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Research Article

Analysis of the Sources and Pattern of Heavy Metal Concentration in Urban Road Dust, Lagos State, Nigeria

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Abstract

Background and Objective: Urban road dust constitutes a serious environmental hazard. In spite of its adverse effect on biotic lives, only few studies have been carried out to compare metal concentration in urban road dust along Trunk A (Federal) and Trunk B (State) roads. This study examined sources and pattern of heavy metals contaminations in urban road dusts along federal and state roads in Lagos Metropolis. **Materials and Methods:** Dust from 6 federal roads and 6 state roads were collected using a dustpan and taken to the laboratory for analysis of Cd, Cr, Cu, Fe, Ni, Pb and Zn using Atomic Absorption Spectrophotometer (AAS) technique. **Results:** Results showed positive and significant associations between Cu and Fe and between Zn and Cu in federal road dust, while in state road dust, positive and significant association existed between Cu and Pb. Result of PCA identified Cu, Fe, Cd, Zn, Pb and Cr as principal heavy metals with high levels of pollution in road dust along federal road, while on state road dust, Pb, Cu, Zn and Fe had high levels of pollution. **Conclusion:** The extracted components identified anthropogenic activities as the major source of metal pollution in the studied road dusts.

Key words: Urban road dust, heavy metals, atomic absorption spectrophotometer, Lagos metropolis, anthropogenic activities

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In Nigeria, road dust is a major means through which heavy metals such as iron (Fe), lead (Pb), manganese (Mn), chromium (Cr) and nickel (Ni) among others may find their way into soils and subsequently into the tissues of plants and human beings[1,2]. The deposition of these heavy metals in the environment and vegetation in particular could constitute health risk to humans through food chain contamination. Urban road dust is obtained from anthropogenic activities through the interface between natural elements and pollution sources[3]. Studies carried out by Shinggu *et al*.[4] and Osakwe[5] have reported increase in the contamination of road dust with heavy toxic metals which is believed to pose serious threat to environmental sustainability. For instance, Ano *et al*.[6] stated that human exposure to heavy metals has risen dramatically in the last 50 years as a result of an exponential increase in vehicular use which result in the distribution of different quantities of heavy metals in road dust.

Road dust is characteristically derived from anthropogenic activities[7]. Globally, heavy metal concentration in dusts mostly in urban soils with complex land uses and human activities is increasingly becoming a health concern. The presence of heavy metals is considered as a valuable indicator for contamination in road dust, sedimented and surface soil[4,7]. When heavy metals accumulate beyond the natural level, they become bio-accumulated and can have the potential to threaten human health[8]. Heavy metals can impair vital biochemical processes thereby posing a threat to plant growth, animal life and human health[9].

Plethora of researches on heavy metal accumulation has been conducted in major cities in Nigeria and Lagos, a mega city in particular which has heavy metal pollution in urban soils and urban road dusts. Consequently, it has become serious with the rapidly industrialization and urbanization during the last two dcades[1,2,10-12]. The result of a research carried out by Okunola *et al*.[1,2] revealed that roadside soils in the city of Kaduna were found to contain high concentrations of the toxic metals Pb and Cd. Adelasoye and Alamu[12] showed that high traffic road contained higher heavy metal pollutants in both soil and vegetation than the low traffic and the microbial population followed the same trend particularly the total viable count. Although there have been substantial number of studies on the concentration of heavy metals in road dust, the vast majority assessed metal concentration in either federal or state roads[4,10,13]. Heavy metals have become a serious threat for public health and environment as well. Therefore, the present examined the pattern and sources of heavy metal intrusion in urban road dust along Trunk A (Federal) and Trunk B (state) roads in Lagos Metropolis. Moreover, the association between heavy metals in federal and state road dusts and the sources of heavy metal pollution in the transportation facilities was also determined.

MATERIALS AND METHODS

Study area: Lagos state is located in the western part of the Nigeria coastline with an area of about 3,577 km. The study area is located within humid tropical climate zone. Swamp forest of the coastal belt and dry lowland rain forest are the two main vegetation types. As a result of its status in Nigeria, it remains the centre of attraction to people from other parts of the country. The area has complex transport system to connect different locations and to meet commuter's needs. The complex and diverse transport system have inherent effect on the environment, particularly the soil.

Data collection procedure: The study was carried out in May, 2018. Stratified and random sampling techniques were employed. The stratified sampling technique was used to divide the roads into Trunk A and Trunk B. Trunk A roads included Lagos-Ibadan Expressway; Lagos-Abeokuta Expressway; Lagos-Badagry Expressway; Oshodi-Apapa Expressway. The Trunk B included old Abeokuta road, Agege motor road; LASU-Iba-Isheri road; Ipaja-Abesan road; Meiran road and Ojo-Alaba road. Random sampling technique was later used to select major roads from the list of Trunk A and B roads. Through this process, 8 Truck A and Truck B roads were identified from which 6 roads from each road type were randomly selected for samples collection. In all, 12 samples were collected using a dustpan. The collected soil samples were air-dried and thereafter; taken to the laboratory for analysis of cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), nickel (Ni), lead (Pb) and zinc (Zn). The contents of Cd, Cr, Cu, Fe, Ni, Pb and Zn were analyzed using Atomic Absorption Spectrophotometer (AAS) technique. Laboratory analysis of metals was conducted in the Department of Agronomy, University of Ibadan, Nigeria.

Data analysis: Data obtained from the laboratory on the concentrations of Cd, Cr, Cu, Fe, Ni, Pb and Zn were analyzed using Person's correlation, principal component analysis (PCA) and cluster analysis. All statistical analyses were carried out with the aid of SPSS (Statistical Package for Social Sciences) Version 20.0 for Windows as well as excel spreadsheet.

RESULTS

Association between heavy metals in federal road dust: The result in Table 1 showed that there were positive and significant associations between Cu and Fe ($r = 0.858$, $p<0.05$) and between Zn and Cu ($r = 0.821$, $p<0.05$). The positive correlation coefficients entailed increase in a metal in road dust would result in a corresponding increase in the other metal and vice versa. For instance, an increase in the content of Cu in road dust would bring about a resultant increase in the content of Cd. This form of relationship applied to other heavy metal contents in federal road dust with positive correlation coefficients. Also, the negative correlation coefficient implied that increase in a metal content would result in a resultant decrease in the other metal.

Association between heavy metals in state road dust: The association between heavy metals in state road dust is shown in Table 2. The result showed that there was a positive and significant association between Cu and Pb ($r = 0.942$, $p<0.05$). It showed that an increase in the content of Cu in dust would bring about a resultant increase in the content of Pb.

Sources of heavy metal pollution in the transportation facilities

PCA result of heavy metal concentration in federal road dust: Results in Table 3 showed that three principal components were extracted and among them PC_1 had strong and positive loadings on Cu (0.913), Fe (0.894), Cd (0.873) and Zn (0.818). The PC_1 represented anthropogenic pollution (that is pollution emanating from diverse human activities around the road network). The PC_2 had only one strong loading on Pb (0.938) which symbolized anthropogenic pollution. The PC_3 had strong loading on Cr (0.969) and also signified anthropogenic origin. The three extracted components identified anthropogenic activities as the main source of pollution or accumulation of metals in road dust along Federal roads in Lagos soil.

PCA result of heavy metal concentration in state road dust: Results in Table 4 showed PC_1 represented anthropogenic pollution. The PC_2 also represented anthropogenic pollution, while PC_3 had strong loading on Fe (0.940) which signified anthropogenic origin. The three extracted components also identified anthropogenic activities as the main source of pollution or accumulation of metals.

Table 1: Zero order correlation matrix

Variables	Cd	Cr	Co	Pb	Ni	Fe	Cu	Zn
Cd	1							
Cr	0.253	1						
Co	0.562	-0.388	1					
Pb	-0.345	0.326	-0.013	1				
Ni	0.103	-0.003	0.557	0.562	1			
Fe	0.790	0.291	0.744	0.252	0.530	1		
Cu	0.663	0.293	0.622	0.296	0.787	0.858*	1	
Zn	0.588	0.127	0.473	-0.137	0.657	0.518	0.821*	1

*Correlation is significant at the 0.05 level (2-tailed)

Table 2: Zero order correlation matrix

Variables	Cd	Cr	Co	Pb	Ni	Fe	Cu	Zn
Cd	1							
Cr	0.268	1						
Co	-0.504	-0.563	1					
Pb	-0.545	0.386	-0.618	1				
Ni	-0.464	-0.359	0.524	-0.448	1			
Fe	0.297	-0.240	0.095	0.506	0.427	1		
Cu	0.291	0.497	-0.560	0.942*	-0.470	0.334	1	
Zn	-0.513	-0.516	0.177	0.071	-0.193	0.083	0.205	1

*Correlation is significant at the 0.05 level (2-tailed)

Table 3: PCA rotated component matrix of heavy metal contents in Federal road dust*

	Principal components			
Metals	PC_1	PC_2	PC_3	Communalities
Cu	0.913	0.359	0.113	0.966
Fe	0.894	0.190	0.136	0.983
Cd	0.873	-0.411	0.186	0.889
Zn	0.818	0.056	-0.035	0.939
Co	0.761	0.100	-0.547	0.937
Pb	-0.055	0.938	0.237	0.853
Ni	0.570	0.753	-0.215	0.976
Cr	0.163	0.130	0.969	0.673
Eigenvalues	3.997	1.810	1.409	
Variance (%)	49.962	22.627	17.608	
Cumulative exp.	49.962	72.589	90.197	

*Underlined coefficients of $\pm \geq 0.8$ are considered significant

Table 4: PCA rotated component matrix of heavy metal contents in state road dust*

	Principal components			
Metals	PC_1	PC_2	PC_3	Communalities
Pb	0.974	0.126	0.182	0.678
Cu	0.951	-0.021	0.015	0.710
Co	0.220	-0.968	-0.094	0.997
Cd	-0.662	-0.398	0.359	0.726
Zn	0.481	0.661	0.098	0.804
Cr	0.369	0.619	-0.437	0.998
Fe	0.335	0.069	0.940	0.905
Ni	-0.597	-0.013	0.669	0.994
Eigenvalues	3.175	1.936	1.702	
Variance (%)	39.689	24.201	21.271	
Cumulative exp.	39.689	63.890	85.161	

*Underlined coefficients of $\pm \geq 0.8$ are considered significant

DISCUSSION

The results showed that federal and state road dusts were polluted with heavy metals and the level of metal pollution was related to the road type and extent of use. It also means that the activities carried out along both federal and state roads degrade the environment with varying amounts of metals. This agreed with the assertion of Poszyler Adamska and Czerniak[14] when they stated that public motor roads affects natural environment to a large extent because automobile act as line sources of heavy metal pollutants. In the two road types, the contents of Cu and Zn tended to be dominant metal indicating that the activities carried out along the two roads favored the accumulation of these metals in the road dusts. This result is consistent with the finding of Morse *et al.*[15], where Cu and Zn were dominant metals in roadside though with low concentration. It is also consistent with those of Yisa *et al.*[16] as they reported the order of metal concentrations in road deposited sediments as Zn, Pb and Cu. Also, the dominance of Cu and Zn was unexpected because they constitute metals with widespread concentration in urban areas. Similarly, Kanu *et al.*[17] stated that Fe, Cu and Zn are the most concentrated metals in the urban roads dusts. The positive association observed between some of the metals suggested the metals had similar sources of pollution, while the negative association suggested otherwise[18]. The heavy metals were found to be released into road dust via vehicular emission and lubricant wastes among other substances that generate different quantities of metals[19]. The result obtained is consistent with earlier studies. For instance, Mafuyai *et al.*[7] attributed heavy metal accumulation in road dust to varying anthropogenic activities. In another study, Ichu *et al.*[20] attributed heavy metal concentration in road dust to roadways and automobiles. The extracted components showed that metal pollution in road dust was significantly induced by anthropogenic activities. This is consistent with the studies of Mafuyai *et al.*[7], Ichu *et al.*[20] and Sulaiman *et al.*[21] when they attributed metal concentration in road dust to anthropogenic impact. This clearly suggested that the level of metals in road dust is as a result of human factor along the transport corridor. A cursory look at the PCA result for both federal and state road dust further showed that Zn and Pb had substantial level of contamination in the road dust, this suggested that these two metals were mostly released from vehicular movement. In a related study, Ichu *et al.*[20] found Zn, Cu and Pb as most common heavy metals released from road travels. Yisa *et al.*[16] identified Zn, Pb and Cu as dominant metals with high concentrations in road deposited sediments. It was observed from the result that road dusts had signs of metal pollution because they contain different quantities of metal. Based on the findings of the study, it is therefore, necessary for government to come up with vehicle inspection and maintenance facilities in order to ensure the effectiveness of vehicles as well as impound vehicles that violate emission standards in the country. However, future studies should look at the seasonal variation in metal concentration in federal and state roads as well as examine the ecological index of metal pollution.

CONCLUSION

The study showed that heavy metal was found in both federal and state road dusts. The study also showed that Zn and Pb were common metals with considerable level of contamination in federal and state road dust. Anthropogenic activities along the road types were responsible for the increasing level of metals in the road dusts. It is therefore, necessary to monitor Zn and Pb in road dust in order to reduce issues associated with bioaccumulation.

SIGNIFICANCE STATEMENT

This study has discovered that Zn and Pb have size able level of contamination in federal and state road dusts, while anthropogenic activities are the principal source of heavy metal pollution in urban road dust. The study has helped to uncover critical areas of heavy metal pollution in federal and state roads with different traffic volumes that previous researchers did not explore. Thus, a new theory on heavy metal pollution in urban roads in relation to traffic volumes and human activities around the transport corridor may be arrived at.

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