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Road Construction and Trace Heavy Metals in Roadside Soils along a Major Traffic Corridor in an Expanding Metropolis

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

City growth often time results in advancement and development in transportation which comes with its attendant changes in road infrastructure and transport support services such as road side mechanic workshops, vulcanizers and bus stops. A byproduct of these attendant contiguous activities and processes is the emission and release of trace heavy metals. Trace heavy metals have been identified as major carcinogens. This study aimed at determining the occurrence and concentration of heavy metals in roadside soils in an expanding third world metropolis. To achieve the aim of the research, the total length of the road within the study section was measured. Ten sample locations were indentified at about 2.5km intervals along the road section under review. The heavy metal concentration was determined the using Buck Scientific 210 VGP Atomic Absorption Spectrophotometer. Heavy metals such as Iron (Fe), Copper (Cu), Cadmium (Cd), Lead (Pb) and Mercury (Hg) were determined. The result of the analysis showed that the concentration values ranged from <0.001 to 48.90 µg/mg. The results also revealed that the

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experimental sample points recorded higher values than the control samples; however, some of the control points had relatively higher concentration values. This observation may have emanated from the low lying trajectory and topography of the surrounding area, which allows run-off from the road side soils to wash off heavy metals and deposit them at these lower lying areas. The sources of these trace heavy metals are attributed to emissions from motor vehicles that ply the road on a day to day basis. Emanating from the findings, this study recommends that improved public transportation and cleaner sources of energy is recommended.

Keywords: Port-Harcourt; Nigeria; soil contamination; trace elements; transportation.

1. INTRODUCTION

Roads are very salient infrastructure that promotes and stimulates advancement in social and economic activities; yet the construction of these same roads have been observed as major contributors to environmental pollution [1]. The presence of trace heavy metals in roadside soils may originate from various day to day anthropogenic activities, such as industry based energy generation and use, construction, vehicle exhaust, waste disposal, as well as the burning of coal and fuel [2]. Vehicles can potentially emit metals such as Zinc (Zn), Copper (Cu), Lead (Pb), and Cadmium (Cd) and organic contaminants including benzene, and Polycyclic Aromatic Hydrocarbons (PAHs) (e.g., naphthalene, acenaphthylene, and anthracene) into the environment. The unabated running of a large number of vehicles on roads can therefore lead to elevated levels of these contaminants in roadside soils and plants. Vehicular emission is at its peak when there is an increase in population, together with an increase in the number of vehicles on roads. Most of the by-products of vehicles contain different fraction particles. These fractions encapsulate the ultrafine particles which are produced in the engines and tailpipes, fine particles which are framed mechanically by the scraped up street materials from the abrasion of road materials, tires and brake linings [3]. These substances migrate to the ground and groundwater along with runoff from the surface of the roads, which is regarded as one of the sources significantly affecting the quality of surface- and groundwater. The content of pollutants in runoff water infiltrating the soil is dependent on many factors, including the intensity of traffic, type of road and condition of the road surface. The increased concentration of heavy metals over a long period of time can be potentially associated with their accumulation in soil and pose a risk to the proper functioning of the water ecosystem [4]. Exhaust traffic-related emissions include gases such as Carbon Monoxide (CO), Carbon Dioxide (CO_2), Nitrogen Oxides (NOx), Sulfur Dioxide (SO_2), and Volatile Organic Compounds (VOCs). These gases are products of either complete or incomplete fuel combustion. Non-exhaust emissions are mainly generated due to leakage of vehicle-related fluids, abrasion of vehicle parts and road surface, and deicing salts as well as cleaning agents. These emissions are released and transported within different compartments of the road surrounding environment by air or water [5]. Emenike & Wekpe [6] posit that in developing countries like Nigeria, growth in population is often accompanied with attendant growth in improved road accessibility which creates an assortment of auxiliary work which range from vehicle fixes, vulcanizer and welders to auto-circuit repairmen, battery chargers and merchants in different facets of road transportation. These activities tend to emit trace heavy metals which are stored into adjacent soils, which are then taken up by plants on such soil. Nonstop introduction of these contaminants in a roadside soil can negatively affect plants, microorganism and people. The higher the convergence of overwhelming metals in soil, the more adverse the impact will be on microbial activities (Soil Science Society of America, N.D.), and disturbance of soil biological systems. Preceding the restricting of leaded gas, a high level of lead in the soil in numerous parts of the world was produced from vehicles. About one million American youngsters in the mid 1990's had high concentration of lead in their blood at levels sufficiently high to cause irreversible harm to their wellbeing [7,8].

The sample site refers to the different points or locations in which the soil samples were collected. This is shown in Table 1.

2. MATERIALS AND METHOD

The data was collected at ten different points at various locations, alongside with a control or a treatment for each corresponding sample location. This control or treatment are areas of none transport activity which is a foot path area. This sample will be presented on a table or chart as well as a graph to show their variation. The total distance of the road were measured, after which, it was divided into different segment, i.e, sp1, sp2, sp3, sp4, sp5, sp6, sp7, sp8, sp9, sp10. The soil samples were collected using a hand auger and was put into a clean polythene bag. The sample collected at each location is labeled according to location of the sample area. The distance of 30cm is taken away from the paved part of the road and the depth in which the sample is collected is between 0-15cm at each point. However, the samples collected were further taken to the laboratory. Also geographic position system (GPS) was used to take the coordinate of the points the samples were collected.

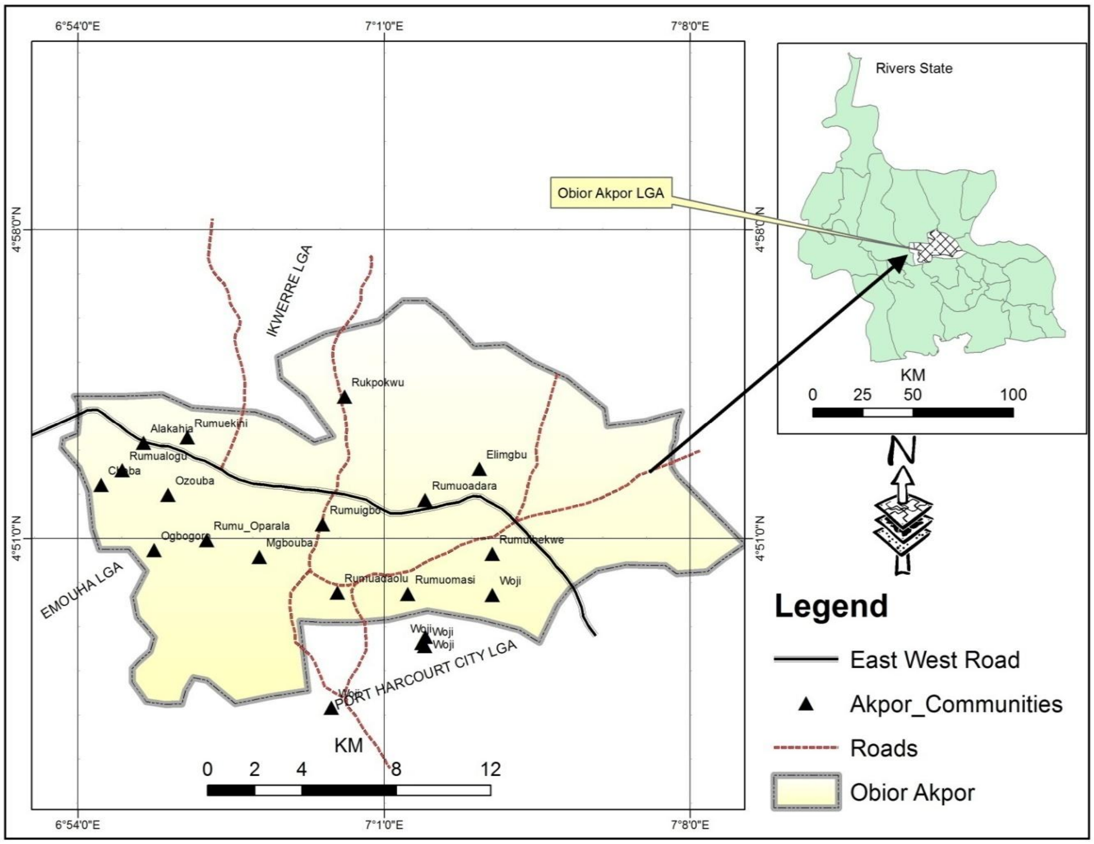

Fig. 1. Study area showing the East West Road

Table 1. Sample location and description

S/N	Sample points	Sample locations	Description of locations
1	Sp 1	Choba	Wilbros Gate
2	Sp 2	Choba	Close to AP filling station
3	Sp 3	Alakahia	After Jovit Fast food Outlet
4	Sp 4	Rumuosi	Salvation Ministries Entrance
5	Sp 5	Rumuosi	Opposite good palace hotel
6	Sp 6	Nkpolu	Charkin Maritime Academy
7	Sp 7	Nkpolu	Four poles before Nkpolu junction
8	Sp 8	Nkpolu	Chico Cement depot
9	Sp 9	Rumuokoro	Just before Agofure motor park
10	Sp 10	Eligbolo	After First bank

2.1 Laboratory Analysis

Each soil sample was air dried in a room temperature for 24±2°C for at least 3-4 days.The samples were ground to fine sand then weighed using a weighing balance. The dried samples were grinded to fine particles and 1.0g of each was weighed into a dried conical flask. However, 10ml of aqua regia mixture of Hydrochloric acid and Nitric acid in the ration of 3:1 was added to the sample for digestion. The sample was stirred with glass rod for proper mixture with the acid, after that, the flask was placed on a heating mantle and heat to dryness. The content was allowed to cool, after which 20ml of de-ionized water was added to it. After which, it was stirred and filtered into a clean and well labeled sample container for analysis. Buck Scientific 210 VGP Atomic Absorption Spectrophotometer model was used to determine the concentration (µg/g) of heavy metals in the samples. The digested samples were used to determine the concentration of Fe, Cu, Cd, Pb and Hg on soil along Choba-Rumuokoro corridor of the East-west road. Data obtained was statistically analyzed using excel. Analysis of variance (ANOVA) was used to determine the level of significance of variations between the samples and T- test was used to determine the level of impact on soil. Also, correlation was used to determine the relationship between samples. Results were considered statistically significant ($P<0.05$).

3. RESULTS

3.1 Results

The results or the quality control study for heavy metals of soils in the road sides along Choba-Rumuokoro corridor of the East-west road using aqua regia mixture of Hydrochloric acid and Nitric acid digestion method are presented in Table 2.

3.2 Discussion

3.2.1 Availability of heavy metals in roadside soils of the study area

Based on the results or data derived from laboratory analysis, it shows that trace heavy metals are present in the soil along Choba-Rumuokoro corridor of the East-west road, Port Harcourt. These trace heavy metals tested includes; Fe, Cu, Cd, Pb, and Hg. From Figs. 1-4, results shows that the concentration of heavy metal in soils along the road varies as the distance increases from the sample points by the roadside away from the roadside and from one point to another along the road. The highest concentrations of heavy metals were Fe, Cu and Cd, with exception of Pb with mean concentration values of 2,742, 0.024, 0.012, -0.025µ/mg respectively and Hg which has low concentration of heavy metals with a value of -0.064µ/mg as the distance increases. Pb has been shown to negatively impact the kidneys, brain, liver, bone marrow, and reproductive organs of humans, and can also have various negative impacts on plants, including morphological, physiological, and biochemical functions [8]. This is as a result of high traffic volume of vehicles along the road. The relatively high metal concentration of some of the samples could be attributed to accumulation due to runoffs from contaminated areas [9]. The control area of Sp 2, Sp4 and Sp9 of Fe were slightly higher than the sample area. For Cu, Sp7 recorded the highest value for control, while in Cd, the sample area are higher than the control. The control point of Sp9,of Pb has a higher value greater than the sample area, while Sp1, Sp2, Sp3, Sp5, Sp6, Sp7, Sp8, and Sp10 are of the same value with exception of Sp4 in which the sample point is higher than the control. At Sp1, Sp3, Sp6, Sp7, Sp8, Sp9 and Sp10 of Hg, the control points values are higher than the sample while Sp2, Sp4 and Sp5 has slight low value than the sample points. This result suggested that the soil along Choba-Rumuokoro corridor of the East-west road, Port Harcourt is contaminated with Fe, Cu and Cd which are caused as a result of not only congestion of vehicles along the road but also due to geographical position, anthropogenic activities, leaching as well as run-off. This is in support of the work of Aslan, Arzu Kenan, Yalçın, Metin, Ferda, and Omer, [10]: in which the concentration of Selenium in lichen decreases with increase in distance, and also Abdullateef, Kolo, Waziri,& Idris [11], on determining the level of heavy metals as an indicator of environmental pollution. Heavy metals with high concentrations in the environment result in health problems adversely affecting the nervous, blood forming, cardiovascular, renal and reproductive systems. The consequences of heavy metal pollution include reduced intelligence, attention deficit and behavioral abnormality, as well as contribution to cardiovascular disease in adults. Heavy metals such as Hg, Cd, and Pb even at extremely low concentrations, are toxic and are potential cofactors, initiators or promoters in many diseases, including increased risk of cancer [12].

Table 2. Heavy metals concentration in soil along the East-west road

Sample Points	Fe	Control	Cu	Control	Cd	Control	Pb	Control	Hg	Control
Sp 1	1.947	1.027	0.011	0.000	0.009	-0.001	0.000	0.000	0.001	0.000
Sp 2	2.447	2.580	0.007	0.000	0.007	0.001	-0.005	0.000	-0.002	-0.001
Sp 3	1.907	0.820	0.017	0.008	0.004	-0.004	0.000	-0.005	0.000	-0.002
Sp 4	1.54	1.740	0.000	-0.001	0.02	0.009	-0.01	0.000	0.000	-0.002
Sp 5	2.047	0.533	0.039	0.02	0.001	0.000	0.000	0.000	0.000	0.000
Sp 6	0.847	0.733	0.027	0.049	0.000	-0.001	-0.010	0.000	0.000	0.000
Sp 7	1.02	0.933	0.024	0.02	0.001	0.000	0.000	0.000	-0.001	0.000
Sp 8	1.247	0.64.0	0.002	0.000	0.007	0.003	0.000	0.005	-0.062	0.000
Sp 9	0.747	0.893	0.010	0.000	0.007	0.000	0.000	0.000	0.000	0.000
Sp 10	1.333	0.987	-0.002	-0.001	0.012	0.000	0.000	0.000	0.000	0.000
Sum	15.082	10.886	0.135	0.095	0.068	0.007	-0.025	0.000	-0.064	-0.005
Average	2.7422	1.9792	0.0246	0.0173	0.0124	0.0013	-0.0046	0.000	-0.0116	-0.0009
Standard Deviation	0.5655	0.6177	0.0132	0.0162	0.0060	0.0034	0.0043	0.0024	0.0196	0.0009

All concentrations are in µg/mg.

Table 3. Geographic position system (GPS) of each sample point

Sample points	GPS(N)	GPS(E)	GPS(N) control	GPS(E) control
Sp 1	4.89786	6.90194	4.8981	6.90152
Sp 2	4.89364	6.91463	4.89378	6.91471
Sp 3	4.8867	6.92489	4.8871	6.92502
Sp 4	4.88446	6.93647	4.88479	6.93586
Sp 5	4.81754	6.95105	4.87754	6.95041
Sp 6	4.87294	6.96104	4.8723	6.9615
Sp 7	4.86936	6.97924	4.86932	6.97926
Sp 8	4.86831	6.98971	4.86841	6.98984
Sp 9	4.86668	6.99974	4.86614	6.99988
Sp 10	4.8658	7.00488	4.86572	7.0051

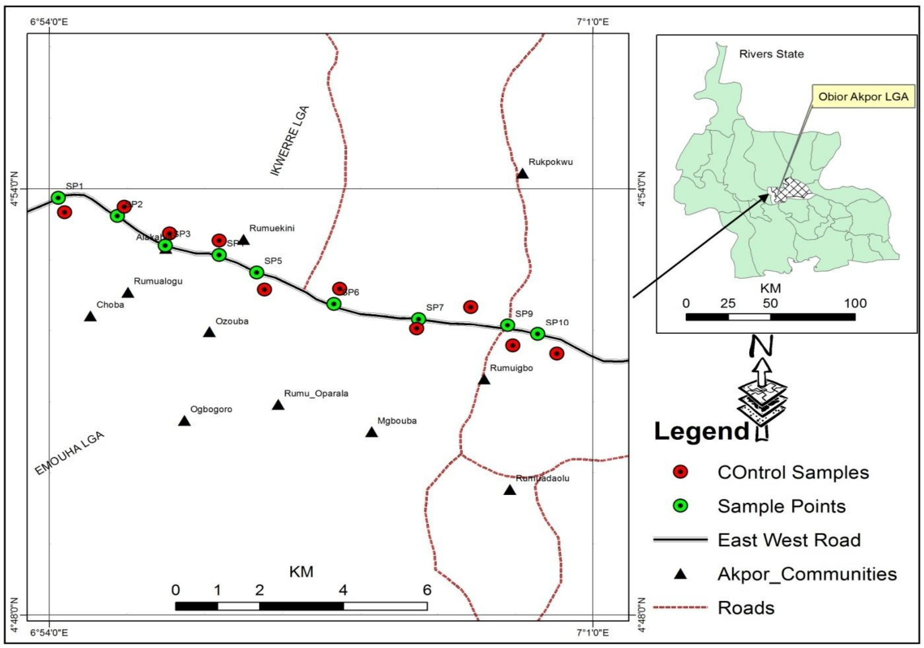

Fig. 2. The East West Road in Obio/Akpor Local Government Area showing sampled points

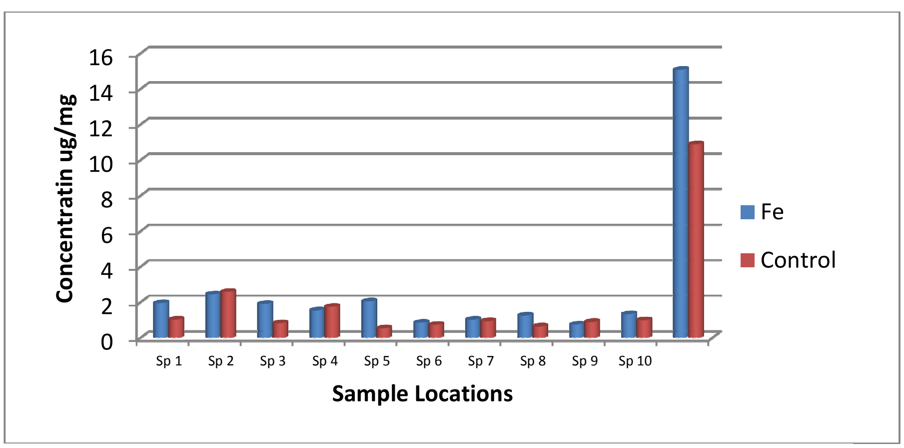

Fig. 3. Concentration of iron across the sample points (Fe)

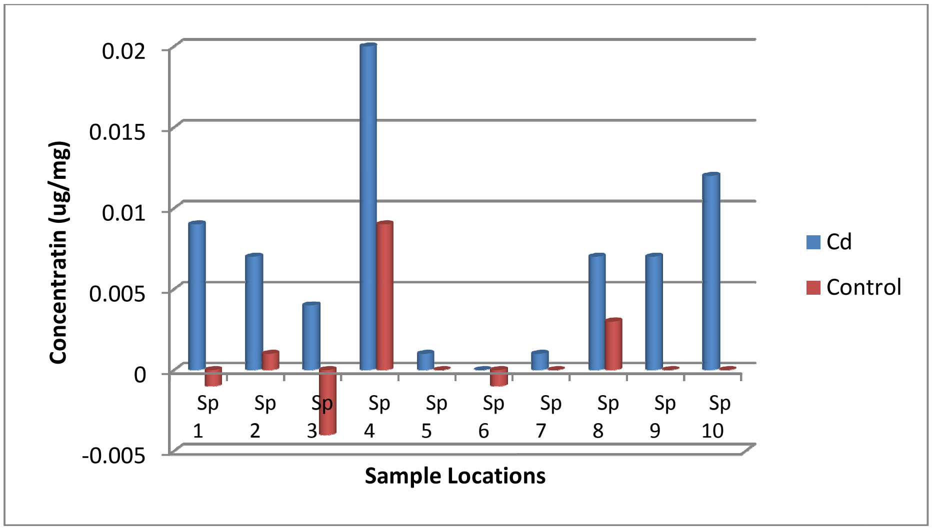

Fig. 4. Concentration of Cadmium (Cd)

Table 4. Comparison with other Studies Elsewhere

S/N	Study Areas	Fe	Cu	Cd	Pb	Hg
1	Ogun state	-	6.98-42.36	0.01-0.35	0.01-26.60	-
2	EU standard	-	50-114	1.0-3.0	90-300	-
3	Kaduna	-	48.00	-	76.92	-
4	Yauri	-	96.13	-	30.09	-
5	China	-	7.26-55.1	0.02-0.33	9.95-56.0	-
6	Present study	14.940-48.940	<0.001-0.780	<0.001-0.240	<0.001	<0.001-0.240

Concentrations are in mg/kg

((Shacklette & Boerngen (1984), Duka (1992), Bradford & Chang (1996), Abida, Ramaih, Harikrishma &Veena (2009), Yahaya (2009) in Olukanmi & Adebiyi (2012)).

The concentration of heavy metals identified along the road from the metal compositional analysis for sample areas shows that the concentration of Fe, Cu and Cd fluctuate and are higher compared to Pb and Hg. Sample point 2 and 5 records the highest value while sample point 1 and 3 are slightly different for iron (Fe). Cu is derived from engine wear, from thrust bearings, bushing and bearing metals, which are common along roadside in the study sites. In a similar study in Nigeria, the results obtained for Cu are higher than 18.00 mg/kg and 1.48 mg/kg reported by Kakulu, [13] and Awofolu, [14] respectively. The concentration of copper obtained from this study is lower than the concentration obtained from those conducted in Kaduna (48.00 mg/kg), [15], Yauri (96.13 mg/kg) [9] and Oti metropolies in Ogun state [16]. When the concentration range obtained from this study was compared with the levels in similar studies elsewhere, the concentration of copper was lower than the concentration recorded for those conducted in the United States, China, Ethiopia and India [17] respectively. The implication of excess Copper through the food chain when taken by man is that it causes gastrointestinal irritation [18]. Cadmium is a very toxic element, with its presence near roads being attributed to dust from the combustion of petrol, in brake linings and is also present in the rubber used for tire production [19,20].

3.2.2 The variation in concentrations of heavy metals in soil along the road

The concentration of heavy metals in the soil varies significantly along the road. These heavy metals vary away from each sample point in each of the heavy metals and also vary from each other. The variation of these heavy metal concentrations is as a result of various anthropogenic activities observed at different points or area as the samples are been collected. For Fe, it is shown that sample point (Sp) 1, 2, 3, 4 and 5 has the highest concentrations. At sp 1, there has been an existence of industrial activity in such location. These have contributed in the increase in concentration of iron (Fe) which has an advert effect on the soil. At Sp2, it is as result of vehicles that are packed at that location. Accumulation of these metals in surface soil is greatly influenced by traffic volume and motor vehicles, which introduce a number of toxic metals into the atmosphere [21,22].

The concentration of heavy metals decrease with an increase in distance from the road side and also fluctuates along Choba- Rumuokoro corridor of the East-west road of Port Harcourt. The influence of distance on potential usage is often conceptualized through distance-decay functions (e.g. 11) expressing the way increasing distance or travel-cost has an inverse effect on the possible usage, i.e. it is less likely that facilities far away is used that those at closer range. At Sp 1, the concentration of Fe decreases as the distance increases to Sp 6, while at Sp 1, 2, 3, 4, and 5 did not decrease much in concentration. This supports the first law of geography i.e areas that are close to each other have similar characteristics than those further apart. The decrease in concentration with an increase in distance is because at Sp5, 6, 7, and 8, does not experience much traffic volume and the level of anthropogenic activities such as auxiliary activity, etc. also, during the construction of the road most of the material used such as bitumen, oil and fuel leakages from the machines used, etc, result to increase in concentration of the soil. The movement of these heavy metals is not random; it is restricted by some factor such as geologic factor. Newton's law of gravitation can be used in this study to explain the distance function. The gravity model postulate that the interaction between any two locations in space is proportional to size (mass) of such places and inversely related to some friction of distance separating them [23].

From Fig. 5, it shows that heavy metals are spatially distributed across the road on the earth surface. Based on Fig. 5, Fe concentration is more abundant on the earth surface across the road compare to other heavy metals tested.

Heavy metals are important element which are required in soil, it has both positive and negation impact to the soil. Base on the data obtained, heavy metals (i.e, Fe, Cu, Cd, Pb and Hg) have impact on roadside soil along Choba – Rumuokoro corridor of the East-West Road. These contaminants which accumulate along roadside exert a constant impact on the biology of the roadside systems by providing a source of slowly dissolving toxic materials [24]. Accumulations of these metals in surface soil are caused by traffic volume and motor vehicles, which introduce a number of toxic metals into the atmosphere [21,22]. Also this contaminant reduces and alters the activities of micro-activities of different organisms.

However, correlation is also used to ascertain the level of relationship that exit between the heavy metals on the earth surface across the sample locations. This is shown in Table 5.

From the Tables 5 and 6, it shows that Cu and Cd, are strongly correlated.

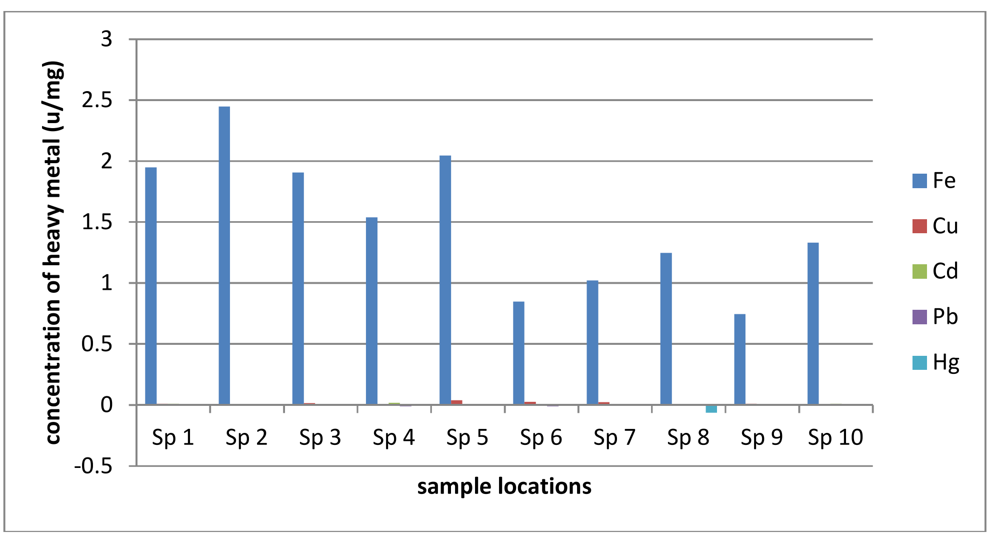

Fig. 5. Distribution of heavy metals across the sample locations

Table 5. Correlation matrix for sampled trace heavy metals

Heavy metals	Fe	Cu	Cd	Pb	Hg
Fe	1				
Cu	0.027338	1			
Cd	0.115397	-0.80721	1		
Pb	0.073984	0.064334	-0.28172	1	
Hg	0.153191	0.306737	-0.00452	-0.20061	1

Table 6. Correlation coefficient of relationship strength

Value of correlation coefficient	Strength of correlation
1	Perfect
0.7-0.9	Strong
0.4-0.6	Moderate
0.1-0.3	Weak
0	No correlated

Source: Adapted after Dancey and Reidy (2004) in Wekpe [25].

4. RECOMMENDATION

Arising from the findings of this research work, the following recommendations are advanced; the state government should provide a public transport system in other to reduce the level of private vehicles on the road. Worn out vehicle should be avoided; this is because most of the vehicle emits more carbon monoxide which is a harmful substance into the environment.

It is also recommended that there should be improved public enlightenment on the need for maintenance, enhancement of fuel quality and the placement of emission standards to mitigate the impact of vehicle emissions on human health should be adopted.

5. CONCLUSION

Road construction and transportation which is a key instrument for every nation's development has both positive and negative impact to the society at large. However, the negative impacts are causing a lot of problems to the natural environment comprising of the soil, air, water as well as impacting human health as well as the ecosystem. This study identified the presence of heavy metals in the soils of roadsides along the east-west road in Port Harcourt Nigeria. There was a marked decrease in the concentration values of the heavy metals as distance increased away from the roadside in most of the sample locations.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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