Investigation and Assessment of Heavy Metal Concentration in Soil Samples Using Enrichment and Contamination Factors Along Four Busy Roads in Parts of Obio/Akpor, Rivers State, Nigeria

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Abstract

Soil and vegetation along high vehicular traffic roads are prone to contamination from vehicular emissions, and wear and tear of vehicular components. The level of heavy metal contamination in soil at different soil depths (0-15cm and 15-30cm) along four busy roads (Aba road, East-West road, Ikwerre road and NTA road) in Obio/Akpor Local Government Area and a control site (Ikwerre Ngwo) in Etche Local Government Area, Rivers State, Nigeria was investigated. Four sampling points were established along each road at a distance of 1Km from each other. Soil pH and conductivity were assessed by the metre method while the levels of ten heavy metals (Ag, Cr, Ni, Co, Mn, Cd, Pb, Cu, Zn and Fe) were determined using Atomic Absorption Spectrophotometry (AAS). The metal distribution pattern observed from the results of analysis was in the order Fe>Mn>Zn>Pb>Cu>Ni>Cr>Co>Ag>Cd. Of all locations sampled, Fe (3162.3±38.31mg/kg) in East/West road had the highest mean concentration while Cd (0.003±0.002mg/kg) in NTA road had the least. The Pollution Load Index (PLI) showed low (0.545) to moderately polluted (2.593) sites but the Enrichment Factors (EFs) for Pb and Cu ranged from moderate to severe enrichment. This means that the soils are contaminated to an extent but not polluted. It is therefore very obvious that the concentration of these metals on roadside will increase with time and pose serious threat to soil, surface and ground water, as well as animal and human health. Continuous monitoring of these metals along the identified and similar roads by relevant government agencies is advocated as a proactive measure to check pollution arising from vehicular movement and indiscriminate abandonment/dumping of spoilt vehicles on roadside.

Key words: Atomic Absorption Spectrophotometry, Soil, Heavy metals, Pollution Load Index, Enrichment Factors

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Introduction

Soil pollution can be defined as the persistent buildup of toxic compounds, salts, disease causing agents or radioactive materials, chemicals etc that have adverse effects on the growth of plants, animals and human health (Okrent, 1999). The quality of soil is closely related to human health more especially to its rate of pollution (Velea *et al.,* 2009; Romic and Romic, 2003). Soil has the ability to transfer pollutants to food chain, human or animal and ground water because it acts as sink to pollution and provides critical environmental interface/avenue where interactions between water, rock and air takes place and also a means of pollution to living organisms, oceans, sediments, surface and ground water (Facchinelli *et al.,* 2001).

Globally, there is great attention of heavy metal enrichment of the soil because they are non-biodegradable and have long biological half-lives (Li *et al.,* 2004). Heavy metals occur naturally in soil by weathering of parent rock or through anthropogenic activities. These heavy metals that occur naturally are often not toxic with little or no threat to the ecosystem (Kanu *et al.,* 2015), but anthropogenic activities result in the elevation of these metals to level that may pose high risk to the health of humans, animals and plants. These might occur from various diffuse (traffic activities) and point (industrial emissions such as coal combustion, power plants, chemical plants, etc) sources (El-Hassan *et al*., 2006). Roadside traffic contributes to high level of heavy metals in the ecosystem by vehicular exhaust (which are produced as a result of incomplete combustion of fuel) and non-exhaust emissions (generated by chemical and mechanical processes). Exhaust emissions release into the atmosphere different pollutants such as particulate matter, carbon monoxide, polycyclic aromatic hydrocarbons (PAHs) and nitrogen dioxide while non exhaust emissions release into the environment pollutants from brake, wear and tear of tires, clutch usage, road abrasion, corrosion of vehicles (Kanu *et al.,* 2015). Arowolo *et al.,* (2000) reported that soils from topsoil and roadside of heavy traffic routes in urban areas are pointers of heavy metal contaminants from atmospheric deposition. Heavy metals like Pb, Cd, Zn and Cu are good pointers of soil contamination because they appear in car components, emissions from industrial incinerators, gasoline and oil lubricants (Popoola *et al.,* 2012). The extent of pollutants that emanate from road traffic are affected by fuel quality and types, types of engine (gasoline or diesel powered engine), age of vehicles and variety vehicles (e.g trucks, cars etc), traffic conditions (light or heavy), tire types etc (Kanu *et al.,* 2015).

Several research works have shown the means of metal enrichment of soil and the plants that grew on them (Szollosi *et al.,* 2009; Del Rio *et al.,* 2002). Heavy metals are harmful because they have the ability to accumulate in different parts of human body and posses adverse health risks to human even when the concentrations are low (Ikeda *et al.,* 2000) due to their persistent and non-biodegradable nature (Duruibe *et al.,* 2007).

The ability of plants to accumulate heavy metals in their tissues has led to rise in metal contents of farm production (Khan et al., 2008a, 2008b). Metal ingestion (Pb, Cd, Ni, Zn, Cu etc) can cause serious depletion of nutrients that are essential in the body which results in decrease in immunological defenses, disabilities related with malnutrition, growth retardation (caused by Pb, Cd, Al, and Mn), psychosocial dysfunctions and a high prevalence of upper gastrointestinal cancer (Turkdogan *et al.,* 2003). Pb and Cd have been shown to have carcinogenic effects (Trichopoulos, 1997). Also elevated levels of Pb, Cd and Cu in fruits and vegetables were associated with high prevalence of upper gastrointestinal cancer (Turkdogan *et al.,* 2003).

Constant monitoring and evaluation of heavy metal contamination is necessary in order to assess the impact in our environment. Different approaches are been applied to assess the severity of heavy metals in soil and to distinguish anthropogenic inputs from natural inputs in heavy metal contaminated soils. These include pollution load index (PLI) and enrichment factor (EF). The worrisome situation of traffic congestion along busy roads in Rivers State and vehicular pollution are not being properly monitored by environmental regulatory bodies and this has led to high level of pollution. This might be attributed to poor maintenance culture of vehicles, importation of fairly used cars, large amount of decomposing car parts that litter the roadside etc, all these pose serious health hazards to inhabitants. Thus, the need for pollution investigation from vehicular sources of the study area.

In this study, soil pH and conductivity at different soil depths (0-15cm and 15-30cm) as well as heavy metal distribution (Ag, Cr, Ni, Co, Mn, Cd, Pb, Cu, Zn and Fe) were investigated. The contamination of the soil based on the extent of contamination using Enrichment Factor (EF) and Pollution Load Index (PLI) (Reddy *et al.*, 2004; Selvaraj *et al*., 2004; Woitke *et al.*, 2003; Aloupi and Angelidis, 2001; Tomllinson *et al.*, 1980) were determined. The main aim of this study is to assess the status of heavy metal in soil along four major roads in Rivers State. This is with the view to establishing the extent of anthropogenic heavy metal contribution and vertical extent of their distribution at the different sites.

Materials and Methods

Description of the Study Area

This study was carried out along four high traffic roads (Aba Road, East-West Road, Ikwerre road and NTA road) in parts of Obio/Akpor Local Government Area. A control site was chosen from Ikwerre Ngwo in Etche Local Government Area both in Rivers State, in Nigeria. The exact geographical co-ordinates of the sampling locations are shown in Table 1. Two distinct seasons are experienced in this area. Rainy season starts from April and ends in October while dry season starts from November and ends in March. The climatic characterization of this area include high relative humidity, high temperature, high sunshine and high rainfall.

Aba road and East-West road are major roads in Obio/Akpor linking other states with Rivers State, which results to a lot of vehicular traffic. Ikwerre and NTA roads are lesser traffic routes. The control (Ikwerre Ngwo) is a rural area and the inhabitants are mostly farmers.

Sample Collection

Samples were collected in the month of December, 2014. The samples were taken at a distance of one meter away from the major road. At each sampling point three top soil (0-15cm) and sub-soil (15-30cm) samples were collected with the aid of soil augar. They were mixed thoroughly to form a composite sample and were transferred quickly into well labeled sterile polyethene bags, and were taken to an analytical laboratory for heavy metal analysis.

QUALITY ASSURANCE (QA)/ CONTROL (QC)

Quality assurance (QA)/control (QC) procedures as prescribed by the United State Environmental Protection Agency (EPA) for analysis of metal was employed. The analytical procedures were controlled by replicating the precised analytical results. The glass wares used for this analysis were from Pyrex, they were washed with 1: 4 nitric acid, rinsed twice with distilled water and oven dried at a temperature of 105^0C for 30 minutes. All reagents used were of analytical grades (BDH Chemical Limited, Poole England) standard solutions prepared from 1000µg/g stock solution of Mn, Cr, Cd, Ag, Cu, Pb, Zn, Ni, Co and Fe were used for flame atomic absorption analysis. In this study, the certified standard reference material used was Accu standard USA. The results obtained are shown in Table 3.

Sample Preparation

The soil samples collected from the sample stations were air-dried at room temperature for 48 hours, crushed and sieved through a 2 mm plastic sieve to remove coarse particles before analysis (Allen *et al*., 1994; IITA, 1979). The pH of the soil sample was determined in 1: 1 soil water suspension. It was stirred for half an hour and allowed to settle for an hour before determining the pH by inserting the electrode of the pH meter (Jenway 3015 model) into the partly settled suspension. The results obtained when the figure on the meter became constant were reported as soil pH in water. Buffer solutions of 4.0, 7.0 and 10.0 were used to calibrate the pH meter before usage while distilled water was used to wash the electrode. Organic carbon content was determined by modified $K_2Cr_2O_7$ digestion of Walkley-Black method (1934). The cation exchange capacity (CEC) was determined by adding 1M KCl to cations (K^+, Na^+, Mg^{2+}, Ca^{2+}) exchanged by neutral 1M $NH_4C_2H_3O_2$ (pH 7) as described in Barton and Karathanasis (1997). K, Na, Mg and Ca were determined by atomic absorption spectrophotometer. The exchangeable acidity was determined by titration and the cation exchange capacity (CEC) was obtained by summation of exchangeable cations and exchangeable acidity. Soil conductivity was obtained electronically using conductivity meter (HACH Ecttesr Microprocessor series model), by inserting the electrode into the mixtures and the figures were recorded when the values on the meter became constant.

For the whole metals in each case, 1gram of the air-dried sample was placed in a clean 100 ml beaker and 2 ml of one normal nitric acid and 20 ml distilled water were added. The mixture was allowed to stand for 15 minutes before digestion by heating gently at a low temperature on a hot plate, allowed to cool for 30 minutes after which the digest was filtered into a 100 ml volumetric flask (Allen *et al.,* 1974; Sahrawat *et al.*, 2002). The blank and sample were digested the same way. The filtrate was analysed for heavy metals using Atomic Absorption Spectrophotometer (AAS) GBC Avanta Programmable A6600. The ASS was calibrated by aspirating a series of working solutions prepared from an Accu standard stock solution of 1000 mg/l for each of the respective metals in triplicates. The operational conditions as well as the instrument's settings were in accordance with the manufacturer's specifications.

Pollution Load Index (PLI)

Attempts were carried out to calculate the PLI using the Tomllison's approach (Tomllinson *et al.,* 1980). This was done in order to obtain proper assessment of the degree of contamination. The PLI shows the number of times by which metal contents in the experimental sites exceed the mean natural background concentration. It also provides a total summation of the overall level of heavy metal toxicity in a particular sample. The control sample was taken to represent natural background. PLI provides an estimate in the metal contamination status and the necessary action to be taken (Angulo, 1996). This is obtained as a contamination factor (CF) of each metal with regard to the natural background value in the soil (Manoj *et al.,* 2012), by the equation;

$$CF = \frac{C_{sample}}{C_{background}} \quad (1)$$

$$PLI = (CF_1 \times CF_2 \times CF_3 \times CF_4 \times \ldots \times CF_n)^{1/n} \quad (2)$$

Where
CF = contamination factor

n = number of metals

C_{sample} = mean metal concentrate in polluted soil

$C_{background}$ = mean natural background value of that metal.

According to Zhang *et al.,* (2011) and Singh *et al.,* (2003), six pollution categories are interpreted and recognized:

$0 < PLI \leq 1$ = unpolluted

$1 < PLI \leq 2$ = moderately to unpolluted

$2 < PLI \leq 3$ = moderately polluted

$3 < PLI \leq 4$ = moderately to highly polluted

$4 < PLI \leq 5$ = highly polluted

$PLI > 5$ = very highly polluted

The Enrichment Factor

The enrichment factor (EF) was used to evaluate the relative contributions of natural and anthropogenic metal inputs to soil

(Adamo *et al.*, 2005; Valdes et al., 2005). It has also been used to indicate the degree of pollution and contamination (Feng *et al.*, 2004). Data from samples taken from the control site (Ikwerre Ngwo in Etche Local Government Area) were used to establish metal normalizer relationships to which data generated from the experimental sites were compared. Based on this technique, metal concentrations were normalized to the textural characteristics of soil. The most used reference elements include; Fe, Mn, Sc and Al (Loska *et al.*, 1997). Fe was used as metal normalizer in this study because Nigerian soils have been reported to be rich in Fe (Ololade *et al.*, 2007). Rubio *et al.*, (2000) defined enrichment factor as;

$$EF = \frac{(X/Fe)_{soil}}{(X/Fe)_{background}} \quad (3)$$

Where;

$(X/Fe)_{soil}$ represents ratio of heavy metal (X) to Fe in the experimental site.

$(X/Fe)_{background}$ represents natural background value of the metal –Fe ratio.

The enrichment factor values close to unity indicate crusted origin, those less than 1.0 suggest a possible depletion of metals, whereas EF > 1.0 indicates that the element is of anthropogenic origin (Zsefer *et al.*, 1996). Birth (2003) categorized enrichment factor into five groups;

i. EF < 1 indicates no enrichment
ii. EF < 3 indicates minor enrichment
iii. EF = 3-5 indicates moderate enrichment
iv. EF = 5-10 indicates moderately severe enrichment
v. EF = 10-25 indicates severe enrichment
vi. EF = 25-50 indicates very severe enrichment and
vii. EF > 50 indicates extremely severe enrichment.

Statistical Analysis

The data obtained were statistically analyzed using Standard Error Mean (SEM) using Microsoft Excel package version 2007. Least significant difference (LSD) ($P < 0.05$) was used to separate means.

Results

The mean values and standard error for soil chemical parameters are shown in Table 2. The pH values of the soil ranged from 4.73 ± 0.1 – 5.12 ± 0.1 with the highest recorded in East/West road and the least recorded in Aba road for top soil, while for sub soil, it ranged from 6.51 ± 0.1 – 7.18 ± 0.1 with the highest recorded in Aba road and the least in NTA road. The conductivity ranged from 150 ± 2.7 – 1858.8± 50 (0-15cm) and 73.3 ± 2.7 – 188.25 ± 10.7 (15-30cm). The highest conductivity for top soil was observed in Ikwerre road and the least was observed in NTA road, while for sub soil the highest was observed for Aba road and the least was observed in Ikwerre road. The organic carbon decreases down the soil profile with the highest value recorded in Aba road (4.85 ±0.07) and the least observed in Ikwerre road (4.23 ± 0.2). Ikwerre road seemed highly enriched with soil macronutrients (Na, Mg, K and Ca) than other locations.

Heavy Metal Distribution

The concentration of heavy metals (Ag, Cr, Ni, Co, Mn, Cd, Pb, Cu, Zn and Fe) and their distribution pattern across different soil profiles is presented in Table 3. From the results obtained, it was observed that the concentration of heavy metals studied were in this order: Fe>Mn>Zn>Pb>Cu>Ni>Cr>Co>Ag>Cd.

Pollution Load Index

The values of the contamination factor (CF) and pollution load index (PLI) are presented in Table 4. The trend is such that the highest CFs was observed in Pb in the four roads. Zn had the lowest CFs for Aba road, Cu had the lowest for East-West road, Co had the lowest for Ikwerre road while Cd had the lowest for NTA road. The decreasing order for of CFs in Aba road was in this order: Pb > Cu > Cd > Co > Mn > Ni > Cr > Ag > Zn > Fe. For East-West was Pb > Ni > Ag > Co > Cr > Mn > Cd > Zn > Fe > Cu. For Ikwerre road was Pb > Cd > Ag > Ni > Zn > Cr > Mn > Fe > Cu > Co while for NTA road it was; Pb > Cu > Co > Ni > Ag > Zn > Mn > Fe > Cr > Cd.

Enrichment Factor

Detailed values of the heavy metals studied with regard to the natural background concentration are presented in Table 5. Variation occurred in the EFs in Aba roads with all metals occurring at levels ≥ 1 while in East-West road with Ag, Cr, Ni, Mn, Cd, Pb, Zn and Fe occurring at values ≥ 1 and Cu < 1. For metals in Ikwerre road, Co, Cr and Cu had E.F < 1.0 which indicated no enrichment, while Fe, Mn, Zn, Ni, Ag and Cd had E. F ≥ 1.0 which fell within the range of minor enrichment, Pb had the highest enrichment factor with values > 9.0 indicating moderately severe enrichment in Ikwerre road. The enrichment factor values for NTA road ranged from no enrichment (Cr (0.7), Cd (0.1)) to minor enrichment Fe (1.0), Zn (1.3), Mn (1.2), Ag (1.5), Ni (1.8). Co had enrichment value ≥ 3.0 indicating moderate enrichment while Cu and Pb fell within the range of moderately severe enrichment.

Discussion

Civilization and continuous urbanization have led to increase in the production of vehicles and industries that pollute our ecosystem. In this study, we observed a narrow soil pH range across the different locations sampled as shown in Table 2. With regards to this parameter, there was no significant difference between roads and distance away from the road. The top soils (0-15cm) across the study area were acidic while the sub-soils (15-30cm) were slightly acidic. Similar results were reported by Edori and Iyama (2017), Uba et al., (2008) and Obasi et al., (2012). pH of soil play vital function in nutrient availability to plants as well as the type of soil organisms found in soil (Arias *et al.*, 2005). The soil pH at each soil layer in the different experimental sites were close and this might suggest that the effects of soil pH on metal's bioavailability is insignificant. Similar observations were made by Isaac (2014) in the assessment of heavy metal contaminated soil with auto-mechanic workshop. The role of pH in solute concentration and in desorption and sorption of contaminant in the soil is very significant (Gillman, 1981; Elliot *et al.*, 1986). The conductivity was generally high for both soil profiles and there was no significant difference (p = 0.05) between the roads and distance from the road.

The cation exchange capacity of the studied area were observed to be high for top soils and decreased down the soil profile for all locations. This implies the availability of soluble salts in the experimental sites (Arias *et al*., 2005). The reduction in cation exchange capacity of the experimental sites as compared to the control site reflects displacement caused by toxic heavy metals which are introduced indirectly by indiscriminate wastes disposal (Isaac, 2014). Organic carbon decreases down the soil profile with Aba road (4.85±0.07) and Ikwerre road (4.23±0.2) having the highest and lowest values respectively. The organic carbon obtained in the control site is significantly higher than those obtained in the experimental sites. Previous studies had shown that higher total organic carbon (>3.0%) levels are associated typically with fine soils and lower with coarse soils (Kamaruzzaman *et al.,* 2009). Organic carbon of soil is obtained by the decomposition of animals, plants and anthropogenic inputs like organic rich wastes or fertilizers, chemical contaminants (Avramidisa *et al.,* 2015).

Average metal concentrations of Ag, Cr, Ni, Co, Mn, Pb, Cd, Cu, Zn and Fe obtained from the study revealed decrease in metal concentration down the soil profile. This explains the mobility of metals down the soil profile. Across all sampled points in all locations studied, Fe, Mn and Zn were observed to be the most concentrated. Similar results were reported by Kanu *et al.,* (2015), where they reported high level of Fe, Cu and Zn in urban road dusts of Jalingo, Taraba State, Nigeria. High level of Fe was observed in the exhaust of car particulates and car derivatives like corrosion of body parts (Lu *et al.,* 2005) and also soils (Robertson *et al.,* 2003). Studies carried out on roadside soils from different locations in Lagos State metropolis, Nigeria, showed elevated level of heavy metals concentration (Olukanmi *et al.,* 2012). This higher value could be as a result of high traffic density in the study area. The principal sources of Zn could be fragmented tires of vehicles (Hopke *et al.,* 1980), lubricating oil of vehicles where Zn compounds are extensively used as anti-oxidants and as dispersant improving agents (Lu *et al.,* 2005). Cu is a common metal in brake lining, thrust bearing and other parts of automobile engine. The corrosion of automobile engine results in metal wear and the release of these metals into the environment which gradually accumulates in the top soil (Lu *et al.,* 2005). Cu replaced asbestos is being used as brake friction material since 1930's (Robertson *et al.,* 2003).

Slight variation exits between the levels of individual metal across all sampling locations but without significant differences ($p<0.05$). This may be due to certain factors such as age of the road, the type of vehicles that ply the roads, mode of waste disposal, soil type etc. Metals like lead (Pb) and cadmium (Cd) that have no biological function calls for public concern (Tchernitchin *et al.,* 1998; Martinez-Tabche *et al.,* 1997). The elevated levels of these metals in the soil pose a very serious threat to ground and surface water.

The values of CFs obtained in this study decreased down the soil profile for all roads.

The very high values of CFs (>1) in Aba road (Pb and Cu), East-West road (Ag, Cr, Ni, Co, Mn, Cd and Pb), Ikwerre and NTA roads (Cd, Pb and Cu) may be due to the influence of anthropogenic activities such as indiscriminate disposal of wastes, corrosion of vehicular parts, burning, and welding activities. The data on PLI of soil samples for Aba road and East/West road (Table 4) were greater than unity (>1) while Ikwerre and NTA roads were less than unity (<1). The results of PLI obtained from this study showed variation in the toxicity status in the experimental sites. Based on the interpretations of Zhang *et al.,* (2011) and Singh *et al.,* (2003), the soils from NTA road (0.545) and Ikwerre road (0.932) were unpolluted, Aba road (1.950) fell in the range of moderately to unpolluted category and East/West road (2.593) fell in the range of moderately polluted.

Reports have shown that high EFs do not really provide a reliable indication of the extent of human interference with the global environment (Sucharova *et al.*, 2012). It was concluded that other factors such as the choice of reference element maybe responsible for high EFs. The differences in EFs from location to location could be attributed to the age of the road indicating the type of anthropogenic activities carried out on the road.

Conclusion

This survey allowed heavy metal determination at different soil layers. The combination of different approaches used for evaluating soil metal contamination facilitate detailed interpretation of soil characteristics with regards to background influences. Major roadsides get polluted daily due to a lot of anthropogenic activities based on enrichment factors. The pollution load index indicated that the soil from experimental sites are of pollution concern. Metal distributions in the experimental sites revealed uneven distribution of metals with the concentration of heavy metals in the increasing order Fe>Mn>Zn>Pb>Cu>Ni>Cr>Co>Ag>Cd, having Fe as the most abundant element. The EF analyzed showed that all studied heavy metals came from anthropogenic sources and it might obviously increase overtime if proactive measures to curb vehicular pollution are not taken. It is important to conduct more studies on heavy metals accumulation to ensure proper management of cities.

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Table 1: GPS of Sample Locations

Locations	**Northings**	**Eastings**	**Elevations (m)**

Obio/Akpor			
Aba Road	04^{0} 53’ 12.3”	007^{0} 08’ 36.4”	5
	04^{0} 52’ 45.8”	007^{0} 07’ 37.1”	20
	04^{0} 52’ 05”	007^{0} 06’ 21.0”	18
	04^{0} 51’ 30.2”	007^{0} 4’ 28.7”	25
East/West Road	04^{0} 51’ 14.7”	007^{0} 04’0 6.6’’	26
	04^{0} 51’ 53.1”	007^{0} 02’ 46.9”	20
	04^{0} 52’ 13.4”	006^{0} 54’ 47.4”	12
	04^{0} 53’ 41.0”	006^{0} 54’ 47.4”	12
Ikwerre Road	04^{0} 55’ 08.2”	006^{0} 59’ 50.0”	25
	04^{0} 54’ 51.2”	006^{0} 59’ 52.3”	25
	04^{0} 53’ 40.8”	007^{0} 00’ 06.8”	24
	04^{0} 53’ 15.3”	007^{0} 00’ 08.0”	22
NTA Road	04^{0} 53’ 49.0”	006^{0} 54’ 25.5”	19
	04^{0} 52’ 44.3”	006^{0} 54’ 39.7”	22
	04^{0} 52’ 06.1”	006^{0} 57’ 28.5”	8
	04^{0} 52’ 06.1”	006^{0} 57’ 28.5”	16
Etche			
Ikwerre Ngwo	4^{0} 54’ 28.8”	7^{0} 6’ 57.6”	21
	4^{0} 55’ 8.4”	7^{0} 5’ 49.2”	19
	4^{0} 56’ 2.4”	7^{0} 5’ 49.2”	20
	4^{0} 55’ 55.2”	7^{0} 4’ 37.2”	20

Table 2: Soil Physico-chemical parameters along the experimental and control sites

Soil Parameters	Aba Road		East/West Road		Ikwerre Road		NTA Road		Control	
Soil Depth (cm)	0 - 15	15 - 30	0 - 15	15 - 30	0 - 15	15 - 30	0 - 15	15 - 30	0 - 15	15 - 30
Na	146.5±4.5	36.3±2.3	266.7±14.7	63.8±3.6	3571.0±80.7	576.5±25.3	149.05±7.4	112.8±30.6	3694.7±3.3	592.1±5.9
Mg	715.2±46.4	232.2±13.5	728.6±12.1	203.2±8.1	739.2±10.9	267.5±10.4	508.7±11.5	248.3±4.4	745.7±5	606.5±11.5
Ca	1022.9±25.2	204.6±6.6	1141.5±28.4	310.0±12.9	1201±22	204.2±14.6	423.1±4.3	26.3±1.6	1209.6±2.7	853.2±14.1
K	137.5±2.1	29.9±1.6	99.58±3.8	35.2±3.3	141.9±29.8	398.5±21.3	68.9±1.5	8.1±0.4	212.21±0.4	110.2±0.6
Basicity	6.0±0.03	1.73±0.2	5.1±0.1	1.96±0.1	7.29±0.2	2.37±0.1	5.53±0.1	2.14±0.1	7.2±0.1	5.26±0.2
N	0.05±0.002	0.001±0	0.04±0.01	0.001±0	0.1±0.01	0.001±0	0.04±0.001	0.001±0	0.1±0.01	0.001±0
P	0.39±0.04	0.001±0	0.21±0.02	0.001±0	1.52±0.1	0.001±0	0.37±0.03	0.001±0	0.47±0.01	0.001±0
pH	4.73±0.1	7.18±0.1	5.12±0.1	6.91±0.2	4.92±0.04	6.54±0.2	5.12±0.04	6.51±0.1	6.29±0.1	5.96±0.1
Conductivity	412.8±16.3	188.25±10.7	150±2.7	73.3±2.7	1858.8±50	250±26.1	421.0±14.7	81.8±4.2	114.2±5.5	58.3±2.6
Organic Carbon	4.85±0.07	2.33±0.1	4.3±0.1	2.12±0.1	4.23±0.2	1.56±0.2	4.26±0.1	1.9±0.1	13.9±0.4	9.1±0.2
Exchange Capacity	4.86±0.2	3.66±0.2	5.74±0.2	3.46±0.2	5.0±0.1	3.9±0.1	4.73±0.1	3.4±0.1	6.3±0.1	4.0±0.03

Table 3: Heavy Metals Concentration in Soils of the Experimental and Control Sites.

	Aba Road		East-West Road		Ikwerre Road		NTA Road		Control	
Soil depth	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
Ag	0.73±0.03	0.001±0	2.56±0.5	0.001±0	0.65±0	0.001±0	0.36±0	0.001±0	0.73±0	0.001±0
Cr	5.5±0.22	1.9±0.1	13.14±1	4.32±0.5	1.97±0	0.001±0	1.22±0	0.001±0	5.39±1	1.85±0.3
Ni	2.67±0.06	0.16±0	13.9±0.7	6.0±0.3	2.16±0	0.001±0	1.49±0	0.001±0	2.58±0	1.14±0
Co	2.21±0.08	0.16±0	5.26±0	1.08±0.1	0.36±0	0.001±0	1.58±0	0.001±0	1.6±0.1	0.65±0.1
Mn	51.4±2.5	19.41±3	85±1.3	28±1.9	27.63±1	6.44±0	16.39±1	4.10±0	43.4±2	21.9±1
Cd	0.2±0.03	0.001±0	0.25±0	0.001±0	0.18±0	0.001±0	0.003±0	0.001±0	0.14±0	0.001±0
Pb	9.10±0.4	2.86±0.3	10.9±0.8	2.9±0.5	6.69±0	1.77±0	3.26±0	0.001±0	0.16±0	0.001±0
Cu	9.26±4.0	2.89±1.6	5.7±0.2	1.9±0.2	5.14±0	1.35±0	6.24±2	4.65±0	15.1±2	7.45±1
Zn	32.65±2.4	9.35±1.3	34.24±1	7.9±1.2	25.3±1	5.48±1	13.97±1	2.92±0	32.52±1	9.72±0.3
Fe	2995±42	1088±44	3162±38	806±74	1453±46	467±20	1045±24	283±13	3217±23	1627±6

Mean± Standard Error

Table 4: Contamination Factor (CFs) of Soil and Pollution Load Index (PLI) of Metals in Different Soil Layers.

Element	Aba Road		East-West Road		Ikwerre Road		NTA Road		Natural Background Concentration[a]	
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
Ag	1.001	1	3.528	1	0.89	1	0.497	1	0.7±0	0.001±0
Cr	1.021	1.051	2.44	2.34	0.77	0.001	0.23	0.01	5.4±1	1.85±0.33
Ni	1.038	0.144	5.41	5.3	0.84	0.001	0.58	0.001	2.6±0.2	1.1±0.2
Co	1.38	0.245	3.29	1.65	0.22	0.002	0.99	0.002	1.6±0.1	0.7±0.1
Mn	1.183	0.885	1.97	1.3	0.63	0.294	0.99	0.002	43.4±2	21.9±1.1
Cd	1.420	1	1.75	1	1.25	1	0.021	1	0.14±0	0.001±0
Pb	55.816	2.855	66.69	2.90	41.04	17.70	20	1	0.16±0	0.01±0
Cu	0.613	0.388	0.38	0.26	0.34	0.18	0.41	0.624	15.1±0	7.45±0.3
Zn	1.004	0.962	1.05	0.81	0.78	0.56	0.43	0.30	32.52±01	9.72±0.6
Fe	0.931	0.669	0.98	0.5	0.45	0.29	0.33	0.17	3217±23	1627±6
PLI	1.950	0.865	2.6	2.5	0.93	0.17	0.55	0.08		

[a] **mean natural background concentration (±SE, n =4)**

Table 5: Mean Enrichment Factors (EF) of Classes of Metals Studied with Respect to the Natural Background.

Metals	Aba Road	East-West Road	Ikwerre Road	NTA Road
Enrichment Factor				
Ag	1.1	3.6	2.0	1.5
Cr	1.1	2.5	0.8	0.7
Ni	1.1	5.5	1.8	1.8
Co	1.5	3.3	0.5	3.0
Mn	1.3	2.0	1.4	1.2
Cd	1.5	1.8	2.8	0.1
Pb	5.9	6.8	9.0	6.2
Cu	6.6	0.4	0.8	5.0
Zn	1.1	1.1	1.7	1.3
Fe	1	1	1	1

Values are calculated based on soil layer 0-15cm only. Normalizing element, Fe, with natural background value of 3217mg/kg