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Full Length Research Paper

Evaluation of heavy metals in roadside soils of major streets in Jos metropolis, Nigeria

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A study of heavy metals in roadside soils is critical in assessing the potential environmental impacts of automobile emission on the soil. The soil samples were collected and analyzed for the levels of Pb, Zn, Mn, Cu, Ni, Cd, Co and Fe using AAS. Results indicate the decreasing order of the average total metal content for the studied metals: Fe > Zn > Mn > Pb > Cd > Cu. Except for Cd, all metals are lower than the levels of those reported in other studies. The absence of Co and Ni indicate no pollution due to these metals. Correlation analysis between metals and the traffic volume (V) indicates significant positive correlation ($p < 0.05$) between Pb, Cd and Mn, and V. This further indicates that the metal pollution in the soil is mostly originated from vehicular emissions e. g. motor vehicles. Therefore, this study provides a practical approach to monitor the level of these metals.

Key words: Heavy metals, roadside, Jos, metropolis.

INTRODUCTION

Roads are important infrastructure that plays a major role in stimulating social and economic activities. However, road construction has also resulted in heavy environmental pollution (Bai et al., 2008).

Several researchers have indicated the need for a better understanding of trace metal pollution of roadside soils (De Kimple and Morel, 2000; Manta et al., 2002). Trace metals in roadside soils may come from various human activities, such as industrial and energy production, construction, vehicle exhaust, waste disposal, as well as coal and fuel combustion (Li et al., 2001). According to Adefolalu (1980) and Mabogunje (1980), in developing countries like Nigeria, improved road accessibility creates a variety of ancillary employment which range from vehicle repairs, vulcanizer and welders to auto-electricians, battery chargers and dealers in other facilitators of motor transportation. These activities send trace metals into the air and the metals subsequently are deposited into nearby soils, which are absorbed by plants on such soils. Sakagami et al. (1982) reported that there was a close relationship between trace metal concentration in roadside soil and those in the dust falls. Trace metals in the soils can also generate airborne particles and dusts, which may affect the air quality (Gray et al., 2003). Among the numerous environmental pollutants, an important role is ascribable to heavy metals whose concentration in soils, water and air are continuously increasing in consequence of anthropogenic activity.

According to Lagerwerff and Specht (1970), while many studies have been made on lead, little attention has been focus on the contamination of other trace metals in the roadside environment. Metals such as iron Fe, Cu, Zn are essential component of many alloy, pipe, wire and tyre in motor vehicles and are released into the roadside environment as a result of mechanical abrasion and normal wear and tear (Harrison et al., 1981). Soil tends to accumulate metals on a relatively long term basis since many metals in the soil are so mobile. This explains the overall higher contamination level of metals in the soil and why, in sampling, the top layer of soil should be taken (Ho and Tai, 1988). Although, there have been considerable number of studies on the concentrations of heavy metals in roadside soils, vast majority have been carried out in developed countries with long histories of industrialization and extensive use of leaded gasoline since 1935 (Otte et al.,

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Table 1. Traffic volume of the sampling roads.

Location	Site code	Average traffic volume per day
Murtala Muhammed way	A	1,521
Yakubu Gowon way 2	B	1,340
Yakubu Gowon way 1	C	1,320
Tudun Wada road	D	1,001
Pam road	E	965
Rukuba road	F	930
Off Yakubu Pam road	G	603

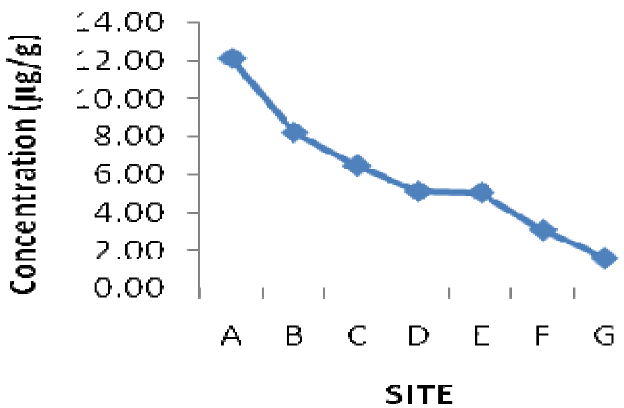

Figure 1. Concentration of Pb across the sampling site.

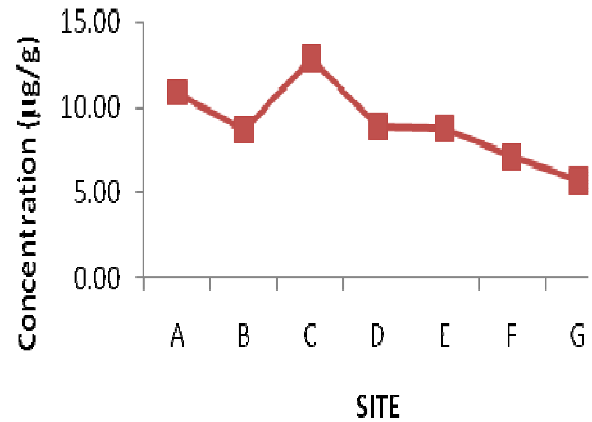

Figure 2. Concentration of Zn across the sampling site.

1991; Mateu et al., 1995). Very few studies were carried out in developing countries such as Nigeria and data on pollutant metal concentrations and distribution in such country is extremely scarce.

Hence, this research work was carried out to ascertain the heavy metal concentrations in roadside soils of major roads of Jos Metropolis as related to traffic volume.

MATERIALS AND METHODS

Sampling description

The sampling locations were chosen to span a wide range of traffic density and to give a good geographical coverage in the Jos city. Seven sites were selected for study within the Jos environment and their locations are as designated below in decreasing order of traffic volume. The traffic density was determined by counting the number of motor vehicles passing the sampling sites over a period of fifteen hours starting 6.00 a.m. to 6.00 p.m. each day for three days (Grace, 2004). The average number of vehicles passing the site per day was then calculated, as shown in Table 1.

Sample collection

Field collection were made in February (2008), about five months into the dry season such that possible wash away or leaching of the heavy metals where avoided. The samples were also collected within two consecutive days such as to minimize temporal changes. At each site, three replicated samples were taken from the surface soil, composite and represented samples preserved in an acid pre-washed cleaned polyethene bags and subsequently treated and analyzed separately.

Sample digestion

All reagent used were of analytical grade and double distilled water was used in all preparation except otherwise stated. The method of Ho and Tai (1988) was used for sample digestions. Samples were sealed in polythene bag and air dried. The samples were grinded using an acid pre-washed mortar and pestle sieved by passing them through a 1 mm mesh. 1 g of soil of each of the samples was accurately weighed and treated with 10 ml aliquots of high purity conc. HNO_3. The mixture was on a hot plate until the sample is almost dry and then cooled. This procedure was repeated with another 10 ml conc. HNO_3 followed by 10 ml of 2 M HCl. The digested soil samples were then warmed in 20 ml of 2 M HCl to redissolved the metal salts. Extract were filtered through filter papers and the volume was then adjusted to 25 ml with doubled distilled water. Metal concentrations were determined by UNICAM SOLAR 32 Data station V7.15 AAS model.

RESULTS AND DISCUSSIONS

The average of triplicate determinations of metal concentrations (Pb, Zn, Cu, Cd, Mn and Fe) in soils of the various sampling sites is presented in µg/g in Figures 1- 6.

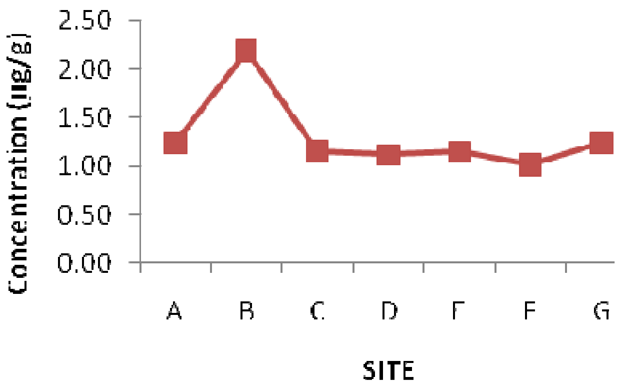

Figure 3. Concentration of Cu across the sampling site.

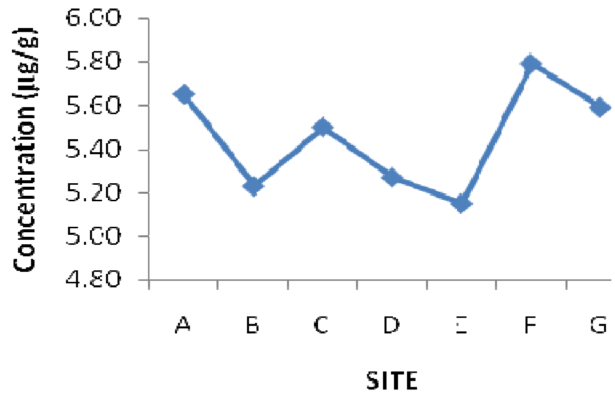

Figure 4. Concentration of Cd across the sampling site.

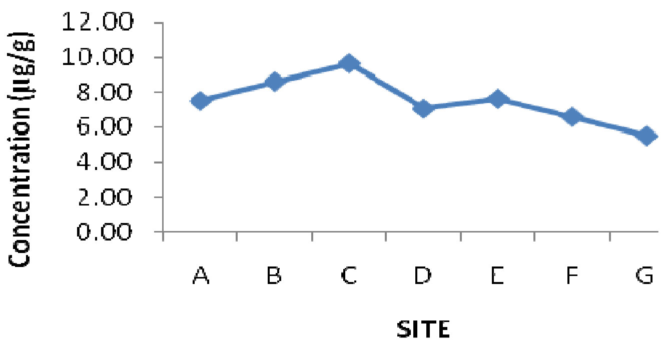

Figure 5. Concentration of Mn across the sampling site.

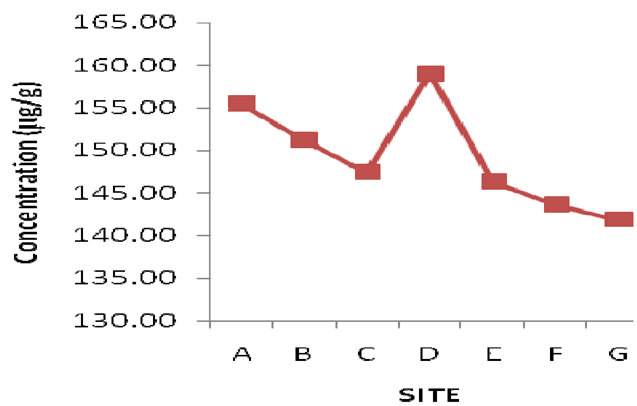

Figure 6. Concentration of Fe across the sampling site.

Analysis of variation of metals among the site indicated significant variations ($p < 0.05$) for all metals except Cd and Cu. The soil pH is generally slightly alkaline across the sites with exception of Site A that is slightly acid.

The roadside soil lead level ranges from a very low concentration of 1.59 (Site G, low traffic volume) to a high concentration of 12.10 µg/g (Site A, high traffic volume). The high mean value of the concentrations attested to the overall high level of contaminations of this metal in the roadside environments. This is in agreement with the report of Lagerwerff and Specht (1970). The high concentrations of lead observed could be attributed to lead particle from gasoline combustion which consequently settles on roadside soils. The case of Site A being more predominant could be attributed to the heavy traffic of the route. At the same way, vehicles are often moving slowly as a result of the heavy traffic jam in this area and this may account for the high level of lead. This is in line with Francek (1992) report that traffic junction and cross roads, records higher levels of metals. Also, it is therefore not surprising that high level of Pb is associated with sites B and C junctions which serve as a mini garage for heavy trucks. This is in addition to the auto mechanic work that dominates the business in the area. Conversely, Site G has the least concentration value of Pb (1.59 µg/g) and this could be expected, because of the least volume of vehicles recorded on the road. Though, the high mean soil lead level confirms that the roadside environment is generally lead enriched despite a relatively low traffic volume compared to other studies (Ho et al., 1987). The mean lead level observed is far lower than that reported by Ho et al. (1987) and Francek (1992).

Zn ranged from 5.67 (Site G) to 12.88 µg/g (Site C). This value is small compared with many other studies (Jaradat and Momani, 1999; Bai et al., 2008). In this study, the Pb/Zn ratio in soil was less than unity with exception of Site A, which is contrary to report that soil-lead pollution may be caused by automobiles (Jaradat and Momani, 1999). However, other reports found a ratio of less than unity, which was related to the local conditions (Davies, 1984; Hewitt and 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 such as zinc dithiophosphates.

Also, the mobility of the metal depends on soil pH and also depends on the organic matter and granulometric

Table 2. Correlation analysis among traffic volume and metals

Parameter	Traffic volume (V)	Pb	Zn	Mn	Cu	Cd	Fe
Traffic volume (V)	1.000						
Pb	.939**	1.000					
Zn	.808*	.674	1.000				
Mn	.758*	.544	.860*	1.000			
Cu	.365	.352	-.029	.349	1.000		
Cd	-.059	-.081	-.110	-.351	-.419	1.000	
Fe	.572	.648	.430	.264	.154	-.344	1.000

** Correlation is significant at 0.01, * Correlation is significant at 0.05.

composition of the soil. Acidic pH makes easier the solubilization of the Zn compounds, although the soils in this study are alkaline with exception of Site A that is slightly acidic. An indication that Zn and other metals remain in soils for a longer.

The Jos city roadside copper level ranges from 1.01 µg/g at Site F to 2.19 µg/g at Site B, along Yakubu Gowon road which serves as one of the major roads with associated ancillary vehicle workshops located along it. Compared to other studies, the value of Cu is less than 27, 61, 24 and 29.7 µg/g reported in literature (Ward et al., 1977; Ndiokwere, 1984; Davies et al., 1985; Jaradat and Momani, 1999), though comparable to 2.78 µg/g obtained along Sixao highway in Southwest China (Bai et al., 2008).

Cd on the hand, was obtained from all the sites, range of 5.15 (Site E) - 5.79 µg/g (Site F) was found. Soils in this study exhibited higher levels of contamination than 0.75 µg/g (Jaradat and Momani, 1999), 2.11 µg/g (Amusan et al., 2003) and 0.88 µg/g (Bai et al., 2008). However, the level of Cd in this study is comparable to 6.8 µg/g reported in North Wale (Davies, et al., 1985) and about 5 times that reported by Ndiokwere (1984). In absence of any major industry in the sampling sites, the levels of Cd could be due to lubricating oils and/or old tires that are frequently used on the rough surfaces of the roads which increase he wearing of tires.

Mn and Fe obtained from this study ranged from 5.51 (Site G) - 9.61 µg/g (Site C) and 141.80 (Site G) - 159.00 µg/g (Site D), respectively. Both Fe and Mn form the composition of soils in northern Nigeria, there availability in a trace amount as obtained in this study could be due to local condition of soil weathering.

Correlation calculations, among concentrations of the heavy metals in surface soil and traffic volume (V) are shown in Table 2. This coefficient measures the strength of a linear relationship between any two variables on a scale of -1 (perfect inverse relation) through 0 (no relation) to +1 (perfect sympathetic relation). In this study, the raw geochemical data was used in calculating the correlation coefficient using the SPSS (Statistical Program for the Social Sciences) computer software package (SPSS Inc., version 13). The results showed significant positive correlations ($p < 0.05$) are present between V: Pb, Zn and Mn, and Mn and Zn. Though mild positive and negative correlation were observed between metals, negative correlation between Cd and V indicate that other sources other than automobile emission could contribute to concentration of this metals in the soils. Significant positive correlations between metals and V could indicate possible contamination of the soils by automobile emissions.

Conclusion

The result of this study generally revealed the presence of all metals with exception of Co and Ni in the roadside soils. The concentrations of the metals in the soils are in the order of Fe > Zn > Pb > Mn > Cd > Cu. The level of Cd at the moment is high compared to other studies in Nigeria. Hence, possible accumulation in the soil and transfer to plants growing along the edge of the highway could occur as a result continual usage of the road by automobile. This can also lead to accumulation of the metal in the tissues of organisms that feed on the plant and other plants growing along the highway. This can be transferred to other consumers in the food chain (Akinola and Adedeji, 2007).

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