Journal of Science Research

Contamination and Ecological Risk Assessment of Lead in Roadside Soil and Dust in Ibadan Metropolis, Nigeria

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Abstract

Vehicular emissions are common sources of lead contamination of roadside soils and dust especially in urban cities. This study investigates current metal levels in roadside soils and dust in Ibadan metropolis and the associated ecological risk assessment. Concentrations of Pb, Zn, Mn and Ni were determined from 234 each of soil and dust samples collected from high, medium and low traffic density locations. The result indicated metals to be in the following decreasing order Pb>Zn>Mn>Ni with lead levels more significant in soils compared to dust particularly along high traffic density locations. Comparatively, current metal levels in soils were higher than values reported for 19 years apart, an indication of extensive urbanization of the city over the years. Principal Component Analysis (PCA) coupled with Cluster Analysis (CA) revealed metal contamination of soils and dust was related to traffic density. Pearson's correlation analysis showed a strong positive correlation between metals in soils and dust further confirming the source. Among the metals, lead showed a higher potential ecological risk than other metals in soils particularly along high traffic density locations. The current levels of lead in soils and dust call for concerted effort to avoid particulate lead exposure to residents and road users.

Keywords: Lead; Ecological Risk Assessment; Roadside Soils; Dust; Principal Component Analysis.

Introduction

Urban soil contamination has been generating significant environmental concerns in recent years, due to rapid urbanization and industrialization, especially contamination due to heavy metals [1,2,3,4] Although heavy metals are naturally found in soils at background concentrations [5], significant levels may come from many different sources like industrial waste disposal, vehicular emissions and other activities [6]. Urban traffic has been identified as major sources of metal contamination of urban soil from deposition by sedimentation, impaction and interception [7]. Roadside soils and dust in urban areas are reservoirs and indicators of heavy metal contamination from vehicular sources [8,9,10]. Particularly, it has been observed that roadside soils and dust near high traffic are often polluted with lead and other metals [11]. Contaminated roadside soils and dust could contribute particulate matter and pollutants to the hydrosphere and the atmosphere during surface runoffs, leaching, weathering and re-suspension [1]. Consequently, pedestrians and residents living in close proximity to roads stands at greater risk of health related issues. Heavy metals in roadside soils and dust have direct influence on public health [8] as they can easily enter the human bodies by dermal contact, dust ingestion or breathing [12]. Studies have shown that human exposure to metals such as Pb, Cd and As results in the accumulation of fatty tissues in the body, this affects the central nervous system and in most cases result in death [13,14,15].

Several studies have focused on the concentration, distribution and source identification of heavy metals in roadside soils and dust [1,7,16,17,18,19,20]. Most results reported showed that the average concentrations of heavy metals are generally higher than regional elemental background values [21,22,23]. Also, total trace metal concentrations in roadside soils were found to decrease exponentially with increasing distances from roadsides [23,24,25,26]. Other factors that influence heavy metal concentrations in roadside soils and dust were meteorological conditions [27], traffic emissions [26,28], transportation period [21] and vehicular type [26].

Over the last few years, Ibadan city, the second largest in Nigeria have consistently witness rapid rural-urban migration. The rapid urbanization of the city has exerted much pressure on its environment particularly in terms of settlement and road expansion, waste disposal and high traffic volume. Road networks are often congested with traffic coupled with increasing numbers of vehicles mostly operated on leaded fuel, there's potential susceptibility to metal contamination of roadside soils and dust. Close proximity of residential houses and market spaces to major road networks could pose serious health risk due to emissions, leaching and over flow of contaminated storm water runoffs. Several studies have been carried out on heavy metal contamination of roadside soils and dust in developed countries, but little information is available for developing countries experiencing rapid urban growth in most of its cities. Since there is no legislation regarding metal concentrations in roadside soil and dust in Nigeria, studies of this kind are rare. In Ibadan city, the most recent study conducted was in June to July of 1998 by Onianwa[29]. The study determined roadside topsoil concentrations and speciation of lead and other heavy metals (zinc, cadmium, chromium, copper, cobalt and nickel), in Ibadan, and the extent to which vehicular traffic density contributes to the level of contamination. Arising from these stand points, the main objectives of this study are: to determine the concentration and ecological risk of lead and other metals (Zn, Mn and Ni) in roadside soil and road dust in Ibadan metropolis in relation to traffic density, ascertain the magnitude of contamination over the years comparable to previous study and to identify their sources and spatial distribution in soils and dust using multivariate statistical analysis.

Materials and Method

Study Area

Ibadan metropolis situates in the southwestern part of Nigeria, the capital city of Oyo State, and consists of five local government areas (Figure 1). Since the late 1990's rapid urbanization has given way to urban construction of new settlements and towns, expanded road networks and high traffic volume. With an aerial extend of about 5350 km^2 the city lies between 70 28′N and 30 48′E, with an estimated population of over 3,738,659 [30] and counting. The city metropolis is a mix of residential, commercial, industrial and agricultural areas. Road networks within the city are classified into express/dual carriage ways, major and secondary roads. The city has a tropical humid climate characterized by two major seasonal trends, dry season (November to March) and wet seasons (April to October), with average annual rainfall of 120 to 250 mm and temperature of 22.5 to 32.6^{o}C. The area is underlined by both igneous and metamorphic rocks of the Precambrian basement complex [31].

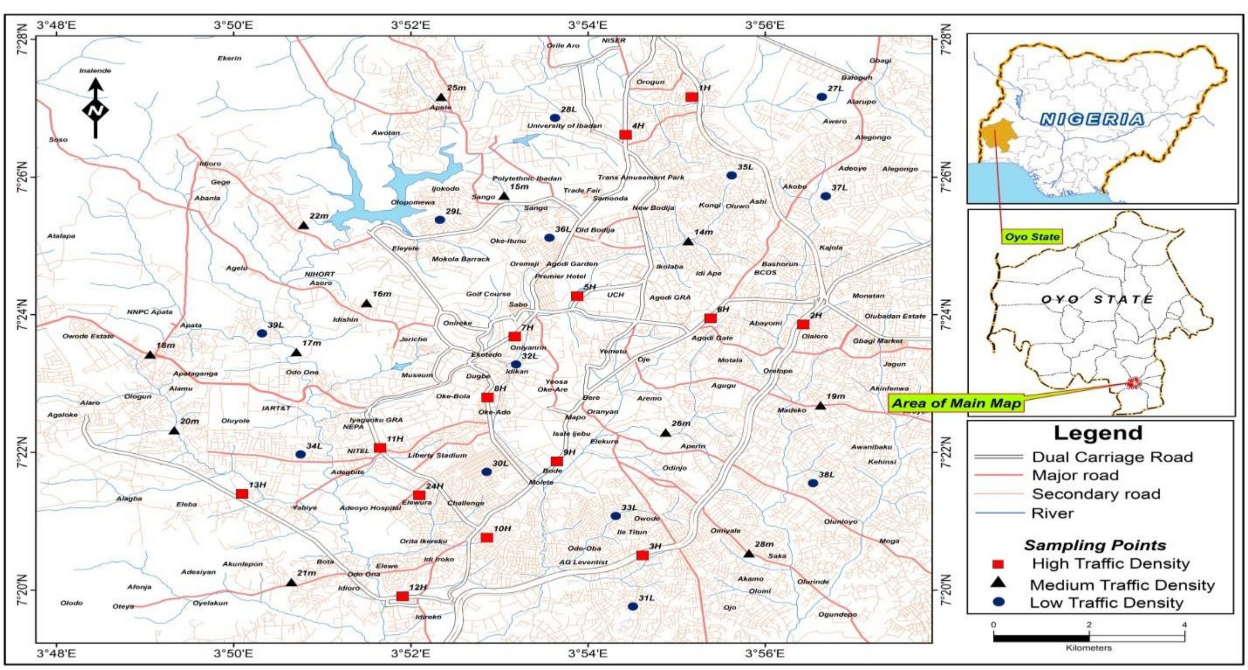

Figure 1. Map of sample locations

Sample Collection

A total of thirty nine (39) sampling locations were identified within Ibadan metropolis for roadside soil and road dust sample collection (Figure 1). Sampling locations were classified according to estimated traffic density per hour. Thirteen (13) sample locations where chosen for high traffic (>2000 vehicles per hour), medium traffic (500 to 2000 vehicles per hour) and low traffic (<500 vehicles per hour) densities. High traffic locations were majorly express/dual carriage ways, major roads for medium traffic and secondary roads for low traffic locations. Samples were collected monthly between January to June 2017: dry season (January to March) and wet season (April to June). Soil and dust samples were each collected at a given location making a total of 234 soil and 234 dust samples collected during the study period. Control soil samples (six) were obtained from location remote from traffic. Similarly, six control dust samples were collected from remote road surfaces far from the city with less than 10 vehicles per hour. Soil (0-10cm) samples were collected from the edge of the roads with stainless steel spatula while dust samples were simultaneously collected on road surface with a small brush and a clean polymethyl methacrylate shovels. All collected samples were kept in sealed polyethylene bags to avoid cross contamination during transportation to the laboratory.

Sample Preparation and Analysis

All the soil and dust samples were air dried at room temperature in the laboratory. The soils were ground and sieved to 2 mm particle size. A known amount, 2.0 grams of each sample was weighed into a glass beaker and digested with 50 mL portion of concentrated aqua regia mixture on a hot plate for 3 hour[32].The concentration of Pb, Zn Mn and Ni were subsequently determined in all extracts using Buck Scientific model 200A Flame Atomic Absorption Spectrophotometer. Commercial BDH standard stock solutions were used for instrument calibration. Blanks were incorporated into every monthly analysis of soil and dust samples. All analysis was performed in duplicates. Recovery study was carried out to validate the extraction procedure. This was done by spiking portions of five previously analyzed soil samples with standards of Pb, Zn Mn and Ni. These were dried, homogenized and subjected to extraction and analytical procedures. The mean percentage recoveries were: 98.6 ± 2.74 for Pb, 96.0 ± 2.95 for Zn, 98.5 ± 3.47 for Mn and 98.4 ± 3.85 for Ni respectively.

Ecological Risk Assessment

The method developed by Hakanson, [33] was adopted to assess the ecological risk due to metal pollution of roadside soils of Ibadan metropolis. This method has been successfully used by many authors [2,4,34] on ecological risk assessment. The potential ecological risk factor of a given contaminant E(i) is defined as:

$$E(i) = Ti \times [Ci/Co] \quad (1)$$

Where Ti is the toxic response factor for a given metal [Pb=Ni=5, Zn=1] developed by Hakanson, [33]. Ci is the concentration of the metal in soil and Co is the background value of the metal. The sum of the individual potential risk factors E(i) gives the potential ecological risk index (RI) and is expressed as:

$$RI = \sum_{i=1}^{n} E(i) \quad (2)$$

The ecological risk factor E(i) and indices RI values derived were classified according to Yuan [4] risk factor standards.

E(i)<40; RI<50 =Low potential ecological risk

40≤E(i)<80; 150≤RI<300=Moderate potential ecological risk

80≤E(i)<160;300≤RI<600 = Considerable potential ecological risk

Statistical Analysis

Descriptive statistics was performed using Excel 2010 (Microsoft Inc., Redmond, USA). Principal component analysis (PCA), cluster analysis (CA) and correlation analysis were used to identify sources and distribution of metals within roadside soil and road dust samples. The analyses were performed using Paleontological Statistical software package (PAST, version 1.38).Analysis of variance tests the significance of metal distribution across the sample locations.

Results and Discussions

Heavy Metal Concentration in Soil and Dust

Average metal concentration in roadside soils and dust are given in Table 1. Compared with road dust metal levels, the average metal content of roadside soils are much higher, suggesting soils as direct natural sink for metals. Based on total accumulated concentration from all sample locations, the metal components in soil and dust were in the following decreasing order; Pb>Zn>Mn>Ni. The lead content of soil and dust ranged from 20.9-423 µg/g and 24.5-137 µg/g respectively, with 43.6% of soil and 12.8% of dust sample locations having lead levels exceeding 100 µg/g. A test of variance among the metals, using a single factor analysis of variance at *p=0.05* indicates significant difference in Pb, Zn, Mn and Ni concentrations across the various sample locations both for soil and dust. These variances among metals in soil and dust suggest possible anthropogenic influence which could majorly be from automobile exhaust emissions. The metal concentrations across the different traffic density locations are summarized in Table 2. High concentrations of all the metals were recorded along high traffic density locations, hence significantly higher than the corresponding control metal levels in soil and dust. Concentrations of these metals decreased exponentially through to the low traffic density locations. This spatial variation in metal levels across the traffic locations is a direct influence of traffic density resulting in varying pollutant emission intensities. The high traffic location records over 2000 against the less than 500 vehicles per hour for low traffic locations. Several studies have also observed that roadside soils near heavy traffic locations are more polluted by Pb and other metals [7,11,29,35]. Concentrations of Pb, Zn, Mn and Ni around low traffic density locations were lower and about same levels with control both for soil and dust. Generally, average concentration of metals (all locations) shows Pb to be of environmental concern with levels as high has 114±77µg/g in soil and 55.5±39.3 in dust within Ibadan metropolis (Table 2).Compared with the previous study, the concentrations of Pb, Zn and Ni levels in roadside soils are slightly higher than levels of 81±140µg/g for Pb, 48±37µg/g for Zn and 10.5±9.7µg/g for Ni respectively reported 19 years ago[29].

Table 1. Average metal concentrations (µg/g) in roadside soil and dust

Location Code	Roadside Topsoil				Road Dust			
	Pb	Zn	Mn	Ni	Pb	Zn	Mn	Ni
1H*	423±377	135±124	109±74.7	65.8±72.7	125±85	66.1±33.3	11.6±9.62	6.47±6.33
2H	366±334	114±86	65.2±29.3	24.5±11.7	112±83	40.0±21.0	12.2±12.7	6.27±6.27
3H	289±174	124±102	96.0±66.0	66.9±71.8	115±62	38.0±30.0	10.4±10.1	8.29±5.99
4H	212±158	107±47	82.0±101	21.3±11.1	46.6±7.46	41.1±39.6	9.78±10.7	4.86±4.76
5H	219±141	88.7±49.2	55.0±20.0	21.1±10.5	94.6±70.1	19.0±15.0	10.2±9.07	4.9±4.3
6H	185±109	93.8±60.1	56.1±18.9	46.9±38.3	83.5±82.9	15.1±10.1	13.0±7.0	5.09±6.33
7H	163±82	101±60	51.1±25.3	24.8±19.8	49.0±14.0	17.7±9.22	10.9±8.76	3.07±5.58
8H	135±134	111±50	54.1±19.6	37.6±23.6	70.6±54.6	13.4±10.1	10.0±13.0	8.91±8.83
9H	145±44	82.2±52.1	37.9±26.7	20.9±7.70	74.7±64.5	12.4±10.3	11.4±8.22	4.03±3.63
10H	125±68	74.9±55.6	58.7±67.0	50.7±34.8	120±137	11.7±8.35	12.7±16.9	2.19±1.70
11H	152±120	65.1±31.9	63.3±36.5	28.9±13.7	86.6±93.4	64.5±46.7	8.46±6.18	2.65±3.62
12H	121±89	99.1±42.3	77.5±26.9	21.6±12.9	85.5±96.6	22.6±7.41	7.76±4.98	2.57±2.68
13H	333±174	138±86	97.2±56.5	56.7±36.2	137±115	48.0±26.0	5.98±5.41	9.27±5.65
14M**	92.4±88.0	51.1±20.3	53.9±34.5	17.0±9.0	25.8±19.4	39.5±17.3	6.28±6.64	1.74±2.92
15M	127±72	48.1±26.0	42.8±27.8	27.2±15.5	40.4±17.9	14.5±5.24	7.38±8.52	3.19±2.48
16M	105±49	47.2±27.5	34.2±25.1	21.7±15.1	26.2±9.47	14.3±4.79	10.6±10.4	1.48±1.47
17M	66.4±41.9	57.6±46.1	35.4±24.3	21.9±21.5	78.8±27.7	17.3±17.9	11.9±12.1	1.81±2.19
18M	93.3±52.2	56.6±37.4	32.5±21.0	29.5±20.5	47.1±34.5	10.9±4.14	10.8±9.09	3.48±3.70
19M	116±85	43.1±15.5	37.0±23.0	16.3±7.20	57.7±27.9	13.9±5.45	8.16±8.71	8.84±10.3
20M	122±84	50.3±16.4	36.4±25.5	13.9±5.53	35.9±23.7	9.85±5.63	3.36±4.79	2.35±2.94
21M	76.7±29.4	43.2±10.1	33.7±17.3	27.6±16.8	65.0±62.0	14.4±12.5	7.03±13.3	16.6±10.5
22M	75.1±41.9	83.1±58.0	36.5±15.8	23.5±18.8	33.6±15.9	17.3±6.5	3.69±4.48	16.0±12.0
23M	70.3±57.9	51.0±19.0	43.2±42.4	36.1±30.0	48.0±29.0	11.6±4.3	5.15±8.4	3.20±3.77
24M	59.6±39.6	61.5±37.5	43.2±37.7	32.8±20.6	35.1±14.5	14.6±4.75	4.83±8.99	2.16±3.29
25M	95.3±58.0	93.8±35.3	36.5±25.9	27.0±20.0	45.1±22.7	50.4±31.7	2.76±4.08	0.89±1.20
26M	50.6±31.7	70.0±23.0	35.0±21.0	25.2±17.9	34.7±28.4	15.3±2.7	1.89±3.02	3.68±4.02
27L***	47.1±14.8	25.8±5.20	32±17.0	23.6±13.1	32.0±19.0	27.7±13.2	3.21±4.61	8.65±9.91
28L	20.9±10.1	33.9±12.5	36.0±20.0	12.2±5.08	26.3±15.2	18.7±12.1	2.96±4.48	0.90±1.01
29L	35.0±21.7	33.0±8.0	34.6±8.36	14.9±12.7	36.2±12.2	10.9±4.98	4.13±7.24	1.34±1.56
30L	38.7±27.7	37.7±12.9	29.8±9.17	21.4±11.3	32.0±23.0	14.3±5.74	3.28±4.96	0.53±1.30
31L	28.2±23.2	30.7±9.86	15.0±7.41	23.8±20.9	27.6±15.3	4.98±6.63	4.33±4.85	0.91±1.15
32L	45.1±29.1	33.7±14.7	20.0±15.0	15.6±10.1	24.5±14.5	12.7±9.29	10.0±15.0	0.54±0.85
33L	23.0±8.52	35.1±24.4	19.5±14.2	17.1±12.8	30.2±15.6	13.1±9.84	4.94±7.45	0.28±0.57
34L	35.5±24.0	31.5±4.65	16.9±10.6	21.3±17.8	32.6±14.7	9.35±7.59	3.0±3.0	0
35L	34.0±32.4	30.3±6.13	23.6±20.5	17.1±10.6	30.0±19.0	6.57±3.5	1.6±1.3	0
36L	24.6±15.0	25.4±5.19	16.0±8.0	24.7±21.1	30.0±16.0	8.09±3.51	2.46±3.13	0
37L	28.3±26.9	27.6±7.91	40.0±31.0	18.8±13.9	28.5±23.6	16.8±12.6	3.18±3.44	0
38L	22.9±18.2	30.0±9.0	17.5±11.1	21.9±15.9	26.6±15.9	15.0±11.0	1.87±2.26	0
39L	26.5±17.0	21.3±4.37	25.3±24.3	18.9±9.10	35.5±25.6	11.1±8.79	2.46±3.72	0

*H-High traffic density areas; **M-Medium traffic density areas; ***L-Low traffic density areas

Statistical T-testing (p=0.05) showed significant difference between present and previous concentrations of Pb, Zn and Ni. These differences in concentrations can be associated to the rapid expansion and urbanization of the city metropolis of the past 19 year's occasion by rural urban drift, increase in population and vehicular traffic emissions. To the best of our knowledge, there has been no report on road dust concentration of metals in Ibadan and lead levels of 55.5±39.3 µg/g investigated in this study is a potential contamination indicator. Rainfall runoff from these road surfaces may contaminate soils or leached into ground water reserves and air born particulates may pose instant health risk to commuters and residents alike. Accumulation factor (AF) of lead was notably high only within the high traffic density locations for roadside soil and dust with values as high as 22 and 21 respectively. The present AF value of 22 is in close agreement with 21.5 previously reported for roadside soils in Ibadan [29]. The AF values for Zn, Mn and Ni were between 1 and 6 for soil and dust suggesting relative low contamination levels (Table 3).

Seasonal indices showed high levels of studied metal elements in soil and dust during the dry season compared to wet season period (Table 4). Levels were similarly found to be higher around high traffic density locations and decreases through the medium to low traffic density locations for both seasons. Statistical T-testing at *p=0.05* showed significant difference among seasonal levels of metals for roadside soil and dust confirming the observed seasonal variation. Low metal levels in soil and dust during the wet seasons can be attributed to surface runoffs occasioned by rainfall which tends to partly wash off and leached contaminants in soil and road surfaces. Furthermore, low precipitation during the dry season tends to accumulate contaminants resulting in the elevated metal levels in roadside soil and dust on road surfaces [35,36].

Table 2. Summary of heavy metal concentrations (µg/g) in the different traffic density locations

Sample Location[a]	Parameter	Roadside soil				Road Dust			
		Pb	Zn	Mn	Ni	Pb	Zn	Mn	Ni
High Traffic Density	Mean ± SD	221±154	103±65	69.4±43.7	37.5±27.6	92.3±74.7	31.6±20.5	10.4±9.42	5.28±5.05
	Range	17.3-978	19.4-355	10.4-281	9.39-194	18.3-388	1.83-155	0-43.9	0-19.8
Medium Traffic Density	Mean ± SD	88.5±56.2	57.5±28.8	38.5±25.9	24.6±16.7	44.1±25.6	18.7±9.45	6.46±7.88	4.99±4.68
	Range	10.4-265	10.4-162	9.33-108	6.89-84.6	10.0-183	2.18-95.4	0-33.9	0-30.7
Low Traffic Density	Mean ± SD	31.5±20.7	30.5±9.61	25.0±15.1	19.3±13.4	30.2±17.6	13.0±8.0	3.62±5.06	1.01±1.26
	Range	4.75-79.4	2.44-67.4	5.21-82.6	4.13-55.3	10.0-74.3	1.08-40.9	0-38.5	0-21.5
All Locations	Mean ± SD	114±77	63.5±34.5	44.3±28.3	27.1±19.4	55.5±39.3	21.1±12.8	6.81±7.45	3.76±3.66
	Range	4.75-978	2.44-355	5.21-281	4.13-194	10.0-388	1.08-155	0-43.9	0-30.7
Control	Mean ± SD	10.1±3.01	18.7±6.66	14.4±8.08	8.82±4.49	4.31±3.03	9.77±3.06	2.41±1.57	1.11±0.89
	Range	5.96-13.7	10.3-28.3	3.21-23.6	4.97-17.4	2.18-10.3	6.43-13.8	0.94-4.38	0.11-2.18

a – High Traffic Density (>2000 vehicle per hour), Medium Traffic Density (500-2000 vehicles per hours, Low Traffic Density (<500 vehicles per hour).

Table 3. Accumulation factor[a] of heavy metal concentrations in roadside soil and dust

Location Traffic Density	Roadside Soil				Road Dust			
	Pb	Zn	Mn	Ni	Pb	Zn	Mn	Ni
High	22	6	5	4	21	3	4	2
Medium	9	3	3	3	10	2	3	4
Low	3	2	2	2	7	1	2	1

a – Ratio of average concentration at given location to concentration at control site.

Table 4. Average seasonal heavy metal concentrations (µg/g) in roadside soil and dust

Location Traffic Density[a]	Dry Season				Wet Season			
	Roadside soil							
	Pb	Zn	Mn	Ni	Pb	Zn	Mn	Ni
High	341±95	152±48	79.6±33.1	56.8±27.6	101±45	52.9±16.0	59.2±34.5	18.3±6.0
Medium	120±54	78.8±18.4	58.5±20.0	36.5±8.15	57.1±27.9	36.2±14.0	18.4±5.94	12.7±3.44
Low	38.6±23.9	36.6±7.52	33.4±13.3	30.3±8.15	24.4±13.9	24.3±5.32	16.7±6.78	8.42±3.11
	Road Dust							
	Pb	Zn	Mn	Ni	Pb	Zn	Mn	Ni
High	140±79	41.5±13.3	17.8±6.07	8.74±3.80	44.3±12.4	21.6±11.5	2.92±2.29	1.81±1.40
Medium	62.0±20.0	20.3±5.48	11.8±7.26	7.85±4.38	26.1±8.25	17.2±6.04	1.08±1.29	2.12±1.57
Low	43.5±13.8	16.5±6.14	6.66±5.81	2.02±0.79	16.9±5.20	9.51±4.56	0.57±0.84	0

a – High Traffic Density (>2000 vehicle per hour), Medium Traffic Density (500-2000 vehicles per hours, Low Traffic Density (<500 vehicles per hour).

Principal component analysis (PCA) was used to identify the source and degree of pollution of metals in roadside soil and dust and the bi plot representation is shown in Figure 2. Arising from the PCA bi plot the first two components accounts for 76.2% of the total variance in metal levels. The first component is a size variable accounting for 65.5% of the overall metal load measured for both soil and dust while the second component accounts for only 10.6%. Points that lie to the right of the metal vector representing high traffic density locations have the highest metal concentrations (65.5% variance), implying that these metals in soil and dust are primarily from vehicular emissions. Those to the left representing medium and low traffic locations have relatively low metal concentrations (10.6% variance). The low traffic routes are clustered together indicating that they all tend to have very low values for all metals and as previously mentioned are comparable with control values. In contrast, points on the right-hand side are more spread out, indicating wide variation in metal concentrations around the high traffic routes. Cluster analysis was used to further identify the sources and classification of the metals (Figure 3). Four clusters were classified based on similarity. Clusters 1- [4H to 12H] and cluster 4- [1H, 2H. 3H and 13H] which lies within the high traffic locations showed high metal concentrations, although cluster 4 is distinct with very high metal levels. Clusters 2- [14M to 26M] and clusters 3- [27L to 39L] represent medium and low traffic locations with similar levels of metal. The results of the cluster and PCA agree well with each other.

Heavy metals in soil usually have complicated relationships due to numerous factors that affect their relative abundance. This factor includes original contents in parent rock materials, soil formation process and anthropogenic contamination[2,36]. Table 5 shows the inter-element Pearson's correlation coefficient between different metal element for soil and dust. A strong positive inter-element correlation was observed for roadside soils (0.667-0.873) as against dust (0.215-0.645). This high correlation level in soil metals levels points to same source. Similarly, a significant positive correlation was observed between roadside soil and road dust metal levels, especially for Pb (0.833).Atmospheric deposition resulting from traffic pollution may explain this strong correlation of Pb in soil and dust [25,28].

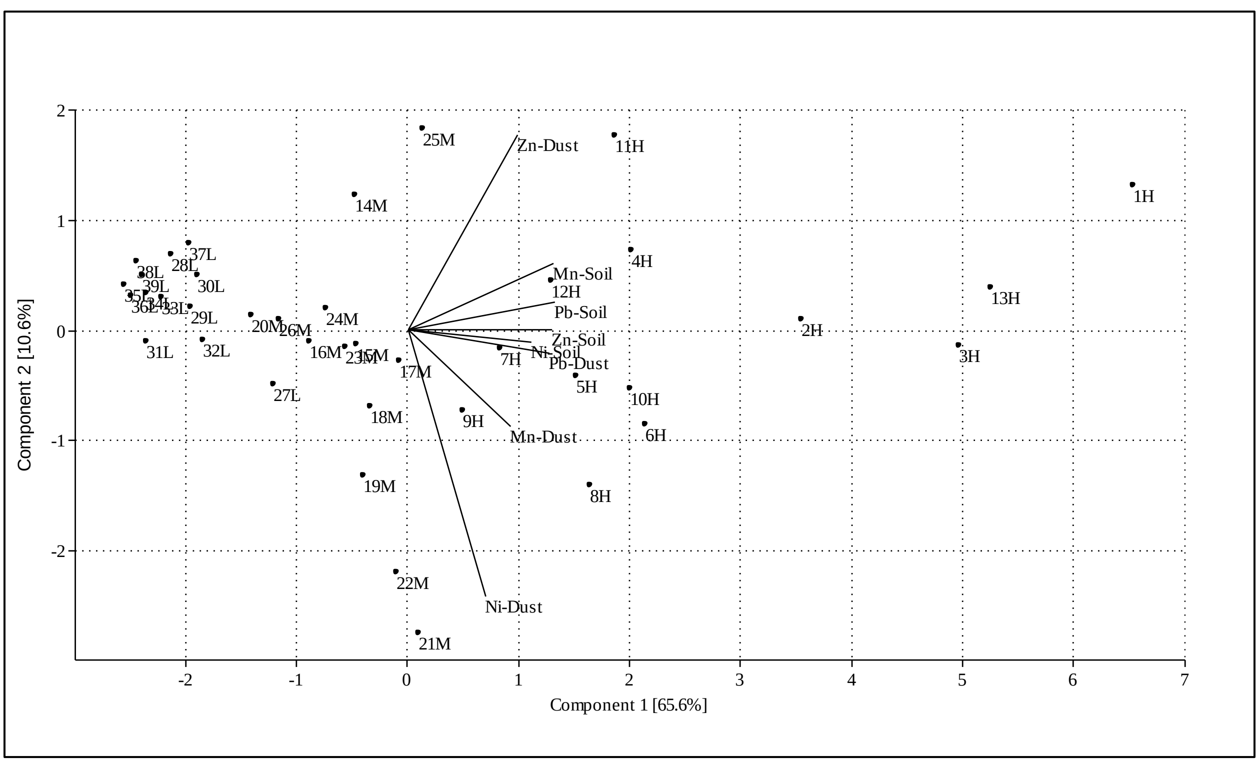

Figure 2. Principal component biplot of correlated metal data for roadside soil and dust

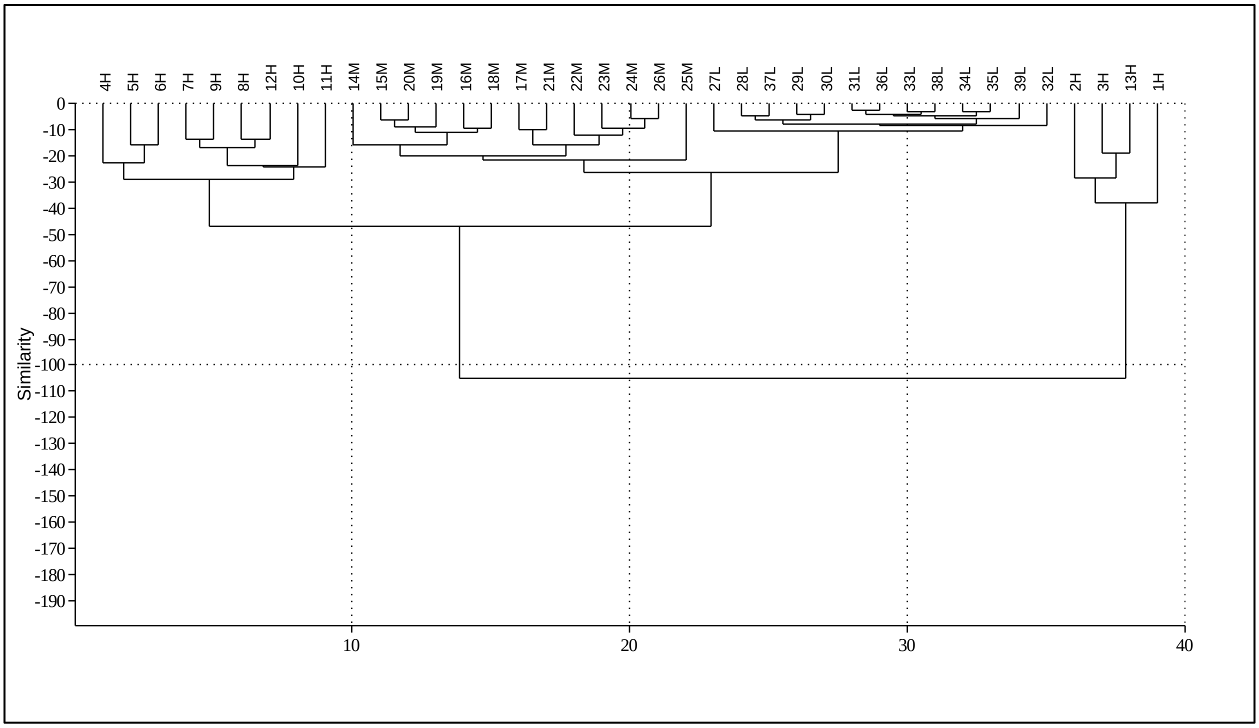

Figure 3. Euclidean cluster analysis of metal data of roadside soil and dust

Table 5. Interelement Pearson's correlation coefficient between soil and dust

	Pb-soil	Zn-soil	Mn-soil	Ni-soil	Pb-dust	Zn-dust	Mn-dust	Ni-dust
Pb-soil	0							
Zn-soil	0.866	0						
Mn-soil	0.873	0.862	0					
Ni-soil	0.667	0.672	0.712	0				
Pb-dust	0.833	0.783	0.801	0.743	0			
Zn-dust	0.680	0.609	0.729	0.454	0.531	0		
Mn-dust	0.624	0.583	0.527	0.422	0.645	0.239	0	
Ni-dust	0.407	0.449	0.374	0.357	0.399	0.215	0.249	0

Table 6. Comparison of metal levels (µg/g) in roadside soil and dust in this study and other cities

	City (Mean)	**Pb**	**Zn**	**Ni**	**Reference**
Roadside soil	Northern England	233	174	-	[41]
	Tehran, Iran	669	614	90.3	[23]
	Seoul, SK	240	271	-	[42]
	Seville,	137	145	22	[8]
	Palermo, Italy	202	138	17.8	[9]
	Osogbo, Nigeria	68.7	42.5	8.38	[24]
	Ibadan, Nigeria	*114*	*63.5*	*27.1*	*This study*
Road dust	Shanghai, China	295	734	84.0	[1]
	Birmingham, UK	48.0	534	41.1	[43]
	Oslo, Norway	180	412	41	[44]
	Madrid, Spain	193	476	44	[44]
	Xi'an, China	231	422	-	[10]
	Bahrian, UAE	697	152	126	[45]
	Ibadan, Nigeria	*55.5*	*21.1*	*3.76*	*This study*

Metal concentrations in roadside soils in this study were compared with soil quality criteria of some countries since there are none in Nigeria. Average lead level (114±77 µg/g) exceeded 50µg/g

Switzerland guide values [37] and 70 µg/g Canadian limits for agricultural soils [38]. About two-thirds (67%) of all the sample locations had lead levels exceeding both Switzerland guide values and Canadian limit for agricultural soils[29,37,38]. However, less than 26% of sample locations had lead levels above 140 µg/g Canadian limit for residential soils. These locations were sited mostly within the high and medium traffic zones. The average lead level in soil is however; lower than the US-EPA level requiring clean-up [39], Netherlands [40] and Canadian limits for commercial and industrial soils [38]. Other metals had levels well below the listed soil quality criteria. Meanwhile, concentration of metals in roadside soil and road dust in this study were compared with those of other cities with similar traffic problems (Table 6). Level of Pb and Zn in the studied soil is relatively lower, especially compared to those reported for in samples from cities as England, Tehran, Seoul, Seville and Palermo. It is interesting to note that the concentrations of Pb, Zn and Ni in roadside soils of Ibadan metropolis was significantly higher than that of Osogbo city which happens to fall within the same southwestern Nigeria. This indicates severe pollution from local traffic as the traffic volume in Ibadan is higher. Nickel level in soil is comparable with those of other cities except Tehran and Osogbo. Measured concentration of Pb, Zn and Ni in road dust in Ibadan metropolis is much lower than other cities except for Birmingham in UK with far less polluted vehicles.

Assessment of Potential Ecological Risk

Table 7 shows the heavy metal potential ecological risk indexes in roadside soils of Ibadan metropolis. The ecological risk factor E(i) of 109 for lead within the high traffic density areas suggest considerable potential ecological risk to the environment. However, over 50% of sample locations within this high traffic density areas have E(i) value exceeding 80. The medium traffic density area indicates moderate potential ecological risk with risk factor of 43.8. The E(i) values of Zn and Ni are all less than 40, indicating that these metals poses a low risk in the soil. Generally, lead poses moderate ecological risk factor to the Ibadan roadside environment with E(i) value of 56.4. The potential ecological risk indices (RI) were calculated to assess pollution by the three heavy metals in the roadside soil. The ecological risk index indicated that Ibadan metropolis was relatively free from contamination with low potential ecological risk values less than 150 which is the threshold for moderate ecological risk consideration [34].

Table 7. Heavy Metal Potential Ecological Risk Indexes in Ibadan Metropolis

Traffic Zones	E(i)			RI	Pollution Degree
	Pb	Zn	Ni		
High Traffic Density	109	5.5	21.3	136	Low ecological risk
Medium Traffic Density	43.8	3.07	13.9	60.8	Low ecological risk
Low Traffic Density	15.6	1.63	10.9	28.1	Low ecological risk
Ibadan metropolis	56.4	3.40	15.4	75.2	Low ecological risk

Conclusion

In conclusion, heavy metal concentrations in roadside soil were significantly higher than road dust. These levels were apparently more in dry season samples. Among all the metals studied, Pb contaminations were obviously heavier in soil and dust, especially, contamination levels were pronounced within the high traffic density locations. Average concentrations of lead, zinc and nickel were exponentially higher in roadside soils than previously reported levels. Source identification using multivariate statistical analysis inferred that distribution of lead in soils and dust was mainly affected by traffic density. Pearson's correlation analysis showed that metals were positively correlated between soil and dust confirming the effect of traffic as a source of contamination. Although, ecological risk index of roadside soil metals in Ibadan metropolis was considered relatively low, the ecological risk factor for lead in over 50% high traffic density locations suggest considerable potential ecological risk to the environment. Close monitoring is required to avoid lead exposure from roadside soils and dust to residents and road users within the city metropolis.

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Journal of Science Research ISSN 1119 7333

Citation: Etim, E. U. Contamination and Ecological Risk Assessment of Lead in Roadside Soil and Dust in Ibadan Metropolis, Nigeria, Volume 17, 2018, pp81-90.