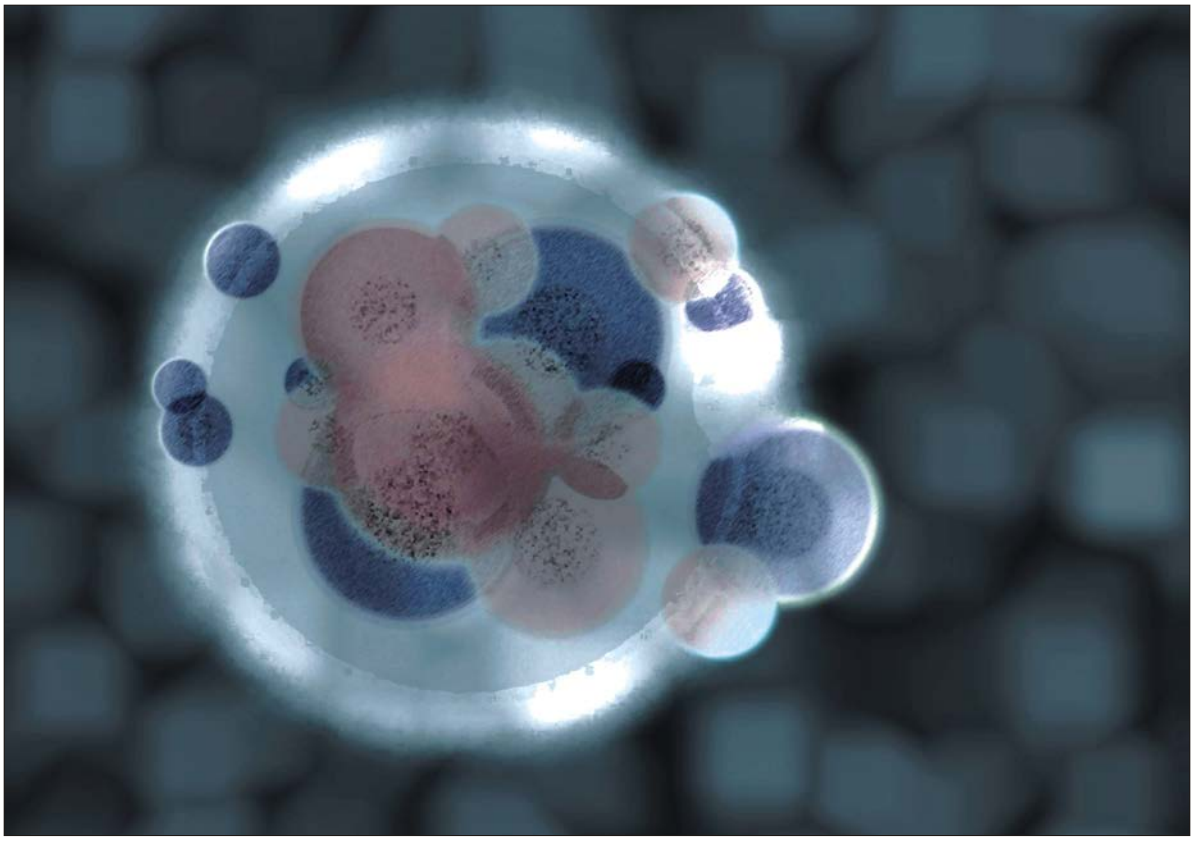

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Heavy Metals Contamination of Roadside Soils and Plants Along Three Major Roads in Eleme, Rivers State of Nigeria

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Abstract: A study to investigate the level of heavy metal pollution in soil and plants (*Panicum maximum* and *Centrosima pubescens*) along 3 major roads (Onne-Akpajo, Refinery and Aleto by-pass roads) in Eleme, Rivers State of Nigeria was carried out. Four sampling points were taken at each road at distances of 0 m and 10 m from the road inward. pH, conductivity, Cu, Zn, Pb and Cd were analyzes for the soil while Cu, Zn and Pb were analyzed for the plants. The pH and conductivity were determined by the meter method while Heavy metals were obtained by AAS. Results showed low pH (4.08±0.2-4.36±0.07) and high conductivity (135.0±25.86-215.0±44.51 μs cm^{-1}) while the Cu (1.55±0.37-4.25±1.38 mg kg^{-1}) Zn (4.07±0.87-11.69±3.03 mg kg^{-1}), Pb (2.69±0.74- 6.92±2.51 mg kg^{-1}) and Cd (0.16±0.01 - 0.26±0.04 mg kg^{-1}) concentrations were low in the soil. Plant showed higher values of heavy metal contamination than soil. Values in the plants were in the range of Pb (136.68 ±10.3-278.4±10.7 mg kg^{-1}), Zn (43.28±1.9 -84.52±3.5 mg kg^{-1}) and Cu (9.26±3.0-18.89±1.8 mg kg^{-1}). These values decreased with increasing distance from the road inward. Therefore, economic plant should not be planted along the roadside of major roads to avoid heavy metal contamination.

Key words: Eleme, heavy metal, contamination, plant, roadside

INTRODUCTION

Environmental degradations resulting from human activities have become a source of concern in our rural and urban areas. Paramount among these environmental challenges is heavy metal pollution. Elevated concentration of trace metals as a result of human activities have been recorded since ancient times (Nriagu, 1996) and mostly associated with areas of intensive industrial activities. However, excessive release of toxic heavy metals into the roadside environment and the associated health implications has become apparent and has developed into a global phenomenon (Li *et al*., 2005).

Lenntech Water Treatment and Air Purification (2004) defined heavy metal as any metallic element that has a relatively high density and is toxic or poisonous even at low concentration. Their pollution of the environment, even at low levels and the resulting long-term cumulative health effects are among the leading health concerns of the world (McCluggage, 1991). Although, heavy metals are essential for proper functioning of the body system, their bioaccumulation at high concentration may pose health threat to humans (Lenntech Water Treatment and Air Purification, 2004) while others like As, Cd and Pb have been reported to have no known bio-importance in human biochemistry and physiology and consumption even at very low concentrations can be toxic (Nolan, 1983). Heavy metals such as Pb, Zn, Cu and Cd can damage nervous connections, cause blood poisoning and cancer in humans.

Heavy metals are emitted from natural and anthropogenic sources. The anthropogenic sources include industrial and automobile emissions (Peplow, 1999; UNEP/GPA, 2004). Oil spillage also contributes to heavy metal pollution. For instance, Tanee and Kinako, (2008) and Tanee and Akonye (2009) reported an increase in heavy metals especially Zn and Cu in crude oil polluted soil. Automobile emission is reported to be one of the largest sources of heavy metal to environment (UNEP/GPA, 2004). Excessive heavy metals accumulation in agricultural land may result in elevated heavy metal uptake by plants (Garcia and Millan, 1998).

There are reports of heavy metal accumulation by plants grown on roadsides in the developed countries, however, few studies have actually been carried out on this area in developing countries (Fakayode and Olu-Owolabi, 2003; Singh *et al*., 2004; Chen *et al*., 2005; Liu *et al*., 2005; Wilson and Pyatt, 2007; Atayese *et al*., 2009).

This study attempts to determine the accumulation of heavy metals in the studied plants and topsoil along some high vehicular traffic roads in Nigeria using Eleme Local

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Government Area of Rivers State as a case study. It is expected that the findings obtained from this study will widen our knowledge on the danger of heavy metal pollution in our environment by providing information on its spread. It may also provide information on the danger of roadside farming-a common practice among peasant rural farmers.

MATERIALS AND METHODS

Description of the study area: The study was carried out along major road in Eleme Local Government area of Rivers state situated in the south-south (Niger-Delta) zone of Nigeria (Fig. 1). The area experiences two distinct seasons-the dry and rainy seasons. The dry season is from November-March and the rainy season from April-October. The climatic condition of the area is characterized by high temperature, high rainfall, high relative humidity and high sunshine.

The soil of the area ranged from well drained to moderately drain except in the coastal areas where the soil is poorly drained. The soil is always low in nutrient content due to the leaching of the nutrient down the soil profile by high rainfall which is always heavy in the area. Eleme Local Government Area is home of many heavy industries in Nigeria. Amongst them are two petroleum refining plants, one petrochemical plant, a fertilizer plant, a shipping terminal and other minor companies associated

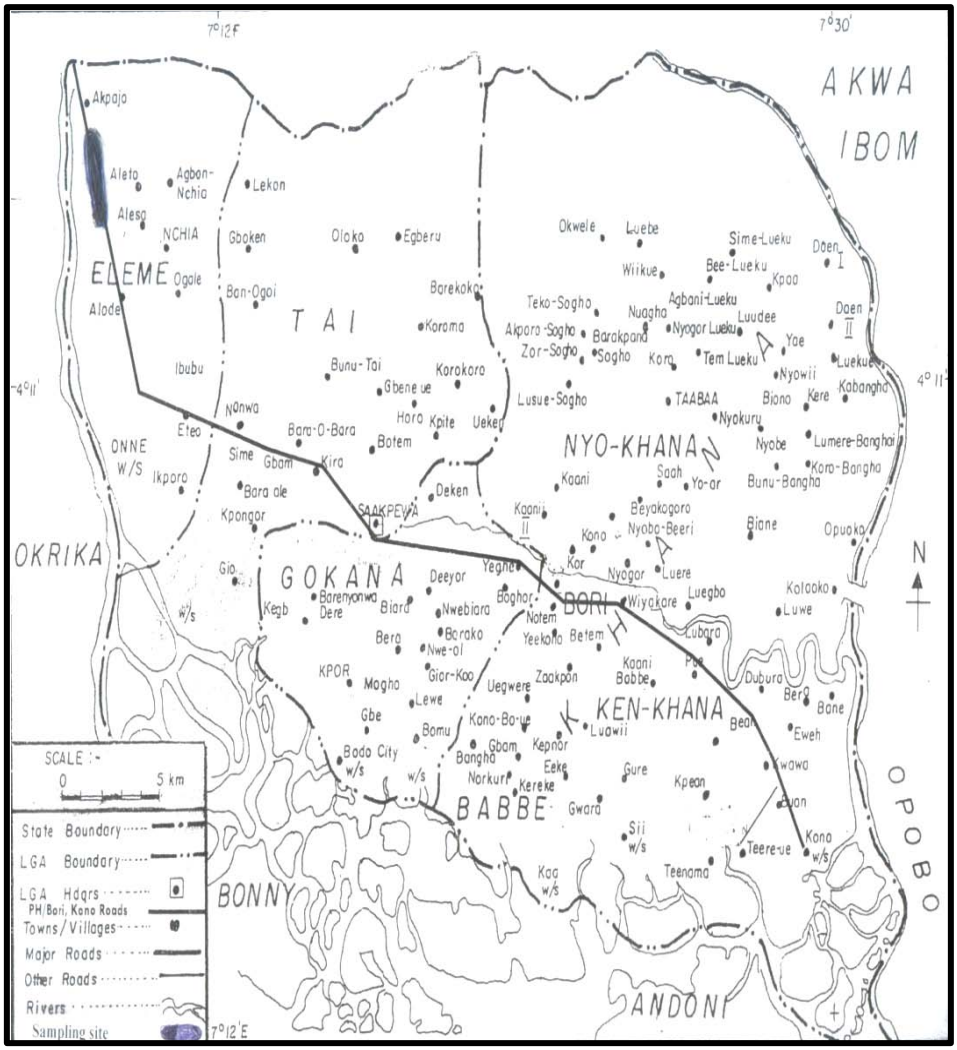

Fig. 1: Map of Ogoni showing sampling area at Eleme

with refined oil storage and marketing . As a result of this, the area has heavy vehicular traffic volume and therefore experiences enormous automobile exhaust emission from heavy duty and smaller vehicles.

Sample collection: Three roads within the area were selected for the study. These were Refinery Road, Akpajo-Onne Junction (along the East-West Road) and Aleto-Eleme By-Pass Road (Fig. 2).

The first two (i.e., Refinery and Akpajo-Onne Junction roads) are heavy traffic routes of more than 2,000 vehicles per day and Aleto-Eleme By-Pass Road is a moderate traffic route of less than 2,000 vehicles per day. Samples were collected in the month of October, 2009. Four sample points along each of these roads (represented by P in Fig. 2) were located with a minimum of one kilometre between sample points. Samples were taken at each of the sample point at a distance of 0 m and 10 m away from the road. At each sample point, three topsoil samples were collected at a depth between 0-5 cm using a spatula and were thoroughly mixed to form a composite sample. These were transferred into polyethene bags to avoid contamination from other sources, labeled with a masking tape and taken to the laboratory for analysis.

Furthermore, two plant species samples found flourishing within 1 m by 1 m of the sample point were also collected from each point. *Panicum maximum* and *Centrosema pubescens* representing monocotyledon and dicotyledon respectively were collected. According to Markert (1993), the criteria for selection of a species as a biomonitor include (1) It should be represented in a large number all over the monitored area and (2) There should be no identification problems. The choice of *Panicum maximum* and *Centrosema pubescens* met these two criteria. Aerial parts of these plants were collected using a clean stainless pair of scissors (Okonkwo and Maribe, 2004). The plant samples were placed in polythene bags, labeled with a masking tape and taken to the laboratory for analysis. Plant specimens and soil samples collected at each sample location were kept together and treated separate from others.

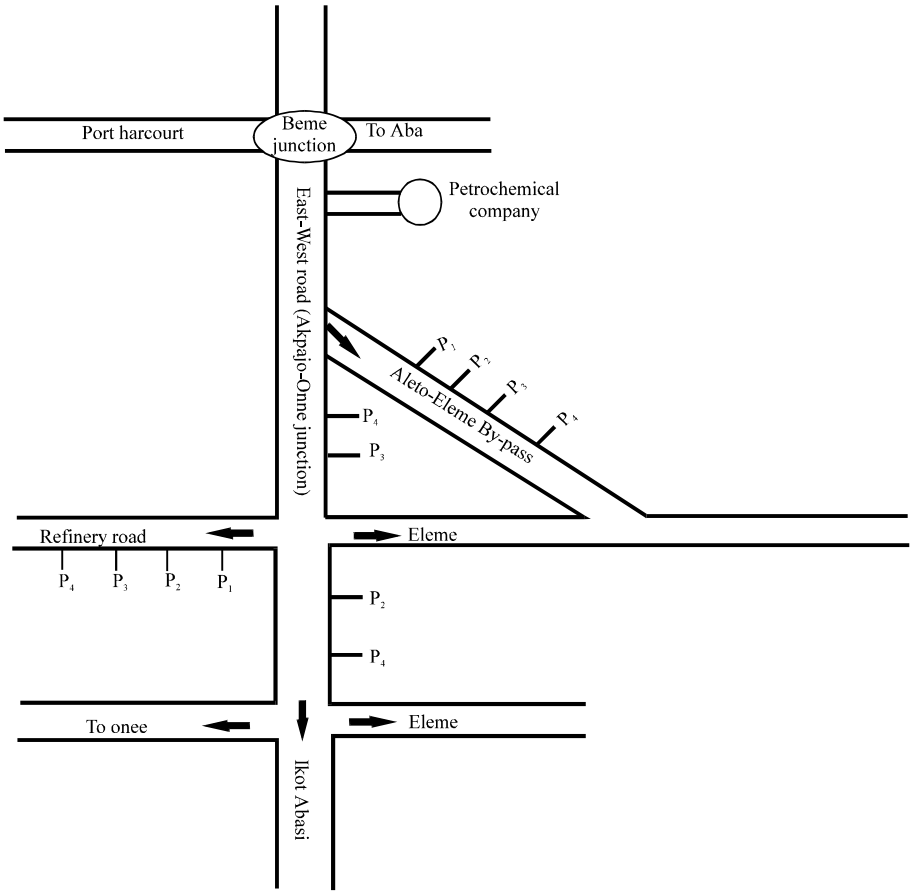

Fig. 2: Sketch map showing sampling locations along the 3 road in Eleme

Analysis of soil samples: Soil samples collected were air-dried and all clods and clumps were removed. Dried soil was sieved using 2 mm sieve to remove course particles before analysis.

The following parameters were analyzed in the soil samples: soil pH, soil conductivity and heavy metals (Cu, Pb, Zn and Cd).

Soil pH and conductivity were determined electronically using pH meter (Jenway 3015 model) and conductivity meter (HACH Ecttesr Microprocessor series model), respectively. Fifty gram of dried soil was placed in 500 mL capacity beaker containing 50 mL of distilled water (i.e., 1:1). The mixture was thoroughly stirred and allowed to stand for 10 min before pH and conductivity values were recorded when the figure on the meters were constant.

One gram (1 g) of the dried soil sample was placed in 100 mL beaker and 3 mL of perchloric acid and 5 mL of nitric acid were added. The mixture was allowed to stand for 15 min before digestion by gently heating at low temperature on a hot plate and allowed to cool for 5 min. The digest was then filtered into 50 mL standard flask. The filtrate was analyzed for heavy metals using Atomic Absorption Spectrophotometers (AAS) BUCK scientific 200A model.

Analysis of plant samples: The plant samples were first rinsed with distilled water and oven-dried at 100°C for 48 h. The plant materials were ground to fine powder. One gram of the powder was digested as described above and analyzed for heavy metals using Atomic Absorption Spectrophotometer (AAS).

Statistical analysis: Data obtained were subjected to statistical analyses using Analysis of Variance and Standard Error Mean (SEM) using Microsoft excel package version 2007. Least significant difference ($p = 0.05$) was used to separate means.

RESULTS

Table 1 showed the results for soil chemical parameters (soil pH and conductivity) and heavy metals content (Cu, Pb, Zn and Cd).

The pH of the studied area was generally low (i.e., acidic). The results for pH ranged from 4.08±0.2 4.36±0.07. There was no significant difference between roads and distance away from the road.

Conductivity was generally high and there was no significant difference ($p = 0.05$) between the roads and distance from the road for the three roads.

The heavy metal content (Cu, Pb, Zn and Cd) showed similarity with soil pH and conductivity, especially in terms of significant differences. Copper (Cu) content of the 3 roads was in the range of 1.55±0.37 mg kg^{-1} (10 m distance on Aleto by-pass road) to 4.25±1.38 mg kg^{-1} (0 m distance on refinery road). Lead (Pb) content in the area was higher than copper content (2.69±0.74-6.92±2.51 mg kg^{-1}). Zinc (Zn) recorded the highest values among the 4 heavy metals analyzed in the range of 4.07±0.87-11.69±3.03 mg kg^{-1}. Zinc was significantly lower ($p = 0.05$) at the Aleto By-Pass Road than the other two roads. Similar result was obtained for soil cadmium (Cd) in which the soil cadmium was significantly higher at 10 m distance on Onne-Akpajo and Refinery roads than the Aleto by-pass road.

Generally, soil pH, conductivity, Cu and Pb concentrations were proportional to the distance from the road, with higher values at the roadside than 10 m from the road. A reverse trend was observed in Zn and Cd showing higher values in the 10 m distance from the road than the roadside especially in the Refinery and Onne- Akpajo roads.

Table 2 showed heavy metal contents in the two plants (*Panicum maximum* and *Centrosema pubescens*) sampled along the three roads.

Zinc content in *Panicum maximum* was in the range of 43.28±1.9-73.16±6.5 mg kg^{-1}. A significantly higher

Table 1: Soil Physico-chemical and heavy metal content along the three roads in Eleme

Parameter	Distance from the road (m)	Onne-Akpajo road	Refinery road	Aleto By-pass
pH	0	4.36±0.07^{a}	4.26±0.08^{a}	4.08±0.2^{a}
	10	4.31±0.14^{a}	4.10±0.17^{a}	4.12±0.13^{a}
Conductivity (us cm^{-1})	0	137.5±11.39^{a}	197.5±25.59^{a}	155.0±35.62^{a}
	10	137.5±29.9^{a}	215.0±44.51^{a}	135.0±25.86^{a}
Cu (mg kg^{-1})	0	2.31±0.53^{a}	4.21±1.38^{a}	2.17±1.1^{a}
	10	1.97±0.15^{a}	3.14±1.28^{a}	1.55±0.37^{a}
Pb (mg kg^{-1})	0	3.19± 0.14^{a}	4.89± 1.44^{a}	3.16±0.92^{a}
	10	3.08±0.47^{a}	6.92±2.74^{a}	2.69±0.74^{a}
Zn (mg kg^{-1})	0	8.36±0. 91^{b}	10.76±2.79^{b}	4.07±0.87^{a}
	10	6.2±0.83^{a}	11.69±3.03^{b}	4.14±0.4^{a}
Cd (mg kg^{-1})	0	0.21±0.04^{a}	0.17±0.03^{a}	0.22±0.03^{a}
	10	0.29±0.01^{b}	0.26±0.04^{b}	0.16±0.01^{a}

Mean±SEM with different superscript between columns means significant difference ($p = 0.05$)

Table 2: Heavy metal accumulation in plants along the 3 major roads in Eleme

Heavy metal (mg kg^{-1})	Plant spp.	Distance from the road (m)	Onne-Akpajo road	Refinery road	Aleto By-pass road
Zn	*Panicum maximum*	0	69.54±5.0^a	64.7±7.7^a	68.92±3.6^a
		10	73.16±6.5^b	43.28±1.9^a	49.66± 0.5^a
	Centrosema pubescens	0	84.52±3.5^b	69.54±2.6^b	48.26±9.4^a
		10	63.25±3.1^a	57.16±12.2^a	49.55±11.6^a
Pb	*Panicum maximum*	0	278.44±10.7^b	236.9±11.1^a	231.88±18.9^a
		10	158.02±12.8^b	144.22±12.8^a	144.80±4.6^a
	Centrosema pubescens	0	146.04±17.5^a	136.68±10.3^a	151.50±6.8^a
		10	154.15±7.7^a	170.82±8.3^b	143.74±5.6^a
Cu	*Panicum maximum*	0	13.10±0. 9^a	17.10±3.6^a	16.68±2.5^a
		10	10.14±6.1^a	10.78±2.2^a	9.26±3.0^a
	Centrosema pubescens	0	18.36±2.4^a	13.46±1.2^a	14.922±0.5^a
		10	18.89±1.8^a	17.52±1.8^a	16.16±2.6^a

Mean±SEM with different superscript represent significance difference @ p = 0.05)

Table 3: Acceptable range of the parameters studies in soil

	Acceptable range[a]	Observed range from this parameters study
pH	5.5-6.5	4.08-4.36
Conductivity (loamy soil) μs cm^{-1}	8-30	137.5-215.0
Cu (mg kg^{-1})	5-50	1.55-4.25
Pb (mg kg^{-1})	5-50	2.69-6.92
Zn (mg kg^{-1})	10.120	4.07-11.69
Cd (mg kg^{-1})	0.7-3	0.16-0.26

[a]HSE-ENV (2004)

Table 4: Comparison of heavy metal concentration in soil analyzed in this study with the level in similar studies

Heavy metal (mg kg^{-1})	This study	Yauri soil[a]	Lagos-Badagry road[b]	Osogbo[c]
Cu	1.55-4.21	0.91-23.72	5.99-20.63	27.69-21.19
Pb	2.69-6.92	35.9-484.9	0.25-4.24	92.07-68.74
Zn	4.07-11.69	79.6-202.4	N/A	56.27-42.45
Cd	0.16-0.26	ND-7.02	ND	0.76-0.6

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

level of Zn was observed at Onne-Akpajo Road. The concentration of Zn decreases with increase in distance away from the road in *Panicum maximum*. Similar trend was obtained in *Centrosema pubescens* in which the Zn content was generally higher at the roadside (i.e. 0 m distance) than 10 m distance for the 3 roads with the highest value recorded at 0 m distance at Onne-Akpajo Road. *Panicum maximum* had the highest Pb content at 0 m at Onne-Akpajo road while *Centrosema pubescens* showed the highest level at Refinery Road. The two plants showed low level of Pb at Aleto by-Pass Road.

The copper (Cu) content in *Panicum maximum* at 0 and 10 m of the three roads were low with no significant difference between them. However, *Centrosema pubescens* recorded higher Cu values (13.46±1.2-18.89±1.8 mg kg^{-1}) than *Panicum maximum* (9.26±3.0-17.10±3.6 mg kg^{-1}).

Table 3 showed the recommended range of the physico-chemical parameters and heavy metal contents in soil. It is observed that pH in the study site in the range of 4.08- 4.36 were below the recommended range of 5.5-6.5 indicating high acidity of soil; while conductivity of 137.5 -215.0 μs cm^{-1} were higher than the recommended range of 8-30 μs cm^{-1}. The high heavy metals concentrations were within the acceptable ranges.

Table 5: Acceptable range of heavy metals in plants as compare to the ones from this study

Metals (mg kg^{-1})	1	2	From this study
Pb	0.2-20	0.05-3	136.68-278.4
Cu	5-20	2.5-25	9.26-18.89
Zn	1-400	15-100	43.28-84.52

1: Bowen (1979); 2: Allen *et al.* (1974)

A comparative analysis of the result obtained from this study and other works done elsewhere in Nigeria is shown in Table 4. Results showed that the concentration of heavy metals obtained from this study was lower than those obtained from other studies such as Yauri, Lagos-Badagry Road and Osogbo Roads. The only exception was Pb in which the result showed that the soil Pb concentration of 2.69-6.92 mg kg^{-1} was higher than the range obtained at Lagos-Badagry road (0.25-4.24 mg kg^{-1}).

Result showed that Pb concentration in the plant (136.68-278.4 mg kg^{-1}) was above the acceptable maximum (recommended) range (0.2-3 mg kg^{-1}) while the other two metals (Cu and Zn) were within the recommended limit (Table 5).

DISCUSSION

Human activities such as industrialization, commercialization and urbanization have adversely increased the amount of heavy metals in our environment

(Nriagu, 1996). Result showed that the soil pH values of the sampled area were generally low (i.e., acidic). Similar result (i.e., low pH) has been reported by Abii and Nwosu, (2009) and Tanee and Albert (2011). Low pH is a characteristic of the tropical soil. The study area is also an industrial area that has heavy vehicular traffic with the emission of gaseous and particulate matters into the atmosphere which dissolves in atmospheric moisture and fall to the soil in rain. There is the possibility that some anions may remain on topsoil with the increase of free radicals, thereby resulting in reduced soil pH. The low pH value is an indication of pollution since most plants and microorganisms perform best at pH close to neutrality (Atlas and Bartha, 1992). The observed low pH could also account for the high conductivity recorded in the area.

Results showed that heavy metal concentrations in the soil decreased with increase in distance from the road with exception of Zn and Cd on Onne-Akpajo Road and Refinery Road. This might be as a result of the heavy automobile traffic especially heavy duty vehicles characteristic of these roads. Habashi (1992) and Fuller (1974) have reported undesirable and unnatural concentration of lead (Pb) in air, water, soil and vegetation particularly near heavily plied automobile free-ways. These range of heavy metals are among the wide range of heavy metals found in fossil fuel which are either emitted into the environment as particles during combustion or may itself be transported in air and contaminate soil (Yahaya *et al.,* 2010). This is in line with the report of UNEP/GPA, 2004 - that combustion and traffic are among the sources of heavy metals into the environment.

Zn was found to have the highest concentration in the soil in the study area, followed by Pb. This is understandable since tyre wears released zinc (Kabata-Pendias and Pendias, 1984). The higher level of Pb might be from the deposition from automobile exhaust since most petroleum fuel contains tetraethyl lead as antiknock (Lenntech Water Treatment and Air Purification, 2004).

Results also showed higher concentration of heavy metal in plants than soil in all the 3 roads sampled. This is an evidence of bioaccumulation or biomagnification of the heavy metals in the plants. When soil is polluted with heavy metals, the metals are taken up by plants and consequently accumulate in their tissues (Trusby, 2003). Animals that feed on these plants also accumulate these metals in their tissues (Horsfall and Spiff, 1999; Peplow, 1999). These may become lethal to the top carnivores.

The concentration of Zn was higher in *Centrosema pubescens* than in *Panicum maximum* and Pb was higher in *Panicum maximum* than *Centrosema pubescens* while Cu was higher in *Centrosema pubescens* than *Panicum maximum*. This suggests that plants have different ability of accumulating particular heavy metals.

It was also observed that the Pb concentrations in the plants were very high when compared with other metals. This suggests that the plant might have absorbed lead (Pb) from other sources apart from the soil. It is possible that the Pb emitted into the atmosphere from the automobile exhaust penetrates through the intercellular spaces of the leaves and accumulate in the plant.

It is observed that the results obtained from this study in terms of heavy metal accumulation in the soil are similar to other studies done elsewhere in Nigeria. This showed that major roads in Nigeria have similar levels of heavy metal pollution.

The high level of Pb accumulation in the plants along the roadsides is an indication of Pb pollution of the roadside plants in which if consumed by humans might have deleterious effect and even death due to biomagnifications.

CONCLUSION

The 3 roads showed different levels of heavy metal contaminations. The level of contamination was more pronounced in the plants than in the soil. Therefore, economic plants should not be cultivated along roads with heavy traffic especially along the roadsides so as to avoid heavy metal toxicity in man and animals. Proper biomonitoring of the environment should be done as often as possible so as to enlighten the public on the dangers of heavy metal pollution.

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