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Roadside Sand Deposits as Toxic Metals' Receptacles along three Major Roads in Port Harcourt Metropolis, Nigeria

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ABSTRACT

Roadside sand deposits are common sights along all roads in city centres like Port Harcourt in Nigeria. Studies have shown that, these sand deposits are receptacles for heavy metals emitted from varying sources. This study therefore, investigated the concentrations of four toxic metals Cadmium (Cd), Chromium (Cr), Lead (Pb) and Nickel (Ni) in roadside sand deposits. Three research questions were addressed using results of analyses of data obtained. Samples were collected along three major busy roads in Port Harcourt City using atomic absorption spectrophotometer, AAS. The results show that all four toxic metals except Cd were significantly available in the sand deposits with mean concentrations as follows: Cadmium 0.00 mg/kg, Chromium 2.81±2.21 mg/kg, Lead 1.09±0.70 mg/kg and Nickel 2.41±1.07 mg/kg. The detected concentrations were found to be high in relation to FEPA and WHO standards. The results also show that the mean concentrations are significantly different among the metals investigated but opposite is the case along the roads investigated. Therefore, the attention of environmental regulatory agencies is hereby drawn to this potential reservoir of environmental toxicants. The unsuspecting public, business operators, and others that depend on these roads for their livelihood are also enjoined to appreciate the dangers on these roads.

Keywords: Sand Deposits, Metals Receptacles, Metal Concentrations, Busy Roadsides, Port Harcourt Metropolis and Nigeria

I. INTRODUCTION

In cities of developing countries like Port Harcourt in Nigeria, roadside sand deposits are common phenomenon due to poor road construction works, dilapidated roads, poor road maintenance culture, improper disposal of silts from drainages, sand run-offs during rains,rickety automobiles, automobile wear and tear and above all poor government policies on road use and regulation of same.At the global stage, some research efforts have been carried out in most developed and developing countries on this subject of roadside metal receptacles, some of such endeavours are discussed as follows:

Saeedi, Hosseinzadeh, Jamshidi and Pajooheshfar (2009)in their study,positthatheavy metals are typical road traffic source contaminants in the local ecological environments.**Zehetner, Rosenfellner, Mentler and Gerzabek (2009)**were of the view that these metals are found in fuels, fuel tanks, engines and other vehicle components, catalytic converters, tires and brake pads, as well as in road surface materials.For**Christoforidis and Stamatis (2009)**,the concentrations of heavy metals in roadside soils are indicators of heavy metals' accumulation through atmospheric deposition and road runoff.

In views of **Chen, Xia, Zhao and Zhang (2010)**,roadside soils are the major reservoirs of traffic-related heavy metals and heavymetal contaminants can easily impact people residing within the vicinity of the roads via suspended dust or direct contact. According to **Winther and Slento (2010),**aspervehicle type, cars are the most important source of emission for all heavy metal species, followedby vans, trucks, buses and 2-wheelers. By using the detailed emission factors and inventorycalculation methods established in the present project, estimates of heavy metal emissionscan be made for other years than 2007. **Khan, Khan and Rehman (2011)** implicated traffic densities as a major source of lead and cadmium contamination of roadside sand deposit along all classes of roads in Pakistan. **Luo,Yu, Zhu, and Li (2011)**contend that the unprecedented pace in the last three decades in urbanization of China has a role in the metals deposition sources.

Wang et al (2012) specifically implicated urbanization ages and land use as sources of heavy metals in Beijing urban soils inside the 5th ring road by even grids sampling. The results of the study revealed that the urban soils in Beijing were contaminated by Cd, Pb, Cu, and Zn. Soils in industrial areas have the highest average Cu and Zn contents, while Pb contents in park areas and Cd in agricultural areas are the highest. The accumulations of Pb and Zn in urban soils increase significantly with sampling plots approaching the city center. And Pb, Cd, and Zn contents in soils in traffic areas also tend to increase in the city center. However, residential areas have the lowest contents of all the four heavy metals. **Zhang et al (2012)**are of the generally opinion that most observational studies on the concentrations of heavy metals in roadside soils were focused on Cu, Zn, Cd and Pb. Clare, Zereini and Püttmann (2013)studied traffic-related trace element emissions and their uptake by plants grown in urban roadside environments in Toronto, Canadain 2010. Soil, plant tissue and plant rhizosphere samples analyzed for Cr, Mn, Cu, Ni, Cd, As, Sb and Pb show metals were more bioaccessible to *O. vulgare* grown in the new soil at the medium traffic volume site, compared to the aged soil at the heavy traffic location.

Port Harcourt city has recently being characterized by escalated road transportation challenges due to very deplorable state of roads, poor road maintenance culture and with almost every household known to own a car on the average leading to very high traffic density in the city with no vehicular movement regulation policy of the government in operation. The city has also been characterized by consistent and persistent infrastructural decay due to over-use of same with suburbs still far from government attention. These and many more factors have resulted in the fast defacing of the city of its garden city status. Major roadsides now serve as natural receptacles for toxic metals' loaded sands from failed portions of the same roads and from very bad roads from other parts of the city. The city centre can hardly be differentiated from the suburbs.

The overall result of these challenges is the elevated presence in the city centre of toxic metals held mainly in the roadside sand deposits and those suspended into the surrounding air by winds and spinning tyres of moving vehicles. With the teeming human commercial and domestic activities along these roads, exposure through inhalation of loaded air and direct body contact is inevitable. This study there attempted to determine the levels or concentrations of these toxic metals in some selected roads in some selected busy locations of the city given the fact these areas are known for hosting high commercial, transportation and domestic activities.

Problem statement

Port Harcourtis strategic to businesses of all sorts especially the Nigerian oil and gas mainstream and allied activities the city. The city's deplorable state of infrastructure such as the road networks and the poor maintenance culture of same coupled with the escalating population challenges, it is expedient that the environment is monitored for the effects of potential pollution from such areas as the roadside sands which are established receptacles in major cities of the world for heavy and toxic metals to proportions yet established in the case of Port Harcourt. This study attempts to independently investigate possible variations in concentrations among the selected roads and metals and to establish the extent of significance of the concentrations of the metals. This is a dimension that has not been considered in available literature in similar studies in the city so as to proffer recommendations to relevant authorities and the unsuspecting teeming population of road users in the city.

Research questions

The following questions were addressed:

1. How significant arethe concentrations of the metals in the roadside sand deposits with respect to environmentally permissible limit, locally and globally?
2. How significant are the concentrations of metals different among the roads investigated.
3. How significant are concentrations of metal

II. LITERATURE REVIEW

Empirical studies of Toxic Metals on Roadside Sand Deposits

Relevant literatures were reviewed globally and locally as follows:

Ayeni, Ndakidemi, Snyman, and Odendaal (2010) conducted a study of river bank and adjacent soil samples from four different sites, Milnerton Lagoon from the lowerDiep River, Cape Town, South Africa were evaluated for ten metals among which were cadmium (Cd), lead (Pb), nickel (Ni), and chromium (Cr).The results showed that most sites were contaminated with metals evaluated.In adjacent soils, the concentration of Pb was0.97-71.7 mg/kg; Cd was 0.0-9.3 mg/kg;Crwas 0.3-2.1 mg/kg; and Ni was 0.02-2.6 mg/kg. Overall, Ni had the lowestconcentrations in the ecosystem.

Chen,Xia,Zhao and Zhang (2010) ina detailed investigation conducted to study the heavy metal concentrations in roadside soils of Beijing,reportedthat concentrations of Cd, Cu, Pb and Zn showed a decreasing trend with increasing distance from the road while such trend was not identified in As, Cr and Ni. In addition, the concentrations of Cd, Cu, Pb and Zn were significantly positively correlated with black carbon (BC) and TOC ($p<0.01$). The soil samples from West 2nd Ring Road with the highest traffic volume had the highest heavy metal concentrations of the 10 roads, and Pb concentration was significantly positively correlated with traffic volumes ($p<0.05$). According to the soil guideline values of China, Cd was considered to have considerable contamination in roadside soils, while Cu, Pb and Zn less, but As, Ni, Cr none. The concentrations of heavy metals in roadside soils of Beijing were considered medium or low in comparison with those in other cities; this may be due to the windy and dry climate in Beijing.

WintherandSlentø (2010)presentedin a report ofnew heavy metals' emission factors for cars, vans, trucks, buses, mopedsand motorcycles for each of the emission sources' fuel consumption, engine oil, tyre wear, brakewear and road abrasion using Arsenic (As), Cadmium (Cd),Chromium (Cr), Copper (Cu), Mercury (Hg), Nickel (Ni), Lead (Pb), Selenium (Se) and Zinc(Zn) as emission components. The following emissionsin total TSP (in brackets) is calculated for the year 2007: As (8 kg), Cd (48 kg), Cr (197kg), Cu (51 779 kg), Hg (28 kg), Ni (158 kg), Pb (6 989 kg), Se (33 kg) and Zn (28 556 kg).

Khan, KhanandRehman (2011) in a study of soil and plant samples collected from roadside sites … and reference site to investigate the contamination of soils and old common plant species with lead (Pb) and cadmium (Cd) in Peshawar City, Pakistan. Significant mean concentrations ofPb and Cd were reported to be 53.9 and 6.0 mg/kg in soils and 49.1 and 10.9 mg/kg in plants, respectively. In yet another study of sample of urban dusts collected from five locations in Owerri metropolis in May and July, **Akhionbare (2011)**revealed mean concentrations per dry weight of 3.00µg/g, 43.59µg/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. Generally, the metals occurred in levels that are below regulatory intervention limits.

Matthews-Amune and Samuel (2012) The content of Cd, Cu, Ni, Pb and Zn in the agricultural soils and cassava (*Manihotesculentus*) leaves from Adogo, Samples of soil and cassava leaves were collected from a site located on a highway, and another in a rural area which served as the reference site. Levels of Cd, Cu, Ni, Pb and Zn in soil and cassava leaves were found to be <0.01, 0.89±0.25, 0.18±0.03, 0.44±0.16, 0.04±0.003 and 0.13±0.0002, 0.15±0.01, 0.06±0.005, 0.07±0.004, 0.06±0.002 µg/g respectively. The levels of heavy metals in roadside agricultural soils and cassava leaves were higher as compared to reference soil levels, with Pb concentration seven times higher than level in soil and cassava leaves in reference soil. The absence of any major industry in the sampling sites the Pb metallic level indicates relation to traffic.**Bada and Oyegbami(2012)**in a study of roadside dusts reported that roads with higher traffic density had higher levels of metals.Yakeem and Onifade (2012) in an evaluation of concentrations of soil metals (Pb, Cd, Cr, Mn, Cu, Fe and Ni) from selected sites (Odo, Oba, Sabo and general areas) along major roads in Ogbomoso reported significantly high levels of these metals.

Akpan and William (20014)in a study of traffic density effect of twenty one numbers elemental Al, Si, P, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Ga, As, Rb, Sr, Zr, Nb and Pbconcentrations in roadside soils in Calabar, Nigeria, revealed the following with concentrations (in ppm), ranging from 9.0±3.8 (Ga) to 192560.3±789.5 (Si) respectively were detected from ten different sample locations. Significant enrichment was obtained for Mn(7.677); Cu(5.189); Zn(5.203, 5.177 and 6.554); Ti (5.723, 5.395 and 5.00); Cr (6.901, 7.323 and 14.321); P(5.683, 5.750) and Si(6.747) respectively, indicating that their concentrations were sufficient to pose environmental problems. High concentrations of Pbin areas of high traffic density and the strong, positive and significant correlation results corroborate with results of enrichment factor, cluster analysis and counting statistics of number of vehicles plying sample locations thereby confirming heavy metals on roadside soils in Calabarto be associated with vehicular emissions.

II. METHODS AND MATERIAL

Sample collection, treatment and analysis

Sample collection was carried by thorough mapping of the entire stretch of each study road using high tension electric power lines' suspension poles.Iwofe/Rumuepirikom(IR) road had 10 sample points,OluObasanjo(OO) road yielded 16 sample points and Iloabuchi(IL) road had 15 sample points totalling 31 number samples. Roadside sand deposits were grabbed from four sides of a designated sample point to make a composite out of which a sample was collected after thorough homogenization of the composite.

Sample treatment and analysis

Collected soil samples were air-dried to constant weight and then sieved through a 500 μm stainless steel mesh wire. Samples of 0.5 g were digested in 20 ml freshly prepared aqua regia (1:3 HNO_3:HCl) on a hot plate for 3 hours, then evaporated and analyzed for metal concentration. The total concentrations of Cd, Cr,Pb and Ni in filtrate were then determined using a flame atomic absorption spectrometer (Varian SpectrAA 220 FS) at wavelengths, λ: Cd = nm, Cr = nm, Pb =217.0 nm; Mn = 279.5 nm; Ni = 232.0 nm and Zn = 213.9 nm, using air acetylene flame.

Data analysis

Data for research question 1 was analyzed using mean and standard deviation while research questions 2 and 3 one-way ANOVA as well as a Scheffe post-hoc analysis question 3 where a significant difference was established.

III. RESULTS AND DISCUSSION

Results

Results of the analyses of data collected in this study are presented according to the research questions as follows:

RQ1: How significant are the concentrations of the metals in the roadside sand deposits with respect to environmentally permissible limit, locally and globally?

Table 1: Mean metals concentration in mg/kg

	IRR		OOR		ILR		Mean±SD		FEPA (2003)	WHO (1984)
	N	Conc.	N	Conc.	N	Conc.	N	Conc.	Conc.	Conc.
Cadmium	10	0.00	16	0.00	15	0.00	31	0.00±0.00	**0.003**	**0.003**
Chromium	10	6.00	16	1.70	15	2.07	31	2.81±2.21	**0.050**	**0.050**
Lead	10	1.40	16	1.29	15	0.74	31	1.09±0.70	**0.010**	**0.010**
Nickel	10	0.00	16	2.09	15	2.72	31	2.41±1.07	**0.020**	**0.020**

Note: IRR-Iwofe/Rumuepirikom road, OOR-OluObasanjo road and ILR-Iloabuchi road
FEPA-Federal Environmental Protection Agency and WHO-World Health Organization

Table 1 shows mean concentrations of the metals investigated in the three roads in Port Harcourt city. All metals except for Cd have concentrations way above the locally and globally stipulated environmentally permissible limits for the metals investigated in soil samples in the environment. The table also shows that the lowest limit of the range of the concentrations is on the higher side of the environmental limits for the metals as depicted by the measure of dispersion. Therefore, the concentrations of the metals are significantly present in the roadside sand deposit in the roads investigated.

RQ2: How significant are the concentrations of metals different among the roads investigated.

Table 2: ANOVAofdifference in metals concentration among roads

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	8.62	2	4.31	1.46	0.24
Within Groups	475.30	161	2.95		
Total	483.93	163			

Table 2 shows a one-way ANOVA of the difference in metals' concentrations on the three roads investigated. The analysis as shown in the table have it that metals' concentrations are not significantly different among the roads investigated with $F_{(2,163)} = 1.46$ @ $p = 0.24$ ($p > 0.05$).

RQ3: How significant are concentrations of metals different among the metals investigated.

Table 3(a): ANOVA of difference in metals' concentrations

	Sum of Squares	df	MeanSquare	F	Sig.
Between Groups	179.83	3	59.94	31.54	0.00
Within Groups	304.10	160	1.90		
Total	483.93	163			

Table 3(a)also shows a one-way ANOVA of the significant difference in concentration among thedifferent metals' concentrations. The result $F_{(3,163)} = 31.54$ @ $p = 0.00$ ($p< 0.05$) shows that there is a significant difference in the concentrations of the metals.

Table3(b): ScheffePost-hoc Multiple Comparison Tests

Metal (I)	Metal (J)	Mean diff. (I-J)	Sig
Cadmium (Cd)	Chromium (Cr)	-2.88*	0.00
	Lead (Pb)	-1.12*	0.01
	Nickel (Ni)	-1.81*	0.00
Chromium (Cr)	Cadmium (Cd)	2.88*	0.00
	Lead (Pb)	1.76*	0.00
	Nickel (Ni)	1.07*	0.01
Lead (Pb)	Cadmium (Cd)	1.12*	0.01
	Chromium (Cr)	-1.76*	0.00
	Nickel (Ni)	-0.69	0.17
Nickel (Ni)	Cadmium (Cd)	1.81*	0.00
	Chromium (Cr)	-1.07*	0.01
	Lead (Pb)	0.69	0.17

*significant mean concentration difference

Table 3(b) shows a post-hoc analysis of the direction and extent of the differences in concentrations of the metals. The table also shows that statistical significant mean concentration exist between Cr and Cd of 2.88 mg/kg, Ni and Cd of 1.81 mg/kg, Cr and Pb of 1.76 mg/kg,Pb and Cdof 1.12 mg/kg, and lastly between Cr and Ni of 1.07 mg/kg. The table shows a non-significant mean concentration difference between Ni and Pb of 0.69 mg/kg.

Discussion

The findings of this study are discussed as follows:

Metals' Concentrations versus Environnementallimit

All metals except for Cd have concentrations way above the locally and globally stipulated environmentally permissible limits for the metals investigated in soil samples in the environment. Therefore, the concentrations of the metals are significantly present in the roadside sand deposit in the roads investigated. This finding corroborates the findings of **Matthews-Amune and Samuel (2012)**The content of Cd, Cu, Ni, Pb and Zn in the agricultural soils and cassava in Adogo, Abuja;**Akpan and William (20014)**in a study of traffic density effect of twenty one numbers elemental Cr, Ni, and Pbconcentrations among others in roadside soils in Calabar. This finding may not be unrelated to the heavy vehicular traffic activities all the roads investigated.

Metal Concentrations versus Roads

The result $F_{(2,163)}$ = 1.46 @ p =0.24 (p > 0.05)shows a significant difference in concentration among the different metals' concentrations.This finding does not corroborate that of **Yakeem and Onifade (2012)** in which Pb, Cr, and Ni correlates significantly in the different roads investigated.This finding may not be unconnected with the almost similar vehicular densities on the roads.

Metal Concentrations versus Metals

The result $F_{(3,163)}$ = 31.54 @ p = 0.00 (p< 0.05) shows that there is a significant difference in the concentrations of the metals.Finding corroborates the works of **Bada and Oyegbami (2012)** in a study of Pb, Cd, Zn and Ni concentrations in roadside dusts in different traffic density Abeokuta and that of**Yakeem and Onifade (2012)** where Pb, Cr, and Ni correlates significantly. This finding may be due to the different levels or modes or even rates of emissions of the different metals from the different sources.

IV. CONCLUSION

From the concentrations of the metals detected in the sand deposits along the three roads, further confirmation is established that the roadside sand are receptacles for metals emitted on these roads. These sands often times get airborne thus aggravating the imminence of toxic metals contamination by inhalation and direct body contact. Therefore, the need for a thorough and more detailed work is inevitable.

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