

# Level of Heavy Metals in Soil Samples from Farmlands along Highways in Parts of Owerri, Nigeria

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**Abstract**— The research was designed to ascertain the concentrations of heavy metals (Cu, Pb, Zn, Ni, Cd) in soil samples from farmlands along highways in parts of Owerri. Soil samples were collected from cassava farms along three major roads with high traffic density and a rural road that served as control location, for possible heavy metals contamination due to vehicular emission. Standard laboratory procedures were adopted to determine the concentration of heavy metals using Atomic Absorption Spectrophotometer (AAS). Contamination factor (CF) and Pollution Load Index were mathematically calculated. The results revealed that the mean concentrations of metals in soil samples in mg/kg ranged from 3.00 – 6.31 for Cu; Pb, 0.09 – 4.00; Zn, 3.97 – 8.59; Ni, 0.001 – 0.96; and Cd, 0.31 – 0.79. These metals showed decrease in concentrations with increase in distance away from the highway. The values of contamination factor (CF) were low except for Cd and Pollution Load Index (PLI) for all soil studied showed no sign of pollution. There was no correlation between traffic density and concentration of heavy metal in soil except for Cd ( $R_s = 0.800$ ). The overall results showed evidence of some heavy metal pollution on the soils with possible cumulative effect over time.

**Index Terms**— Level, Heavy Metals, Soil, Farmlands, Highways, Owerri.

## I. INTRODUCTION

Roads serve as major links among communities through which foods and other important commodities are transported. It is an essential amenity that plays a major role in enhancing social and economic activities. However, road construction has also resulted in heavy environmental pollution especially on soils (Bai *et al.*, 2009). Environmental pollutants are widely distributed in air, water, soils and sediments. Among environmental pollutants, metals are of particular concern, due to their potential toxic effects and ability to bio-accumulate in ecosystems (Censi *et al.*, 2006). Reports have shown that roadside soils may be contaminated from various anthropogenic activities such as industrial and energy production, vehicle exhaust, waste disposal as well as coal and fuel combustion (Li *et al.*, 2001). These activities send trace metals into the air and the metals subsequently deposited into nearby soils, which are absorbed by plants on

such soils. Public motor roads affect natural environment to a large extent because automobiles act as line sources of heavy metal pollutants (Poszyler-Adamska & Czemiak, 2007). Samples of soil from lands near motorways in some urban cities in Nigeria such as Jos, Osogbo, Ibadan and other cities, have been studied (Abechi, *et al.*, 2010; Fakayode & Olu-Owolabi, 2003; Onianwa, 2001; Ihenyen, 1998). Again, roadside soils in UK (Thornton, 1982), Holland (Edelman & Bruin, 1986), India (Kuhad *et al.*, 1989), and Botswana (Mmolawa *et al.*, 2011), have also been studied. Roadside soil pollution in these studies was attributed to traffic. Thus, emissions from heavy traffic are a global phenomenon. Copper, Zinc, Cadmium, and Lead are the typical metal pollutants due to traffic activities.

With the rapid increase in number of motor vehicles on highways recently, and consequent boost in commercial and industrial activities; ranging from vehicle repairs, vulcanizing and welding to auto-electricians, battery chargers and dealers in other facilitators of motor transportation (Taofoek & Tolulope, 2012), considerable amounts of some heavy metals are likely to be emitted regularly as long as the nearby sources remain active.

Studies on heavy metals pollution of soil have been reported widely in literature over the years. Zauro *et al.* (2013) investigated extent of some heavy metal contamination in soil of farmlands around Sokoto metropolis. Concentration of Cd, Cr, Cu, Pb and Zn in all the soils samples ranged from 0.20 – 39.975 ug/g dry weight. Olatunji *et al.* (2013) carried out research on heavy metal concentrations in selected arable agricultural soils in South-Western Nigeria and reported that the application of micronutrient supplements such as fertilizer, animal manure and sewage sludge in bid to enhance soil productivity and crop yield, poses the risk of heavy metals elevation and nutrients depletion in arable lands. Okereke *et al.* (2014) evaluated level of heavy metals in agricultural lands in Idemili, Anambra and documented high concentrations of heavy metals of public health importance such as Lead (Pb). In another study of heavy metals in soil around Wukari, Achadu *et al.* (2015) carried out a research work on “assessment of heavy metals (Pb, Cd, Zn and Cu) concentrations in soils along a major highway in Wukari, North-Eastern Nigeria”. The extent of the heavy metals contamination was assessed, as analytical data were subjected to pollution calculation methods. The contamination factors (CF) revealed extreme contamination of the sites and an increased trend in the heavy metal concentrations was

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observed in sites with more human activities. Again, the pollution load index (PLI) showed that the sites were severely polluted as the PLI of the metals from each sample site exceeded the PLI of the background (control) sample (0.7). They concluded that the study sites pollution is mostly due to automobile emissions.

Heavy metals in roadside soils of major streets in Jos metropolis have been evaluated and correlated to traffic volume with decreasing order of the average total levels of the studied metals: Fe > Zn > Mn > Pb > Cd > Cu (Abechi *et al.*, 2010).

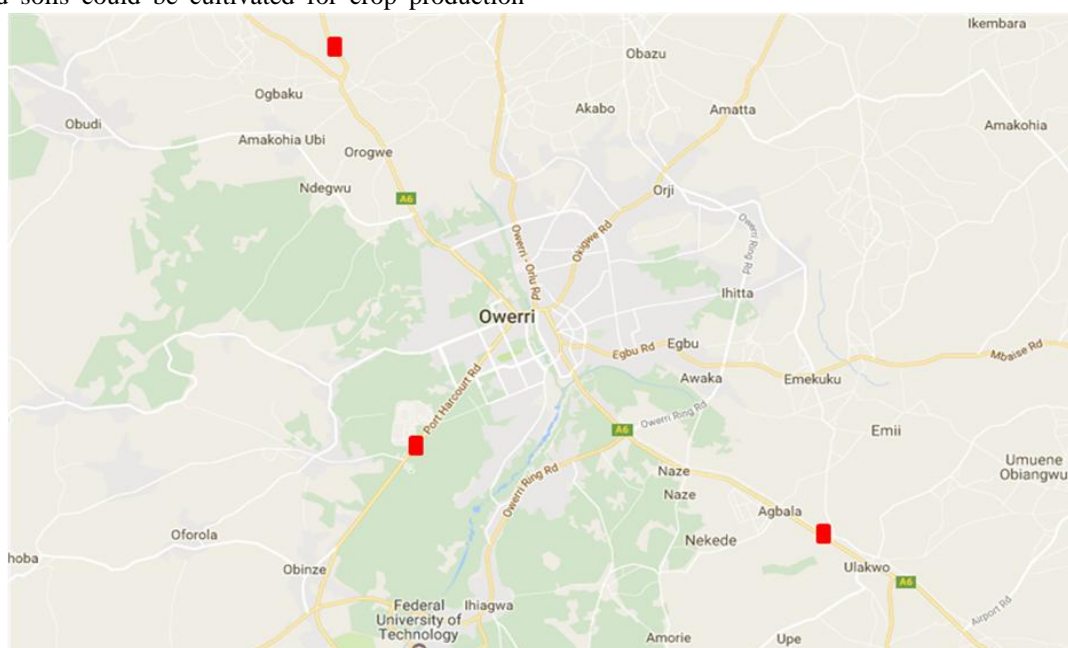
Christopher & Therese (2010) studied heavy metal contamination of surface soil in relationship to land use patterns in Benue State to assess soil environmental quality. Results revealed that metals levels were generally high in mineralized and urban soils and lower in agricultural soils whilst forest soils were polluted by anthropogenic sources. Mineralized soils developed from weathered sulphides were rich in lead (Pb), zinc (Zn), and cadmium (Cd). Urban soils accumulated Cu, Zn, and Cd most probably from refuse dumps, gasoline combustion and farming. Agricultural soils were enriched in arsenic (As) and to a lesser degree, Pb and Cd, originating most probably from the application of pesticides, manure and fertilizers. A pollution index (PI) based on plant-tolerant contamination levels, indicates that multi-element contamination in soils is low and implies that the sampled soils could be cultivated for crop production

especially away from point sources of pollution. High traffic density has been linked with high levels of heavy metals (Pb, Cd, Cr, and Zn) in soil from roadsides in Ogbomoso, Nigeria (Adelasoye & Ojo, 2014). The heavy metal distribution inwards from the edge of the road did not show consistency up to 30 m. Increase in metallic levels at a distance beyond 35 m off the road edge is reported to be attributed to geological and/or biological decomposition of leaf litters (Luilo & Othman, 2006)

## II. MATERIALS AND METHODS

### Study Area

The sampling locations were chosen to span a wide range of traffic density and to give a good geographical coverage in Owerri, Imo State. Owerri consists of three Local Government Areas including Owerri Municipal, Owerri North and Owerri West; it has an estimated population of about 401,873 as of 2006 and is approximately 100 square kilometres in area. Geographic coordinates of Owerri, lies within Latitude: 5°29.0178' North, Longitude: 7°1.995' East with elevation above sea level: 73 m = 239 ft. Owerri has a tropical wet climate with average temperature is 26.4 °C. Some major roads that go through the city are: PortHarcourt road, Aba road, Onitsha road, and Okigwe road with other roads within the city. Three sites selected for study is shown in Figure 1.



**Figure 1: Owerri map (Google satellite map, 2016) Sample Collection**

A total of 12 samples of soil were randomly collected from farm lands near highways in parts of Owerri, Nigeria. Three locations situated along busy roads were selected: Onitsha-Owerri road, PortHarcourt-Owerri road, and Aba-Owerri road. Another location, characterized by low traffic densities, Oforola, a rural settlement was selected as control. This location is sparsely populated and basically residential with no industrial activities. Soils were sampled at 0-10 cm depth at distance intervals of 10, 15, and 20 meters from the roadway using a surface-sterilized auger and put into a polythene bag. Three soil samples were taken from three points from each distance and mixed together to form

composite samples and transported to the laboratory for analyses.

### Soil Sample Preparation and Digestion

All clods and crumbs were removed from the soil samples, then, mixed uniformly and air-dried. Soils were sieved through a 2mm sieve to remove coarse particles before sub-sampling for chemical analysis. Measured 0.5g of air-dried ground soil was transferred to 25ml conical flask; 5ml of concentrated H<sub>2</sub>SO<sub>4</sub> was added followed by 25ml of concentrated nitric acid (HNO<sub>3</sub>) and 5ml of concentrated hydrochloric acid (HCl). The contents of the tube were heated at 200°C for 1hr in a fuming hood and then cooled to room

temperature. After cooling, 20ml of distilled water was added and the mixture was filtered to complete the digestion. Finally, the mixture was transferred to a 50ml volumetric flask, filled to the mark and left to settle for at least 15 hours. The filtrate was analyzed for total Cu, Fe, Mn, Pb, Zn, Ni, and Cd using Atomic Absorption Spectrometer (AA500F).

**Heavy Metal Analysis**

The determination of the heavy metals (Cu, Pb, Zn, Ni, and Cd) content of the cassava and soil samples respectively was carried out according to the standard procedures of the Atomic Absorption Spectrophotometer (AAS). In each case, the hollow cathode lamp of the element under investigation, the analyte elements were fixed in the burret assembly of the atomic absorption spectrophotometer. The instrument was switched on. The fuel and oxidant used were acetylene and compressed air respectively. The burner was lit and a flame established from the acetylene compressed air as fuel/oxidant. The standard solution of each element under investigation was aspirated into the nebuliser-burner assembly and the corresponding absorbance reading obtained from the digital read out of the Atomic Absorption Spectrophotometer at the wavelength of the element under investigation. This was followed by the aspiration of the sample solution and the absorbance reading obtained from the digital read out. The concentration of the element in the sample was obtained by extrapolation from the standard curve. This was repeated for the entire element under investigation using their hollow cathode lamp and at their different wavelengths.

**Pollution Load Index of Soil along Highways**

The degree of soil pollution for each metal was measured using the pollution load index (PLI) technique which depends on soil metal Contamination factor (CF)

The level of contamination of soil by metal is expressed in terms of a contamination factor (CF) calculated as:

$$CF = \frac{C_s}{C_b} \dots \dots \dots \text{Equation 1}$$

Where;  $C_s$  is the concentration of heavy metal in soil and  $C_b$  is background value for heavy metal using the values from DPR-EGASPIN (2012) due to metal background values have not been reported yet for the study area. The classification of contamination factor is:  $CF < 1$ , refers to low contamination;  $1 \leq CF < 3$ , means moderate contamination;  $3 \leq CF \leq 6$  indicates considerable contamination and  $CF > 6$  indicates very high contamination.

Each site was evaluated on the extent of metal pollution by employing the method based on the pollution load index

**Table 1: Mean concentrations of heavy metals in soil samples from farmlands along highways in Owerri**

Heavy metal	Concentrations (mg/kg)			
	OWR-OSH	OWR-PHC	OWR-ABA	Control
Cu	6.16±0.0436	6.08±0.01	6.237±0.0751	3.0533±0.0503
Pb	2.5867±1.2309	1.416676±0.878	2.75±0.661	0.1033±0.0153
Zn	6.86±1.4982	5.983±0.0153	5.973±0.0577	4.0667±0.1343
Ni	0.7567±0.176	0.5467±0.0929	0.5833±0.0586	0.0001±0
Cd	0.553±0.208	0.5777±0.1319	0.8367±0.117	0.323±0.0152

Legends: **OWR-OSH**: Owerri-Onitsha road; **OWR-PHC**: Owerri-PortHarcourt road; **OWR-ABA**: Owerri-Aba road.

(PLI) as follows:

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \dots \times CF_n)^{1/n} \dots \dots \dots \text{Equation 2}$$

Where n is the number of metals studied (five in this study) and CF is the contamination factor calculated as described in Equation 1. The PLI provides simple but comparative means for assessing a site quality, where a value of  $PLI < 1$  denotes perfection;  $PLI = 1$ , presents that only baseline levels of pollutants are present, and  $PLI > 1$  would indicate deterioration of site quality. The following modified equation was used to assess the PLI level in soils.

$$PLI = C_{\text{Soil}} (\text{Sample}) / C_{\text{Reference}} (\text{Reference}) \dots \dots \dots \text{Equation 3}$$

Where;  $C_{\text{soil}}$  (Samples) and  $C_{\text{reference}}$  (Reference) represent the heavy metal concentrations in the soil proximal to roadsides and reference soils respectively (Liu *et al.*, 2005).

**Statistical Analysis**

Data generated were analyzed using the Statistical Package for Social Sciences 10. The data were expressed in terms of descriptive statistics while the figures were presented with mean values of triplicates. The statistical significance was computed using pair samples T-test at  $P < 0.05$

**III. RESULTS**

**Mean concentrations of Heavy metals in farmlands along Highways**

The mean concentrations of heavy metal in farmlands along highways in parts of Owerri are shown in Table 3.1 with Owerri-Onitsha road recording levels of Cu, Pb, Zn, Ni, Cd, as 6.16mg/kg, 2.59mg/kg, 6.86mg/kg, 0.76mg/kg, 0.55mg/kg respectively. Owerri-PortHarcourt road recorded highest value of 6.08mg/kg and least value of 0.5467mg/kg of Ni while Owerri-Aba road also recorded highest value (6.23mg/kg) of Cu and least value (0.58mg/kg) of Ni.

The overall metal concentrations (Cu, Pb, Zn, Ni, and Cd,) in soils of the sampling sites at different distances are presented in Figures 2a – 2e. The level of copper in soil samples along Owerri-Aba road ranged from 6.18mg/kg - 6.23mg/kg while Owerri-Onitsha road recorded highest copper content at 15m distance with 6.33mg/kg. The level of Pb at 10m, 15m, 20m away, recorded lower values along Owerri-Aba road compared to higher values recorded along Owerri-Portharcourt road. Zn level along Owerri-Onitsha road fluctuated between were 9.82mg/kg and 5.90mg/kg as the control location recorded low values of Cd and Ni at 10m, 15m, 20m respectively.

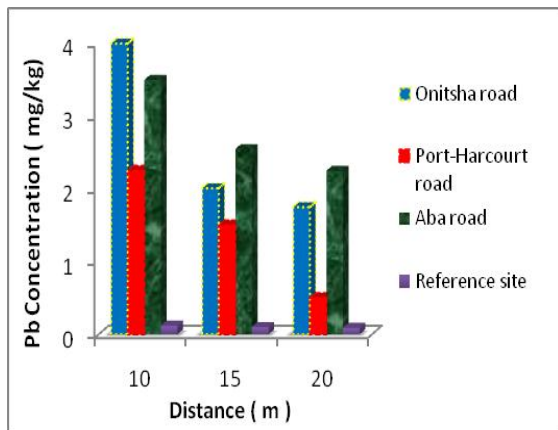


Figure 2a: Total Pb level in soil samples

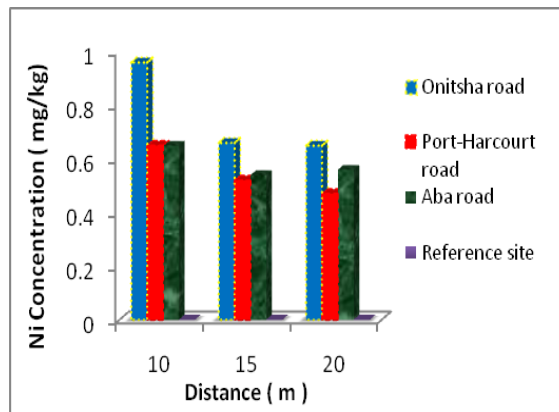


Figure 2d: Total Ni level in soil samples

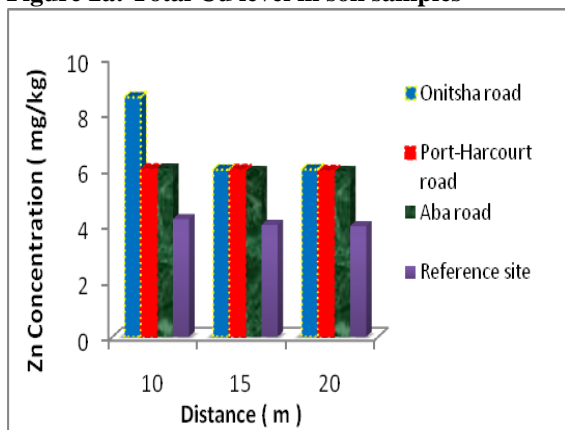


Figure 2b: Total Zn level in soil samples

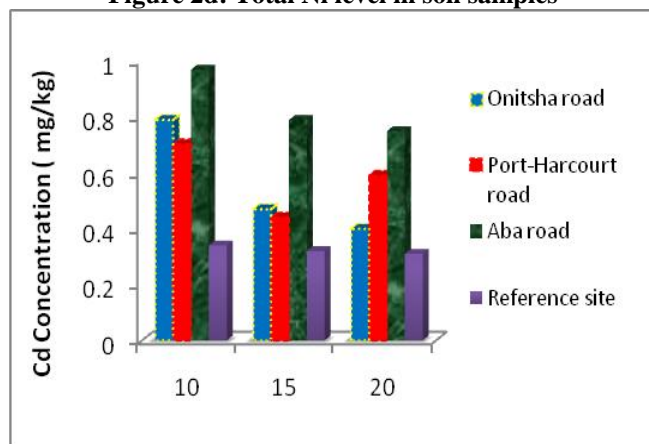


Figure 2e: Total Cd level in roadside soils

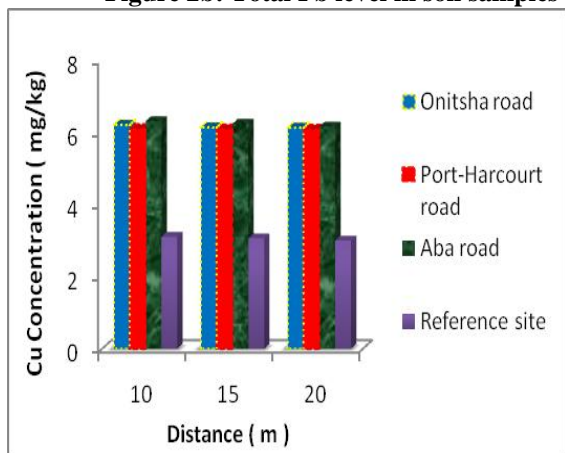


Figure 2c: Total Cu level in soil samples

**Contamination factor and Pollution load Index**

Using the contamination factor categories previously described, all the sites had low contamination of the heavy metals except along Owerri-Aba road, which had moderate contamination of Cadmium (1.05) (Table 2).

Figure 3 shows the result of the PLI for the three sites. Based on the result, the three sites could be said to be in a pristine condition because they showed no sign of pollution.

Table 2: Contamination factor of heavy metals

METAL	Contamination Factor (mg/kg)		
	OWR-PHC	OWR-OSH	OWR-ABA
Cu	0.171	0.169	0.173
Pb	0.030	0.017	0.032
Zn	0.049	0.043	0.043
Ni	0.022	0.014	0.017
Cd	0.686	0.725	1.05

Legends: ONITSHA- Onitsha-Owerri road; PH- Portharcourt- Owerri road; ABA- aba-Owerri road.

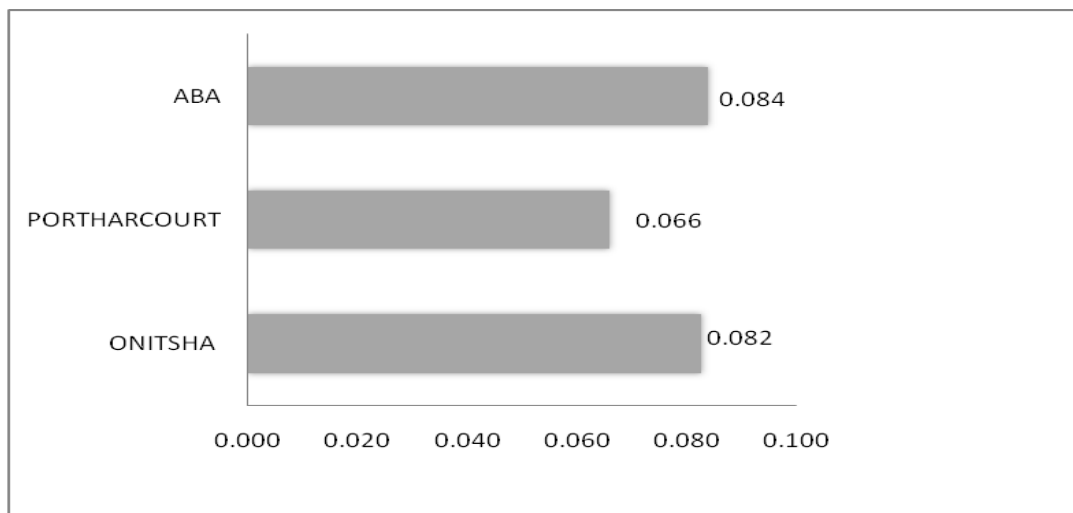


Figure 3: Pollution Load Index of sampled areas

Statistical correlation of heavy metals in soil at different distance

In comparing the mean difference in heavy metal concentration between distance and Cassava soil, only Cu and Ni showed significant increase in concentration at  $\alpha = 0.05$  as one moves from the 20m region to the 10m region (Table 3). Though there was no significant difference in the mean difference on concentration of the other heavy metals (Pb, Zn and Cd), the values showed an increasing trend as one moves from the 20m region to the 10m region.

Table 3: Mean difference in concentrations between distance and farmland soil.

Metal	Distance					
	10- 15m	Sig. diff	15 - 20m	Sig. diff	10-20m	Sig. diff
Cu	0.0675±0.02611	0.042	0.00±0.02611	1.000	0.0675±0.02611	0.042
Pb	0.3675±0.53103	0.520	0.9400±0.53103	0.137	0.5725±0.53103	0.330
Zn	0.6975±0.52070	0.229	0.0100±0.52070	0.985	0.6875±0.52070	0.235
Ni	0.13500±0.05302	0.044	0.0100±0.05302	0.857	0.14500±0.05302	0.034
Cd	0.09575±0.09820	0.367	0.02750±0.0982	0.789	0.12325±0.09820	0.256

IV. DISCUSSION

Lead contents in the soils varied significantly from site to site. Pb content in soils ranged from 0.5 – 4.00mg/kg along the entire roadside soil sampled. Its concentrations were higher than WHO/FAO (2001) limit. This result is consistent with the report of Oyedele & Funtua (2001) on Kaduna- Zaria highway Nigeria. The range value for Pb in this study is lower compared to FCT soils (Kabiru *et al.*, 2015), Bauchi soils (Kakulu, 1989), Urban soils of Amman, Jordan (Jiries, 2003), and Urban soils of Lagos, Nigeria (Atayese *et al.*, 2009), Aba soils (Ijeoma & Princewill, 2011), and soils of Honolulu, USA (Sutherland *et al.*, 2000). It is, however, higher ( $0.013 \pm 0.006 - 0.225 \pm 0.020 \mu\text{g/g}$ ) in soils of Malaysia (Yap *et al.*, 2010). Furthermore, high Pb levels have also been reported in roadside soil along sampling points with heavy vehicular emissions (especially patronizing the mechanic and block industry) by various researchers (Othman *et al.*, 1997; Al-Chalabi & Hawker, 2000; Ubwa *et al.*, 2013; Olayiwola, 2013). Lead pollution in urban soil has been attributed to combustion of gasoline that contains tetraethyl lead used as anti-knock agent. Ragwan *et al.* (2015) opined that the level of Pb could be increased with decreased pH of soil samples due to the presence of other ions causing exchanged hydrogen ions into the solution, thus decreasing the pH of solution. In this study, Pb content decreased with increase in distance. It has been reported that Lead content in soil increases steeply

close to a highway with high volume of traffic (Alloway, 1996). However, concentration of lead in the soil could be from automobile exhaust fumes as well as dry cell batteries, sewage effluents, runoff of wastes and atmospheric depositions which could cause its bioaccumulation in plant via uptake from the soil and eventual entry into the food chain (Opaluwa *et al.*, 2012). It was revealed by Atuanya *et al.* (2003) that higher lead concentration in soils has toxic effect on microorganisms inhabiting the soil which consequently alters the flora and fauna of a location. Lead is known for lead poisoning in humans as well as chronic neurological disorders especially in foetus and children hypertension, and other respiratory problems in adults.

The soil concentrations of Cu were between the ranges 3.91-8.59 mg/kg, lower than the permissible limit recommended by Dutch standard of 36 mg/kg. The value of Cu recorded in the soil samples was highest along Owerri-Onitsha road, Owerri-PortHarcourt road and Owerri-Aba road at 10m distance, which agrees with some other reported studies from N-5 Pakistan (Khan *et al.*, 2011), Lithuania’s highways (Jankaitė *et al.*, 2008). However, the value is much lower than the ones obtained from North Central Nigeria, 80.13mg/kg (Ogundele *et al.*, 2015), A-71 Motorway in France Highway, Istanbul, 122.37mg/kg (Sezgin *et al.*, 2003). Copper is a microelement which is essential in plant growth and occurs generally in soil, sediments and air. Cu content has been reported to differ according to the soil type and pollution source. Fatoki &

Ayodele (1991) opined that Zn and Cu concentrations in soil are functions of traffic density. The high concentration in some locations may be as a result of burnt vehicles along the major roads as copper is commonly found in electrical wirings, engine wear, brake linings (Manno *et al.*, 2006). This could find its way into the roadside soils.

The concentration range for Cd in the soil sample was 0.32 – 0.55mg/kg. The concentration of Cd decreased with the increase of distance and reaches a relatively low value (0.97 mg/kg) at 20m from the road edge. The observed concentration values of Cd were much higher than the background value (0.31mg/kg). The level of Cd in this study is lower than values obtained in soils of Malaysia (Yap *et al.*, 2010). Some studies gave a result of 5.2µg/g in roadside soils in Lancaster (Harrison *et al.*, 1981), and 4.2µg/g on a highway roadside soil in London (Culbard *et al.*, 1988). The results obtained in this study were within the range of reported results obtained in Hong Kong and Lagos, Nigeria (Ndiokwere, 1984). Sources of Cd in the urban areas could be more from metal plating and lubricating oils. It could also be due to rough surfaces of the roads which increase the wearing of tyres, and run-offs from the roadsides (Ho & Tai, 1988). Also, human activities can contribute to increased Cd levels as a result of urban-industrial activities and/or agricultural practices. McBride (1994) opined that concentrations above 0.5 mg/kg could reflect the influence of human activity. In the study, some locations exceeded this value, indicating a slight increase in this heavy metal in relation to the normal level.

Zn ranged from 3.97mg/kg (control site) to 8.59mg/kg (Owerri-Onitsha road) at 20m to 10m distance. This value is low compared with many other studies (Jaradat & Momani, 1999; Bai *et al.*, 2009). The observed level is lower than 30.8 mg/kg – 219.23 mg/kg, reported in roadside soil of Nigeria (Ogundele *et al.*, 2015), 300-530µg/g reported in Lancaster (Harrison *et al.*, 1981), and 25.68±4.67 mg/kg reported for 10m from roadside soil in Osogbo, Nigeria (Fakayode & Olu-Owolabi, 2003). In Alicante, Spain, an average Zn content of 57.8 mg/kg was reported by Mico *et al.* (2006); 80.7mg/kg was reported in a study in Assiut, Egypt. About 0.51 mg/kg was reported in a study carried out in China (Mico *et al.* 2006) which is lower than the observed level in this study. In this study, the Pb/Zn ratio in soil was less than unity as it has been reported that soil-lead pollution may be caused by automobiles. However, other reports found a ratio of less than unity, which was related to the local conditions (Hewitt & Candy, 1990). Since no major industry exists in the study areas such as smelting operations, we may assume that the primary sources of Zn are probably the attrition of motor vehicle tire rubber exacerbated by poor road surfaces, and the lubricating oils in which Zn is found as part of many additives example zinc dithiophosphates (Abechi *et al.*, 2010). Thus, the probable sources of Zn on this highway could be due to deposits from automobiles and other anthropogenic activities.

The concentration of Nickel in the present study like the other metals decreased with increase in distance. Decreasing metal concentration with increasing distance from the road might be due to heavy metal emitted from vehicle exhaust in particulate forms which are forced to settle under gravity closer to road edges (Haygarth & Jones, 1992) as cited by

Amusan *et al.* (2003). However, other studies reported higher mean values, 99.80 mg/kg at Nigde –Adana Highway (Yalcin *et al.*, 2007), 26.70 mg/kg at Beijing (Chen *et al.*, 2010), 128.82 mg/kg at Edrine Turkey (Aktas *et al.*, 2010). Similar results were obtained in soils of Valencia, and in the fertile Granada Valley (Campos, 1997). The normal soil Ni content varies from 1 to 100 mg/kg (Kabata-Pendias & Pendias, 2001). In this study all sampled soils were below this range. None of agricultural soils exceeded the reference value of Pérez *et al.* (2002) for agricultural soils in Murcia and all of them were below the maximum permissible concentration (Kabata-Pendias & Pendias, 2001). Comparing with the control sample, it has been observed that roadside samples are more contaminated with Nickel. Vehicular traffic is the most probable source of Nickel on roadside soil. The concentration of Pb, Zn and Cd showed a mean value with no significant difference for the three sampled location and control, while the values for Cu and Ni showed a high level of significance at  $p < 0.05$ . Though there was no significant difference in the mean concentration of the heavy metals (Pb, Zn and Cd), their values show an increasing trend as one moves from the 20m region to the 10m region.

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