

# ASSESSMENT OF TRACE METALS CONTAMINATION OF SOILS AROUND SOME AUTOMOBILE MECHANIC WORKSHOPS IN OYO SOUTH-WESTERN NIGERIA

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## ABSTRACT

This study was carried out to determine the level of soil contamination by metals around some automobile mechanic workshops in Oyo town in order to assess their possible adverse health implications on man and his environment. Concentrations of metals above certain levels have been shown to impair man's health. Automobile mechanic workshops are sources of metals discharge into the environment and most of these workshops in Oyo are sited within residential areas. 12 samples of top soils were therefore collected from some automobile mechanic workshops within Oyo town and analyzed for Lead (Pb), Manganese (Mn), Zinc (Zn), Chromium (Cr), Vanadium (V), Copper (Cu), Strontium (Sr), Cobalt (Co), Nickel (Ni) and Cadmium (Cd) using the Inductively Coupled Plasma Mass Spectrometry (ICP-MS) technique. The indices of contamination including Geo-accumulation index, Contamination Factor, and Degree of Contamination were used to determine the pollution status of the soils. Pb and Zn were the main metals of pollutant status with Pb having very high Contamination Factor, and the soils in general showing very high degree of contamination. This high level of Pb and Zn in the environment is significant with possible health risk to man and his environment.

**KEYWORDS:** Automobile mechanic workshops, Contamination Factor, Degree of Contamination, Geo-accumulation Index, Oyo town, Soils.

## INTRODUCTION

Human civilization and development has led to rapid industrialization and urbanization of our societies. Resulting from rapid industrialization, urbanization (Jiang et al.2013) and the attendant economic activities such as mining (Navarro et al, 2008) agriculture (Vaalgamoia and Conley 2008, Syed et al. 2012), industries and transportation (Jaradat et al. 2005; David and Sunday, 2012), is the generation of huge waste, leading to the contamination of environmental resources. The various wastes generated release trace metals into the environment. Although trace metals are essential for healthy biological function, they can become toxic to living things at concentrations above that required for normal biological activities (Fraga, 2005).

It has been noted that toxicity of metals can cause enzyme inactivation, acute mental skipping, and severe damage to gastrointestinal tract, kidney, liver and the central nervous system (Landrigan,1994). Also, heavy metal toxicity has an inhibitory effect on plant functions (Johansson et al., 1998).

Consequently, metal pollution because of its adverse effect on man is of global concern and effort is being made at regulating their discharge into the environment. One direct effect of urbanization is the contamination of urban soils, which subsequently serves adversely as a transmitter of many pollutants to surface waters, groundwater, atmosphere and food (Hani and Kariminejad, 2010). Once in the food chain and ecosystem, trace metals become a potential risk to man

(Tamane, 2008; Cai et al, 2011). Soils around automobile mechanic workshops are particularly susceptible to metal contamination (Ololade, 2014; Olanrewaju et al, 2015).

There has been a gradual increase in the number of automobile mechanic workshops in many cities of Nigeria as a result of urban development and increase in population. Waste from these automobile mechanic workshops are disposed and dumped indiscriminately into the environment often leading to soil contamination (Aelion, Davis, McDermott and Lawson, 2009). Generally, studies have shown that soils around automobile mechanic workshops are more polluted than the surrounding soils in metals like Pb, Ni, Cd, Cu, Cr, Mn and Zn which are often contained as additives in some lubricants and gasoline (Ololade, 2014).

Currently Oyo town is experiencing an increase in population and economic activities as a result of influx of workers and intakes into recently established tertiary institutions and industries. This increase in population has led to an increase in the frequency of automobile mechanic activities and number of automobile mechanic workshops. The implication of this is that the environment will experience an increase in automobile/automobile mechanic workshop related metal pollution. Therefore it is important to determine the concentration and degree of metal contamination in soils around these mechanic workshops in order to estimate possible health risks on the inhabitants of Oyo town. This study is therefore aimed at the determination of concentrations and degree of trace metals contamination in soils around some automobile

workshops in Oyo town using Geoaccumulation index and Degree of Contamination of the trace metals in the soils.

## 2.0 MATERIALS AND METHODS

### 2.1 Study Area and Sampling

This investigation was carried out within twelve automobile mechanic workshops in Oyo town, south-

western Nigeria. Oyo town is about 50km north of Ibadan and is located within longitude 3 55 E and 3 57 E and latitude 7 50 N and 7 52 N. Oyo town lies mostly on lowlands which are punctuated by rocky outcrops and series of hills. The study area has undulating topography with moderate elevations ranging from 53m to 317m above sea level (Fig. 1).

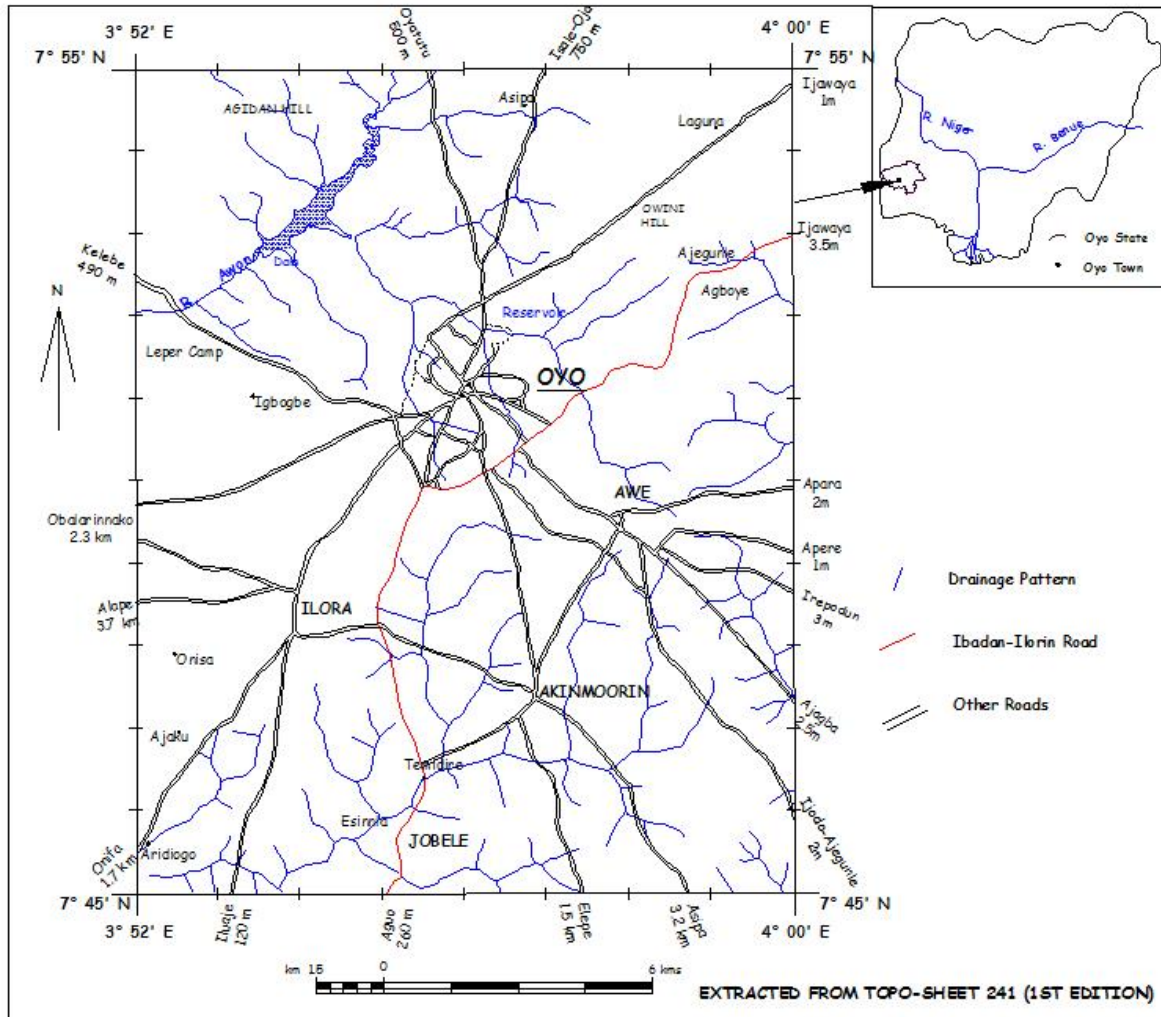
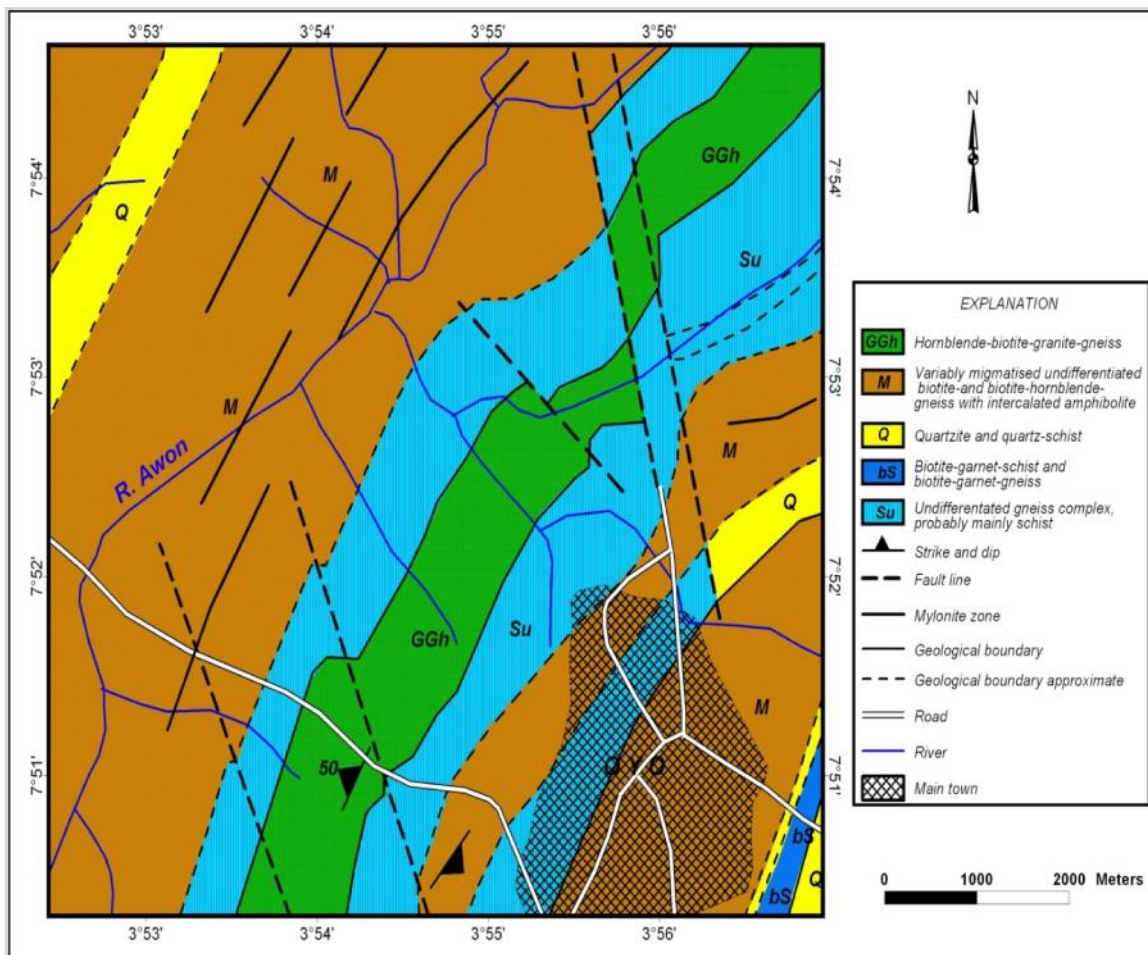


Fig. 1: Map of Oyo town (extracted from topo-sheet 241 1<sup>st</sup> edition)

Oyo town lies within the tropical rain forest belt which exhibits the typical climate of averagely high temperatures, high relative humidity and generally two rainfall maxima regime during the rainfall period of March to October. The mean temperature are highest at the end of the harmattan (averaging 28 C ) that is from the middle of January to the onset of the rains in the middle of March, even during the rainfall months temperature range between 25 C and 35 C almost throughout the year (Filani and Akintola, 1982). Rainfall

figures vary from average of 120mm at the onset of heavy rains to an average between 800mm and 1500mm. Oyo town lies within the Precambrian Basement Complex of South-western Nigeria, which is part of the Proterozoic mobile belt located between the West-African and Congo Cratons (Jones and Hockey, 1964; Rahaman, 1976; Dada, 2006). Rock types in the study area include migmatite, quartzite, biotite schist, biotite gneiss, granite, granite gneiss, and biotite-garnet schist (NGSA, 2008) (Fig. 2).



**Fig. 2:** Geological Map of Oyo town and its environs (published by Nigeria Geological Survey Agency, 2008)

Samples for this study were collected from some selected automobile mechanic workshops in Oyo town (Fig. 3, Table 1). The workshops were selected to represent various commercial centers of Oyo town where vehicular activities are relatively high. Topsoil

samples were taken from 12 different locations at a depth of 0 to 15 cm with plastic hand trowels into polyethylene bags and marked to indicate the location of collection, the GPS readings were also noted.

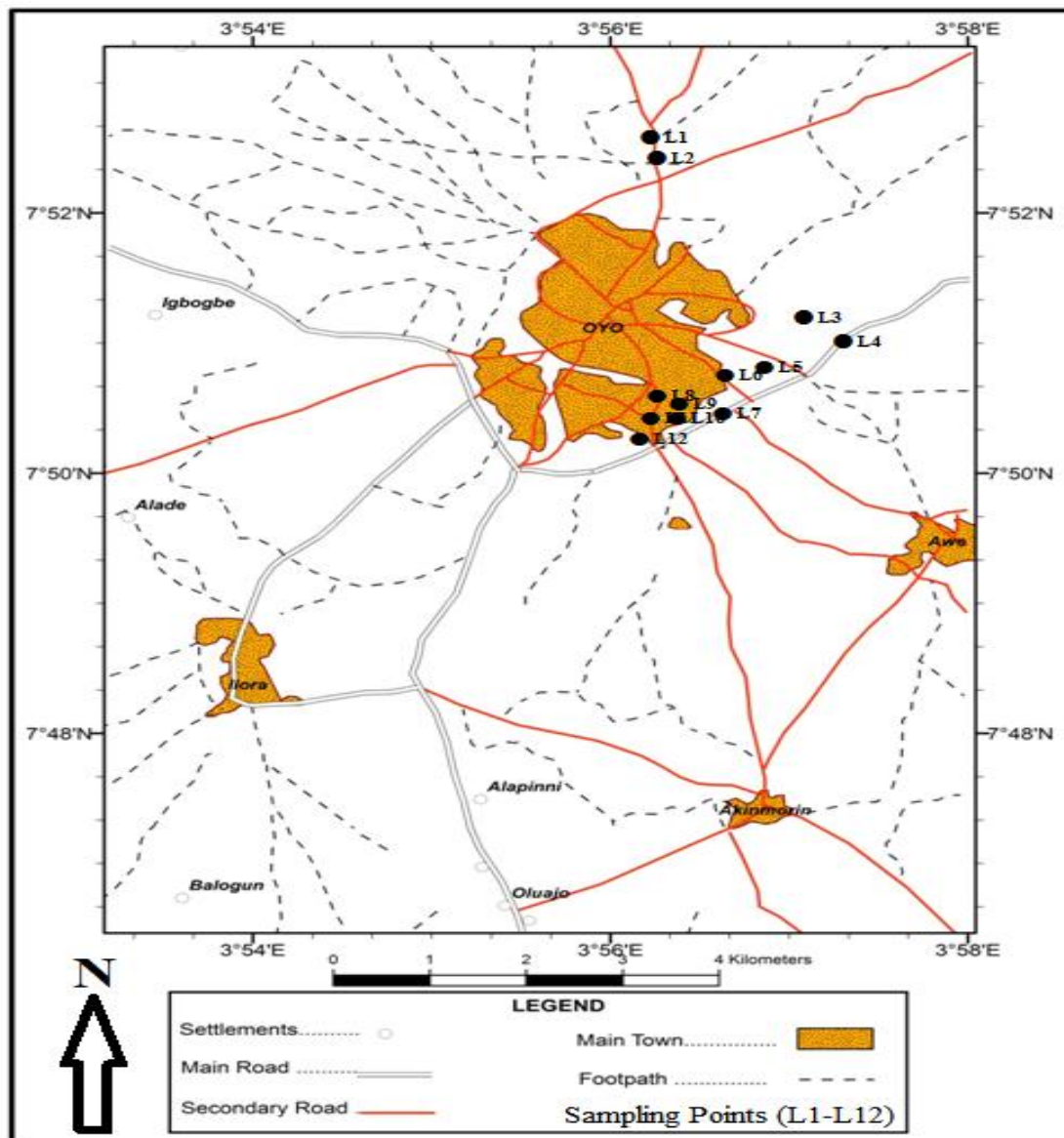


Fig. 3: Points of sample collection in Oyo

Table 1: Sampling Locations

S/N	Sampling location	Latitude	Longitude
L1	Alasila junction, Sabo	N 07° 52 35.2	E 003° 56 08.2
L2	Isale Oyo area, Sabo	N 07° 52 26.8	E 003° 56 10.6
L3	Adewale street junction, Ajegunle	N 07° 51 08.4	E 003° 57 03.5
L4	Beside Bizinlahi filling station, Ajegunle	N 07° 51 00.1	E 003° 57 16.1
L5	Akunlemu garage extension beside School of Surveying	N 07° 50 34.5	E 003° 56 48.8
L6	Inside Akunlemu garage, along Ogbomoso-Oyo road	N 07° 50 34.1	E 003° 56 35.4
L7	Beside FIRS building, Opposite Awe junction	N 07° 50 25.7	E 003° 56 36.4
L8	Front of Gbadegesin's palace, Oke-Apo	N 07° 50 30.9	E 003° 56 11.9
L9	Behind Anglican Secondary School, Ajagba	N 07° 50 28.5	E 003° 56 19.2
L10	Behind Methodist Maternity Centre, Ajagba	N 07° 50 25.6	E 003° 56 18.4
L11	Behind Speaker OYHA's house, Ajagba	N 07° 50 24.4	E 003° 56 14.2
L12	Durbar road, Tengba	N 07° 50 14.4	E 003° 56 10.0

The soil samples were air dried in the laboratory, and sieved through a <math><0.075\text{mm}</math> polyethylene sieve to remove stones, roots, coarse

materials and other debris. To prevent contamination, after a sample from a location was sieved, the sieve and the pan were thoroughly brushed out and cleaned with

acetone before another sample was put in for sieving and this was done all through the sample preparation. Samples that appeared too clustered were disaggregated in a porcelain mortar with a pestle. The shaking was done by a mechanical sieve shaker and then the sieved portion (<0.075mm) was collected and a fraction packaged into air-tight polythene bag which was later sent to ACME laboratories, Vancouver, Canada for further geochemical analysis.

Aqua Regia Digestion Method was employed to digest the soil samples. 0.5g of each sample was digested using aqua regia (0.5ml H<sub>2</sub>O, 0.6ml concentrated HNO<sub>3</sub> and 1.8ml concentrated HCl) for 2 hours at 95°C. The solutions were then cooled and diluted to 10ml with deionized water in readiness for trace element determination of the samples.

**2.2. Sample Analysis**

The samples were analyzed using the Inductively Coupled Plasma Mass Spectrometry (ICP-MS). This was achieved by ionizing the sample with inductively coupled plasma and then using the spectrometer to separate and quantify the ions. In inductively coupled plasma, plasma is energized by inductively heating the gas with an electrical coil. The plasmas used in spectrochemical analysis are essentially electrically neutral, with each positive charge on an ion balanced by a free electron. The concentrations of elements in each sample was determined through calibration with certified reference materials.

**2.3. STATISTICAL ANALYSIS OF THE SOIL SAMPLES**

**2.4. Descriptive Statistics**

The mean, range and standard deviation were calculated for the samples.

**2.5. Correlation Factor**

The degree of correlation between two variables is usually calculated by applying a coefficient of correlation on data containing the two variables. A perfect positive correlation between the two variables results in a coefficient of +1, a perfect negative correlation between two variables results in a coefficient of -1, and a total absence of correlation in a coefficient of 0. Intermediate values between +1, 0 and -1 are interpreted by degree of correlation. Thus, 0.98 indicates high positive correlation, -0.95 indicates high negative correlation and 0.09 indicates low positive correlation.

**2.6. CONTAMINATION INDICES**

**2.7. Geoaccumulation Index**

The Index of geoaccumulation (Igeo) was used for the assessment of soil contamination. It is computed using an equation developed by Muller (1969) and it is expressed mathematically as:

$$I_{geo} = \log_2 C_n / 1.5 B_n$$

Where:

C<sub>n</sub> is the measured concentration of the element in the soil sample fraction

B<sub>n</sub> is the geochemical background value (the average crustal abundance value for each metal was used for this study).

The constant 1.5 allows for analysis of natural fluctuations in the content of a given substance in the environment and very small anthropogenic influences.

The soil quality can be subsequently referred to using the following values of Igeo as shown in Table 2

**Table 2:** Classes of Geoaccumulation Index (Igeo) after Muller, 1969.

Class	Igeo Value	Soil Quality
0	Igeo ≤ 0	Practically Uncontaminated
1	0 < Igeo ≤ 1	Uncontaminated to Moderately Contaminated
2	1 < Igeo ≤ 2	Moderately Contaminated
3	2 < Igeo ≤ 3	Moderately to Heavily Contaminated
4	3 < Igeo ≤ 4	Heavily Contaminated
5	4 < Igeo ≤ 5	Heavy to Extremely Contaminated
6	Igeo > 5	Extremely Contaminated

**2.8. Contamination Factor (C<sub>f</sub>) and Degree of Contamination (C<sub>deg</sub>)**

Soil contamination could also be assessed using the parameters: Contamination Factor and Degree of Contamination (Loska et al., 2004). In the version suggested by Hakanson (1980), soil contamination was assessed by comparing the observed concentration with pre-industrialized levels (average shale concentration).

$$C_f = C_{0-i} / C_n^i$$

Where:

C<sub>0-i</sub><sup>i</sup> = mean concentration of metals from at least 5 sampling sites.

C<sub>n</sub><sup>i</sup> = pre – industrial concentration (for this work: the average crustal value was used) of the individual metal

Contamination factor is a single element index (Table 3). The sum of the Contamination Factor for all studied metals yield the contamination degree C<sub>(deg)</sub> of the entire studied area and is represented by four classes (Table 4).

**Table 3:** Categories of Contamination factor

Class of Contamination factor	Soil Category
$C_f^i < 1$	low contamination factor
$1 < C_f^i < 3$	moderate contamination factor
$3 < C_f^i < 6$	Considerable contamination factor
$C_f^i$	Very high contamination factor

**Table 4:** Categories of Contamination degree

Class of Contamination degree	Soil Category
$C_{deg} < 8$	low degree of contamination
$8 < C_{deg} < 16$	moderate degree of contamination
$16 < C_{deg} < 32$	Considerable degree of contamination
$32 < C_{deg}$	Very high degree of contamination

### 3.0. RESULTS AND DISCUSSIONS

Results obtained from the geochemical analysis for the soil samples (Table 5) were subjected to various statistical analyses such as descriptive statistics,

correlation and factor analysis. Geoaccumulation index, contamination factor and degree of contamination were also applied in determining the level of contamination of the soils.

**Table 5:** Result of the Geochemical Analysis

	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ni (ppm)	Co (ppm)	Mn (ppm)	Cd (ppm)	V (ppm)	Cr (ppm)	Sr (ppm)
L 1	78	345	255	15	33	946	0.4	83	82	26
L 2	152	203	383	22	29	1453	0.5	56	47	89
L 3	34	25	74	15	34	1636	0.4	66	66	12
L 4	44	99	118	15	43	1620	0.4	117	75	32
L 5	95	123	374	132	66	1193	0.4	125	902	9
L 6	13	14	45	6	10	584	0.4	24	25	14
L 7	135	522	219	21	46	1831	0.4	173	140	17
L 8	169	10000	608	16	14	657	0.9	59	50	27
L 9	38	86	113	14	23	981	0.4	66	45	27
L 10	46	50	191	21	23	1135	0.4	62	53	49
L 11	142	307	555	27	27	1123	0.8	110	93	53
L 12	90	3028	745	19	17	729	0.9	100	67	66

#### 3.1. DESCRIPTIVE STATISTICS

#### 3.2. Geochemical Results

The statistical summary of the elemental concentrations in the soil samples were presented in the Appendix.

The minimum value for Cu is 13.00ppm while the maximum value is 169.00ppm with a mean value of 86.33ppm and standard deviation of 52.78ppm. Pb ranged from 14.00ppm to 10000.00ppm with a mean and standard deviation of 1233.50ppm and 2883.70ppm respectively. Zn has a mean and standard deviation of 306.67ppm and 228.51ppm respectively; it also ranges from 45.00ppm to 745.00ppm.

The minimum value for Ni is 6.00ppm, while the maximum value is 132.00ppm with a mean of 26.92ppm and standard deviation of 33.51ppm. Co ranged from 10.00ppm to 66.00ppm with a mean value and standard deviation value of 30.42ppm and 15.60ppm respectively.

Mn has a mean value of 1157.33ppm and a standard deviation value of 407.39ppm, and ranged from 584.00ppm to 1831.00ppm.

The minimum value for Cd is 0.40ppm, while the maximum value is 0.90ppm. It has a mean value of 0.53ppm and standard deviation value of 0.21ppm. Cr ranged from 25.00ppm to 902.00ppm with a mean value and standard deviation value of 137.08ppm and 242.66ppm respectively. Sr has a minimum value of 9.00ppm and maximum value of 89.00ppm, a mean value of 35.08ppm and standard deviation value of 24.47ppm. V ranged from 24.00ppm to 173.00ppm, with a mean value of 86.75ppm and standard deviation value of 40.08ppm.

#### 3.3. Correlation Matrix

The inter-elemental relationship was determined by measurement of their correlation coefficients (Table 6).

**Table 6:** Correlation Matrix for metals in the soils

	Cu	Pb	Zn	Ni	Co	Mn	Cd	Cr	Sr	V
Cu	1.000									
Pb	<b>.525</b>	1.000								
Zn	<b>.720</b>	<b>.597</b>	1.000							
Ni	.154	-.124	.175	1.000						
Co	.087	-.389	-.165	<b>.745</b>	1.000					
Mn	.069	-.459	-.373	.086	<b>.652</b>	1.000				
Cd	<b>.592</b>	<b>.724</b>	<b>.906</b>	-.128	-.457	-.478	1.000			
Cr	.098	-.138	.106	<b>.990</b>	<b>.776</b>	.100	-.188	1.000		
Sr	.399	.016	<b>.511</b>	-.241	-.330	-.040	.425	-.350	1.000	
V	.344	-.149	.184	.374	<b>.707</b>	<b>.572</b>	-.011	.407	-.148	1.000

The correlation coefficients vary widely from a minimum value of -0.011 between Cd and V to a maximum value of 0.990 between Ni and Cr. Cu showed a high positive correlation with Pb, Zn and Cd, and a low positive correlation with Ni, Co, Mn, Cr, Sr and V. Pb showed a high positive correlation with Cu, Zn and Cd, negative correlation with Ni, Co, Mn, Cr and V, and a low positive correlation with Sr.

Zn showed a high positive correlation with Cu, Pb, Cd and Sr, a negative correlation with Co and Mn and a low positive correlation with Ni, Cr and V. Ni showed a high positive correlation with Co and Cr, a low negative correlation with Pb, Cd and Sr and a low positive correlation with Cu, Zn, Mn and V.

Co showed a high positive correlation with Ni, Mn, V and Cr and a low negative correlation with Pb, Zn, Cd and Sr and a low positive correlation with Cu. Mn showed a high positive correlation with Co, and V, a negative correlation with Pb, Zn, Sr and Cd, and a low positive correlation with Cu, Ni, and Cr.

Cd showed a high positive correlation with Cu, Pb and Zn, a negative correlation with Ni, Co, Mn, V, and Cr, and a low positive correlation with Sr. Cr

showed a high positive correlation with Ni, and Co, a negative correlation with Pb and Sr, and a low positive correlation with Cu, Zn, Mn and V.

Sr showed a high positive correlation with Zn, a negative correlation with Ni, Co, Mn and V. V showed a high positive correlation with Co and Mn, a negative correlation with Pb, Cd and Sr and a low positive correlation with Cu, Zn, Ni, and Cr.

### 3.4. Factor Analysis

A varimax-rotation analysis was applied to the data set to separate between different components of the soil and the distribution of these components over the study area. The varimax-rotation analysis was also used to evaluate the possible sources of metals in this study. The metals were divided into three distinct factor groupings with Eigen values higher than one. Elemental loadings in these factors were given in Table 7, and the factor loadings which are greater than 0.50 are significant in the interpretation of the data. Table 8 explained the total system variance of the metals in the soils.

**Table 7:** Factor Analysis showing the Rotated Component Matrix of the Study Area

	Component		
	1	2	3
Cu	<b>.856</b>	.058	.280
Pb	<b>.676</b>	-.005	-.469
Zn	<b>.961</b>	.092	-.102
Ni	.084	<b>.941</b>	.148
Co	-.164	<b>.710</b>	<b>.665</b>
Mn	-.248	-.011	<b>.910</b>
Cd	<b>.895</b>	-.145	-.299
Cr	.014	<b>.970</b>	.144
Sr	<b>.522</b>	-.520	.188
V	.220	.380	<b>.744</b>

**Extraction Method:** Principal Component Analysis.

**Factor 1:** Cu, Pb, Zn, Cd and Sr (Felsic mineral-rich lithology, and anthropogenic influence)

**Factor 2:** Ni, Co and Cr (Mafic mineral-rich lithology)

**Factor 3:** Co, Mn and V (Geochemical affinity and mafic mineral-rich lithology)

**Table 8:** Total variance of metals in soils of the study area

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.932	39.324	39.324	3.932	39.324	39.324	3.331	33.314	33.314
2	2.985	29.851	69.174	2.985	29.851	69.174	2.777	27.773	61.088
3	1.490	14.899	84.073	1.490	14.899	84.073	2.299	22.985	84.073
4	.875	8.753	92.826						
5	.419	4.193	97.019						
6	.168	1.684	98.703						
7	.088	.881	99.584						
8	.029	.294	99.878						
9	.011	.107	99.985						
10	.002	.015	100.000						

**Extraction Method:** Principal Component Analysis.

### Factor 1: Cu, Pb, Zn, Cd and Sr

Factor 1 which explains 33.314% of the system variance (Table 8) has a high positive factor loading on Cu, Zn and Cd, and a moderate positive factor loading on Pb and Sr. According to Goldschmidt's classification of elements, Cu, Pb, Zn, and Cd are classified as chalcophile. However Sr is classified as a Lithophile.

Cu in the earth's crust is most abundant in mafic and intermediate rocks. It is considered among the mobile heavy metals in hypogenic processes and it is a very versatile trace cation which exhibits a great ability to chemically interact with mineral and organic components of soils. The concentrations of Cu in surface soils reflects the bioaccumulation of the metal as well as the anthropogenic sources (Kabata-Pendias and Pendias 2001). In the soils of the study area, Cu has a high positive correlation with both the anthropogenic and geogenic metals indicating that its contribution to the soils was from both geogenic and anthropogenic sources.

Pb has a high chalcophilic property. The natural content of Pb in soils is inherited from host rocks but most topsoils enriched in Pb are as a result of widespread pollution. Zn is distributed uniformly in magmatic rocks; however, the sources of Zn could be linked to emission and paints from vehicles, as well as wearing down of batteries. Pb and Zn showed a high positive correlation which indicates that their contribution to the soils of the study area was influenced partly by anthropogenic sources.

Cd is strongly associated with Zn in its geochemistry with the chemical composition of the rock as the main factor determining its content. Sr is a relatively common trace element in the earth's crust and it is likely to concentrate in intermediate magmatic rocks. The content of Sr is highly controlled by the parent rocks and climate.

### Factor 2: Ni, Co and Cr

Factor 2 which explain 27.77% of the total system variance (Table 8), has a high positive factor

loading on Ni, Co and Cr. According to Goldschmidt's classification of elements, Ni and Co are classified as siderophiles but they can behave as chalcophiles and lithophiles in the earth's crust while Cr is classified as lithophile.

Ni is believed to be strongly associated with Mn and Fe oxides in most soils, less than 15 to 30% of the total Ni is extracted with the Mn oxides. In surface horizons, Ni appears to occur mainly in organically bound forms, a part of which may be easily soluble chelates. Anthropogenic sources of nickel include steel works, metal plating and coinage of body parts of vehicles, and fuel combustion.

The abundance of Cr indicates that they are mainly associated with ultramafic and mafic rocks. The Cr contents of soils are inherited from the parent materials and are therefore usually highly concentrated in soils derived from mafic rocks. Co has a high concentration in ultramafic rocks in the earth's crust. The concentration of Co in soils is inherited from parent materials. Soils over mafic rocks and soils derived from clay deposits contain the highest amounts of this metal. Co closely resembles Mn and Fe, and its distribution in soils is strongly determined by Mn oxide phase formation.

### Factor 3: Co, Mn and V

Factor 3 which accounts for 22.985% of the total system variance (Table 8), has a moderate positive factor loading on Co and a high positive factor loading on Mn and V. According to Goldschmidt's classification of elements, Mn and V are classified as lithophiles whereas Co can behave as both lithophile and siderophile on the earth's surface.

V is concentrated mainly in mafic rocks. The geochemical characteristics of V are strongly dependent on its oxidation state (+2, +3, +4 and +5) and on the acidity of the media. V is known to form various complexes of cationic and anionic oxides and hydroxyl oxides; therefore V displays various behaviours.



Mn is one of the most abundant trace elements in the lithosphere. Their highest concentrations are usually associated with mafic rocks. In the soils of the study area, the association of Co and V in this factor is controlled by the geochemical affinity of the elements. V is identified to have preference for organic matter while Co has affinity for Fe-Mn phase (Pendias and Pendias-Kabata 2001). The association of elements in this factor is influenced by both mafic mineral-rich lithology and geochemical affinity. As shown by the geological map of Oyo town and environs mafic mineral-rich rocks in the

area include biotite garnet schist, biotite schist, and biotite gneiss. These rock types are rich in mafic minerals such as biotite and hornblende.

### 3.5. CONTAMINATION INDICES

#### 3.6. Geoaccumulation Index ( $I_{geo}$ )

Geoaccumulation indices were calculated using the average crustal abundance value for each metal as background value. The range of Geoaccumulation indices for the soils of the study area is presented in Table 9.

**Table 9:** Range of Geoaccumulation indices for soils of the study area

Metals	Minimum	Maximum
Cu	-3	1
Pb	0	9
Zn	-1	3
Ni	-4	0
Co	-2	1
Mn	-1	0
Cd	-1.4	-0.2
Cr	-3	3
Sr	-6	-3
V	-2.8	0.1

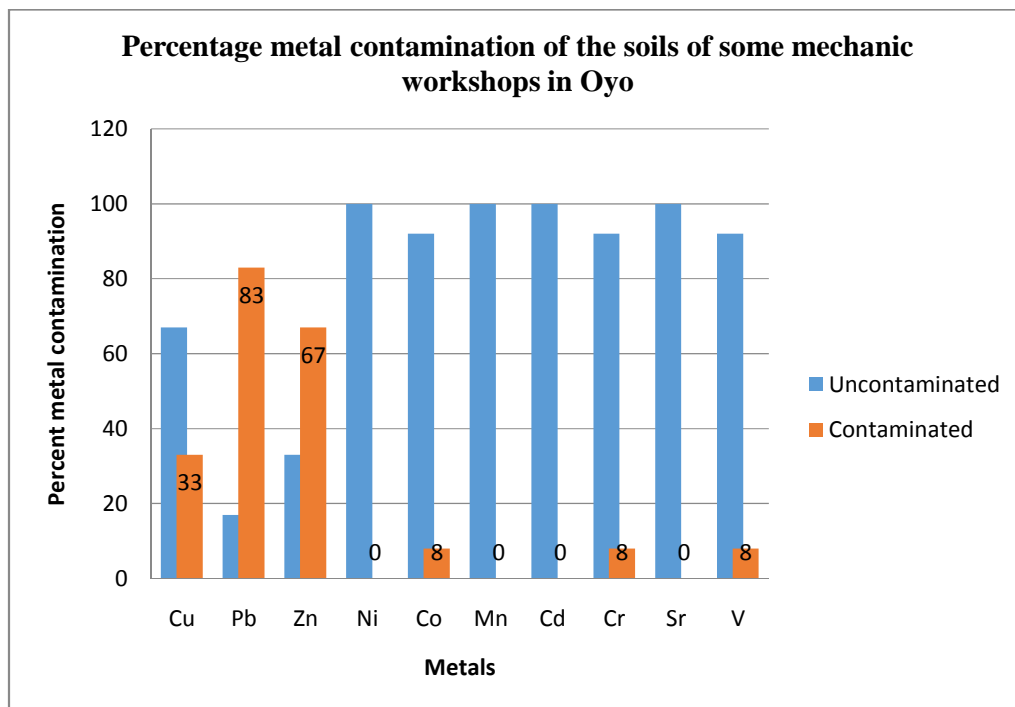
Cu ranged from -3 to 1 indicating a soil that is practically uncontaminated to moderately contaminated by Cu (Table 9). Pb ranged from 0 to 9 which showed that the soils were practically uncontaminated to extremely contaminated in Pb (Table 9). The high value of Pb could be linked to automobile emissions, wear and tear of tyres. Zn ranged from -1 to 3 which showed that the soil is practically uncontaminated to heavily contaminated by Zn (Table 9). The high value of Zn could be linked to lubricating oils in which it is added as an additive. Ni ranged from -4 to 0 which showed that the soils are practically uncontaminated by Ni (Table 9). Co ranged from -2 to 1 showing that the soils are practically uncontaminated to moderately contaminated by Co (Table 9). The presence of Co could be linked to Lithium cobalt oxide ( $LiCoO_2$ ) which is widely used in lithium ion battery as cathode. Mn ranged from -1 to 0

which showed that the soils are practically uncontaminated by Mn (Table 9). Cd ranged from -1.4 to -0.2 indicating that the soils are practically uncontaminated by Cd (Table 9). Cr ranged from -3 to 3 which showed that the soils are practically uncontaminated to heavily contaminated by Cr (Table 9). Sr ranged from -6 to -3 showing that the soils are practically uncontaminated by Sr (Table 9). V ranged from -2.8 to 0.1 which showed that the soils are practically uncontaminated to moderately contaminated by V (Table 9).

The percentage of metal in each class of geoaccumulation index and the percentage of metal contamination in the study area is as shown in Table 10 and Figure 4 respectively, while the range of geoaccumulation indices for each metal is shown in Figure 5.

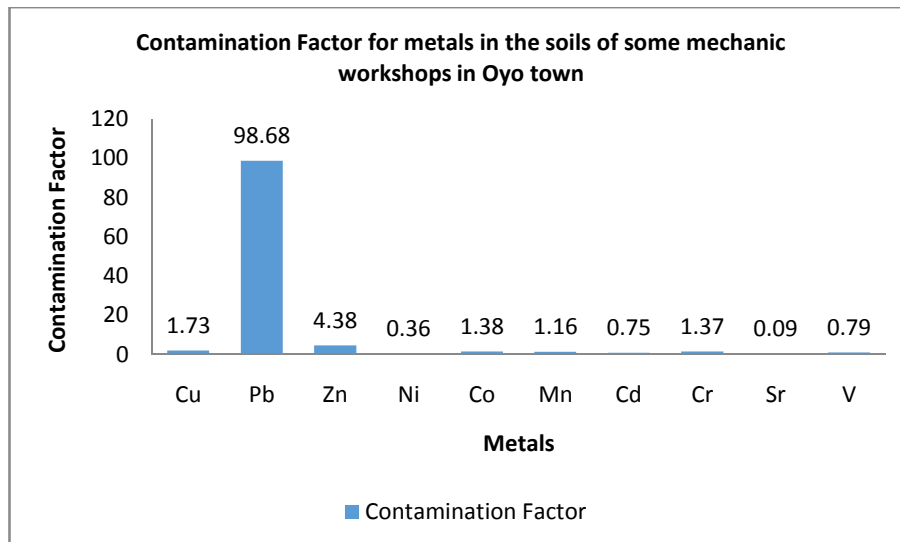
**Table 10:** Percentage of Metals in each class of Geoaccumulation Index for soils of the study area

Class	Igeo Value	Soil Quality	% Cu	% Pb	% Zn	% Ni	% Co	% Mn	% Cd	% V	% Cr	% Sr
0	Igeo 0	Practically Uncontaminated	67	17	33	100	92	100	100	92	92	100
1	0 < Igeo 1	Uncontaminated to Moderately Contaminated	33	8	25	-	8	-	-	8	-	-
2	1 < Igeo 2	Moderately Contaminated	-	17	25	-	-	-	-	-	-	-
3	2 < Igeo 3	Moderate to Heavily Contaminated	-	17	17	-	-	-	-	-	8	-
4	3 < Igeo 4	Heavily Contaminated	-	17	-	-	-	-	-	-	-	-
5	4 < Igeo 5	Heavily to Extremely Contaminated	-	8	-	-	-	-	-	-	-	-
6	Igeo > 5	Extremely Contaminated	-	16	-	-	-	-	-	-	-	-



**Figure 4:** Percentage Metal contamination of the soils of some mechanic workshops in Oyo town





**Figure 6:** Contamination factor for metals in the soil of some mechanic workshops in Oyo town

Ni, Cd, Sr and V showed a low factor of contamination with values 0.36, 0.75, 0.09 and 0.79 respectively. Cu, Co, Mn and Cr showed a moderate factor of contamination with values 1.73, 1.38, 1.16 and 1.37. Zn showed a considerable factor of contamination with 4.38 while Pb showed a very high factor of contamination with 98.68.

The degree of contamination which gives an assessment of the overall contamination of the soils has a value of 110.69 (Table 12) which indicates a very high degree of metal contamination due to the very high value for Pb contamination factor.

**Table 12:** Hakanson's Categories of Contamination degree

Class of Contamination degree	Soil Category	Degree of contamination for the studied soils
$C_{deg} < 8$	Low degree of contamination	
$8 \leq C_{deg} < 16$	Moderate degree of contamination	
$16 \leq C_{deg} < 32$	Considerable degree of contamination	
$C_{deg} \geq 32$	Very high degree of contamination	110.69

## CONCLUSIONS

The mean concentration of the metals in the soils around some automobile mechanic workshops in Oyo town as shown by this study was in the order Pb>Mn>Zn>Cr>V>Cu>Sr>Co>Ni>Cd. Factor analysis gave three factor groupings; Factor 1: Cu, Pb, Zn, Cd and Sr were mainly sourced from felsic mineral-rich lithologies and anthropogenic activities. Felsic minerals found in the rocks of Oyo town include plagioclase feldspars, microcline, quartz and muscovite. Factor 2: Ni, Co, and Cr were sourced mainly from mafic mineral-rich lithologies. Mafic minerals found in the rocks around Oyo town include biotite, and hornblende. Factor 3: Co, Mn, and V were sourced mainly from mafic mineral-rich lithologies and further influenced by geochemical affinity. Overall, the elemental association in the soils was influenced by lithology, geochemical affinity and anthropogenic activities such as indiscriminate disposal of domestic waste, and auto-mechanic workshop activities. Results of Geoaccumulation Index showed that the soils are practically uncontaminated by Ni, Mn,

Cd and Sr, practically uncontaminated to moderately contaminated by Cu, Co and V, moderate to heavily contaminated by Zn and Cr and practically uncontaminated to extremely contaminated by Pb. Also the soil showed considerable Contamination Factor for Zn and Very high contamination factor for Pb. An overall assessment showed that the soils have very high degree of contamination value of 110.69. This extreme value of degree of contamination portend a great danger to the health of plant, animal and man in these areas.

In view of the very high degree of soil contamination around auto-mechanic workshops in Oyo town, measures should be put in place to control further contamination of the environment. It is therefore pertinent that all mechanic workshops in this area be relocated to the outskirts of the town and a mechanic "villages" be established in carefully selected locations. Also, a more environmentally friendly method of waste disposal and management should be put in place, rather than the current practice of indiscriminate disposal of waste products from mechanic workshops.

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## APPENDIX

## Statistical summary of elemental concentrations in the soils

	N	Minimum	Maximum	Sum	Mean	Std. Deviation
Cu	12	13.00	169.00	1036.00	86.33	52.78
Pb	12	14.00	10000.00	14802.00	1233.50	2883.70
Zn	12	45.00	745.00	3680.00	306.67	228.51
Ni	12	6.00	132.00	323.00	26.92	33.51
Co	12	10.00	66.00	365.00	30.42	15.60
Mn	12	584.00	1831.00	13888.00	1157.33	407.39
Cd	12	0.40	0.90	6.30	0.53	0.21
Cr	12	25.00	902.00	1645.00	137.08	242.66
Sr	12	9.00	89.00	421.00	35.08	24.47
V	12	24.00	173.00	1041.00	86.75	40.08
Valid N (listwise)	12					