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Evaluation of Heavy Metal Pollution from Vehicular Exhausts in Soils along a Highway, Southwestern Nigeria

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Abstract— *The Lagos-Ibadan Expressway is the busiest inter-state route in Nigeria and one of the largest road networks in Africa. It handles more than 250,000 PCUs (Passenger Car Units) daily. Amount of metal emissions being released daily from vehicles plying this road into the environment (air, soil, plant and water) is great! This study evaluated heavy metal composition in soils resulting from exhausts pollution from vehicular movement along Lagos-Ibadan Expressway. A total of two hundred and seventy-six soil samples were collected at 5, 15 and 25 m away from the edge of the road. The soil samples were collected with hand auger from the surface to a depth of 10 cm during both dry and wet seasons. Heavy metal concentrations were determined using Atomic Absorption Spectrophotometer (AAS). The heavy metal concentrations found in sampled soil during dry season in $mg.kg^{-1}$ along the study sites revealed the following, Zn (558.03, 21.98), Pb (130.96, 3.64), Cr (24.08, 1.09), Cu (97.43, 4.41) and during wet season Zn (532.51, 5.72), Pb (120.52, 1.85), Cu (79.90, 1.05), Cr (19.82, 0.22). The results indicated a general reduction in heavy metal concentrations in the soil collected during rainy season, when compared with soil collected during dry season. Index of geo-accumulation (I_{geo}) of sampled soils revealed that contamination ranged from moderate to extreme in all the study locations during dry and wet seasons. Potential ecological risk Index (PERI) of the individual location in the study area ranged from 4.38 to 146.84. However, the total PERI of study area was 1136, which indicated that Lagos – Ibadan Expressway is generally polluted with heavy metals. Fe, Mn, Zn, Pb, Cu and Cr are the major heavy metal pollutants found in the soils during dry and wet seasons. The source of these heavy metals being vehicular exhausts emissions along Lagos – Ibadan Expressway.*

Keywords— ***Contamination, heavy metals, Potential Ecological Risk Index, soil, vehicular exhausts.***

I. INTRODUCTION

In many parts of the world today, vehicular exhaust emissions from heavy-duty trucks and other vehicles constitute one of the sources of plant and soil pollution (Akbar *et al.*, 2006). Olukanni and Adebiyi, (2012); Ezemokwe *et al.*, (2017) and Fosu-Mensah *et al.*, (2017) observed that heavy metals affect the ecosystem especially along major highways through these emissions. Soils along roadsides often contain high concentrations of heavy metals and other contaminants. These metals are released from fuel burning (either gasoline or diesel), wearing out of tires, leakage of oils, and corrosion of car metal parts (Dolan *et. al.*, 2006; Olukanni and Adebiyi, 2012). The resultant effect has adversely affected plants, soil, water, air and animals including humans in many urban areas around the world.

Lagos-Ibadan Expressway is a major highway in southwestern Nigeria that links other parts of the country. Nigeria, like other developing countries and some developed countries, has a problem of roadside pollution.

As Africa's most populous nation, Nigeria has its share of smog-filled cities, congested roads, aging vehicles, leaded fuel usage among others, which invariably resulted in large scale pollution of our highways by heavy metals through emissions from vehicle exhausts.The road under study (Lagos – Ibadan Expressway) is one of the busiest highways in Africa. It regularly witness vehicular traffic congestion since it was commissioned in 1978 and vehicular pollution has not been checked by environmental regulatory authorities, leading to elevated levels of pollution year in year out. The pollution level is critical and might be attributed to the poor economic situation of Nigerians. Large importation of old and fairly-used cars and poor vehicle maintenance culture cause increase in the emissions of dangerous substances through the exhaust pipes of vehicles. Large number of irreparable and decomposing car parts litter the road surfaces and roadsides. These expose the residents to serious health risks.

Little or no attention has been placed on metal contamination of the major roads in the country despite its direct contact with a greater part of the population. Poszyler-Adamska & Czerniak (2007) considered vehicle exhausts as first line of source of heavy metal pollutants in any major highway. Simon *et al.* (2013) pointed to the role of traffic emissions in the pollution of Wien soil by Cu, Pb, and Zn. These are the most important metal pollutants from heavy traffic exhaust owing to their presence in fuel as antiknock agent (Suzuki *et al.*, 2009; Atayese *et al.*, 2010). Hence, this present work deals with the evaluation of heavy metals pollution in soils along Lagos-Ibadan Expressway, south western Nigeria, from vehicular exhausts emissions. The objectives of the study are to determine the: (i) concentrations of the prevalent heavy metals in soils along Lagos – Ibadan Expressway from vehicular exhausts emissions; (ii) seasonal effects of heavy metals on soil along the highway; and (iii) level of pollution along Lagos-Ibadan expressway using Pollution Assessment Indices.

II. MATERIALS AND METHODS

2.1 The study area

The study was carried – out along Lagos-Ibadan expressway. The highway stretches from Ibadan (07º19.647'N, 003º52.528'E, 170 m a.s.l) through Ajanla Farms (06º55.140'N, 003º38.174'E, 58 m a.s.l) to 7up Bus stop at the Lagos end (06º35.976'N, 003º22.710'E, 30 m a.s.l). It covers a distance of 115 km.

The topography from Ibadan end of the road is high hills ranging from 58m to 170 m above sea level (Fig. 1) and characterized by low lying lands with gentle slopes in the vicinity of Sagamu Interchange.

Geologically, Lagos-Ibadan expressway is partly underlain by the crystalline rocks of the Precambrian Basement Complex and partly by the sedimentary rocks of the Dahomey basin. The Dahomey basin is a West African Atlantic Margin basin which is made up of Tertiary to Recent and Creteceous sediments (Omotsola & Adegoke, 1981; Obaje, 2009). Lying unconformably above the basement rocks is Abeokuta formation. This formation is overlain by Ewekoro formation which is in turn overlain by the Benin formation (Coastal Plain Sands).

2.2 Sampling Design

The area sampled covered a distance of 115km from Lagos end to Old Tollgate in Ibadan. Sampling started from 7up Bus - stop in Lagos through Ajanla Farms to Tollgate in Ibadan (Table 1). Soil samples were collected at intervals of 5 km in a zigzag manner across the expressway (Fig. 2). The samples were collected using hand auger from the surface to a depth of 10 cm. At each location, three subsamples were taken at 5 m, 15 m and 25 m away from the edge of the road (Fig. 3). These three subsamples were then made into one representative sample. The collected soil samples were stored in polythene bags and labelled apropriately and the coordinates of the sampling locations taken with a Global Positioning System (GPS). This sampling was done during dry and wet seasons for two consecutive years – 2015 and 2016. In all, a total of two hundred and seventy-six (276) samples, consisting of sixty- nine (69) samples each in both dry and wet seasons, were collected throughout the duration of the sampling exercise. Spots with obvious signs of disturbance, such as animal burrowing, engine oil spillage and landfills, construction sites, accidental vehicle deposit sites, burnt materials and/or deposits of any industrial waste were avoided. The samples were then taken to the laboratory for analysis.

2.3 Soil preparation, digestion and analysis

The soil samples were air-dried at room temperature to remove moisture. Thereafter, they were disaggregated and sieved using 2mm sieve size prior to digestion. The sieved soil samples were, then, packed into bottles and labelled appropriately. 5 g of the sieved samples were digested by adding HNO_3/Perchloric acid (2:1) and the mixture was then placed inside a digestor until a colourless fume was observed. It was then removed, filtered and the required volume of 50 ml was made by adding ultra-pure water. The digested samples were kept in clean polyethylene bottles in a refrigerator prior to analysis. Three replicates of the digested samples were then analyzed for the following heavy metals: Cr, Pb, Cu, Zn, Fe, Mn, Ni and Co using Atomic Absorption Spectrophotometer (Buck Scientific AAS, Model 210VGP, Chapman & Pratt 1961). All the concentrations were recorded in mg/kg. Accuracy and precision of the analytical procedures were ensured by the analyses of standard reference materials and replicate samples. Blanks were also analyzed, contents of all the elements in the blanks were below the detection limits.

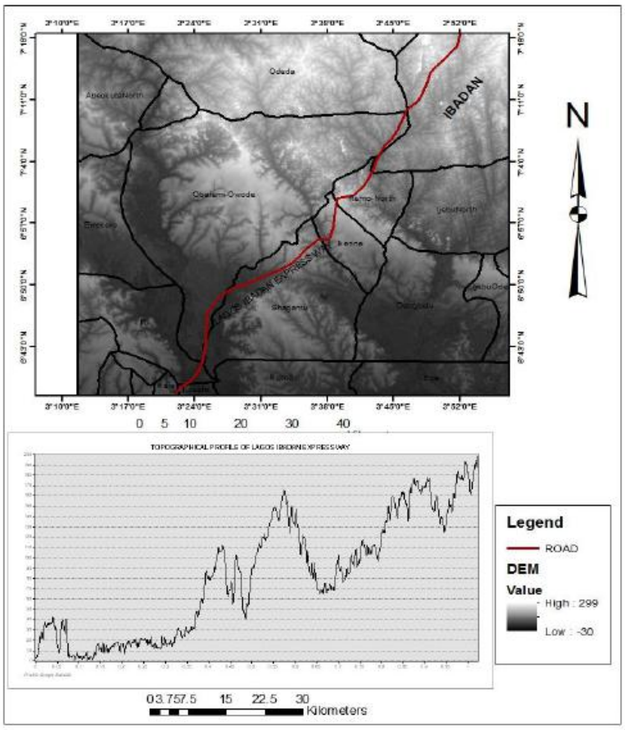

Fig. 1: Topographical Map and Digital Elevation Model (DEM) of Lagos-Ibadan Expressway Profile (Arcgis 10.3.1 Version).

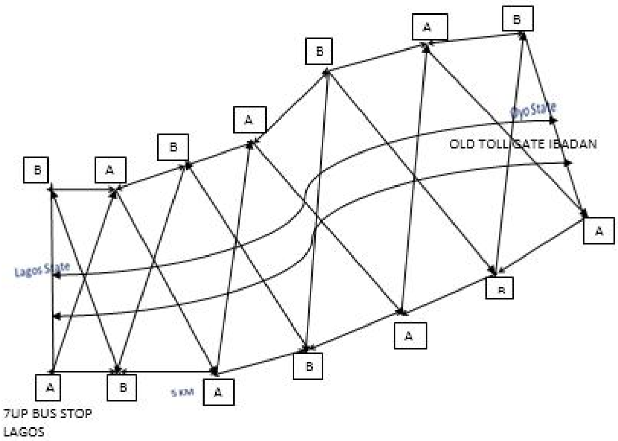

Fig. 2: Systematic zigzag sampling along Lagos-Ibadan Expressway in dry season (January 2015 and January 2016) and in Wet Season (July 2015 and July 2016)

Table 1. Coordinates, Elevations of Sampled Locations along Lagos-Ibadan Expressway

Location Name/Distance From Lagos (Km)	Coordinates N	Coordinates E	Elevation (M) A.S.L	Location Code
7up B/S Lagos (0)	06°35.976'	003°22.710'	30	L1
Secretariat (5)	06°37.494'	003°21.827'	18	L2
Opic (10)	06°39.194'	003°23.713'	11	L3
Arepo (15)	06°41.579'	003°24.910'	3	L4
Ile-Epo (20)	06°44.211'	003°25.175'	24	L5
Nasfat/Cntrl (25)	06°46.921'	003°25.451'	27	L6
Redeemed Area (30)	06°48.921'	003°27.103'	14	L7
Ileke Town (35)	06°49.998'	003°29.322'	15	L8
Mowe 1 (40)	06°51.147'	003°31.849'	34	L9
Mowe 2 (45)	06°52.483'	003°34.352'	91	L10
Mallo Fuel (50)	06°54.146'	003°35.881'	68	L11
Ajanla Farm (55)	06°55.140'	003°38.174'	58	L12
Trailer Park (60)	06°59.878'	003°39.106'	106	L13
General Park (65)	07°00.103'	003°40.653'	142	L14
Max Fuel (70)	07°01.958'	003°42.362'	85	L15
Quarry Jnctn (75)	07°04.321'	003°43.249'	61	L16
Stark Fuel (80)	07°06.450'	003°44.722'	92	L17
Namy Sch Area (85)	07°08.716'	003°45.884'	104	L18
Dominon (90)	07°10.770'	003°47.553'	126	L19
M/Mariana H (95)	07°13.950'	003°48.812'	153	L20
Aramed (100)	07°15.240'	003°50.076'	145	L21
Underb Guru (105)	07°17.135'	003°51.768'	132	L22
Toll Gate Ib (110)	07°19.647'	003°52.528'	170	L23

N = Northings, E = Eastings, a.s.l = above sea level

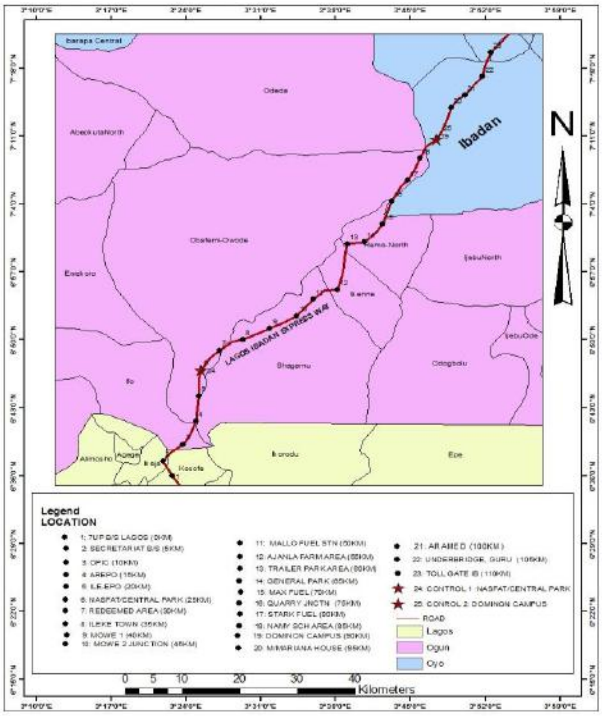

Fig. 3: Itinerary followed During Sample Collection along Lagos-Ibadan Expressway (ArcGIS 10.3.1 Version)

2.4 Data analysis and assessment of heavy metal pollution

The geochemical data from the laboratory were then subjected to statistical analyses using the SAS Statistical software 2014 version. Parameters evaluated are mean and standard deviation of the heavy metal concentrations at 5 m, 15 m and 25 m of each sampling point along the road from Lagos to Ibadan using Duncan's Multiple Range Test. In order to assess the pollution level of the soil, Index of geo-accumulation (I_{geo}), Single Ecological Risk Index (Ei) and Potential Ecological Risk Index (PERI) were computed using Excel™ Software 2007 version

2.4.1 Index of geo-accumulation (I_{geo})

Index of geo-accumulation (I_{geo}) (Muller, 1981) was calculated using the formula below:

$I_{geo} = \mathrm{Log}_2 (C_m/1.5*B_m)$ Equation 1

Where

C_m = Measured concentration of the examined metal in soil samples; and

B_m = Geochemical background reference value of the same metal.

The background reference adopted in this study was based on the world soil average abundance of metals by Levinson (1974). The constant 1.5 is the background matrix correction factor due to the lithogenic effects. The geo-accumulation values were interpreted using the I_{geo} classification shown in Table 2

Table 2. Classification of Geo-accumulation Index (I_{geo}) (After Muller, 1981)

Index	Value	Degree of Contamination
I_{geo}	$I_{geo} \leq 0$	Uncontaminated
	$0 < I_{geo} \leq 1$	Uncontaminated to moderately contaminated
	$1 < I_{geo} \leq 2$	Moderately contaminated
	$2 < I_{geo} \leq 3$	Moderately to strongly contaminated
	$3 < I_{geo} \leq 4$	Strongly contaminated
	$4 < I_{geo} \leq 5$	Strongly to extremely contaminated
	$I_{geo} \geq 5$	Extremely contaminated

2.4.2 Single Ecological Risk Index (Ei)

Single Ecological Risk Index (Ei), of a contaminant in an area, was calculated using this formula:

$E_i = T_i * CF_i$ Equation 2

Where

E_i = Single Ecological Risk Index, T_i=Toxic Response Factor for a given metal, CF_i = Contamination Factor (CF) for the same metal.

Prior to the computation of E_i, CF_i was first computed using the formula;

$CF_i = C_m/B_m$ Equation 3

Where

C_m = Measured concentration of the examined metal in soil samples; and

B_m = Geochemical background reference value of the same metal

The background reference in this study was based on the world soil average abundance of metals by Levinson (1974). The Ecological Risk Index values were interpreted using the classification by Hakanson (1980) (Table 3)

2.4.3 Potential Ecological Risk Index (PERI)

Potential Ecological Risk Index (PERI) was computed using this formula:

PERI (RI) $= \Sigma E_i$ Equation 4

Where

Σ = summation, E_i= Single Ecological Risk Index.

Both the Single Ecological Risk Index (E_i) and Potential Ecological Risk Index (PERI) values were interpreted using the classification in Table 3.

Table 3. Ecological Risk Index (Hakanson 1980)

E_i	Pollution Degree	RI	Risk Level	Risk Degree
$E_i < 30$	Low	RI < 40	A	Low
$30 \leq E_i < 60$	Medium	40 ≤ RI < 80	B	Medium
$60 \leq E_i < 120$	Strong	80 ≤RI < 160	C	Strong
$120 \leq E_i <240$	Very strong	160≤RI < 320	D	Very strong
$E_i \geq 240$	Extremely strong	RI ≥320	-	-

III. RESULTS AND DISCUSSION

3.1 Heavy metal concentrations in sampled soil collected during dry and set seasons

The results of the mean heavy metal concentrations in soil samples collected during dry and wet seasons at 5m, 15 m and 25 m away from the edge of the road are presented in Tables 4a and 4b. The tables revealed that the mean concentrations of the analyzed heavy metals obtained at a distance of 5m away from the edge of the road, during both dry and wet seasons, were significantly higher (P>0.05) than all the other mean concentrations obtained at 15m and 25m away from the edge of the road. The mean concentrations of the heavy metals in the soil were in the order Fe > Mn > Zn > Pb > Cu > Cr > Co > Ni. Metals such as Fe, Mn, Pb and Zn showed considerable elevated concentrations in the soil.

When the results obtained from this study were compared with that of HSE – ENV (2004), the range of Cu values, for example, was lower than the range obtained from this study. This result is also true for Pb as well as Zn (Table 5). Similarly, the concentrations of the elements from this study were higher than those obtained from Yauri soil, Lagos – Badagry road as well as Osogbo area. For example, the range of concentration values from Yauri soil, Lagos-Badagry road and Osogbo area were 0.91 – 23.72(mg.kg^{-1}), 5.99 – 20.63(mg.kg^{-1}) and 27.69 – 21.19(mg.kg^{-1}) respectively for Cu. These values were lower than the 1.05 – 97.43(mg.kg^{-1}) range obtained from this study (Table 6). Table 7 revealed that the results obtained from this study were very similar to those obtained in India and Ethiopia.

3.2 Index of Geo-Accumulation (I_{geo}) of Sampled Soil during Dry and Wet Seasons

The Index of geo-accumulation (I_{geo}) for soil samples collected during the dry season is as shown in Fig. 4. A critical study of the table revealed that Fe had the highest I_{geo} values while Ni and Co had the lowest. The I_{geo} values for Fe obtained at distances 5m, 15m and 25m from the edge of the ranged from 28.71 – 28.88 with the highest value obtained at a distance of 5m away from the edge of the road. Co, on the other hand, had I_{geo} values of 1.71, 0.89 and 0.25 at 5m, 15m and 25m respectively away from the edge of the road. A similar trend was observed for the I_{geo} values for sampled soil in the raining season, Fe had the highest I_{geo} values, while Ni and Co had the lowest values (Fig. 5). The I_{geo} values for the elements are in the order Fe > Mn > Zn > Pb > Cr > Cu > Co > Ni. For all the analyzed elements, the I_{geo} values reduces with distance away from the edge of the road.

3.3 Single Ecological Risk Index (E_i) and Potential Ecological Risk Index (PERI) of Sampled Soil during dry and wet Seasons from the Edge of the Road

The Single Ecological Risk Index (E_i) for a single element and Potential Ecological Risk Index (PERI) of sampled soil during dry season for the study are shown on Table 8. These E_i values decrease as the distance from the edge of the road increases. The table revealed that elevated values of E_i were obtained for Cu while the E_i values for Cr, Mn, Ni and Co were very low. The range of *Ei of the heavy metals are* 0.11-0.34 for Cr, 4.59-13.54 for Pb, 28.32-45.71 for Cu, 1.42-1.99 for Zn, 0.21- 0.24 for Mn, 0.002-.007 for Ni and 0.009-0.023 for Co. In terms of the total Single Ecological Risk Indices (Σ*Ei)* of the analyzed heavy metals, Σ*Ei* is in the order Cu > Pb > Zn > Mn = Cr > Co > Ni. Therefore, Cu was the key influencing factor causing potential ecological risk.

Table 4a. Heavy Metal Mean Concentrations in Sampled Soil Collected during Dry and Wet Seasons from the Edge of the Road

DST	Cr		Pb		Cu		Zn	
	mg.kg^{-1}		mg.kg^{-1}		mg.kg^{-1}		mg.kg^{-1}	
	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season
5m	15.24±10.67^{a}	10.27±8.48^{a}	54.17±51.06^{a}	84.76±47.00^{a}	41.14±30.20^{a}	31.72±26.40^{a}	189.48±166.88^{a}	158.65±157.52^{a}
15m	9.75±6.17^{b}	6.94±4.73^{b}	34.75±32.88^{b}	29.96±29.79^{b}	31.59±26.24^{b}	26.03±23.44^{b}	153.85±140.82^{b}	139.32±133.48^{b}
25m	4.92±2.64^{c}	3.42±2.09^{c}	18.34±19.53^{c}	15.72±18.11^{c}	25.49±23.73^{c}	21.99±22.44^{c}	134.58±130.65^{c}	129.44±128.13^{c}

*mean on the same column followed by the same letter are not significantly different at P<0.05. (Duncan's Multiple Range Test). DST = Distance

Table 4b. Heavy Metal Mean Concentrations in Sampled Soil Collected during Dry and Wet Seasons from the Edge of the Road

DST	Fe		Mn		Ni		Co	
	mg.kg^{-1}		mg.kg^{-1}		mg.kg^{-1}		mg.kg^{-1}	
	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season
5m	15746.71±2780.15a	13212.61±2732.31^{a}	200.08±50.46a	175.03±42.48^{b}	0.09±0.13a	0.05±0.08^{a}	0.25±0.20^{a}	0.17±0.15^{a}
15m	14319.42±2238.08b	13020.96±2310.04^{ab}	187.82±48.34b	174.43±47.88^{ab}	0.04±0.07b	0.04±0.06^{b}	0.14±0.14^{b}	0.11±0.09^{b}
25m	13975.91±2622.84c	13129.91±2569.51^{b}	181.74±48.55c	176.79±48.02^{a}	0.02±0.07c	0.03±0.05^{c}	0.09±0.14^{c}	0.09±0.11^{c}

*mean on the same column followed by the same letter are not significantly different at P<0.05. (Duncan's Multiple Range Test). DST = Distance.

Table 5. Comparison of Acceptable Range of few Heavy Metals in Some Studies with the Heavy Metals in Sampled Soil in the Present Study

[a]HSE-ENV (2004)

Metals (mg kg^{-1})	Acceptable range[a]	Observed range from this study
Cu	5 – 50	1.05 – 97.43
Pb	5 – 50	1.85 – 130.96
Zn	10 – 120	5.72 – 558.03

Table 6. Comparison of a few Heavy Metals Concentration in Sampled Soil in the Present Study with Similar Studies within Nigeria

Heavy metals (mg.kg^{-1})	This study	[a]Yauri soil	[b]Lagos-Badagry road	[c]Osogbo area
Cu	1.05 – 97.43	0.91 - 23.72	5.99 - 20.63	27.69 - 21.19
Pb	1.85 – 130.96	35.9 - 484.9	0.25 - 4.24	92.07 - 68.74
Zn	5.72 – 558.03	79.6 - 202.4	NA	56.27 - 42.45

[a]Yahaya *et al*., (2010); [b]Adeniyi & Owoade (2010); [c]Fakayode & Olu-Owolabi (2003); NA: Not applicable

Table 7. Comparison of a few Heavy Metals concentration in Sampled Soil in the Present Study with Similar Studies in the World

Metals mg kg^{-1}	This Study	[a]Study in U.S.A	[b]Study in China	[c]Study in Poland	[d]Study in India	[e]Study in Ethiopia	[f]EU Reg Standard
Cu	2.67 – 97.43	2.86 – 101	7.26 – 55.1	2.0 – 18.0	5.34 – 198.23	23.7 – 93.0	50 – 114
Pb	3.64 – 130.96	4.62 – 55.4	9.95 – 56.0	7.1 – 50.1	ND – 623.95	20.3 – 325.4	90 – 300
Mn	113 – 271.62	43 – 2532	134 – 1740	83 – 1122	NA	NA	1500
Ni	0.003 – 0.24	2.44 – 69.4	7.73 – 70.9	2.0 – 27.0	343 – 1409	47.3 – 200.6	50

Source; [a]Yahaya *et al.*, (2010); [b]Shacklette & Boerngen (1984); [c]Bradford *et al*., (1996); [d]Dudka (1992); [e]Abida *et al.*, (2009) and [f]Melaku *et al*., (2005). ND= Not Detected; NA =Not Available

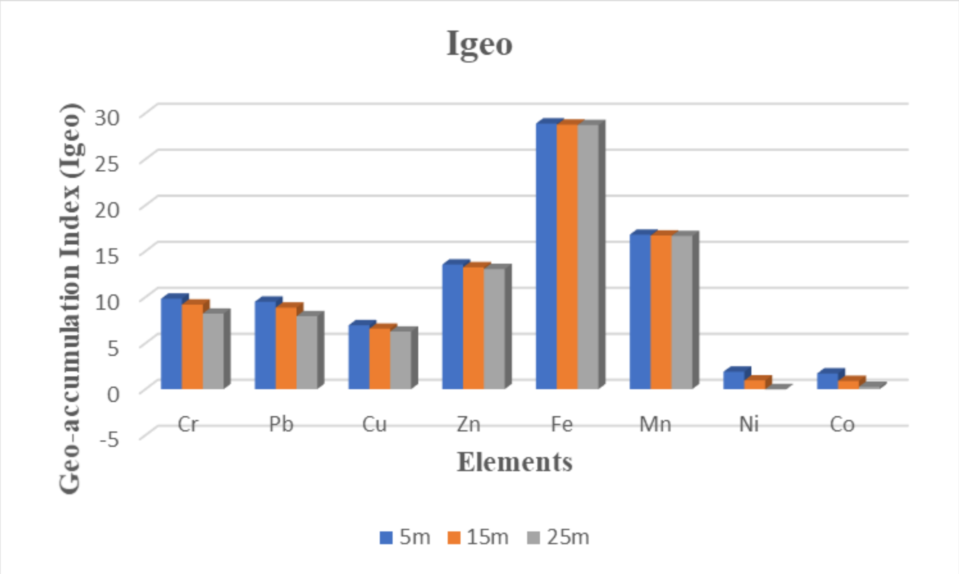

Fig. 4: Index of Geo-accumulation for sampled soil during dry season from the edge of the road inwards

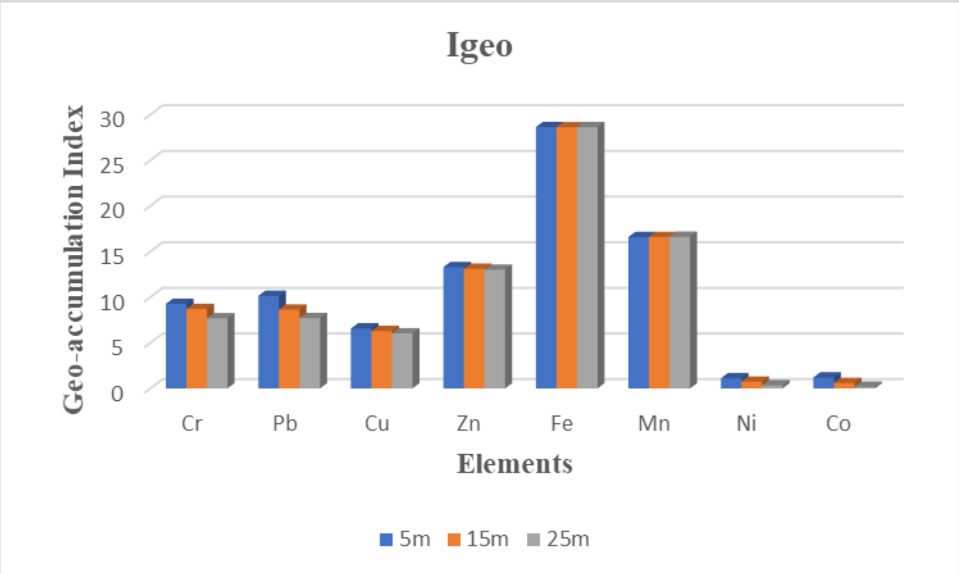

Fig. 5: Index of Geo-accumulation for sampled soil during wet season from the edge of the road inwards

Similar trends were observed for both *Ei* and PERI values for the sampled soil during wet season. Both the *Ei* and PERI values for the analyzed elements reduce with increasing distance away from the edge of the road. For example, while the PERI values was 58.77 at 5m, it reduced to 38.45 and 30.15 at 15m and 25m respectively. The range of *Ei of the heavy metals are* 0.08-0.23(Cr), 3.93-21.19(Pb), 24.44-35.25(Cu), 1.36-1.67(Zn), 0.21(Mn), 0.002-.004(Ni) and 0.0085-0.0173(Co). In terms of the total Single Ecological Risk Indices (Σ*Ei)* of the analyzed heavy metals, Σ*Ei* is in the order Cu > Pb > Zn > Mn > Cr > Co > Ni (Table 9). Therefore, Cu was the key influencing factor causing potential ecological risk.

The RI for the soil ranged between 34.86 - 62.05 and 30.15 – 58.77 for the soils in dry and wet seasons respectively.

Table 8. Single Ecological Risk Index (E_i) and Potential Ecological Risk Index (PERI) for Sampled Soil during Dry Season from edge of the Road

DIST	*Ei*							PERI
	Cr	Pb	Cu	Zn	Mn	Ni	Co	
5 m	0.34	13.54	45.71	1.99	0.24	0.007	0.023	62.05
15 m	0.22	8.69	35.10	1.62	0.22	0.003	0.014	46.07
25 m	0.11	4.59	28.32	1.42	0.21	0.002	0.009	34.86
PERI=Σ*Ei*	0.67	26.81	109.14	5.03	0.67	0.011	0.047	142.98

Table 9. Single Ecological Risk Index (E_i) and Potential Ecological Risk Index (PERI) for Sampled Soil during Wet Season from edge of the Road

DIST	E_i							PERI
	Cr	Pb	Cu	Zn	Mn	Ni	Co	
5m	0.23	21.19	35.25	1.67	0.21	0.004	0.0173	58.77
15m	0.15	7.49	28.92	1.47	0.21	0.003	0.0114	38.45
25m	0.08	3.93	24.44	1.36	0.21	0.002	0.0085	30.15
PERI=ΣE_i	0.46	32.61	88.61	4.50	0.62	0.008	0.0371	127.37

IV. DISCUSSION

The results of the heavy metal concentrations for sampled soil during dry and wet seasons at 5m, 15m, and 25m from the edge of the road revealed that the mean concentrations of heavy metals reduce as the distance increases away from the edge of the road. This is also in agreement with Mohammed & Folorunsho (2015) that the closer the soil is to the road, the more likely it will be polluted or contaminated by vehicular/human activities. Concentrations of heavy metals (Cr, Pb, Cu, Zn, Fe, Mn, Ni, Co) in soil were higher in dry season than in wet season at the same distance away from the road. These could probably be due to the fact the elements which were enriched at the top may be depleted/leached at the surface of the soil by rains (Ndiokwere, 1984). Furthermore, erosion, topography, vegetation cover, temperature, soil type and other human activities may be other factors that could add to or reduce the concentrations of these metals in soil in some of the locations along the study area and in general.

However, Pb concentration of 84.76 mg/kg was found to be highest at 5m during wet season when compared with Pb concentration of 54.17 mg/kg recorded during dry season at the same distance. This may be as a result of other anthropogenic activities apart from pollution from vehicular emissions.

The reasons for extremity in concentrations of some of these heavy metals (e.g. Fe, Mn and Zn) in the study area may be as a result of the closeness of some locations to parks especially those around Trailer Park, General Park, Toll Gate, and Ibadan. Other places like 7up Bus stop, OPIC and Redeemed Church which are prone to heavy traffic may likely acquire more deposits of some of these heavy metals.

The main pollutant found in sampled soil during dry and wet seasons are Zn, Fe, Cu, Pb and Mn. All the heavy metals mentioned above are actually associated with lead fuel, fuel burning (either gasoline or diesel), wear out of tires, leakage of oils, corrosion of car metal parts, traffic and other human activities. These are the daily activities experienced in the study area, Lagos – Ibadan expressway. According to Huntzicher *et al.*, (1975); Ndiokwere, (1984) about 75% of Pb is emitted from the exhaust of motor vehicles in particulate form and it is also an important component of anti-knock fluid in petrol. Zn could also be present in tyres of motor vehicles.

Also the research work compared heavy metals obtained in the sampled soil with other previous studies in Nigeria. The result from other parts of the country indicated that Cu range is higher in Lagos-Ibadan Expressway than that of Yauri soil, Lagos – Badagry road and Osogbo area. This should be expected because the volume of traffic experienced in the study area, Lagos-Ibadan expressway, is far more than in any other part of the country. This is also applicable to Zn while Pb was within the range of what was obtained at Yauri soil (Adeniyi & Owoade, 2010; Fakayode & Olu-Owolabi, 2003; Yahaya *et al*., 2010). Furthermore, the heavy metals concentrations obtained in this study are very similar to those of India and Ethiopia. This may be so because heavy metal emissions from vehicular emissions and other similar human activities are not regulated in most of the developing countries, India and Ethiopia inclusive.

The geo-accumulation index (I_{geo}) values for the soil samples were interpreted using Muller (1981) classification. The average I_{geo} values for the heavy metals (at 5m, 15m and 25m) in the soil samples in both dry and wet seasons are generally higher than 6 especially for Cr, Pb, Cu, Zn, Mn and Fe. This is an indication that the soil along Lagos – Ibadan Expressway are extremely contaminated with respect to these elements. The average I_{geo} values for both Co and Ni ranged between 0 – 2 (i.e. $0 < I_{geo} \leq 2$) for both wet and dry seasons, indicating that the soils are uncontaminated to moderately contaminated. It also showed that pollution, in most of the study area, is not as a result of geological activities but as a result of vehicular movements and other anthropogenic activities. However, the average I_{geo} for Ni showed a negative value, at a distance of 25m away from the road, which indicates that the metal is not a pollutant to that environment at that location. Therefore, the source of the metal at this location could probably be from the rocks underlying the area. Furthermore, the I_{geo} values for soil sampled during dry season were higher than I_{geo} values for soils collected during wet season in the study area over the same period of time.

Single Potential Ecological Risk Index of metals in the soil was also assessed. During dry season, only Cu showed the highest risk index of 45.71 at 5m from the edge of the road, which reduced to 28.32 at 25m from the edge of the road. The total Single Ecological Risk Indices (ΣEi) of the analyzed heavy metals, ΣEi, is in the order Cu > Pb > Zn > Mn = Cr > Co > Ni. Therefore, Cu was the key influencing factor causing potential ecological risk. The RI at 5m (62.05) and 15m (46.07) away from the road indicated that the soil potential ecological risk index was level B corresponding to moderate ecological risk. A similar result was obtained for the *Ei* of the elements during wet season. The total ΣEi being in the order Cu > Pb > Zn > Mn = Cr > Co > Ni while the RI values indicated that the soil ecological risk index was medium at a distance of 5m away from the road.

V. CONCLUSION

There was a general reduction in heavy metal concentrations in the soil samples collected in rainy season when compared with sampled soil in dry season and when moved 5 m, 15 m and 25 m away from the edge of the road.

Index of geo-accumulation (I_{geo}) of sampled soil revealed that contamination ranged from uncontaminated to extreme contamination in the study locations during dry and wet seasons. The I_{geo} for Ni showed negative values in many sites which is an indication that the metal is not a pollutant from exhaust and the source is probably geogenic. The sampling points 5m away from the road exhibited a medium potential ecological risk for Cu.

The research results showed that Fe, Mn, Zn, Pb, Cu and Cr are the major heavy metal pollutants in the soil during dry and wet seasons, while Ni and Co are the least prevalent. A critical factor that could have contributed significantly to deposition and accumulation of these heavy metals in the soil for both seasons is the volume of traffic along Lagos-Ibadan Expressway which varied from time to time. Constructions, refuse dumps, effluent or release of industrial waste, accident on the highway resulting into spillage of dangerous chemicals into the environment may also have contributed to the deposition of these heavy metals in soil.

The study area, Lagos – Ibadan Expressway, is highly polluted and the major source of pollution is through anthropogenic activities, which are mainly from exhaust emissions from vehicular movement along the expressway over time. The study has also provided some relevant baseline information for accessing the public health risks, which could arise from living, farming, grazing or fish ponds along Lagos-Ibadan Expressway. For the people that have been living along the highway for years it is advisable for such people to go for comprehensive medical test to know their health status as regards the amount of heavy metals present in their body before it is too late.

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