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Assessment of Trace metal contamination of soils around New Garage Motor Park in Ibadan, southwestern Nigeria

Roland A. Isibor

Department of Earth Sciences, Ajayi Crowther University, Oyo, Oyo State, Nigeria.

Abstract

In order to assess the level of metals concentrations and possible contamination around the New Garage motor park in Ibadan, fourteen topsoil samples were collected and analyzed for Mo, Cu, Pb, Zn, Ni, Co, Mn, Sc, As, Sr, Cd, V, and Cr using the Inductively Coupled Plasma Mass Spectrometry (ICP-MS) technique. Indices of contamination including geoaccumulation index, contamination factor and degree of contamination were applied to the data set in order to determine the level of these metals contamination of the soils. Results showed that the mean concentration of the metals were in the following order: Mn>Pb>Zn>Cr>V>Cu>Sr>Ni>Co>Sc>As>Mo>Cd. Elemental associations, as determined by factor analysis, indicated four metal groupings. Generally, the metals associations in the soils were influenced mainly by rock types, geochemical affinity and anthropogenic input. Results of the geoaccumulation index showed a soil that is practically uncontaminated to extremely contaminated by the metals studied. Cd and Pb showed considerable contamination factor and very high contamination factor respectively. The overall assessment of the soils of the New Garage motor park area using the degree of contamination indicated a soil with very high degree of contamination with a value of 48.84. This study showed that the soils around the New garage motor park is highly contaminated by the metals studied with possible severe health implications.

Keywords: Geoaccumulation index, Contamination factor, Degree of contamination, Soils, Motor Park, Ibadan.

1.0 Introduction

Trace metals enter into the environment as a result of natural geochemical processes and from several anthropogenic sources. Anthropogenic sources arising mostly from industrialization and urbanization include waste from industries, markets, automobile, agricultural and domestic activities [1]. The excessive concentration of some of these trace metals leads to the pollution of the environment and consequently poses issues of health to man.

Emissions from automobile, which has been shown to contain metals such as Pb, Zn, Cd, and Ni, has been shown to be the greatest single source of contamination to the environment [2]. In Nigeria, exhaust from automobiles account for about 80% of air pollution and increased automobile transportation has contributed markedly to the problem of soil contamination in most cities [3].

Ibadan city is underlain by the Precambrian Basement Complex of South-western Nigeria. Several workers have described the general geology of the Nigerian basement complex,However, based on the classification scheme developed for the Basement Complex by Jones and Hockey[4],Rahaman [5]and Dada[6], the rock suites were classified as follows:Migmatite - Gneiss Quartzite Complex Suite, Metasedimentary and metavolcanic rocks (Schist Belts), Pan African Granitoids, Undeformed acid and basic dykes. These rock suites have undergone four major orogeny including the Liberian (2800±200my), the Eburnean (2100±200my) Kibarian (1100±250my), and the Pan African (600±150my) [7, 8, 9].

The New Garage in Ibadan is a large public motor park built by the state government for proper regulation and control of public intra/inter-state transportation. It serves as terminal for several vehicles travelling to different states of Nigeria from Ibadan. In addition to this function, several other support activities take place in the New Garage motor park including servicing and repairs of auto-vehicles. These activities generate wastes such as grease oil, suspended solids, cyanides, alkali organic solvents containing trace metals that may be injurious to plants, animals and man [10]. Consequently, it is important

Corresponding author:Roland A. Isibor, E-mail:jeremiah204@yahoo.com Tel.: +2348037157200

to assess the possible trace metal contamination of the New Garage area of Ibadan.
The objective of this study is therefore, to determine the concentrations and degree of trace metal contamination of soils in the New Garage area of Ibadan using soil metal concentration, geoaccumulation index, Contamination factor and Degree of contamination index.

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 $3^0 50'30''$ E and $3^0 56'00''$E and latitude $7^0 17'30''$ N and $7^0 23'00''$ N. Notable areas covered by the study area include Podo and Aiyetoro (Fig. 1).Ibadan falls within the humid tropical region having an averagely high temperature of 26.6^0C throughout the year with a mean temperature of about 21^0C. The relative humidity of the area is averagely high throughout the year and this is attributable to the prevalence of moisture-laden tropical maritime air mass over the area. Generally, between March and October, Ibadan is under the influence of the moist maritime south-west monsoon winds (wet season), while the dry season occurs normally 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 [11].

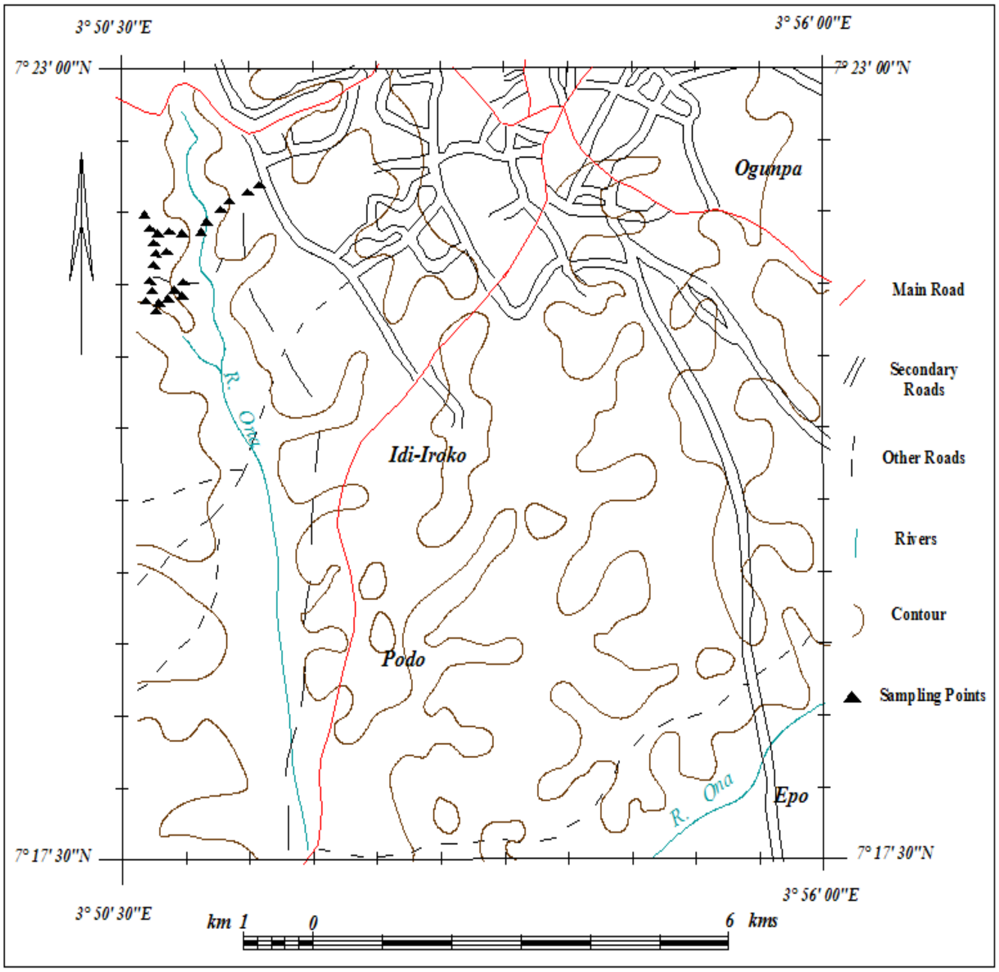

Fig. 1: Location map showing New Garage area of Ibadan

Geologically, Ibadan is underlain by Precambrian Basement Complex of South-western Nigeria.The Nigerian basement complex, composed mainly of magmatic and granitic gniesses, extends westwards and is continuous with the Dahomeyan of the Dahomey-Togo-Ghana region. It lies within the Pan African mobile belts, to the east of Africa craton [4, 5, 6]. Quartzite, banded gneiss, augen gneiss, and amphibolite are examples of rock types found within the study area (Fig. 2).

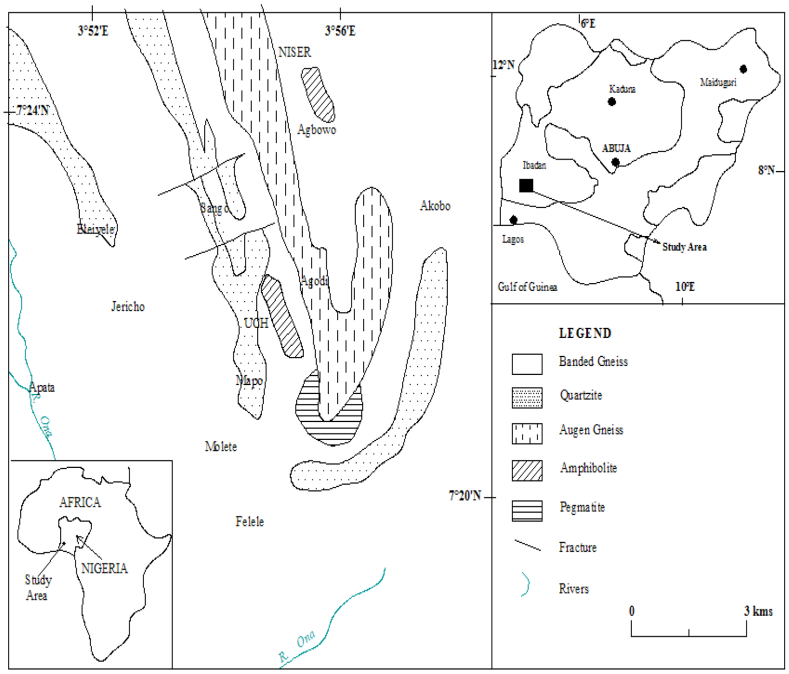

Fig. 2: Geological Map of Ibadan.

Samples for this study were collected from the New Garage motor park area of Ibadan (Fig. 3). Topsoil samples were taken from 14 different locations at a depth of 0 to15 cm. In order to avoid possible metal contamination the samples were collected using plastic hand trowel and kept in polyethylene bags.

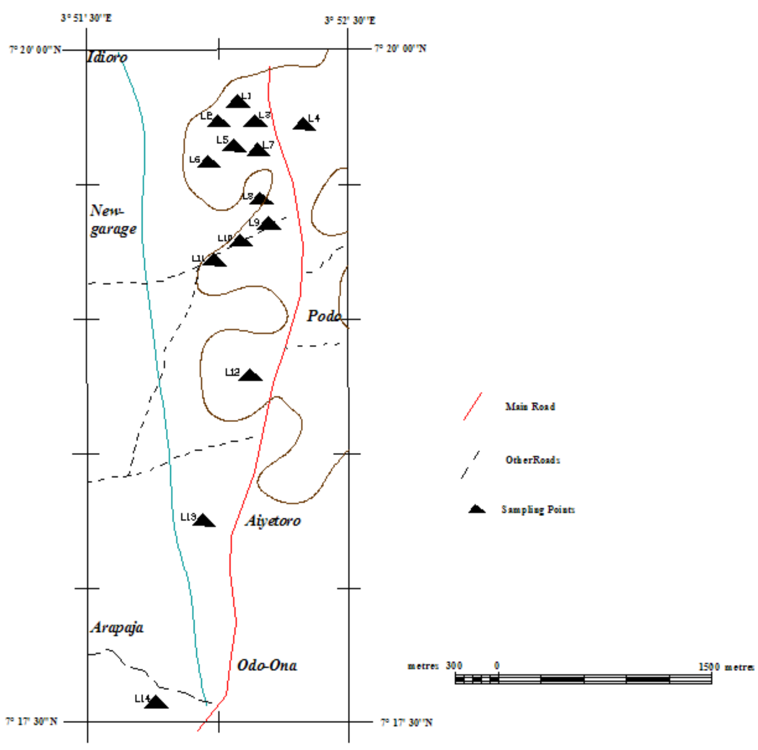

Fig. 3: Points of Sample Collection

The soil samples were air dried for two weeks in the laboratory. The dried sample were then disaggregated, where necessary, in a mortal and sieved through a <0.075mm polyethylene sieve.Sieving was done by the use of a mechanical sieve shaker. The fine grained portion (<0.075mm) was collected and packed into air-tight polythene bag which was later sent to ACME laboratories, Canada for geochemical analysis.
Aqua Regia Digestion Method was employed to digest the soil samples. To achieve this 0.5g of each sample was digested using aqua regia (0.5ml H_20, 0.6ml concentrated HNO_3 and 1.8ml concentrated HCl). After 2 hours of heating at 95°C, the solutions were cooled and diluted to 10ml by volume with deionized water.

2.2 Analytical Methods

The Inductively Coupled Plasma Mass Spectrometry (ICP-MS) techniquewas used to determine the concentration of the elements. This involved converting the aqueous sample to aerosols via a nebulizer. The aerosols were transported to the inductively coupled plasma where the elements are heated and excited to different atomic and/or ionic states and produce characteristic optical emissions (lights). These emissions are separated based on theirrespective wavelengths and their intensities are measured (spectrometry). The intensities areproportional to the concentrations of the elements in the aqueous sample.

2.3 Data Analysis

Series of statistical and geochemical techniques were employed to analyze the data generated. The statistical analysis include descriptive statistical analysis such as mean, median, mode, and standard deviation. The degree of correlation between the studied metals was determined from the correlation matrix. Principal component analysis was also used for apportioning and identifying pollution sources.

2.4 Contamination Indices

Three contamination indices, Geo-acccumulation index, Contamination factor, and Degree of contamination were used for the quantification of the level of pollution of the selected metals in the study area [12, 13, 14]. The Index of geoaccumulation (Igeo) was computed using an equation developed by Muller [12] and expressed mathematically as:

$$Igeo = \log_2 Cn/1.5Bn \quad (1)$$

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 level of soil pollution wass then compared to the following values of Igeo as shown in Table 1.

Table 1: Classes of Geoaccumulation Index (Igeo) after Muller [12].

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

The factor of contamination compares the currently observed elemental concentrations with that of its pre-industrialized level [13]. The factor of contamination is computed using the following formula:

$$C^i_f = C^i_{0-i}/C^i_n \quad (2)$$

Where:
C^i_{0-i} *= mean concentration of metals from at least 5 sampling sites.*
C^i_n *=pre – industrial concentration (for this work: values obtained from a controlled sample from Olapiti village, an area free from industrial influence was used as background) of the individual metal*
Contamination factor is a single element index (Table 2). The degree of contamination is the summation of the contamination factors for all studied metals as shown in Table 3.

Table 2: Categories of Contamination factor

Class of Contamination factor	Soil Category
$C^i_f < 1$	low contamination factor
$1 \leq C^i_f < 3$	moderate contamination factor
$3 \leq C^i_f < 6$	Considerable contamination factor
$\leq C^i_f$	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 Geochemical Results

Results showed that the minimum value for Mo is 0.40ppm while the maximum value is 2.90ppm, with a mean value of 1.29ppm and standard deviation value of 0.76ppm (Table 4). Cu ranged from 13.80ppm to 184.70.00ppm and it has a mean value and standard deviation value of 47.57ppm and 42.26ppm respectively (Table 4). Pb ranged from 16.40ppm to 6670.40ppm, with a mean value of 569.53 and standard deviation of 1758.21. Zn has a mean value and standard deviation value of 216.00ppm and 218.93ppm; it also ranged from 54.00ppm to 877.00ppm (Table 4).
The minimum value for Ni is 5.90ppm, while the maximum value is 92.40ppm with a mean value of 24.80ppm and standard deviation value of 27.05ppm. Co ranged from 7.80ppm to 43.30ppm with a mean value and standard deviation value of 15.49ppm and 10.80ppm respectively. Mn has a mean value of 720.71ppm and a standard deviation value of 279.98ppm, and it also ranges from 422.00ppm to 1315.00ppm (Table 4).
Sc ranged from 1.60ppm to 7.10ppm, with a mean value of 3.08ppm and a standard deviation of 1.51. As has a minimum value of 0.40ppm, maximum value of 4.30 a mean value of 1.54ppm and a standard deviation of 47.39. Sr ranged from 11.00ppm to 199.00ppm, with a mean value of 42.14ppm and a standard deviation of 47.39. The minimum value for Cd is 0.09ppm, while the maximum value is 2.50ppm. It has a mean value of 0.42ppm and standard deviation value of 0.66ppm. V ranged from 28.00ppm to 108.00ppm, with a mean value of 57.21ppm and standard deviation value of 48.15ppm. Cr ranged from 22.00ppm to 181.00ppm with a mean value and standard deviation value of 70.64ppm and 48.15ppm respectively (Table 4).

Table 4: Statistical summary of elemental concentrations in the soils of New Garage area

	N	Minimum	Maximum	Sum	Mean	Std. Deviation
Mo	14	.40	2.90	18.00	1.28	.76
Cu	14	13.80	184.70	666.00	47.57	42.26
Pb	14	16.40	6670.40	7973.40	569.53	1758.21
Zn	14	54.00	877.00	3024.00	216.00	218.93
Ni	14	5.90	92.40	347.20	24.80	27.05
Co	14	7.80	43.30	216.80	15.89	10.80
Mn	14	422.00	1315.00	10090.00	720.71	279.98
Sc	14	1.60	7.10	43.10	3.08	1.51
As	14	.40	4.30	21.50	1.54	1.12
Sr	14	11.00	199.00	590.00	42.14	47.39
Cd	14	.09	2.50	5.87	.42	.65
V	14	28.00	108.00	801.00	57.21	23.85
Cr	14	22.00	181.00	989.00	70.64	48.15
Valid N (listwise)	14					

3.2 Correlation Matrix

Analysis of the correlation matrix (Table 5)indicated the following relationshipbetween the metals studied.A high positive correlation exist between Mo, Cu, Pb, Zn, Ni, As, Cd and Cr, which indicated a probable common underlying factor (source) for these metals. A negative or low correlation exist between these set of metals and Co, Mn, Sc, Sr, and V, which indicated a possible common underlying factor for Co, Mn, Sc, Sr and V but different from the first set of metals.

Table 5: Correlation Matrix for metals in the soils

	Mo	Cu	Pb	Zn	Ni	Co	Mn	Sc	As	Sr	Cd	V	Cr
Mo	1.000												
Cu	**.731**	1.000											
Pb	**.588**	**.937**	1.000										
Zn	**.810**	**.885**	**.877**	1.000									
Ni	**.533**	.221	.089	.188	1.000								
Co	-.017	-.127	-.202	-.026	.482	1.000							
Mn	.412	-.049	-.182	.227	**.571**	**.696**	1.000						
Sc	-.317	-.136	-.232	-.377	.041	.176	-.096	1.000					
As	**.798**	**.805**	**.723**	**.773**	.319	-.036	.044	-.286	1.000				
Sr	-.103	-.021	-.084	-.076	.039	.102	.154	.251	-.019	1.000			
Cd	**.803**	**.927**	**.919**	**.893**	.332	-.238	-.003	-.313	**.786**	-.021	1.000		
V	.056	.023	-.125	.003	.331	**.822**	.453	.436	.152	.103	-.181	1.000	
Cr	**.529**	.199	.132	.200	**.928**	**.598**	**.613**	.002	.338	-.048	.270	**.515**	1.000

3.3 Factor Analysis

A common first step of many data analyses that involve more than a few variables is to run a correlation matrix of all variables and then examine it for expected (and unexpected) significant relations. The correlation matrix shows the strength of a linear relationship between any two variables. Its scale of measurement range from 1 (perfect sympathetic relation) through 0 (no relation or random relation) to -1 (perfect inverse relation).Principal component extraction method was applied in order to reduce the data set into principal components that will indicate common underlying factors. The metals studies were divided as a result into four 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 7explained the total system variance of the metals in the soils.

Table 6: Factor Analysis showing the Rotated Component Matrix of the Study Area

	Component			
	1	2	3	4
Mo	**.727**	**.601**	-.165	-.066
Cu	**.975**	.069	.040	-.027
Pb	**.953**	-.095	-.077	-.077
Zn	**.913**	.166	-.224	.046
Ni	.156	**.874**	.097	.197
Co	-.144	.332	.049	**.904**
Mn	-.077	**.734**	-.126	.457
Sc	-.200	-.042	**.881**	.148
Sr	-.012	.037	**.577**	-.021
Cd	**.927**	.238	-.082	-.225
V	.027	.177	.345	**.887**
Cr	.153	**.820**	-.002	.401

Table 7: 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	5.883	39.223	39.223	5.883	39.223	39.223	5.025	33.499	33.499
2	3.930	26.199	65.422	3.930	26.199	65.422	3.441	22.939	56.437
3	1.957	13.044	78.465	1.957	13.044	78.465	2.246	14.976	85.784
4	1.098	7.319	85.784	1.098	7.319	85.784	2.156	14.370	85.784
5	.930	6.199	91.983						
6	.563	3.752	95.736						
7	.390	2.600	98.336						
8	.107	.712	99.048						
9	.089	.592	99.641						
10	.041	.272	99.912						
11	.010	.066	99.978						
12	.003	.017	99.996						
13	.001	.004	100.000						

The factor groupings are as follows:

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

Factor 1 which explains 33.499% of the system variance (Table 7), has a high positive factor loading on Mo, Cu, Pb, Zn, As and Cd (Table 6). 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: Mo, Ni, Mn and Cr

Factor 2 which explain 22.94% of the total system variance (Table 7), has a high positive factor loading on Mo, Ni, Mn and Cr (Table 6). The elemental association in Factor 2 is controlled mainly by mafic mineral-rich lithologies.

Factor 3: Sc and Sr

Factor 3 which accounts for 14.98% of the total system variance (Table 7), has a moderate positive factor loading on Sr and a high positive factor loading on Sc (Table 6). According to Goldschmidt's classification of elements, Sc and Sr are lithophiles elements. The association of elements in this factor is influence by both mafic mineral-rich lithology, geochemical affinity and anthropogenic contributions.

Factor 4: Co and V

Factor 4 accounted for 14.37% of the total system variance (Table 7) has a high positive loading on Co and V (Table 6). The association of elements in this factor is influence by both mafic mineral-rich lithology and geochemical affinity.

3.4 Contamination Indices

3.5 Geoaccumulation Index (I_{geo})

Commonly the average crustal value is used as background for calculation of Geoaccumulation indices however for this study a controlled sample from Olapiti village an area free from industrial influence was used as background value (Table 8) for each metal.The range of Geoaccumulation indices for the soils of the study area is presented in Table 9.

Table 8: Result of the 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**

Table 9: Range of Geoaccumulation indices for soils of New Garage

Metals	Minimum	Maximum
Mo	-0.8	1.3
Cu	-0.8	2.9
Pb	-1.1	7.6
Zn	-1.3	2.7
Ni	-1.3	2.7
Co	-1.3	1.1
Mn	-1.4	0.3
Sc	-1.4	0.8
As	-1.2	2.3
Sr	-1.5	2.7
Cd	-0.7	4.1
V	-1.5	0.4
Cr	-1.7	1.3

Mo ranged from -0.8 to 1.3 indicating asoil that is practically uncontaminated to moderately contaminated in Mo (Table 9).Cu ranged from -0.8 to 2.9 which showed that the soils were practically uncontaminated to heavily contaminated in Cu (Table 9).Pb ranged from -1.1 to 7.6 indicating a soil that is practically uncontaminated to extremely contaminated by Pb. The high value of Pb in the area could be linked to automobile emissions from high traffic density, mechanic workshops, and wear and tear of tires. 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 to which Zn is added as an addictive. Ni ranged from -1.3 to 2.5 which showed that the soilsare practically uncontaminated to heavily contaminated by Ni (Table 9). In the soils of New garage area, the highest concentration of Ni (2.7) at location 10 is attributed to the contributions of mechanic workshop in that area. Ni is used as electrodes in Nickel-cadmium batteries, in which nickel hydroxide is the positive electrolyte.Co ranged from -1.3 to 1.1 showing that the soils are practically uncontaminated to heavily contaminated by Co (Table 9). The high 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 -0.9 to 0.3 which showed that the soils are practically uncontaminated to moderately contaminated by Mn (Table 9). Cd ranged from -0.7 to 2.9 indicating that the soils are practically uncontaminated to heavily contaminated by Cd (Table 9). The high value of Cd could be linked to the book publishing, and plastic manufacturing companies in the area.Cr ranged from -2 to 1 which showed that the soils are practically uncontaminated to moderately contaminated by Cr (Table 9). Sr ranged from -2 to 3 showing that the soils are practically uncontaminated to heavily contaminated by Sr (Table 9). V ranged from -1 to 0 which showed that the soils are practically uncontaminated by V (Table 9).Sc ranged from -0.6 to 0.2, which showed that they are practically uncontaminated to moderately contaminated by Sc (Table 9).As ranged from -1 to 0 which showed that the soils are practically uncontaminated by As. The high value of As can be linked to the activities of some industries such as smelting, animal feed mills. As is an addictive in feed mills. Furthermore, the classes of index of geoaccumulation was divided into two: Contaminated and Uncontaminated. The uncontaminated include all values from zero and below. This include all negative geoaccumulation values, while the contaminated include all values from zero and above. This include all positive geoaccumulation values. Figure 4 showed the range of uncontaminated to contaminated for each metal in the soil of the study area.

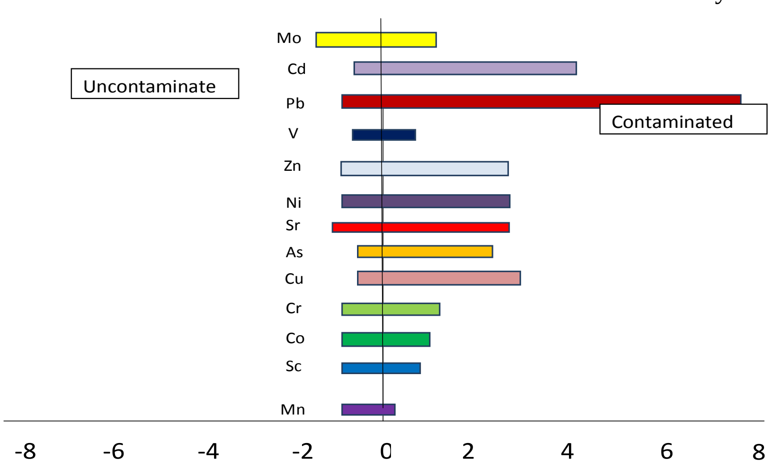

Figure 4: Geoaccumulation Index (Igeo) for metal of the study area

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 5 respectively.

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	57	21	14	29	43	86	71	79	36	29	43	43	43
1	0 < Igeo ≤ 1	Uncontaminated to Moderately Contaminated	29	50	29	36	36	7	29	21	36	50	14	57	43
2	1 < Igeo ≤ 2	Moderately Contaminated	14	21	29	21	7	7	nil	nil	21	14	29	nil	14
3	2 < Igeo ≤ 3	Moderate to Heavily Contaminated	nil	7	14	7	14	nil	nil	nil	7	nil	7	nil	nil
4	3 < Igeo ≤ 4	Heavily Contaminated	nil	nil	7	7	nil	nil	nil	nil	nil	7	nil	nil	nil
5	4 < Igeo ≤ 5	Heavily to Extremely Contaminated	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	7	nil	nil
6	Igeo > 5	Extremely Contaminated	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	7	nil	nil

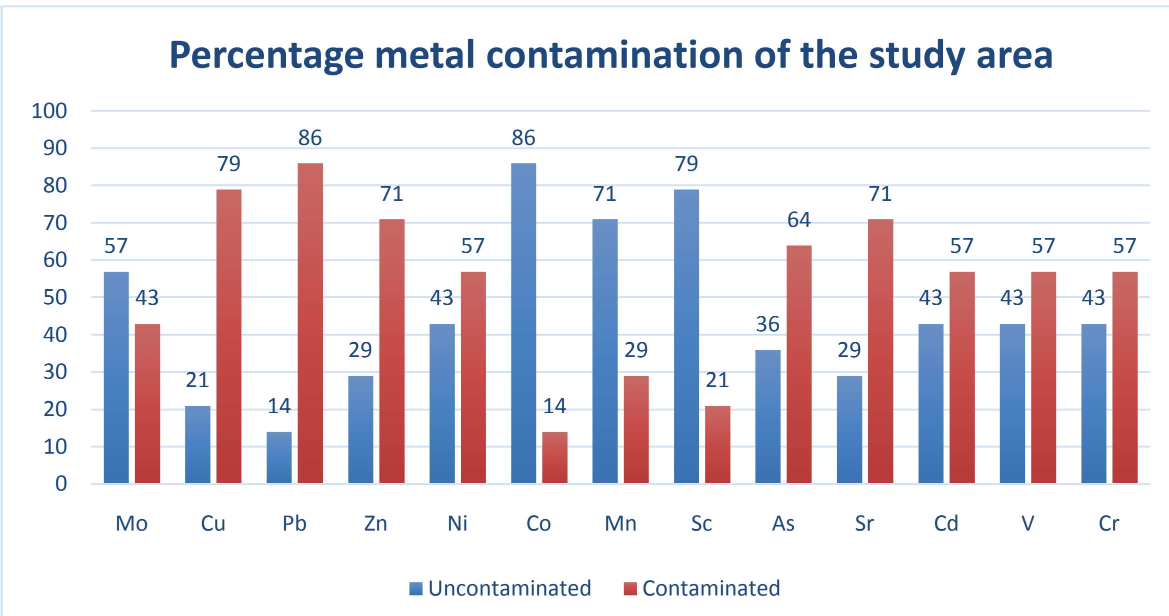

Figure 5: Percentage Metal contamination of the soils of the study area

3.6 Contamination Factor and Degree of Contamination

The Factor of Contamination showed that the soils of New Garage motor park area is only slightly contaminated byMn (0.99), moderately contaminated by Mo (1.53), Cu (2.88), Zn (2.44), Ni (2.65), Co (1.19), Sc (1.25), As (2.52), Sr (2.03), V (1.07), Cr (1.45), considerably contaminated by Cd (4.51) and highly contaminated by Pb (24.33) (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**							0.99						
$1 \leq C^i_f < 3$	**Moderate Contamination Factor**	1.53	2.88		2.44	2.65	1.19		1.25	2.52	2.03		1.07	1.45
$3 \leq C^i_f < 6$	**Considerable Contamination factor**											4.51		
$C^i_f \geq 6$	**Very High Contamination Factor**			24.33										

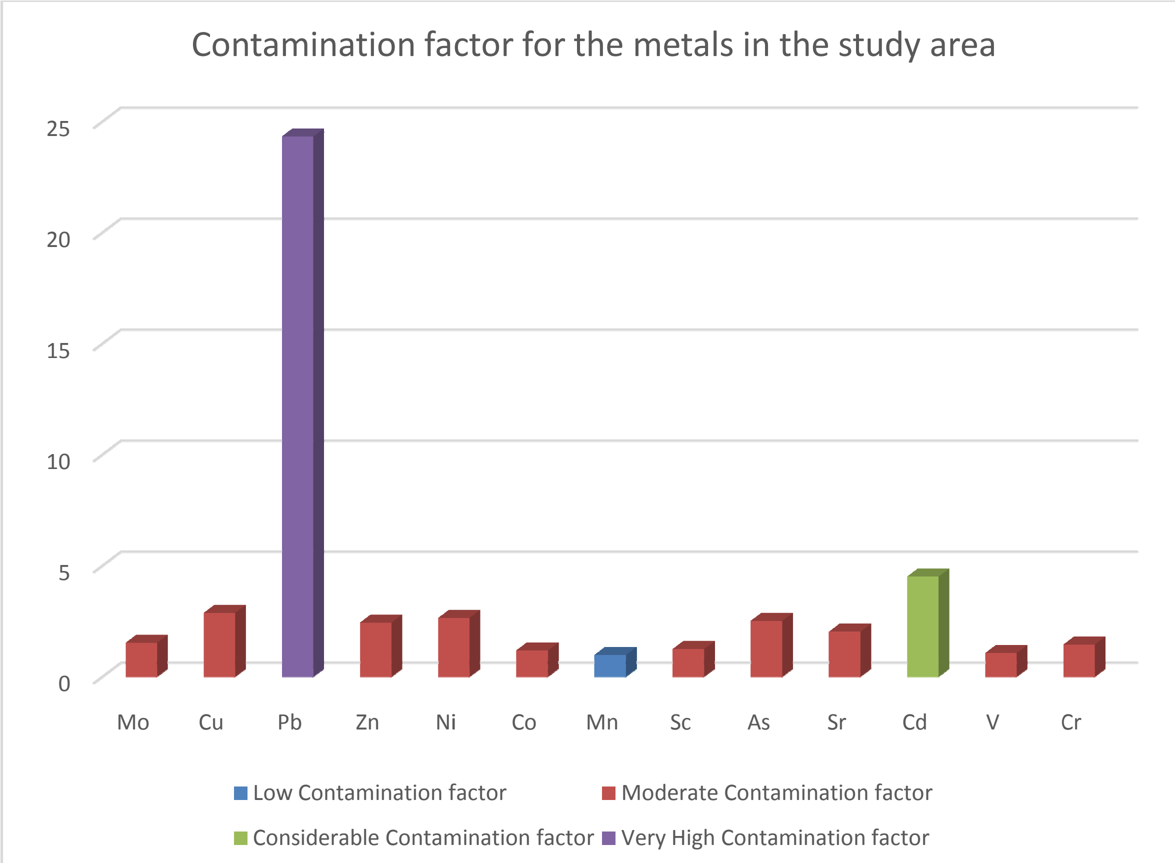

Fig 6: Contamination factor for metals in the soils of the study area

An assessment of the overall pollution of the soils of New Garage motor park area using the degree of contamination showed that area is very highly polluted (Tables 12).

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	
$32 \leq C_{deg}$	Very high degree of contamination	48.84

4.0 Conclusions

The mean concentration of the metals in the soils around New Garage area of Ibadan is in the order Mn>Pb>Zn>Cr>V>Cu>Sr>Ni>Co>Sc>As>Mo>Cd. Four elemental groupings were obtained from factor analysis; Factor 1: Mo, Cu, Pb, Zn, As and Cd were mainly sourced from felsic mineral-rich lithologies and anthropogenic activities. Factor 2:Mo,Ni, Mn and Cr were sourced mainly from mafic mineral-rich lithologies . Factor 3: Sc and Sr were sourced mainly from mafic mineral-rich lithologies and further influenced by geochemical affinity. Factor 4: Co and V were sourced from mafic-mineral rich lithologies. Generally, the elemental associations in the soils were influenced by lithology, geochemical affinity and anthropogenic activities. Results of Geoaccumulation Index showed that the soils were practically uncontaminated to moderately contaminated by Mn, Sc and V, moderately contaminated by Mo, Co, and Cr, moderate to heavily contaminated by Cu, and As, heavily contaminated by Pb, Zn and Sr, heavily to extremely contaminated by Cd. Moreover, the soil showed considerable Contamination Factor for Cd and Very high contamination factor for Pb. Overall the soils have very high degree of contamination value of 48.84. Generally, the very high degree of contamination for the study area and the considerable factor of contamination for Cd and the very high contamination factor for Pb indicated an area with very high level of metal contamination which portends a great danger to the health of plant, animal and man.

5.0 References

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