Evaluation of some Heavy Metals in Soils along a Major Road in Ogbomoso, South West Nigeria

Taofeek A. Yekeen* and Tolulope O. Onifade
Department of Pure and Applied Biology, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.
* E-mail of the corresponding author: tayekeen@yahoo.com

Abstract
Evaluation of the concentration of soils metals (Pb, Cd, Cr, Zn, Mn, Cu, Fe, and Ni) from selected sites (Odo Oba, Sabo and General Areas) along a major road in Ogbomoso was made in comparison with control site, LAUTECH Campus (LC) based on contamination factor and pollution indices. The metal levels in the sites revealed that: General > Sabo > Odo Oba > LC for the analyzed metals except Fe of which highest value was obtained in the control site. Contamination indices showed that Sabo and general were considerably polluted while Odo Oba was moderately polluted relative to control. The values of pollution level index obtained for these three sites (PLI >1) indicates deterioration of site quality. Significant correlation between some of the metals (Pb, Cr and Ni) studied and average daily traffic volume showed that the contamination could be from automobile emissions. The accumulation of these metals in soil especially in the residential areas may add to the body burden of the residents. Further investigation is highly necessary to study the concentrations and health implications of these metals in residents of the linear settlements along this major road in Ogbomoso.
Key words: Heavy metal, Traffic volume, Pollution, Soil, Ogbomoso

1. Introduction

Roads serve as major link 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). Besides this, 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). Public motor roads affects natural environment to a large extent because automobile act as line sources of heavy metal pollutants (Poszyler-Adamska and Czemiak, 2007). Excess of metal pollutants deposited on soils may be transformed and transported to vegetation (Atayese *et al*., 2009) and from plants they pass on to animals and human being (Suzuki *et al*., 2008). There have been several reports on road side soils in some urban cities in Nigeria including soils from Jos (Abechi *et al*., 2010), Osogbo (Fakayode and Olu-Owolabi, 2003) and Ibadan (Onianwa *et al*., 2001) and other cities (Ihenyen, 1998a; 1998b). Roadside soils in U.K. (Thornton, 1982), Holland (Edelman & Bruin, 1986) and India (Kuhad *et al*., 1989), Botswana (Mmolawa *et al*., 2011) have also been studied. Road side soil pollution in these studies was attributed to traffic. Thus, emissions from heavy traffic are a global phenomenon.

Heavy metals frequently reported in literature with regards to potential hazards and occurrences in contaminated soils are Cd, Cr, Pb, Zn, Fe and Cu (Alloway, 1995; Akoto *et al*., 2008). Emission from heavy traffic were reported to contain Lead, Cadmium, Zinc and Nickel which are present in fuel as anti-knock agent (Suzuki *et al.*, 2008; Atayese *et al*., 2009). Vehicle exhausts, as well as several industrial activities emit these heavy metals such that soils, plants and even residents along roads with heavy traffic loads are subjected to increasing levels of contamination with heavy metals (Ghrefat & Yusuf, 2006). Soils are critical in assessing the potential environmental impacts of automobile emissions and several researchers have indicated the need for a better understanding of heavy metal pollution of roadside soils (De Kimple & Morel, 2000; Manta *et al*., 2002). In Nigeria, over the years, the number of vehicles plying roads kept on increasing as more heavy trucks and trailers are been used for transportation of goods across different zones because rail system was abandoned. One of the major roads that do witness such is the road that linked north and south of Nigeria together via Ibadan - Ilorin. This road was constructed over three decades ago to pass through the city of Ogbomoso (8°07'59.88"N and 4°15'00"E).

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 the heavy metals into the air and are subsequently deposited into nearby soils which are absorbed by plants (Adefolalu, 1980; Mabogunje, 1980). Heavy metals in the soil can also generate airborne particles and dust which may affect the quality of air (Gray *et al*., 2003). Inhalation of substantial quantities of heavy metal particle over period of time may add tohuman body burden of the metals and constitute health risk. Among the numerous environmental pollutants, heavy metals plays an important role as its concentrations in soil, water and air are continuously increasing due to anthropogenic activities (Gray *et al*., 2003). This current study sought to evaluate the levels of some selected heavy metals in the soil samples along a major road in Ogbomoso.

2. Materials and Methods.

2.1 Study sites and sample collection.

The study areas selected (Odo Oba, Sabo and General Areas) are major locations along Oyo – Ilorin road, within Ogbomoso while LAUTECH Campus (LC) was used as control site. Three replicate samples of the surface soil were collected from each site into pre-cleaned acid washed polythene bags. The replicates samples were pooled, air dried, sieved and stored until analyzed.

2.2 Heavy metal analysis

Sample digestions and analysis were done as described (Ho & Tai, 1998) with slight modification. Eight selected heavy metals (Cadmium, Cd; Chromium, Cr; Zinc, Zn; Manganese, Mn; Iron, Fe; Copper, Cu; Nickel, Ni and Lead, Pb) were analyzed in three replicates. All reagents used were of analytical grade and doubled distilled water was used for all preparations. All glass materials were thoroughly washed, soaked overnight in dilute HNO_3 (10%), rinsed with distilled water and oven dried before usage. Air dried samples were grinded using mortar and pestle, and sieved with 2mm mesh size. 2 g of each of the soil samples was accurately weighed and treated with 10 ml aliquots of high purity concentrated HNO_3. The mixture was heated on a hot plate until the sample was almost dry and then cooled. This procedure was repeated with another 10ml of concentrated HNO_3 followed by 10 ml of 2M HCl to re-dissolve the residue. The extracts were then filtered through Whatman filter paper (no. 42) into 50ml capacity bottle and brought up to volume with doubled distilled water. Heavy metal concentrations were determined using Atomic Absorption Spectrophotometer (Buck 210 AAS, 2005, USA).

2.3 Traffic volume

The traffic load was determined as previously described by Fakayode & Olu-Owolabi (2003) with slight modification. The volume of the traffic was estimated by visual counting of the number of vehicles passing on both sides of the road for 60 min between 08-09h for 7 days. The average traffic volume (ATV) per hour was extrapolated.

2.4 Assessment of metals contaminations

The level of contaminations of heavy metals in road side soils were assessed by contamination indices. Contamination factors (*Cf*), the degree of contamination (*Cd*), the pollution load index (PLI) and Geoaccumulation index (I-geo) were used. *Cf* and *Cd* were calculated as suggested by H åkanson (1980) through these formulas:

$Cf = Cs / Cb$ (1)

$Cd = \sum Cf$ (2)

Where, Cs is the measured concentration of the examined metal in the road side soil and Cb is the geochemical background concentration or reference value of the metal or the background value of heavy metals in the uncontaminated soil (Khairy *et al*., 2011). H åkanson (1980) suggested four classes of *Cf* to evaluate the metal contamination levels as shown in Table 1. Four categories of *Cd*as suggested were used to evaluate metal contamination levels (Table 1). If the *Cd* value exceeds 20, then itis necessary to take immediate counter measures to reduce heavy metal contamination in the soil.

Furthermore, each site was evaluated for the extent of metal pollution by employing the method based on the pollution load index (PLI) developed by Thomilson *et al.* (1980), as follows:

$PLI = (Cf_1 \times Cf_2 \times Cf_3 \times Cf_4 \ldots Cf_n)^{1/n}$ (3)

Where n is the number of metals studied and *Cf* is the contamination factor calculated as described in Equation 1. The PLI provides simple but comparative means for assessing a site quality. The rank of values of PLI and its implication is shown in table 1 (Thomilson *et al.*, 1980).

Geoaccumulation index (I geo)

Geoaccumulation index (I geo) defined as enrichment of metal concentration above baseline concentrations was calculated using the method proposed by Muller (1969). This method assesses the metal pollution in terms of seven (0 to 6) enrichment classes ranging from background concentration to very heavily polluted, as follows:

$I\ geo = Log_2\ [\ Cs/(1.5 \times Cb)]$ (4)

The factor, 1.5 introduced in this equation was to minimise the effect of possible variations in the background values, Cb, which may be attributed to lithogenic variations in soils. The seven proposed descriptive classes for I geo values are given in Table 1 (Muller, 1969).

2.5 Statistical analysis

Analysis of variance (one way ANOVA) was used to compare the mean metal concentrations among the sites. Further evaluation was done via Duncan’s multiple range tests. Pearson correlation was used to evaluate association between metals and traffic volume. Dendogram was generated to show cluster relationship among the studied sites. Statistical significance was described at 0.05 and 0.01 probability. The statistical analysis was performed using SPSS software, version 15.

3. Results

The means value obtained for the metals at different site are as shown in figure 1. All metals evaluated were detected in the three sites except Cd in Odo Oba and LC. Highest value of Pb was observed in Sabo which was significantly different from that of General. Both values were significantly different from the values from Odo Oba and LC. The mean values in other metals were highest in General and were significantly different from the values obtained in Sabo except in Mn and Cu. The trend of metal occurrence showed that LC<Odo Oba< Sabo< General except for Fe, Mn and Cr. Similar trend was observed in ATVof the studied sites. The ATV values were 603.5 (±5.68), 1715.17 (±10.6), 1830.50 (±14.83) and 38.67 (±2.58) per hour for Odo Oba, Sabo, General and LC, respectively.

The values obtained for contamination factor (*Cf*) for each of the metal in their specific location is as shown in figure 2. Zn for Sabo and General reflected low contamination ($Cf<1$) while moderate Zn contamination was observed in Odo Oba. The values obtained for Fe in the three locations were low. All metals, except Fe and Zn in Odo Oba, showed moderate contamination. Sabo and General have similar pattern of low Fe and Zn contamination; Mn, Cu and Ni were ranked as moderate while Pb and Cr showed considerable level of contamination ($3<Cf<6$). However highest value of Pb was observed in Sabo while highest level of Cr was in General area.

The degrees of contamination by heavy metals in the sites were 9.1, 15.5 and 16.6 for Odo Oba, Sabo and General, respectively (Figure 3). These results showed that road side soils along the major road in Ogbomoso have moderate contamination ($5 <Cd< 10$) for Odo Oba while the degree of contamination was considerable ($10 <Cd< 20$) for Sabo and General Areas.

Further more, the values obtained for Pollution Level Index (PLI>1, Figure 4) from the sites relative to LC showed that the sites had deteriorated in their quality in the order of: Odo Oba < Sabo< General. Values obtained from I geo (Figure 5) revealed that all evaluated metals in Odo Oba were at low level of contamination. The levels of Mn, Cu and Ni in both Sabo and General areas soil samples indicates uncontaminated to moderate (I geo class 1) while Pb and Cr indicates moderate contamination (I geo class 2).

Association between average traffic volume and values of heavy metals were evaluated using Pearson correlation. Positive correlation was observed between ATV and the heavy metals except for Zn and Fe where negative correlation values were obtained (Table 2). However significant difference was observed only with Pb, Cr and Ni. Positive correlation was also observed between Pb and Cr, Cd and Ni, Cr and Ni, Cu and Ni while negative correlation was observed between Zn and Mn. The levels of cluster relationship between sites were evaluated using dendogram. Odo Oba and LAUTECH were closely associated while Sabo and General also showed cluster association (Figure 6).

4. Discussion

The result of the heavy metals as observed in Sabo and General area were higher compared to LAUTECH(control). This high mean concentrations of metals compared to control may be due to high traffic volume which attested to the overall high level of contaminations of this metal in the roadside environments. Lagerwerff & Specht (1970), Abechi *et al*. (2010) and Moore & Moore (1976) had similarly reported that motor vehicles introduce a number of toxic metals into the atmosphere adjacent to roadways, which eventually contaminate road side soil.

Lead values observed in this study (5-10mg/kg) excluding control were lower compared to average Pb level of 63.69±27.31 mg/kg reported for Osogbo at equivalent of 5m from road side (Fakayode & Olu-Owolabi, 2003), 81±140 mg/kg in Ibadan (Onianwa, 2001), 15.28–76.92µg/g for Kaduna (Okunola *et al*., 2007) in Nigeria and other place outside the country like 167±330 mg/kg in Tyne-side, UK (Mellor & Bevan 1999), 38.6–187.7 mg/kg in Egypt (Nasralla & Ali, 1985), 90±53 mg/kg in Hong Kong (Chen *et al*., 1997). The value obtained for Pb in this study was in the range (1.59 - 12.10 µg/g) reported for major streets in Jos (Abechi *et al* 2010), 0.25-4.24 µg/g for Lagos – Badgry express way (Adeleke *et al*., 2010) while it was higher than 0.02–0.23 for Lagos (Awofolu, 2005) and 0.04 - 0.21 µg/g for Bostwana (Mmolawa *et al.*, 2011).

The Cd was observed only in Sabo and general areas and the values obtained could not be compared to control site thus excluded from the analysis of contamination indices. However, Cd values were higher compared with 0.45±0.12 mg/kg reported for soil samples from high traffic area, 10m from road side in Osogbo (Fakayode & Olu-Owolabi, 2003) and 0.24-0.35 mg/kg reported for roadside topsoil in Arctic catchments, Northern Europe (Reimann *et al.*, 1997).

High correlation was observed between traffic volume and Cr in this study. The range obtained 2.0 -5.0mg/kg for sample points along the road which was higher than that of control. This may serve as indication of pollution due to traffic density. Zinc and Iron have negative correlation with ATV which indicates that their source of contamination might not be majorly from volume of vehicle plying the road. High occurrence of Fe from the control site showed that it might be from lithogenic sources. Similar observation has been reported in previous studies (Al-Momani, 2009; Mmolawa *et al*., 2011).

The value of Zn obtained was lower than 25.68±4.67 mg/kg reported for 10m from roadside soil in Osogbo (Fakayode & Olu-Owolabi, 2003) while Fe value was lower compared with 141.80 - 159.00 µg/g reported for Jos, Nigeria (Abechi *et al*., 2010).

Manganese and copper were not significantly correlated with traffic volume while Ni and Pb showed significant correlation. Positive and negative correlations were also observed between metals. ATV showed negative correlation with Zn and Fe which indicates that other sources other than automobile emission could contribute to concentration of these metals in the soils. Significant positive correlations between ATV and Pb, Ni, and Cr indicate possible contamination of the soils by automobile emissions. As observed in this study, previous studies have also attributed contamination of soil by Pb, Ni and Cr as well as other metals to automobile emissions (Abechi *et al*., 2010; Mmolawa *et al*., 2011). Although the value obtained for metal were lower compared with heavily polluted areas in the world, heavy metals values obtained from sites along the major road relative to control site showed that Sabo and General areas were more pollution impacted compared with Odo Oba as revealed by the contamination assessment models; *Cf*, *Cd*, and I geo. However, PLI revealed that the three sites tested have been deteriorated by the heavy metals.

The assessed soils were collected on bared soil 5-10m from the road. Since there is linear settlement along this road, the increase of metals in soil due to automobile emission could add to body burden of residents in this zone.Corroborating this is the report that residents along roads with heavy traffic loads are subjected to increasing levels of contamination with heavy metals (Ghrefat & Yusuf, 2006). This may result from inhalation of dust particles along side with metals, accumulation of which might have serious effects on the health of inhabitants.

5. Conclusion

Assessment of soils metals (Pb, Cd, Cr, Zn, Mu, Cu, Fe, and Ni) from selected sites along a major road in Ogbomoso was made in comparison with control site based on contamination indices revealed that Sabo and General Areas were considerably polluted while Odo Oba is moderately polluted. The PLI values for the three sites were >1 which indicates deterioration of site quality. Significant correlation between some of the heavy metals (Pb, Cr, and Ni) studied with ATV showed that the contamination could be from automobile emissions. The accumulation of these metals in soil in the residential areas may add to the body burden of the residents. Therefore, further investigation is highly necessary to study the concentrations and health implications of these heavy metals in residents of linear settlements along this major road in Ogbomoso.

Acknowledgement: Authors appreciate the suggestion of Dr M. A. Azeez, Department of Pure and Applied Biology, LAUTECH, on the statistical analysis of the data.

References

Abechi, E.S., Okunola, O.J., Zubairu, S.M.J., Usman, A.A. & Apene, E. (2010) Evaluation of heavy metals in roadside soils of major streets in Jos metropolis, Nigeria.*Journal of Environmental Chemistry and Ecotoxicology*.**2**(6): 98-102.

Adefolalu, A.A. (1980). ‘Transport and rural integrated development in: proceedings of the National conference on: Integrated Rural Dev. Women Dev., 1: 294-299.

Adeniyi, A.A. & Owoade, O.J. (2010). Total petroleum hydrocarbons and trace heavy metals in roadside soils along the Lagos–Badagry expressway, Nigeria *Environ Monit Assess***167**: 625-630.

Akoto, O., Ephraim, J.H. & Darko, G. (2008).Heavy metal pollution in surface soils in the vicinity of abundant raiway servicing workshop in Kumasi, Ghana.*Int. J. Environ. Res.***2**(4): 359–364.

Alloway, J.B. (1995). Soil pollution and land contamination. In: Harrison RM (Ed). Pollution: Causes, effects and control. The Royal Society of Chemistry, Cambridge.

Al-Momani, I.F. (2009). Assessment of trace metal distribution and contamination in surface soils of Amman, Jordan.*Jordan J. Chem.*, **4**(1); 77–87.

Atayese, M.O.; Eigbadon, A.I.; Oluwa, K.A. & Adesodun, J.K. (2009).Heavy metal contamination of amaranthus grown along major highways in Lagos..*Afr. Crop. Sci. J.***16**:225-235

Awofolu, O.R. (2005). A survey of trace metals in vegetation, soil and lower animal along some selected major roads in metropolitan Lagos. *Environmental Monitoring and Assessment*, **105,** 431–447.

Bai, J., Cui, B., Wang, Q., Gao, H. & Ding, Q. (2009). ‘Assessment of heavy metal contamination of roadside soils in Southwest China’.*Stoch. Environ. Res. Risk Ass.***23** (3): 341-347.

Chen, T.B., Wong, J.W.C., Zhou, H.Y., Wong, M.H.(1997) Assessment of trace metal distribution and contamination in surface soils of Hong Kong. *Environ Pollut,***96**(1):61–68

De kimple, C.R. & Morel, J.F. (2000). Urban soil Management: a growing Concern. *Soil Sci.*, **165**: 31-40.

Edelman, T. & de Bruin, M.D. (1986): *Background values of 32 elements in Dutch topsoils, determine with non-destructive neutron activation analysis*. P. 89-99. In: J.W. Assink (ed). Contaminated soil. Martinus Nijhoff Publ. Dardrecht, the Netherlands.

Fakayode, S.O. & Olu-Owolabi, B.I. (2003) Heavy metal contamination of roadside topsoil in Osogbo, Nigeria: its relationship to traffic density and proximity to highways. *Environmental Geology*.**44**:150–157.

Ghrefat, H. & Yusuf, N. (2006).Assessing Mn, Fe, Cu, Zn and Cd pollution in bottom sediments of Wadi Al-Arab Dam, Jordan.*Chemosphere***65**: 2114–2121.

Gray, C.W., Mclaren, R.G. & Roberts, A.H.C. (2003). 'Atmospheric accessions of heavy metals to some New Zealand pastoral soils'. *Sci. Total Environ.*, **305**: 105-115.

Hakanson, L. (1980). Ecological risk index for aquatic pollution control, a sedimentological approach. *Water Res.* 14: 975–1001.

Ho, Y.B. & Tai, K.M. (1988). 'Elevated levels of lead and other metals in roadside soils and grass and their use to monitor aerial metal depositions in Hong Kong'.*Environ. Pollut. J.*, **49**: 37-51.

Ihenyen, A,E.(1988a) Assessment of heavy metal pollution in roadside sediments in Benin City, Nigeria.*Geologia*. **3**:187-197

Ihenyen, A.E. (1998b): Heavy metal pollution studies on roadside sediments in Metropolitan Lagos, Nigeria. *Environmental Science*, **6**; 1-6.

Khairy, M.A., Barakat, A.O., Mostafa, A.R. & Wade, T.L. (2011). Multielement determination by flame atomic absorption of road dust samples in Delta Region, Egypt. *Microch. J.*,**97:** 234–242.

Kuhad, M.S., Malik, R.S. & Singh, A. (1989): Background levels of heavy metals in agricultural soils of Indo-Gangetic Plains of Haryana. *J. Indian Soc.Soil Sc.***37:** 700 – 705.

Lagerwerff, J.V.& Specht, A.W. (1970). 'Contamination of roadside soil and vegetation with Cadmium, Nickel, Lead and Zinc'. *Environ. Sci. Technol.*,**4:** 583-586.

Li, X.D., Poon, C.S. & Pui, S.L. (2001). Heavy metal contamination of urban soils sndstreer dusts in Hong Kong. *App. Geochem.*,**16:** 1361-1368.

Mabogunje, A.L. (1980). 'Development process a spatial perspective' Hutchinson and Co publishers Ltd. pp. 234-244

Manta, D.S., Angelone, M., Bellanca, A., Neri, R. & Sprovieri, M. (2002). Heavy metal in urban soils: A case study from the city of Palermo (Sicily), Italy. *Sci. Total Environ.*, **300**: 229-243.

Mellor, A. & Bevan, J.R. (1999). Lead in the soils and stream sediments of an urban catchment in Tyneside, UK. *Water Air Soil Pollut*.**112** (3/4):327–348

Mmolawa, K.B., Likuku, A.S. & Gaboutloeloe, G.K. (2011) Assessment of heavy metal pollution in soils along major roadside areas in Botswana.*African Journal of Environmental Science and Technology*, **5**(3):186-196.

Moore, J.W. & Moore, E.A. (1976).*Environ Chemistry*. Academic Press. New York. 556pp

Muller, G. (1969). Index of geoaccumulation in sediments of the Rhine river. *Geol. J.* **2**(3): 108–118.

Nasralla, M.M. & Ali, E.A. (1985). Lead accumulation in edible portionsof crops grown near Egyptian traffic roads. *Agric Ecosyst Environ.*, **13**:73–82

Okunola, O.J., Uzairu, A. & Ndukwe, G. (2007).Levels of trace metals in soil and vegetation along major and minor roads in metropolitan city of Kaduna.*Nigeria*, 6, 1703–1709.

Onianwa, P.C. (2001) Roadside topsoil concentrations of lead and other heavy metals in Ibadan, Nigeria. *Soil Sediment Contam* **10**(6): 577–591

Poszyler-Adamska, A. & Czemiak, A. (2007). Biological and chemical indication of roadside ecotonic zones.*L. Environ. Engg. Landscape Management,***15**(2): 113a-118a

Reimann, C., Boyd, R., de Caritat, P., Halleraker, J.H., Kashulina, G., Niskavaara, H., Bogatyrev, I. (1997) Topsoil (0–5 cm) composition in eight Arctic catchments in northern Europe (Finland, Norway and Russia).*Environ Pollut* **95**(1):45–56

Suzuki, K., Yabuki, T. & Ono, Y. (2008). Roadside Rhododendron pulchrum leaves as bioindicators of heavy metal pollution in traffic areas of Okayama. Japan. *Environ. Monit. Asses.* **149**:133-141

Thomilson, D.C., Wilson, D.J., Harris, C.R. & Jeffrey, D.W. (1980). Problem in heavy metals in estuaries and the formation of pollution index. *Helgol. Wiss. Meeresunlter.* **33**(1–4): 566–575.

Thornton, I. (1982). *Implications of Geochemical background data in relation to hazardous wastes managements* p.57–67. In: DD. Hemphill (ed). Trace substances in environmental Health, 16 Univ. of Missouri, Columbia.

Table (1): Different types of model and the categories for the description of soil contamination

Model		Class	Description	Sources
Contamination Factor				Håkanson (1980)
		Cf<1	Low	
		1< Cf <3	Moderate	
		3 < Cf < 6	Considerable	
		6 < Cf	Very high	
Degree of Contamination				Håkanson (1980)
		Cd<5	Low	
		5 < cd < 10	Moderate	
		10 < Cd < 20	Considerable	
		20 < Cd	Very high	
Pollution level Index				Thomilson *et al.* (1980).
		PLI < 1	Perfection	
		PLI = 1	Base line level of pollution	
		PLI > 1	Deterioration of site quality	
Geometrical index				Muller (1969),
	I geo Value	I geo Class	Designation of soil class	
	>5	6	Extremely contaminated	
	4-5	5	Strongly to extremely contaminated	
	3-4	4	Strongly contaminated	
	2-3	3	Moderately to strongly contaminated	
	1-2	2	Moderately contaminated	
	0-1	1	Uncontaminated to moderately contaminated	
	0	0	uncontaminated	

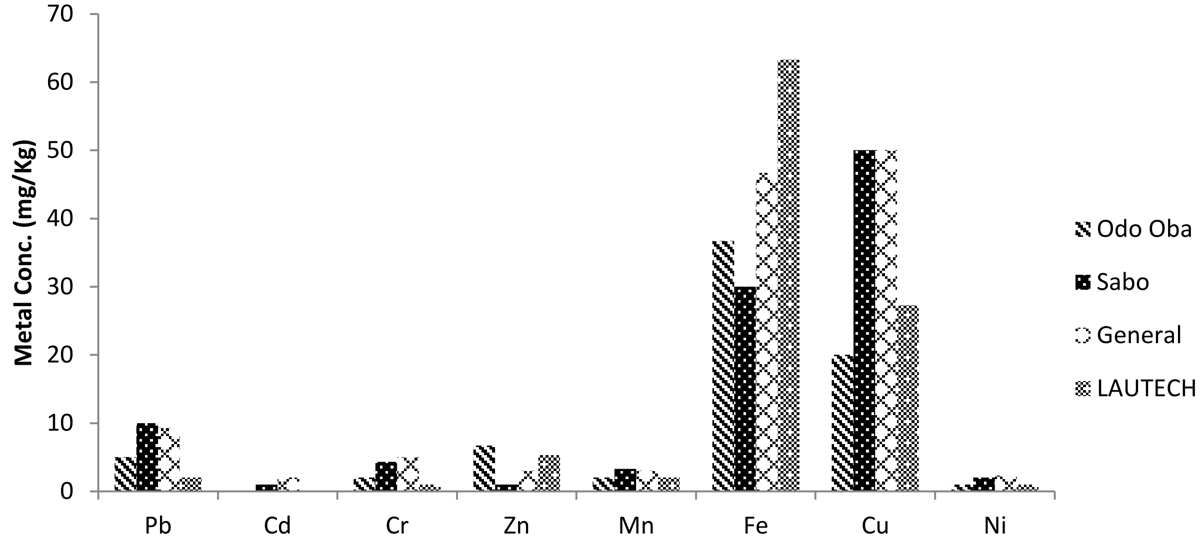

Figure 1: Heavy metal concentrations in road soil along a major road in Ogbomoso

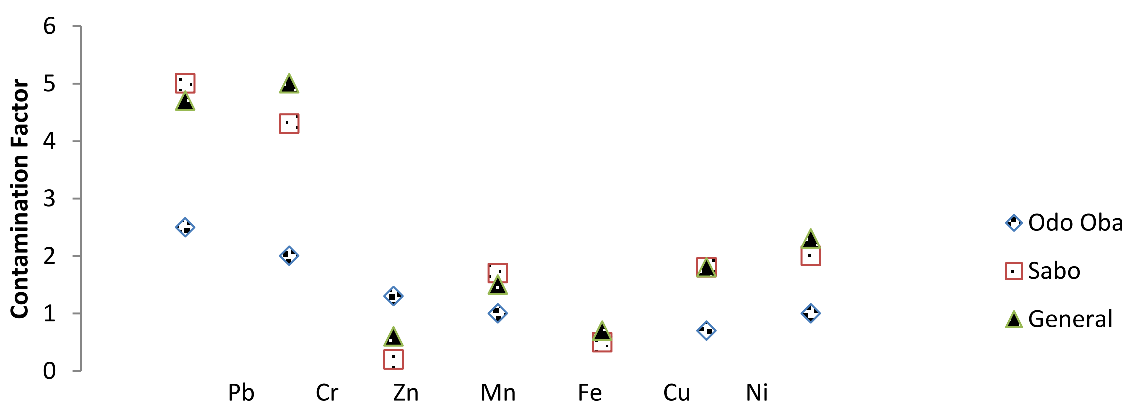

Figure 2 Contamination factors for heavy metals along roadside soils for each sampled zone.

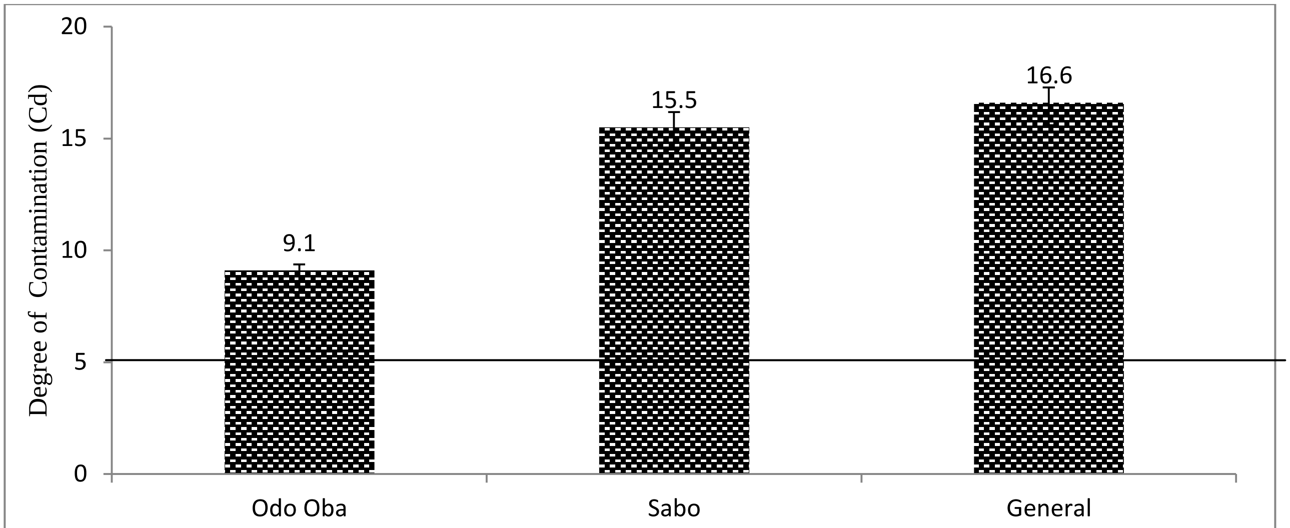

Figure 3: Degree of contamination of the selected sites for heavy metal evaluation from road side soil

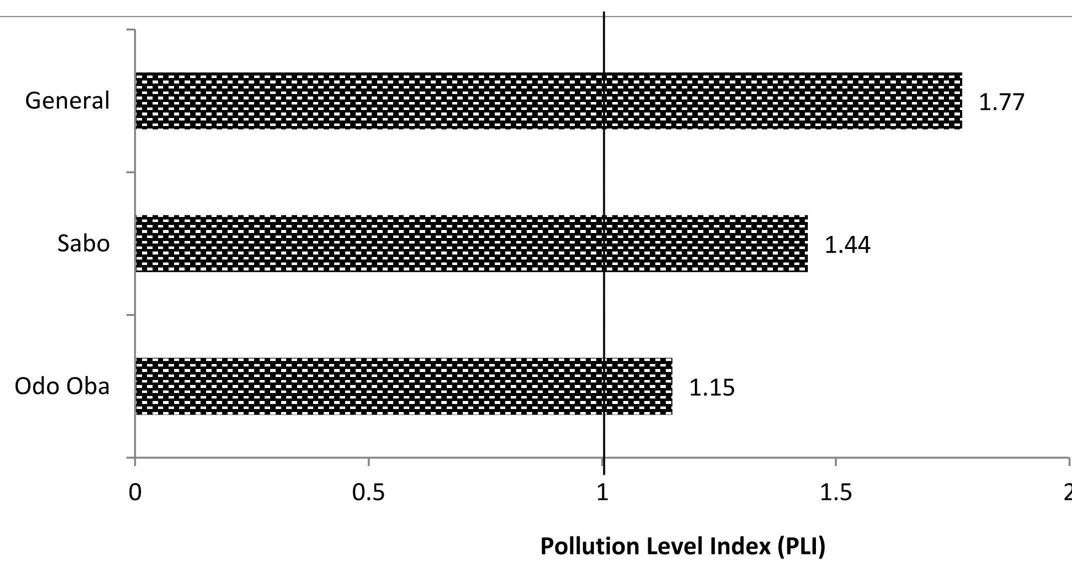

Figure 4: Pollution Level Index from the selected sites along major road in Ogbomoso

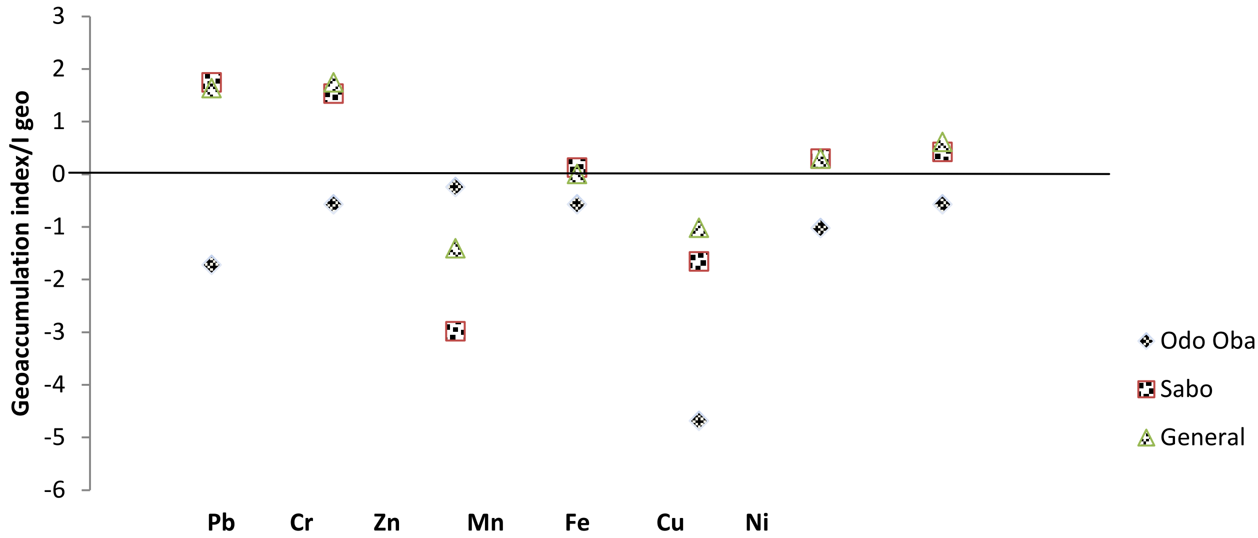

Figure 5: Geoaccumulation indices of heavy metals from road side soils along a major road

Table 2: Correlation between average traffic volume and the heavy metals evaluated along a major road in Ogbomoso

	ATV	Pb	Cd	Cr	Zn	Mn	Fe	Cu	Ni
ATV	1.000								
Pb	0.990*	1.000							
Cd	0.894	0.820	1.000						
Cr	0.994**	0.968*	0.937	1.000					
Zn	- 0.806	-0.816	-0.692	-0.787	1.000				
Mn	0.937	0.941	0.812	0.921	-0.962*	1.000			
Fe	-0.620	-0.717	-0.219	-0.539	0.409	-0.542	1.000		
Cu	0.894	0.863	0.888	0.905	-0.945	0.965*	-0.312	1.000	
Ni	0.957*	0.913	0.967*	0.976*	-0.844	0.934	-0.317	0.965*	1.000

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
ATV : average traffic volume

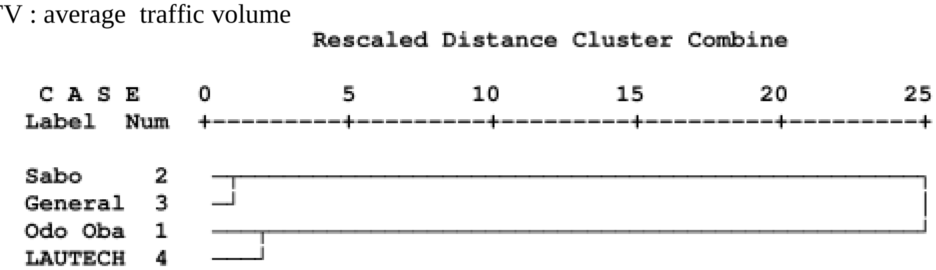

Figure 6: Cluster association of site based on level of heavy metal occurrence