industrial incinerators emissions (Popoola*et. al.*, 2012). The degree of emissions of pollutants originating from road traffic are affected by vehicle age, fuel type and quality, wide variety of vehicle (e.g., passenger cars, trucks, etc.) and engine types (e.g., diesel or gasoline powered engine), type of tire, road conditions and traffic conditions (e.g., heavy or light traffic), etc.

Regular monitoring and assessment of heavy metals pollution in our environment are necessary in order to study the impact of developmental projects on the environment. To assess the severity of soil contamination and to distinguish between natural and anthropogenic inputs in the soil, several approaches have been applied,such as Enrichment Factor (EF), Geo-accumulation Index (Igeo), Pollution Load Index (PLI) and Sediment Quality Guidelines (SQG) (Barakat *et. al.*, 2012; Manoj and Padly, 2012; Salah *et. al.*, 2012).

Jalingo witnessed vehicular traffic congestion on the major roads in the past decade and vehicular pollution has not been checked by environmental regulatory authorities, leading to elevated levels of pollution. The situation is worrisome and might be attributed to the poor economic disposition of Nigerians, large importation of old and fairly-used cars, the poor vehicle maintenance culture causes an increase in the emissions of dangerous substances through the exhaust

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pipes of vehicles; and a large number of irreparable and decomposing car parts litter the road surfaces and roadsides. These expose the residents to serious health risks. In Nigeria, the State Environmental Protection Agency (SEPA) and the Federal Environmental Protection Agency (FEPA) are saddled with the responsibility of enforcing environmental laws, regulations and standards in order prevent people, industries and organizations from polluting the environment. Unfortunately, these bodies have not lived up to expectation as their impact is not felt. Presently, there is neither a legislative frame work nor a set standard in the state to monitor emissions from mobile sources. Therefore, there is a need to investigate the extent of pollution from vehicular sources in this town. Furthermore, despite the vast majority of studies on metal contents of street dust done in developed countries with long histories of industrialization, relatively very few of such studies were done in developing countries like Nigeria. Little interest has been focused on metal contamination of street dust despite its direct contact with a great part of the population. The present study aims at using the various contaminant assessment indices to assess the pollution levels in road dusts. The expected results of the present study will assist the public and the concerned authorities in planning adequate pollution control measures.

2. Materials and Methods

2.1. Study Area

Jalingo is a rapidly growing city in the North-Eastern region of Nigeria. It is the administrative headquarters of Taraba State which is located between latitude 6°30' and 8°30' N and between Longitude 9°00' and 12°00' E (Figure 1). The state has a tropical wet and dry climate, the dry season lasts for a minimum of five months (November to March) while the wet season spans from April to October. It has an annual rainfall of about 8000 mm. According to the 2006 census figures released by the National Population Commission, Nigeria, Jalingo has a total population of 118,000 inhabitants. Jalingo is a city with no major industry. The major pollution source is the emission from traffic and power generating sets and human activities such as indiscriminate dumping of waste.

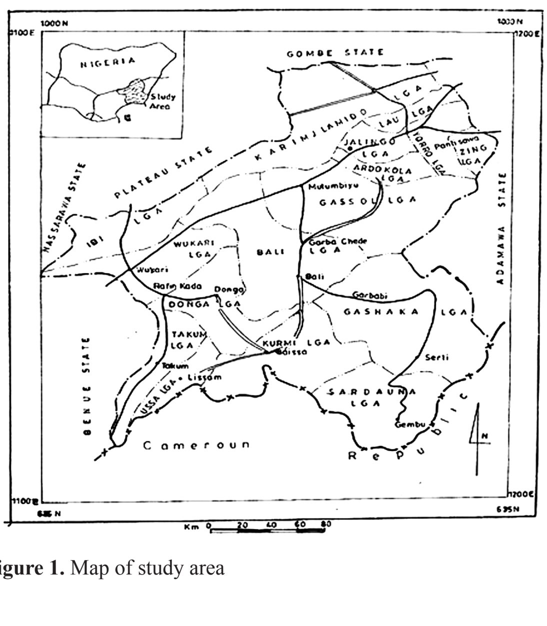

Figure 1. Map of study area

2.2. Sample Collection, Preparation and Analysis

Two major roads, namelyHammaruwa way (about 5 km) and Palace Way (about 3 km) were chosen for this study. The roads were chosen because of the considerable high traffic density of about 10,000 vehicles including tricycles per day. Figure 2 shows the traffic congestion in Hammaruwa way. Dust samples were collected along the roads on the tarred surface by sweeping with a broom and a plastic scoop and were transferred into a clean, self-sealing polythene bags to avoid contamination. The samples were collected during the dry season (February, 2013) when it was assumed that enough dust would have accumulated on the road surface. In the laboratory, the samples were air dried at room temperature for some days to reduce mass contribution of water and to avoid any chemical reactions. The samples were sieved using a 1 mm sieve mesh (Zhang *et. al.*, 2011) to remove particles such as glass, plant debris, refuse and small stones.

For the analysis of the total concentration of heavy metals (Fe, Pb, Cd, Cu and Zn), 0.5 g of samples were digested in 20 ml freshly prepared aqua regia (a mixture of concentrated Hydrochloric acid and Nitric acid in the ratio 3:1) in a microwave digestion oven, then evaporated and analyzed for metal concentration. The contents of Fe, Pb, Cd, Cu and Zn were analyzed using a Flame Atomic Absorption Spectrophotometer (Buck 210 Model) at the Adamawa State University, Mubi, Nigeria.

Table 1: Heavy Metal Concentration

Hammaruwa Way					
sample	Fe (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
HW 3	22.56	0.003	0.002	0.58	2.26
HW 9	20.89	0.002	0.002	0.35	2.57
HW 15	21.69	0.001	0.001	0.62	2.55
HWL1 1m	23.40	0.017	0.003	6.02	3.36
HWL1 2m	22.79	0.003	0.003	0.46	2.78
Mean	22.27	0.005	0.002	1.61	2.70
S.D	0.98	0.007	0.0008	2.47	0.41
Palace Way					
sample	Fe (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
PW 3	22.97	0.019	0.003	1.64	3.41
PW 8	20.77	0.002	0.002	0.36	2.50
PW 10	19.54	0.008	0.003	0.67	1.58
PW 12	21.49	0.002	0.001	0.37	2.54
PW 14	23.98	0.033	0.003	2.16	3.68
Mean	21.75	0.013	0.0024	1.04	2.74
S.D	1.76	0.01	0.0009	0.82	0.83

Figure 2. View of vehicular congestion releasing pollutants in Jalingo metropolis

3. Results and Discussion

The concentrations of heavy metals (Fe, Pb, Cd, Cu and Zn) in samples from the two Jalingo urban roads are presented in Table 1. Results showed comparable values of the concentrations of heavy metals in both road surfaces, suggesting similar sources of emissions. Mean concentrations of heavy metals in these roads in mg/kg are 22.27 ± 0.98 and 21.75 ± 1.76 Fe, 0.005 ± 0.007 and 0.013 ± 0.01 Pb, 0.002 ± 0.0008 and 0.0024 ± 0.0009 Cd, 1.61 ± 2.47 and 1.04 ± 0.82 Cu and 2.70 ± 0.41 and 2.74 ± 0.83 for HW and PW, respectively. This indicates that the concentration of heavy metals in these urban roads exist in the following order: Fe > Zn > Cu >Pb> Cd.

Fe, Cu and Zn are the most concentrated in the urban roads dusts. High concentration of Fe was found in car exhaust particulates and other car derivatives such as corrosion of body parts (Hopke *et. a*l., 1980; Lu *et. a*l., 2005) as well as soils (Robertson *et. a*l., 2003). The concentration of Fe in Jalingo urban road dust is comparable to roadside sediment from London (mean, 27.332 ± 5.930 mgg^{-1}) and Halton (mean Fe, 22.630 ±7.983 mgg^{-1}) in UK (Crosby, 2012). Studies conducted on roadside soils from selected locations in Lagos Metropolis, Nigeria, revealed higher concentrations of heavy metals (Olukanmi *et. a*l., 2012). This higher value is attributed to the higher traffic density in Lagos, being a mega city and a major industrial and commercial hub in Nigeria. Since there is no major industry in the study area, such as smelting operations, the primary sources of Zn might be derived from fragmented vehicle tires (Hopke *et. a*l., 1980), lubricating motor oil in which Zn compounds are used extensively as anti-oxidants and as detergent/dispersant improving agents (Lu *et. a*l., 2005). Cu is a common element in automobile thrust bearing, brake lining and other parts of the engine. Corrosion causes metal wear in the automobile engine and releases heavy metals to the environment and, eventually, accumulation in the topsoil (Lu *et. a*l., 2005). Cu replaced asbestos and has been used as a brake friction material since the 1930's (Hopke *et. a*l., 1980; Robertson *et. a*l., 2003). The concentration of Cu obtained in this study is consistent with values obtained for low traffic volume areas of road side soils of Ijebu-North Local Government Area, Ogun State, Nigeria (Adedeji *et. a*l., 2013). According to the latter study, Cu ranged between 0.92 and 2.01 mg/kg with a mean value of 1.41 mg/kg. The concentration of lead was found to be low. The low Pb level of the Jalingo road dust might be due to the drop in the use of Pb as additives in fuel.

The correlation between certain geochemical concentration parameters can establish influencing factors and indicate potential sources (Robertson *et. a*l., 2003; Crosby, 2012). The results of the correlation analysis between heavy metals performed using Microsoft Excel 2007 is shown in Tables 2 and 3 for the HW and PW, respectively. The strong positive correlation between almost all the metals indicates similar sources in most cases enhanced geochemical concentrations compared to background levels indicates anthropogenic influences (Crosby, 2012).

Table 2: Pearson correlation Coefficients between with heavy metals contents of Hammaruwa Way

	Fe	Pb	Cd	Cu	Zn
Fe	1				
Pb	0.703391	1			
Cd	0.678469	0.620239	1		
Cu	0.658394	0.990023	0.514673	1	
Zn	0.572983	0.881208	0.644508	0.883236	1

Table 3: Pearson correlation Coefficients between heavy metals contents of Palace Way

	Fe	Pb	Cd	Cu	Zn
Fe	1				
Pb	0.821533	1			
Cd	0.238381	0.68321	1		
Cu	0.851579	0.987095	0.692028	1	
Zn	0.983614	0.75762	0.216757	0.802339	1

3.1. Assessment of Heavy Metals Contamination Status in Jalingo Road Dusts

A. Assessment According to United States Environmental Protection Agency (USEPA) Standards

The level of heavy metal contamination is assessed by a comparison with the Sediment Quality Guidelines (SQG) proposed by USEPA since Nigerian Federal Environmental Protection Agency (FEPA) does not currently have SQG for land pollution. These criteria for the measured heavy metals are presented in Table 4. The result of the present study shows that the samples from the urban roads are not polluted.

Table 4: EPA Guidelines for Sediments

Metal (mg/kg)	Not Polluted	Moderately Polluted	Heavily Polluted	Present Study
Fe	<30	-	-	19.54 - 23.98
Pb	< 40	40 - 60	> 60	0.001- 0.033
Cd	-	< 6	> 6	0.001- 0.003
Cu	< 25	25 – 50	> 50	0.35- 2.16
Zn	< 90	90 - 200	> 200	1.58- 3.68

(Barakat et. al., 2012; Saha and Hossain, 2011)

B. Assessment According to Geo-accumulation Index (Igeo)

The Geo-accumulation index is usually employed in order to determine the metal contamination in sediments by comparing the current concentration with background levels (pre-industrial levels). The Igeo is determined following Muller (1979) as:

$$I_{geo} = log_2 \left(\frac{C_n}{1.5\ B_n} \right) \qquad (1)$$

where Cn is the concentration of the examined metal n in the sample, Bn is the geochemical background concentration of the metal n and the factor 1.5 is background matrix correction factor due to lithogenic effects (Manoj and Padhy, 2012). In this study, the world average shale values for heavy metals given by Turakin and Wodepohl (1961), where Fe = 47200 mg/kg, Pb= 20 mg/kg, Cd = 0.3 mg/kg, Cu = 45 mg/kg and Zn = 95 mg/kg, was used as Bn.

Based on the Igeo values, Muller (1981) distinguished seven classes of sediments as presented in Table 5. The results of the Igeo for the road dust samples from the two roads are presented in Table 6. All the samples show that Igeo< 0 for each heavy metal determined indicating that the samples are unpolluted.

Table 5: Index Classification of Sediment Quality

Igeo Values (Muller, 1981)	Class	Sediment Quality
≤ 0	0	Unpolluted
0 – 1	1	Unpolluted to moderately polluted
1 – 2	2	Moderately polluted
2 – 3	3	Moderately polluted to highly polluted
3 – 4	4	Highly polluted
4 – 5	5	Highly polluted to very highly polluted
>5	6	Very highly polluted
CF Values (Hakanson, 1980)	**Class**	**Sediment Quality**
CF <1	1	Low contamination
1≤ CF < 3	2	Moderate contamination
3 ≤ CF < 6	3	Considerable contamination
CF ≥ 6	4	Very high contamination
CD Values (Ahdy and Khaled, 2009)	**Class**	**Sediment Quality**
CD < 6	1	Low degree of contamination
6 ≤ CD <12	2	Moderate degree of contamination
12 ≤ CD < 24	3	Considerable degree of contamination
CD ≤ 24	4	Very high degree of contamination

Table 6: Geo-accumulation Index (Igeo) for HW and PW

Sample	Fe	Pb	Cd	Cu	Zn
Hammaruwa Way					
HW 3	-11.62	-12.70	-7.81	-6.86	-5.98
HW 9	-11.73	-13.87	-7.81	-7.59	-5.79
HW 15	-11.67	-14.87	-8.81	-6.77	-5.80
HWL1 1m	-11.56	-10.79	-7.23	-3.49	-5.41
HWL1 2m	-11.60	-12.70	-7.23	-7.20	-5.68
Mean	-11.64	-12.99	-7.78	-6.38	-5.73
S.D	0.07	1.53	0.65	1.65	0.21
Palace Way					
sample	**Fe**	**Pb**	**Cd**	**Cu**	**Zn**
PW 3	-11.59	-10.63	-7.23	-5.36	-5.39
PW 8	-11.74	-13.87	-7.81	-7.55	-5.83
PW 10	-11.82	-11.87	-7.23	-6.66	-5.42
PW 12	-11.69	-13.87	-8.81	-7.51	-5.81
PW 14	-11.53	-9.83	-7.23	-4.97	-5.28
Mean	-11.67	-12.01	-7.66	-6.41	-5.55
S.D	0.12	1.84	0.69	1.20	0.26

C. Assessment According to Contamination Factor (CF) and Degree of Contamination (CD)

The contamination factor and the degree of contamination are used to assess the pollution load of the sediments with respect to heavy metals. The CF for each metal is calculated following Manoj and Padhy (2012) as follows:

$$CF = \frac{\text{Measured concentration of metal}}{\text{Background concentration of the same metal}} \quad (2)$$

The CD for each sample is calculated as the sum of all contamination factors (Ahdy and Khaled, 2009). The CF and CD values for the two road samples are shownin Table 7. Results show that CF in all samples is < 1, indicating low heavy metal contamination and CD is < 6 in all samples implying low degree of contamination (Table 7).

Table 7: Results of Contamination Factor, Degree of Contamination and Pollution Load Index PLI for Jalingo Urban Roads

Sample	Contamination Factor (CF)					CD	PLI
	Fe	Pb	Cd	Cu	Zn		
Hammaruwa way							
HW 3	0.00048	0.00015	0.0067	0.013	0.024	0.044	0.0027
HW 9	0.00044	0.0001	0.0067	0.0078	0.027	0.042	0.0028
HW 15	0.00046	0.00005	0.0033	0.0138	0.027	0.045	0.0031
HWL1 1m	0.00050	0.00085	0.0100	0.1380	0.035	0.184	0.0073
HWL1 2m	0.00048	0.00015	0.0100	0.0100	0.029	0.050	0.0029
Mean	0.00047	0.00026	0.0073	0.0370	0.028	0.073	0.0038
S.D	0.00002	0.00030	0.0030	0.0600	0.004	0.060	0.0020
Palace Way							
Sample	**Contamination Factor (CF)**					**CD**	**PLI**
	Fe	**Pb**	**Cd**	**Cu**	**Zn**		
PW3	0.00049	0.00095	0.0100	0.036	0.036	0.083	0.0057
PW8	0.00044	0.00010	0.0067	0.008	0.026	0.041	0.0023
PW 10	0.00041	0.00040	0.0100	0.015	0.017	0.043	0.0034
PW 12	0.00046	0.00010	0.0033	0.008	0.027	0.039	0.0020
PW 14	0.00051	0.00170	0.0100	0.048	0.039	0.099	0.0070
Mean	0.00046	0.00065	0.0080	0.023	0.029	0.061	0.0040
S.D	0.00004	0.00070	0.0030	0.020	0.009	0.030	0.0020

D. Assessment according to Pollution Load Index (PLI)

The Tomlison Pollution Load Index (Tomlinson *et. a*l., 1980) indicates how much a sample exceeds the heavy metal concentrations for the natural environments and gives an assessment of overall toxicity status for a sample (Angulo, 1996). In this study, PLI is determined following the method proposed by Tomlinson *et. a*l., (1980)as follows:

$$PLI = \sqrt[n]{(CF1\ x\ CF2\ x \ldots\ldots\ldots\ldots..CFn)} \quad (3)$$

where CF is the contamination factors and n is the number of parameters. The results of PLI are shown in Table 7. The results of our measurements show that the samples are not polluted. PLI values vary from 0 (unpolluted) to 10 (highly polluted) as follows: PLI = 0 (background concentration); 0 < PLI ≤ 1 (unpolluted); 1 < PLI ≤ 2 (moderately to unpolluted); 2 < PLI ≤ 3 (moderately polluted); 3 < PLI ≤ 4 (moderately to highly polluted); 4 < PLI ≤ 5 (highly polluted) and PLI > 5 (very highly polluted) (Zhang et al, 2011; Singh et al, 2003).

E. Assessment According to Enrichment Factor (EF).

The EF is a convenient measure of geochemical trends and is used for making comparisons between areas (Sinx and Helz, 1981). It is used to distinguish between anthropogenic and natural sources of metals. The values of EF are obtained using the following equation:

$$EF =: \frac{(M/_{Fe})sample}{(M/_{Fe})background} \quad (4)$$

where is the ratio of metal to Fe concentrations of the sample of interest. The is the ratio of the natural background value of the metal to Fe concentration. As we do not have a metal background value for our study area, we used the world average shale values Turakin and Wedepohl (1961). EF values, less than 1.5, suggest that heavy metals are derived mainly from natural (crustal) source such as weathering process while EF values greater than 1.5 suggest that the sources are more likely to be anthropogenic (Zhang and Liu, 2002). The results of EF for this study are shown in Table 8. Results show that all the metals, except for Pb, have been enriched. The mean EF value of Pb in both HW and PW are < 1.5 indicating crustal influence such as weathering process as source of Pb. Other metals - Zn, Cd and Cu - all indicated anthropogenic influx, which is likely from vehicular activities.

Table 8: Table 8. Enrichment factors EF for Jalingo Urban Roads

Sample	Pb	Cd	Cu	Zn
Hammaruwa Way				
HW 3	0.31	13.95	26.97	49.77
HW 9	0.23	15.06	17.57	61.12
HW 15	0.11	7.25	29.98	58.41
HWL1 1m	1.72	20.17	269.84	71.34
HWL1 2m	0.31	20.71	21.17	60.61
Mean	0.54	15.43	73.11	60.25
S.D	0.67	5.47	110.08	7.70
Palace Way				
Sample	**Pb**	**Cd**	**Cu**	**Zn**
PW3	1.95	20.55	74.89	73.76
PW 8	0.23	15.15	18.18	59.80
PW 10	0.97	24.16	35.96	40.18
PW 12	0.22	7.32	18.06	58.72
PW 14	3.25	19.68	94.48	76.25
Mean	1.32	17.37	48.31	61.74
S.D	1.29	6.47	34.69	14.43

4. Conclusion

The concentrations of five heavy metals (Fe, Pb, Cd, Cu and Zn in dust samples collected from two major road from Jalingo metropolis were analyzed. Among the major conclusions of this study are the following:

1. The concentration of heavy metals determined decreased in the order Fe < Zn < Cu <Pb< Cd. This showed Fe, Zn and Cu are the most abundant elements in the dust samples. Based on the USEPA sediment quality guidelines, the concentrations of these metals are within the acceptable level and thus the dust samples were not polluted.
2. The strong positive inter-correlation between Fe, Pb, Cd, Cu and Zn suggests that the metals originate from similar sources.
3. Results of geo-accumulation index, degree of contamination and PLI points to the low contamination and unpolluted nature of the dust samples.
4. Analysis of the Enrichment factor, however, showed that apart from Pb, all other metals analyzed are enriched and the enrichment comes from anthropogenic activities. It is evident that these heavy metals may increase over time if proactive steps are not taken to check pollution sources like vehicular emissions, which may pose serious health risks in the near future.
5. It is necessary to conduct further studies on the accumulation of heavy metals to ensure effective protection and management of urban environment. Finally, the results obtained from the present work may hopefully provide a significant reference value for future studies of these areas and other regions in Taraba State, Nigeria

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