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ASSESSMENT OF TRACE METAL CONTAMINATION OF SOILS AROUND OLUYOLE INDUSTRIAL ESTATE, IBADAN, SOUTHWESTERN NIGERIA

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ABSTRACT

This study was carried out to determine the level of metals contamination of the soils around Oluyole industrial estate in Ibadan. Oluyole industrial estate has heavy concentration of manufacturing industries that generate a lot of waste products capable of introducing metals into the environment. Consequently, twenty-one topsoil samples were collected and analyzed for Molybdenum (Mo), Copper (Cu), Lead (Pb), Zinc (Zn), Nickel (Ni), Cobalt (Co), Manganese (Mn), Scandium (Sc), Arsenic (As), Strontium (Sr), Cadmium (Cd), Vanadium (V) and Chromium (Cr) using the Inductively Coupled Plasma Mass Spectrometry (ICP-MS) technique. The degree of contamination was assessed using geoaccumulation index, contamination factor and degree of contamination. The mean concentration of metals was in the order: Mn>Cr>Zn>V>Pb>Cu>Ni>Sr>Co>Sc>As>Mo>Cd. Factor analysis indicated three factor groupings. Factor 1 included Mo, Cu, Pb, Zn, As, Sr and Cd. Factor 2 is made up of Ni, Co, Mn, Sc, Sr, V and Cr while Factor three included Sc and V. These elemental associations were influenced mainly by lithology, geochemical affinity and anthropogenic activities. The geoaccumulation index showed that the soils were Practically uncontaminated to Moderately contaminated by Zn, Mn, Sc, and Cr, Moderately contaminated by Mo, Cu, Pb, Ni, Co, As, Cd and Moderately to heavily contaminated by Ni and Sr. Results of Contamination factor also showed that the soils have moderate contamination factor for all metals studied excepting Ni which has considerable contamination factor. The considerable degree of contamination with a value of 28.23 showed that the soils were highly polluted by the metals studied posing a potential health risk to human life and the environments.

KEYWORDS: Oluyole Industrial Estate, Contamination Factor, Degree of Contamination, Geo-accumulation index, Soils.

INTRODUCTION

In recent years, advancement in technology, urbanization and industrialization has contributed to the increase in the discharge of metals into the environment through media such as industrial effluents, auto-vehicle emissions, solid waste disposals, fertilizer application in soils and domestic wastes (Olukanmi and Adeoye, 2012). It has been shown that soils can act as depository for pollutant metals as a result of adsorption processes which bind these metals to it (Popoola et al, 2012). High concentration of these metals will eventually lead to the contamination of such soils. Soil contamination by trace metals is of major concern to man because at high concentration metals can cause harm to human life and the environment (Mtunzi et. al., 2015).

Ibadan city is underlain by the Precambrian Basement Complex of South-western Nigeria, which is part of the Proterozoic mobile belts located between the West-Africa and Congo Cratons. The Nigerian Basement Complex comprises of Migmatite-Gneiss Quartzite Complex; the metavolcanic and metasedimentary rocks (Schist Belts); the Pan-African Granitoids; and the Undeformed acid and basic dykes (Jones and Hockey, 1964; Rahaman, 1976; Dada, 2006).The basement complex has been affected by four major orogenies including the Liberian (2800±200my), the Eburnean (2100±200my) Kibarian (1100±250my), and the Pan African (600±150my) (Rahaman, 1988; Obaje, 2009; Olayinka, 1992).Soils are products of weathering of underlying rocks. Consequently, elemental concentrations in soils are influenced by lithogenic inputs as well as anthropogenic inputs. The elemental concentration in the soils of the Oluyole industrial estate will therefore be influenced by the underlying basement rocks as well as anthropogenic inputs particularly industrial emissions, and wastes.

The Oluyole industrial estate in Ibadan is an area with heavy concentration of industries manufacturing different products. Prominent among these industries are Procter & Gamble, Zartech, Yale, Steel Works, Obasanjo Farms, and 7Up Bottling Company. These industries generate a lot of wastes which contain trace metals that are introduced into the immediate environment as effluents and emissions. Metals that may be present in these effluents and emissions include lead, zinc, cadmium and nickel which are priority environmental pollutants. Assessing the pollutant status of Oluyole industrial estate is therefore relevant and of great importance.

This study, therefore, is aimed at determining the concentrations and degree of trace metals contamination of soils in the Oluyole industrial area of Ibadan using the level of soil metal concentration, Geoaccumulation index, Contamination factor and Degree of contamination.

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2.0. MATERIALS AND METHODS

2.1. Study Area and Sampling

The study area is covered by the Ibadan 261 N.E sheet (scale 1:50,000) and lies within longitudes 3°50′30'' E and 3°56′ 00''E and latitude 7°17′30'' N and 7°23'00'' N (Figure 1). The major area covered by this study is the Oluyole industrial estate. Three major landform units – hills, plains and river valley dominate the scenery of the study area. The hills are the most striking features of Ibadan town, although they constitute less than 5 percent of the total area, while the plains form extensive landform system in the area. The elevation is between 80m and 210m above sea level. The third landform system is the river valley which are the narrowest landform in the area. Ibadan generally is characterized by two distinct climatic seasons; the rainy and dry seasons. Between March and October, Ibadan is under the influence of the moist maritime south-west monsoon winds which blow inland from the Atlantic Ocean. This period is marked by constant rainfall and is referred to as the rainy season. The dry season occurs from November to February when the dry dust laden winds blow from the Sahara desert. Within the two seasons there are slight variation in intensity of the rain and the dryness (Filani, 1982).

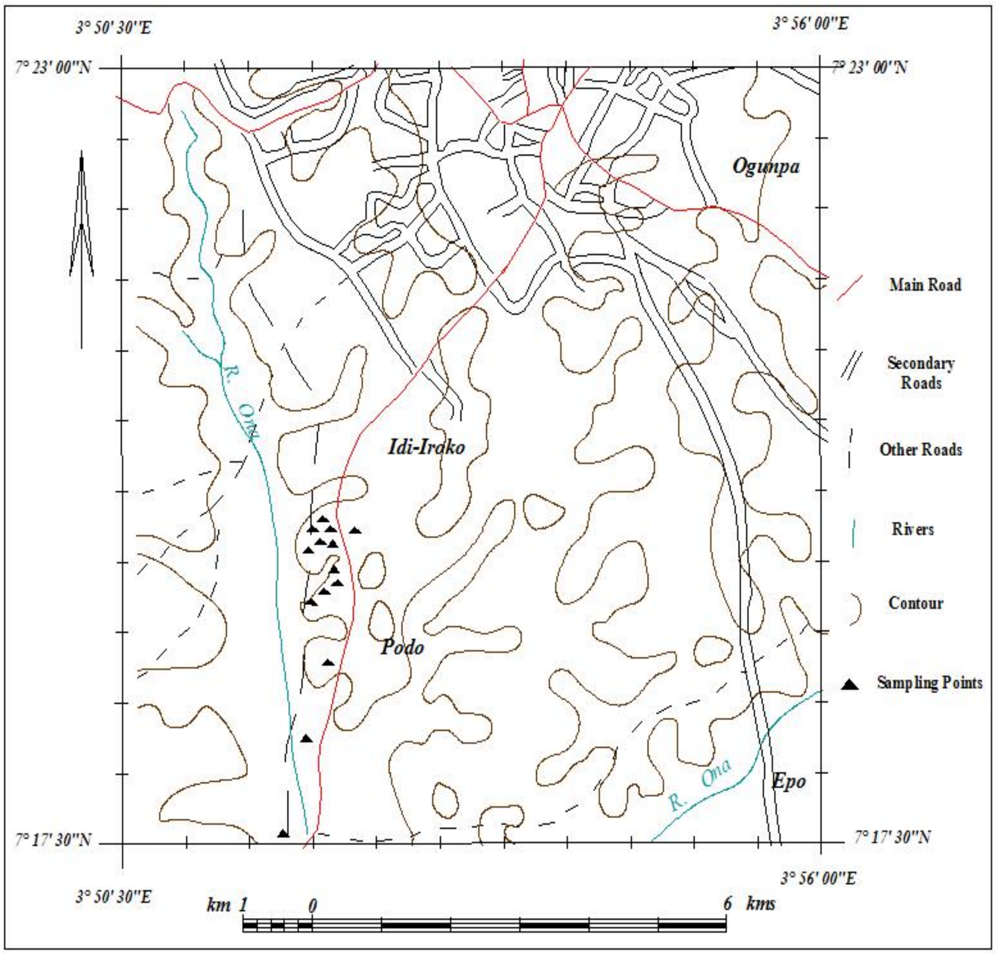

Fig. 1: Map of Oluyole industrialarea (extracted from Ibadan 261 N.E sheet: Scale 1:50,000)

Ibadan lies within the Precambrian Basement Complex of South-western Nigeria, which lies to the east of the West-African craton characterized by rocks formed by late Precambrian to early Paleozoic orogenies. The Nigerian basement complex extends westwards and is continuous with the Dahomeyan of the Dahomey-Togo-Ghana region. Rock types in the study area include quartzite, banded gneiss, augen gneiss, and amphibolites (Fig. 2).

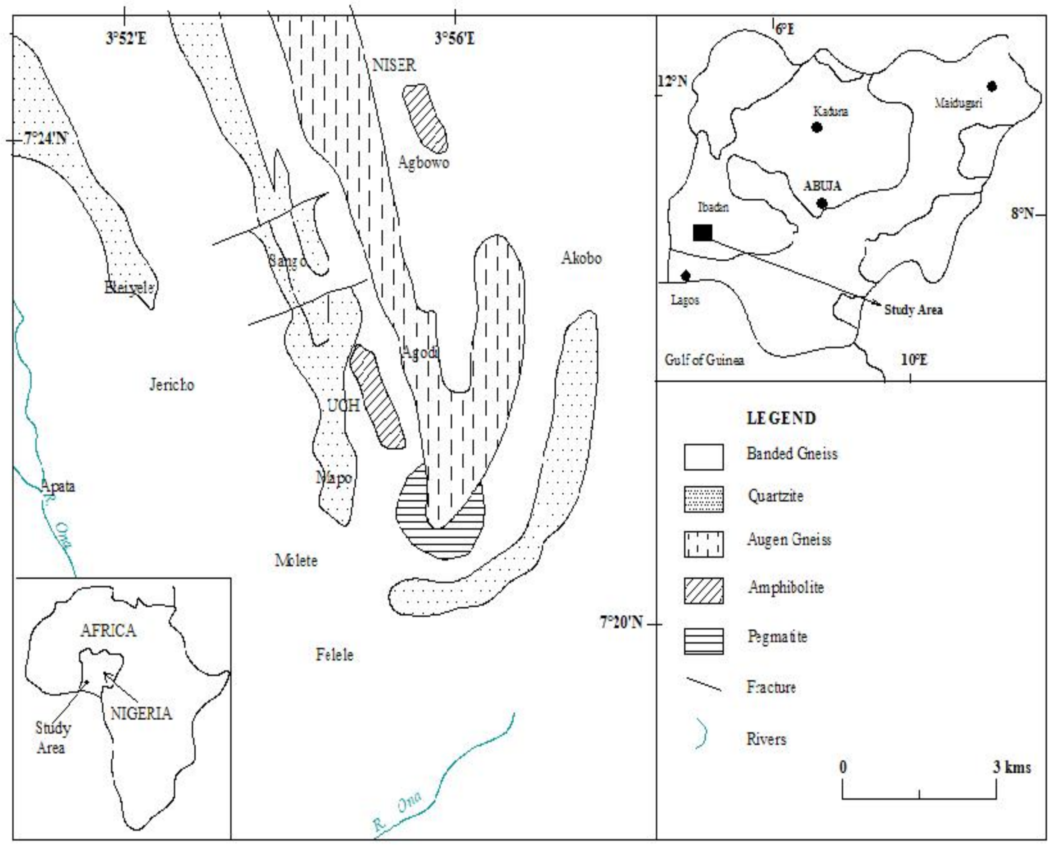

Fig. 2: Geological Map of Ibadan(modified after Grant, 1970).

Samples for this study were collected from the Oluyole industrial layout area of Ibadan (Fig. 3). Topsoil samples were collected randomly from 21 different locations around the industrial estate based on distribution of industries. They were collected at a depth of 0 to15 cm using plastic hand trowels and placed into polyethylene bags. The bags were marked to indicate the location of sample collection. The GPS readings for each sample point was noted.

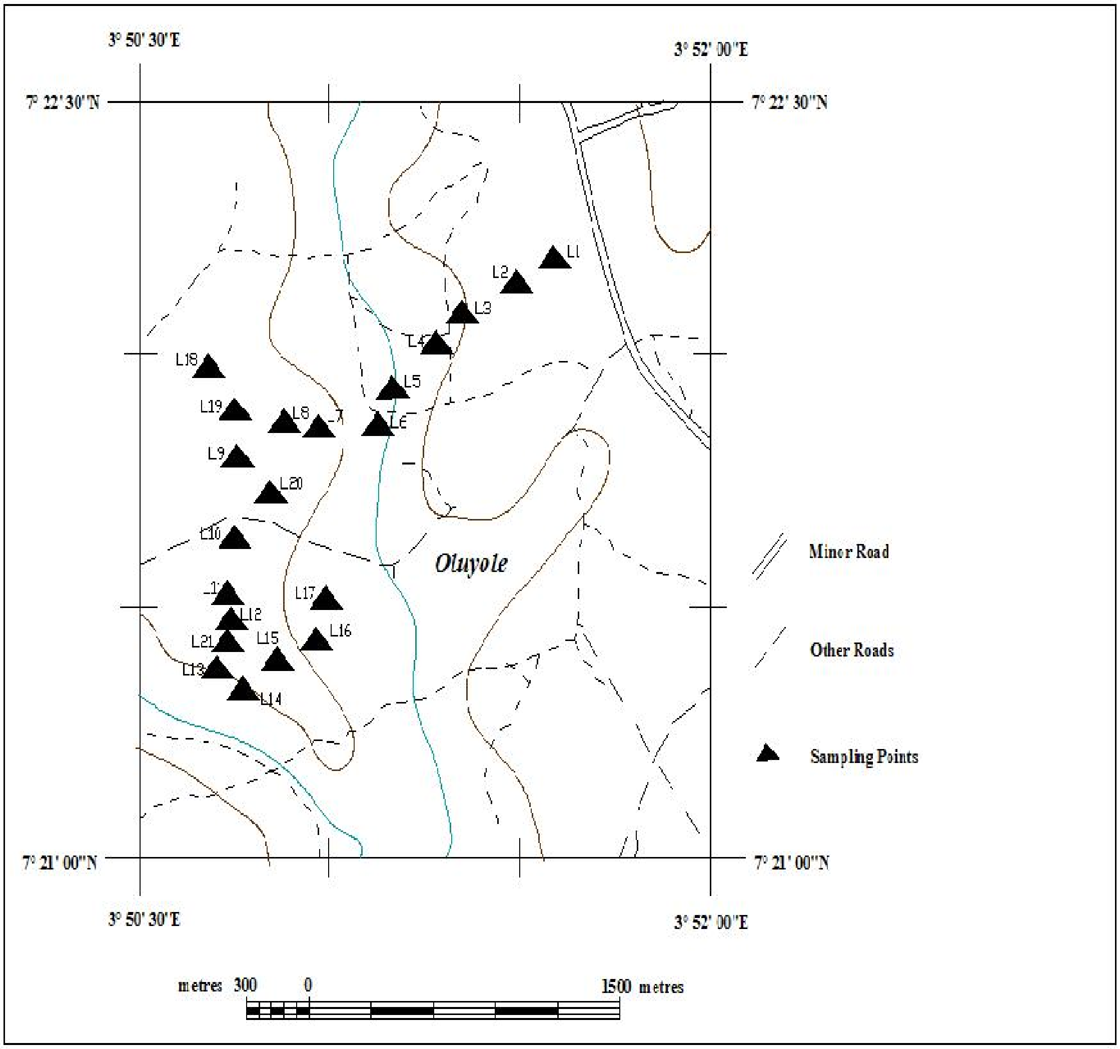

Fig. 3: Points of sample collection in Oluyole industrial estate.

The soil samples were air dried in the laboratory, and sieved through a <0.075mm polyethylene sieve to obtain fine grained samples for chemical analysis. Samples that were too clustered were disaggregated in a porcelain mortar with a pestle before sieving. The shaking was done by a mechanical sieve shaker and then the sieved portion (<0.075mm) was collected and a fraction packed into air-tight polythene bag which was later sent to ACME laboratories, Vancouver, Canada for 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_2O, 0.6ml concentrated HNO_3 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) technique. This was achieved by ionizing the sample with inductively coupled plasma and then using 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 spectro-chemical 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 material such as single or multi element reference standards.To ensure high – level dependability of geochemical analysis and reliability of the instrument, Quality Control and Quality Assurance (QC and QA) measures were taken. Analysis of sets of geochemical standards whose concentrations had previously been determined ensured the quality of the analysis. For this work, the United States Geological Survey (USGS) geochemical Standards GXR – 6, GXR – 5, GXR – 4, GXR – 2, and GXR – 1 were used to ascertain the degree of accuracy of the analytical instrument. Furthermore, to ensure the reliability of results of the analysis, blank samples were also analyzed at regular intervals during sample analyses.

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, 0.96 indicates high positive correlation, -0.83 indicates high negative correlation and 0.09 indicates low positive correlation.

2.7. CONTAMINATION INDICES

2.8. 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:

$$\mathbf{Igeo = log_2 Cn/1.5Bn}$$

Where:
Cn is the measured concentration of the element in the soil sample fraction
Bn is the geochemical background value (value from a controlled sample from Olapiti village an area free from industrial influence was used as background 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 1.

Table 1: 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

2.9. Contamination Factor (C_f) and Degree of Contamination (C_{deg})

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).

$$C^i_f = C^i_{0-i}/C^i_n$$

Where:
$\mathbf{C^i_{0-i}}$ **=** mean concentration of metals from at least 5 sampling sites**.**
$\mathbf{C^i_n}$ =pre – industrial concentration (for this work,soil sample from Olapiti village was used as background) of the individual metal

Contamination factor is a single element index (Table 2). The sum of the Contamination Factor for all studied metals yield the contamination degree C($_{deg}$) of the entire studied area and is represented by four classes (Table 3).

Table 2: Categories of Contamination factor

Class of Contamination factor	**Soil Category**
C^i_f <1	low contamination factor
1 ≤ C^i_f <3	moderate contamination factor
3 ≤ C^i_f <6	Considerable contamination factor
≤ C^i_f	Very high contamination factor

Table 3: Categories of Contamination degree

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

3.0. RESULTS AND DISCUSSIONS

3.1. Elemental Concentrations and Inter-Elemental Relationships

The analytical results for the soils of Oluyole industrial estate is presented in Table 4, while a summary of the descriptive statistics for the concentration of metals obtained is shown in the Appendix. Results shows that the mean value increased as follows: Mn>Cr>Zn>V>Pb>Cu>Ni>Sr>Co>Sc>As>Mo>Cd.

Table 4: Analytical results for the soils of Oluyole industrial area

	Mo (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ni (ppm)	Co (ppm)	Mn (ppm)	Sc (ppm)	As (ppm)	Sr (ppm)	Cd (ppm)	V (ppm)	Cr (ppm)
L1	2.5	60.3	69.0	178	23.2	18.1	629	1.6	1.5	22	0.4	63	81
L2	1.4	26.6	36.0	90	12.6	11.6	429	1.4	1.1	31	0.1	53	87
L3	1.3	60.1	113.9	147	18.1	30.2	1283	7.1	1.0	56	0.2	94	73
L4	2.2	76.0	270.8	243	18.2	20.1	975	2.6	3.4	90	0.3	70	77
L5	0.7	24.6	43.0	81	19.2	27.2	800	1.9	0.9	27	0.1	56	45
L6	1.0	39.1	50.0	106	17.4	13.9	596	3.2	0.8	21	0.1	49	52
L7	1.1	41.6	67.1	146	24.0	32.6	1062	4.0	1.2	18	0.2	80	96
L8	1.0	33.2	37.6	107	20.5	20.7	740	2.5	0.9	20	0.1	56	79
L9	1.2	37.2	26.7	49	75.8	42.5	975	2.8	1.7	52	<0.1	113	145
L10	0.9	24.9	18.9	34	58.1	38.1	858	2.3	1.2	33	<0.1	79	121
L11	0.6	17.5	14.1	26	29.0	17.1	416	7.5	1.0	20	<0.1	57	93
L12	0.6	16.2	11.4	19	33.9	22.1	455	1.9	1.2	20	<0.1	63	104
L13	0.8	40.3	26.4	76	94.3	60.3	1397	3.0	1.3	59	<0.1	106	137
L14	1.0	24.9	18.8	27	47.7	34.3	749	5.9	1.9	20	<0.1	97	143
L15	0.8	26.0	24.2	43	45.4	29.1	719	2.1	1.6	36	<0.1	80	104
L16	1.0	27.8	34.5	67	26.7	19.2	469	3.6	1.1	21	0.2	60	93
L17	1.1	29.9	30.6	123	18.7	8.4	266	4.2	0.6	18	0.2	30	52
L18	1.2	27.3	26.9	89	50.3	33.0	749	2.3	1.4	35	0.2	73	101
L19	1.3	35.9	57.8	122	13.2	10.1	479	2.4	1.1	18	0.3	49	61
L20	2.2	39.9	92.2	110	20.5	23.8	843	4.8	2.1	13	0.1	127	78
L21	0.8	27.0	19.8	35	59.4	30.8	805	4.4	1.3	52	<0.1	75	105

The minimum value for Mo is 0.60ppm while the maximum value is 2.50ppm. It has a mean value of 1.18ppm and standard deviation value of 0.52ppm. Cu ranged from 16.20ppm to 76.00ppm and a mean value and standard deviation value of 35.06ppm and 14.83ppm respectively. Pb ranged from 11.40ppm to 270.80ppm, with a mean value of 51.89 and standard deviation of 56.66. Zn has a mean value and standard deviation value of 91.33ppm and 56.80ppm; it also ranged from 19.00ppm to 243.00ppm.

The minimum value for Ni is 12.60ppm, while the maximum value is 94.30ppm. It has a mean value of 34.58ppm and standard deviation value of 22.32ppm. Co ranged from 8.40ppm to 60.30ppm with a mean value and standard deviation value of 25.87ppm and 12.23ppm respectively. Mn has a mean value of 747.33ppm and a standard deviation value of 287.64ppm, and it also ranges from 266.00ppm to 1397.00ppm.

Sc ranged from 1.40ppm to 7.50ppm, with a mean value of 3.40ppm and a standard deviation of 1.74. As has a minimum value of 0.60ppm, maximum value of 4.30 a mean value of 1.35ppm and a standard deviation of 0.59. Sr ranged from 13.00ppm to 90.00ppm, with a mean value of 32.48ppm and a standard deviation of 19.21. The minimum value for Cd is 0.09ppm, while the maximum value is 0.40ppm. It has a mean value of 0.15ppm and standard deviation value of 0.09ppm. V ranged from 30.00ppm to 127.00ppm, with a mean value of 72.86ppm and standard deviation value of 23.85ppm. Cr ranged from 45.00ppm to 145.00ppm with a mean value and standard deviation value of 91.76ppm and 28.55ppm respectively.

The inter-elemental relationship as determined from the correlation matrix (Table 5) indicate a very strong relationship between Pb-Cu, Zn-Cu, Zn-Pb, Co-Ni, Cr-Ni. A strong relationship is exhibited by Cu-Mo, Zn-Mo, Mn-Co, As-Pb, Cd-Zn, V-Co, V-Mn, V-Sc, Cr-Co. A fairly strong relationship is also established between Pb-Mo, Sc-Ni, Sc-Co, Sc-Mn, As-Mo, As-Cu, Sr-Cu, Sr-Pb, Sr-As, Cd-Mo, Cd-Cu, Cd-Pb, V-Ni, Cr-Co.

Table 5: Correlation Matrix for metals in the soils of Oluyole industrial estate

	Mo	Cu	Pb	Zn	Ni	Co	Mn	Sc	As	Sr	Cd	V	Cr
Mo	1.000												
Cu	**.757**	1.000											
Pb	**.666**	**.854**	1.000										
Zn	**.754**	**.885**	**.833**	1.000									
Ni	-.340	-.206	-.375	-.508	1.000								
Co	-.247	.003	-.168	-.301	**.873**	1.000							
Mn	.093	.492	.323	.211	.487	**.803**	1.000						
Sc	.197	.238	.080	-.041	**.587**	**.674**	**.661**	1.000					
As	**.584**	**.543**	**.719**	.383	.107	.172	.324	.294	1.000				
Sr	.176	**.567**	**.596**	.322	.375	.423	**.607**	.403	**.581**	1.000			
Cd	**.678**	**.666**	**.531**	**.767**	-.403	-.360	-.074	-.199	.243	.107	1.000		
V	.196	.195	.090	-.138	**.557**	**.730**	**.718**	**.811**	.469	.300	-.278	1.000	
Cr	-.223	-.216	-.321	-.525	**.834**	**.746**	.374	.435	.270	.245	-.369	**.627**	1.000

3.2. Factor Analysis

A varimax-rotation analysis was applied to the data set to distinguish between the various components of the soil in order 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 6, and the factor loadings which are greater than 0.50 are significant in the interpretation of the data. Table 7 explains the total system variance of the metals in the soils.

Table 6: Factor Analysis showing the Rotated Component Matrix of the metals in the soils of Oluyole industrial estate

	Component		
	1	2	3
Mo	**.758**	-.268	.494
Cu	**.939**	.146	.151
Pb	**.940**	.050	.078
Zn	**.941**	-.173	-.013
Ni	-.384	**.835**	.175
Co	-.204	**.889**	.285
Mn	.294	**.775**	.293
Sc	.035	**.583**	**.678**
As	**.591**	.279	.417
Sr	**.553**	**.742**	-.109
Cd	**.895**	-.145	-.299
V	-.022	**.545**	**.799**
Cr	-.381	**.661**	.327

Extraction Method: Principal Component Analysis.

Factor 1: Mo, Cu, Pb, Zn, As and Cd (Felsic mineral-rich lithology, and anthropogenic influence)
Factor 2: Ni, Co, Mn, Sc, Sr, V and Cr (Geochemical affinity and mafic mineral-rich lithology)
Factor 3: Sc and V (Geochemical affinity and mafic mineral-rich lithology)

Table 7: Total variance of metals in soils of Oluyole industrial estate

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	6.267	41.781	41.781	6.267	41.781	41.781	4.919	32.796	32.796
2	5.058	33.718	75.499	5.058	33.718	75.499	4.668	31.122	63.918
3	1.249	8.324	83.823	1.249	8.324	83.823	2.986	19.905	83.823
4	.863	5.751	89.574						
5	.689	4.592	94.166						
6	.429	2.863	97.028						
7	.156	1.042	98.070						
8	.113	.752	98.823						
9	.078	.523	99.346						
10	.041	.276	99.622						
11	.020	.134	99.756						
12	.019	.127	99.883						
13	.009	.060	99.943						

Extraction Method: Principal Component Analysis.

Factor 1: Mo, Cu, Pb, Zn, As, Sr and Cd

Factor 1 which explains 32.796% of the system variance (Table 8), has a high positive factor loading on Mo, Cu, Pb, Zn, and Cd (Table 7), and a moderate positive factor loading on As and Sr. Elemental association in Factor 1 is influenced mainly by Felsic mineral-rich lithology, anthropogenic influences and geochemical behaviour. According to Goldschmidt Cu, Pb Zn As and Cd are all chalcophilic, while Mo can behave both as chalcophile and lithophile in the earth's surface.

Factor 2: Ni, Co, Mn, Sc, Sr, V and Cr

Factor 2 which explain 31.122% of the total system variance (Table 8), has a high positive factor loading on Ni, Co, Mn and Sr and a moderate positive factor loading on Sc, V and Cr (Table 7). The elemental association in Factor 2 is controlled mainly by geochemical affinity and mafic mineral-rich lithologies. All the metals in this group are siderophilic.

Factor 3: Sc and V

Factor 3 which accounts for 19.905% of the total system variance (Table 8), has a moderate positive factor loading on Sr and a high positive factor loading on Sc (Table 7). The association of elements in this factor is influenced by both mafic mineral-rich lithology, and geochemical affinity.

3.4. CONTAMINATION INDICES

3.5. Geoaccumulation Index (I_{geo})

Geoaccumulation indices were calculated using value from a controlled sample from Olapiti village (Table 8) as background for each metal. This area is remote, and lack any modern producing company. Industrial influence in this area is therefore minimal.

Table 8: Result of sample from Olapiti village close to Oyo Town

	Mo Ppm	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Co ppm	Mn ppm	Sc ppm	As ppm	Sr ppm	Cd ppm	V ppm	Cr ppm
L1	0.9	20.3	20.9	22	13.6	23.1	1054	4.8	0.4	12	0.09	89	85
L2	0.5	24.9	24.2	28	11.8	16.7	1286	2.4	0.4	82	0.1	38	29
L3	0.8	21.5	21.5	24	14.4	23.6	1068	5.0	0.6	11	0.1	95	91
L4	0.7	14.2	24.9	297	7.2	8.4	690	2.4	0.4	15	0.1	40	31
L5	0.5	8.8	33.3	145	5.5	6.5	504	1.7	0.4	21	0.09	28	23
L6	0.8	10.3	25.1	176	8.2	8.1	501	2.2	0.5	9	0.09	39	30
L7	0.6	12.0	16.1	83	5.7	7.7	404	1.4	0.4	10	0.09	31	28
L8	0.6	11.8	17.7	36	10.5	14.8	676	2.5	0.4	14	0.09	40	27
L9	0.5	22.3	14.3	50	7.8	12.1	578	1.3	0.4	27	0.09	24	17
L10	2.5	19.2	35.7	25	8.8	9.5	484	4.7	2.2	7	0.09	110	127
Mean	**0.8**	**16.5**	**23.4**	**89**	**9.4**	**13.1**	**725**	**2.8**	**0.6**	**21**	**0.09**	**53**	**49**

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 Oluyole Industrial Estate

Metals	Minimum	Maximum
Mo	-1.0	1.1
Cu	-0.6	1.6
Pb	-1.6	2.9
Zn	-3.0	1.0
Ni	-0.2	2.7
Co	-1.2	1.6
Mn	-2.0	0.0
Sc	-1.6	0.8
As	-0.6	1.9
Sr	-1.0	2.0
Cd	-0.7	1.4
V	-1.0	1.0
Cr	-1.0	1.0

Mo ranged from -1.0 to 1.1 indicating asoil that is practically uncontaminated to moderately contaminated in Mo (Table 9).Cu ranged from -0.6 to 1.6 which showed that the soils were practically uncontaminated to moderately contaminated in Cu (Table 9).Pb ranged from -1.6 to 2.9 indicating a soil that is practically uncontaminated to moderately to heavily contaminated by Pb (Table 9). The high value of Pb in the area could be linked to automobile emissions, and wear and tear of tyres. Zn ranged from -3.0 to 1.0 which showed that the soil is practically uncontaminated to moderately contaminated by Zn (Table 9). Ni ranged from -0.2 to 2.7 which showed that the soilsare practically uncontaminated to heavily contaminated by Ni (Table 9). The highest concentration of Ni (2.7) in the soils is attributed to the contributions of mechanic workshop in that area. Co ranged from -1.2 to 1.6 showing that the soils are practically uncontaminated to moderately contaminated by Co (Table 9). The concentration of Co could be linked to Lithium cobalt oxide ($LiCoO_2$) which is widely used in lithium ion battery as cathode. Mn ranged from -2.0 to 0.3 which showed that the soils are practically uncontaminated to moderately contaminated by Mn (Table 9). Cd ranged from -0.7 to 0.0 indicating that the soils are practically uncontaminated by Cd (Table 9). Cr ranged from -1.0 to 1 which showed that the soils are practically uncontaminated to moderately contaminated by Cr (Table 9). Sr ranged from -1.0 to 2.0 showing that the soils are practically uncontaminated to moderately to heavily contaminated by Sr (Table 9). V ranged from -1.0 to 1.0 which showed that the soils are practically uncontaminated to moderately by V (Table 10).Sc ranged from -1.6 to 0.8, which showed that they are practically uncontaminated to moderately contaminated by Sc (Table 9).As ranged from -0.6 to 1.9 which showed that the soils are practically uncontaminated to moderately contaminated by As.

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	% Mo	% Cu	% Pb	% Zn	% Ni	% Co	% Mn	% Sc	% As	% Sr	% Cd	% V	% Cr
0	Igeo ≤ 0	Practically Uncontaminated	62	10	48	57	10	29	57	81	10	53	62	29	5
1	0 < Igeo ≤ 1	Uncontaminated to Moderately Contaminated	33	76	33	43	48	57	43	19	76	23	24	61	95
2	1 < Igeo ≤ 2	Moderately Contaminated	5	14	14	nil	23	14	nil	nil	14	19	14	10	nil
3	2 < Igeo ≤ 3	Moderate to Heavily Contaminated	nil	nil	nil	nil	19	nil	nil	nil	nil	5	nil	nil	nil
4	3 < Igeo ≤ 4	Heavily Contaminated	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
5	4 < Igeo ≤ 5	Heavily to Extremely Contaminated	nil	nil	nil	nil	nil	nil	Nil	nil	nil	nil	nil	nil	nil
6	Igeo > 5	Extremely Contaminated	nil	nil	nil	nil	nil	nil	Nil	nil	nil	nil	nil	nil	nil

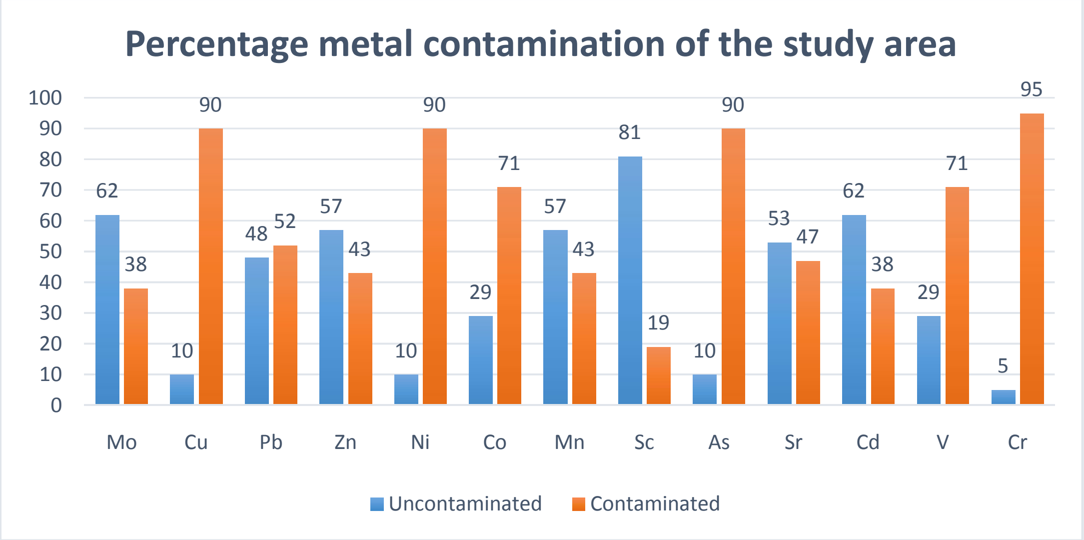

Figure 4: Percentage Metal contamination

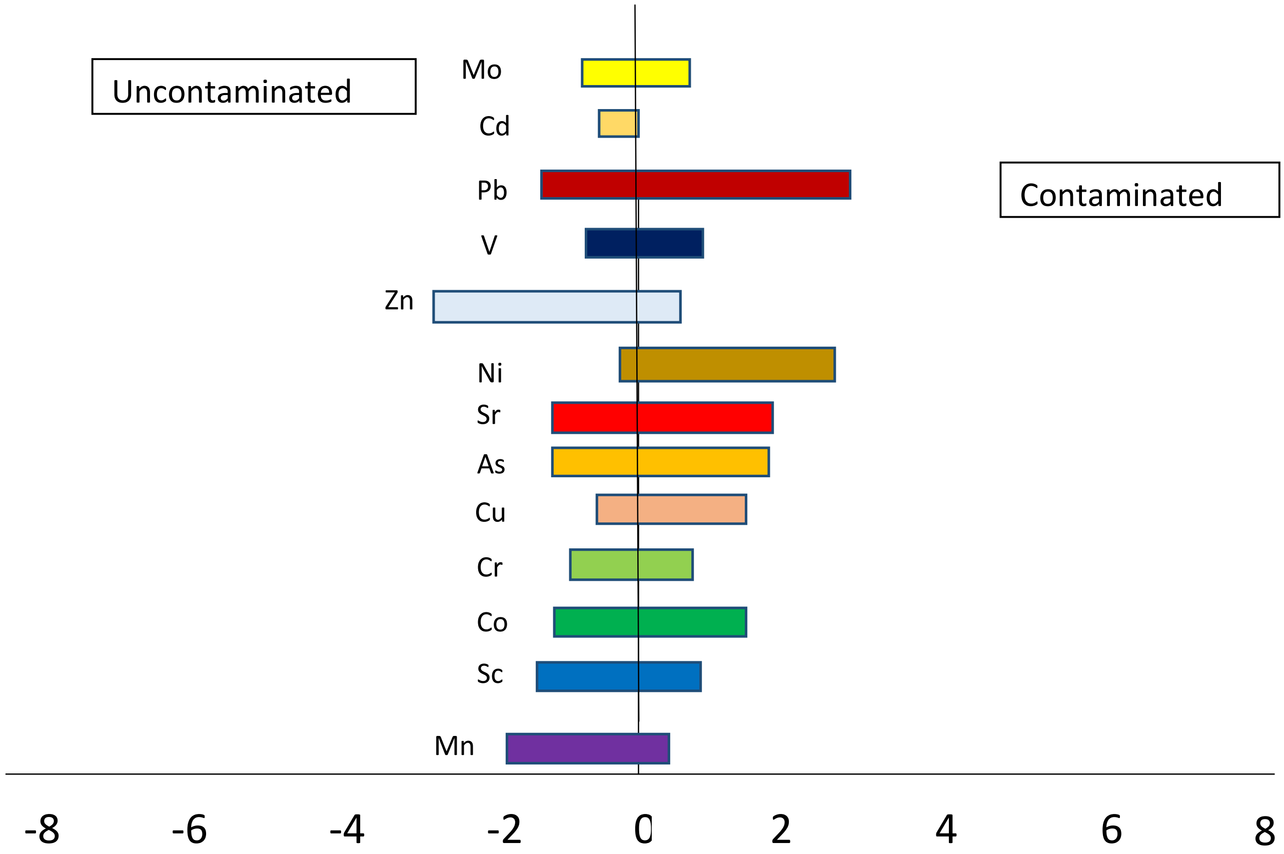

Figure 5: Geoaccumulation Index (Igeo) for metal of the study area

3.6. Contamination Factor and Degree of Contamination

The level of contamination in the soils of the study area as shown by the categories of contamination factor is presented in Table 11 and Figure 6.

Table 11: Contamination Factors for the Soils of the study area

Categories		Mo	Cu	Pb	Zn	Ni	Co	Mn	Sc	As	Sr	Cd	V	Cr
$C^i_f < 1$	Low Contamination factor													
$1 \leq C^i_f < 3$	Moderate Contamination Factor	1.40	2.10	2.00	1.00		2.00	1.03	1.40	2.00	2.00	2.00	1.00	1.80
$3 \leq C^i_f < 6$	Considerable Contamination factor					4.00								
$C^i_f \geq 6$	Very High Contamination Factor													

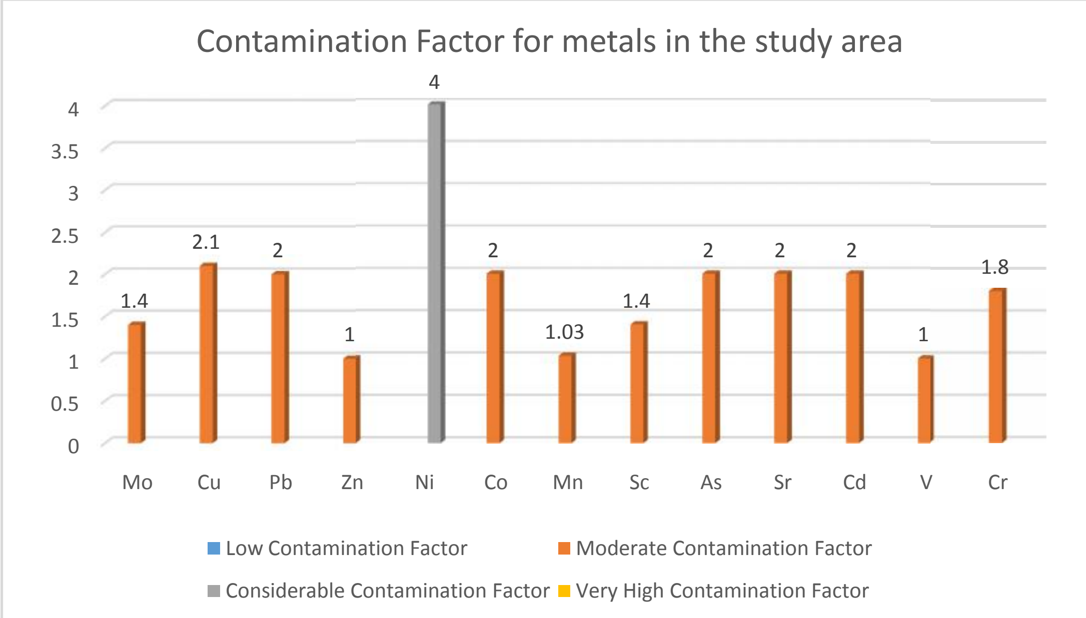

Fig 6: Contamination factor for metals in the soils of the study area

The soils of Oluyole Industrial estate showed a Moderate Contamination Factor for all the metals studied excepting only Ni. The Contamination Factor values are as follows: Mn (1.03), Mo (1.40), Cu (2.10), Zn (1.00), Co (2.00), Sc (1.40), As (2.00), Sr (2.00), V (1.00), Cr (1.80), Pb (2.00), Cd (2.00) andNi (4.00), which showed a considerable factor of contamination.

The degree of contamination which gives an assessment of the overall contamination of the soils of the study area is presented in Table 12. The quantification of the overall Degree of Contamination (28.23) of the soils of Oluyole industrial estate indicated a Considerable Degree of metal contamination (Table 13).

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	28.23
$32 \leq C_{deg}$	Very high degree of contamination	

CONCLUSIONS

The mean concentration of the metals in the soils around Oluyole industrial estate area of Ibadan as shown by this study was in the order Mn>Cr>Zn>Pb>Cu>Ni>Sr>Co>Sc>As>Mo>Cd. Factor analysis yielded three factor groupings; Factor 1: Mo, Cu, Pb, Zn, As, Sr and Cd were mainly sourced from felsic mineral-rich lithologies and anthropogenic activities. Factor 2: Ni, Co, Mn, Sc, Sr, V and Cr were sourced mainly from mafic mineral-rich lithologies and influence by geochemical affinity. Factor 3: Sc and V were sourced mainly from mafic mineral-rich lithologies and further influenced by geochemical affinity. Generally, the elemental association in the soils was influenced by lithology, geochemical affinity and anthropogenic activities. Results of Geoaccumulation Index showed that the soils were Practically uncontaminated to Uncontaminated/Moderately contaminated by Zn, Mn, Sc and Cr, moderately contaminated by Mo, Cu, Pb, Ni, Co, As, Cd, moderate to heavily contaminated by Ni and Sr. Moreover, the soil showed Moderate Contamination Factor for all the studied metals excepting Ni which showed Considerable Contamination factor. Overall the soils have considerable degree of contamination value of 28.23. Generally, the considerable degree of contamination for the study area by the studied metals and the considerable factor of contamination for Ni indicated an area with possible health danger to plant, animal and man.Most of the metal contamination of soils in this area derives from industrial activities in the area.

Consequently, it is recommended that these industries improve on their waste disposal techniques in order to reduce the risk posed to the environment through the current practice of indiscriminate disposal of their waste products.

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APPENDIX

Statistical summary of elemental concentrations in the soils of Oluyole industrial estate

	N	Minimum	Maximum	Sum	Mean	Std. Deviation
Mo	21	.60	2.50	24.70	1.18	.52
Cu	21	16.20	76.00	736.30	35.06	14.83
Pb	21	11.40	270.80	1089.7	51.89	56.66
Zn	21	19.00	243.00	1918.00	91.33	56.80
Ni	21	12.60	94.30	726.20	34.58	22.32
Co	21	8.40	60.30	543.20	25.87	12.24
Mn	21	266.00	1397.00	15694.00	747.33	287.64
Sc	21	1.40	7.50	71.50	3.40	1.74
As	21	.60	3.40	28.30	1.35	0.59
Sr	21	13.00	90.00	682.00	32.48	19.21
Cd	21	.09	.40	3.22	.15	.09
V	21	30.00	127.00	1530.00	72.86	23.85
Cr	21	45.00	145.00	1927.00	91.76	28.55
Valid N (listwise)	21					