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Geochemical Assessment of Soils around Metal Recycling Industrial Areas in Ikorodu, Southwestern Nigeria

By Smart, M. O., Fawole O.A., Isola J. O. & Olatunji O.A

University of Ibadan

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Geochemical Assessment of Soils around Metal Recycling Industrial Areas in Ikorodu, Southwestern Nigeria

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The Enrichment Factor calculated also showed extremely high enrichment of lead in the soils of the study area (621). The contamination factor calculated showed that Pb and Zn are the elements contaminating the soils mostly. While zinc moderately contaminated the soil of the study area with a contamination factor of 4, lead extremely contaminated the soil with a contamination factor of 89. The other elements showed less contamination of the soils of the study area. The Pollution Load Index (PLI) showed the soils of the study area are not highly polluted (PLI<1) but highly contaminated.

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I. Introduction

Heavy metals are released into the environment by both natural and anthropogenic sources. Soils derived from the physical and chemical weathering of parent materials contain elevated levels of trace elements form the natural sources, the fossil fuel combustion, abrasion of vehicular components and their exhaust emissions, incinerators, power plants and foundry operation. (Jung, 2001, Lee *et. al* 2005, Park *et.al* 2006). Mining, smelting and the associated activities are known to cause contamination and pollution to soils, plants, atmosphere and surface waters through anthropogenic sources. Among the numerous environmental pollutants, an important role is ascribable to heavy metals whose concentration in soils, water and air are continuously increasing in consequence of anthropogenic activity.

According to Adefolalu (1980) and Mabogunje (1980), in developing countries like Nigeria, improved road accessibility creates a variety of ancillary employment which range from vehicle repairs, vulcanizer and welders to auto-electricians, battery chargers and dealers in other facilitators of motor transportation, disposal of industrial wastes, application of fertilizers, metal sheets wire, pipes, unaccessible rocks and burning of coal. These activities send trace metals into the air and the metals subsequently are deposited into nearby soils, which are absorbed by plants on such soils concentration in roadside soil and those in the dust falls. Trace metals in the soils and rocks can also generate airborne particles and dusts, which may affect the air quality human beings breath in (Gray *et al*., 2003). In the ecological environment heavy metals deposition in soils suppresses plant growth by blocking plant cores and disrupting photosynthesis (Choi *et al*., 2008), and is one of the most important contributors to environmental stress (Petrovský and Ellwood, 1999). Soil typically comprises a complex mixture of different elements and compounds (Dallarosa *et al.,* 2008) with heavy metal content particularly significant due to its toxicity and harmful effects on health.

Since trace metals in soils are emitted both from natural sources such as deserts and bared soils (Choi *et al*., 2001; Fang *et al*., 2002; Zhang *et al*., 2010b) and from anthropogenic processes, a challenge to these investigations is to separate contributions from the two primary causes. In urban areas the diversity of possible anthropogenic emissions renders source assignation difficult (Choi *et al*., 2001; Kim *et al*., 2008; Zhang *et al*., 2012b). Although many investigations show that geochemical methods are useful for detecting trace metal sources (Wang et al., 2005; Kim et al., 2007), they are time-consuming and expensive.

II. Methodology

The study area falls within the tropical rainforest zone of Nigeria with annual rainfall ranging between 1500mm and mean annual temperature distribution of

Author α σ ρ: Department of Crop Production Technology, Federal College of Forestry, Jericho, Ibadan. e-mail: fawoleolakunle@yahoo.com
Author ω: Department of Geology, University of Ibadan.

27°c with two distinct seasons, the dry and wet seasons. The wet season occurs between occurs between April and October with a break in August, the dry season lasts from November to April with a cold harmattan spell between December and January. The temperature averages about 25°c in the rainy season and about 28°c in the dry season. Materials used for field sampling include the soil auger, generator, Global Positioning System (GPS), stepdown transformer, field boots and notebooks, sample bags, heavy duty elbow length rubber gloves, etc. The sample locations were concentrated mainly on Iron and Steel industries which are located within Ikorodu area covering a distance of about 5km.

The soil samples were taken at a depth ranging from 0-15cm within the topsoil. The samples were collected using a soil auger. The samples were taken at each sample location site and kept inside the sample bags. They were later air dried for three weeks and then brought to the lab for sieving. The soil samples were sieved to a minimal size of 75μm and analysed for elemental constituents.

III. Results and Discussion

The results for the geochemical analysis revealed varying concentration for different elements in the sampled media employed in the study. The identified trace element content of the analysed soil samples include Mo, Cu, Pb, Zn, Ni, Co, Mn, V, Sr, Cr and Ba. Other elements like As, Au, Be, Cd, Y, Nb, e.t.c were found to be below the Metal Detectable Limit (MDL) and were screened out.

The descriptive statistical table (table 1) shows that most of the elemental concentrations are enriched in soil. Mean concentration of Lead (Pb) in soils (1782ppm) observed around the factories can be said to be high when compared with Ibadan, Benin and UK soils which have concentration of 95.1ppm, 232.2ppm, and 300ppm respectively (Odewande and Abimbola, (2008), Olatunji *et.al* (2014), Chen *et.al* (1999)). This may be due to the smelting of Pb, disposal of factory wastes especially tyre wears practised in the area and unused metal scraps containing high concentration of Pb. The lowest values of Pb were recorded around less-built areas with roads that have less traffic suggesting that disposal of wastes (which are always close to the industries) has contributed to the high presence of Pb in the area of study.

The mean concentration of Zinc (3887ppm) present in the area of study area shows an average high concentration Zn when compared also with Ibadan and Benin soils with mean concentrations of 22.86ppm and 758.5ppm respectively (Odewande and Abimbola (2008), Olatunji *et.al* (2014)). This could be to due Zn usage in galvanizing of iron practised in the area thereby forming aerosols with the geogenic atmospheric particles present in the area which later settles in the soils.

The average concentration of Copper (474ppm) noticed in the soils of one of the industry could be said to be high when compared to the average mean of copper found in the soils of Ibadan and US soils with concentrations of 4.74ppm and 7.4ppm respectively (Oyeleke *et al.,* 2015, Tahir *et al*., 2007). This may be due to the smelting of copper in the industries and application of agricultural chemicals.

Manganese (Mn) has a high concentration of 950ppm and the highest mean value of 8414ppm indicating that it is the most widely distributed element in the soils of the area of study. This can be due to its geogenic factor in the soil in addition with Mn usage in production of dry batteries, which are later disposed in the area, and its usage as alloy of metal to provide strength and magnetism.

Molybdenum (Mo), Nickel (Ni), Cobalt (Co), Vanadium (V), Strontium (Sr) and Chromium (Cr) all have highest concentrations less than the ASC in the soil indicating little or no significance to the distribution of elements in the area of study.

a) *Factor Analysis*

The 11 elements (Mo, Cu, Pb, Zn, Ba, Co, V, Sr, Ni, Cr and Mn) were subjected to factor analysis, the computation was done using SPSS computer software package. Four factors were identified from the factor analysis and this accounted for 97.35% of the total factors present in the soil samples (Table 3)

Factor 1: Mo, Cu, Zn, Ni, and Ba accounted for approximately 37.11% of the total variance of all the components in the soil. These elements can be said to be derived anthropogenic source especially unused metal scraps and batteries

Factor 2: Pb and Sr accounted for approxiamtely for 25.08% of the total variance of all components in the soil. These elements were derived from smelting of metal ores, disposal of sewage, fossil fuel combustion and incineration at waste dumps which are some of the activities present in the area.

Factor 3: Mn and Co accounted for 18.11% of the total variance of all components in the soil. These elements were derived from manufacturing of alloys, steel and iron products.

Factor 4: Ni and Cr accounted for 17.04% of the total variance of all components in the soil. These were derived from smelting activities going on in the area of study.

b) *Environmental Assessment*

The quality of the environmental media was assessed using geo-accumulation index, Enrichment Factor (EF), Contamination Factor (CF), and Pollution Load Index (PLI) *c) Geochemical Accumulation Index*

The Geochemical accumulation index was used to assess the level of pollution in the soil around the study area. It is calculated by using the equation developed by Muller (1969) as used by Olatunji *et al*., (2014) and it is expressed as;

$$Igeo = Log_2(C_n/1.5*B_n)$$

Where Igeo is the geochemical accumulation index, C_n is the observed concentration of each metal in the soil or dust samples, B_n is the background value obtained for each metal while 1.5 is the multiplication constant.

According to Muller's Geo-accumulation index table (table 4) the calculated Geo-accumulation index showed that Pb, Zn and Ba (0-3, 0-1, and 1 respectively) are metals that have mostly impacted the soils in the study. This is also reflected in the geo-accumulation plot (fig 1). Zinc and Barium have moderate geo-accumulation index (0-1) which could be due to Zn usage in galvanizing iron and presence of Ba in the hazardous waste site found in the area. Pb geo-accumulation index ranges from being unpolluted to strongly polluted. Strong pollution of Pb is observed in some of the soils in the study area. This could be due to smelting of recycled lead and heavy traffic congestion. Co, Mn, V, Sr, Cr, Mo, Ni, all have negative geo-accumulation index, indicating they have not attained the status of pollutant.

d) Enrichment Factor

The Enrichment Factor (EF) classification, Table 5 (Simex and Helz, 1981) was used to evaluate the status of environmental enrichment of metals in the area. As the EF increases the contribution of the anthropogenic origin also increases.

The calculated Enrichment Factor summarized below, table 6 (according to Simex and Helz, 1981) showed that Cu, Mn, V, Sr, Cr have deficient to minimal enrichment (0-1) in the soil samples. Zn has a minimal to significant enrichment of the soils while (1-6) while Pb showed minimal to extremely high enrichment of the soils (1-621), indicating high influence of Pb associated activities in the area of study. The extreme high enrichment of Pb could be due to combustion of fuel and disposal of tyre wears found in the area. The increment in the enrichment of Cu, Mn, V, Sr, Cr, Zn and Pb in soils of the study area also shows an increase in anthropogenic impact on the soils.

e) Contamination Factor

The contamination factor calculation was used to determine the level of contamination of elements in the soil.

Contamination Factor = Mean concentration/ background value of metal

Hakanson *et.al* (1980) classification table (table 7) showed that Sr, Co, Ni and Cr are not forming any form of contamination with the soil of the area. Mo, Mn, Cu and Ba have moderately contaminated the soils (1, 1, 1 and 2 respectively). Zn has contaminated the soil considerably (4) while Pb showed a very high contamination of the soil (89) due to disposal of tyre wears and smelting of recycled lead. These are as reflected in the summarized table below (Table 8).

f) The Pollution Load Index

Pollution Load Index (PLI) was used to measure the quality of the area of study. The soils of the area are generalized and the quality is measured using the Contamination Factor and the number of elements studied. The equation for PLI is thus expressed as;

PLI = (CF1*CF2*…*CFn) 1/n, where n is the number of metals and CF is the Contamination Factor of each medium.

Though it was noticed that there have been contamination by metals of some of the soil samples collected, the pollution load index was calculated to check whether the contamination can lead to pollution of the area. Using the PLI classification (Table 6), it can be concluded that individual soil samples shows little pollution in the area of study while collectively, it can be deduced that the area is not polluted but tending towards pollution (PLI=0.50).

IV. Conclusion and Recommendation

Metal concentration and distribution in soils of Ikorodu metal recycling industrial area using various environmental assessment revealed different levels of contamination. The various evaluation revealed that Pb and Zn are the most enriched in the soils and are also the main causes of contamination in the study area and their major source is from the metal-laden soil generated in the area. The industries (especially those close to the road) are agents of high contamination to the soils of the study area and are also enriching the already present geogenic elemental composition of the area.

Though the pollution level is not high presently, increasing urbanization and industrial activities will increase the contamination rate thereby leading to pollution. The contamination and enrichment of metals (through soils) occurring in the area of study is enough factor to check the activities of these Iron and Steel Industries. The rate of Lead and Zinc concentration they release to the soil is so high and having adverse effect on the livelihood of the area. Consequently, greater environmental awareness needs to be done to develop ways to reduce environmental contamination. Buildings close to these industries should be evacuated or the industries concerned should be relocated away from the habitable environment.

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Table 1: Summary Table for Soil Samples Metal Concentration

Metals	Soil Samples Range	Mean	ASC
Mo	0.8-2	14	2
Cu	14-84	474	50
Pb	13-9945	1782	20
Zn	84-776	3887	90
Ni	6-17	114	80
Co	4-8	58	20
Mn	386-950	8414	850
V	37-70	237	130
Sr	12-309	545	400
Cr	20-43	324	100
Ba	30-49	512	25

Table 2: Total Variance Explained for Metals in Soil Samples

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cummulative %	Total	% of Variance	Cummulative %
1	11.610	52.775	52.775	11.610	59.612	59.612	7.522	37.110	37.110
2	5.685	25.840	78.615	5.685	19.003	78.615	5.662	25.082	62.192
3	2.392	10.873	89.488	2.392	10.873	89.488	4.400	18.114	80.306
4	1.550	7.862	97.350	1.550	7.862	97.350	3.654	17.044	97.350
5	.402	1.827	98.361						
6	.271	1.233	99.594						
7	.035	.160	99.754						
8	.026	.120	99.874						
9	.020	.089	99.963						
10	1.6E-16	7.3E-16	100.000						
11	5.8E-17	2.6E-16	100.000						

Table 3: Component Matrix

	Factor 1	Factor 2	Factor 3	Factor 4	Communalities
Mo	0.73	0.24	0.31	0.52	0.96
Cu	0.93	0.11	-0.13	0.20	0.93
Pb	0.41	0.73	0.43	0.31	0.99
Zn	0.95	-0.04	0.11	0.13	0.93
Ni	0.74	0.22	0.18	0.60	0.99
Co	0.17	-0.94	-0.08	0.25	0.99
Mn	-0.38	-0.70	0.60	-0.03	0.97
V	-0.01	-0.30	0.95	0.12	1.00
Sr	0.39	0.74	0.46	0.27	0.99
Cr	0.33	-0.13	-0.15	0.92	0.99
Ba	0.79	0.27	0.42	0.32	0.99
Eigenvalues	4.08	2.76	2.66	1.87	
% variance	37.11	25.08	18.11	17.04	
%cummulative	59.61	85.16	91.57	97.35	

The loadings with a value ≥ 0.60 are marked in bolds in the table.

Table 4: Geo-accumulation Index Classification (Muller, 1969)

Classes	Ranges	Remarks
0	≤0	Unpolluted
1	0-1	Unpolluted to Moderately polluted
2	1-2	Moderately polluted
3	2-3	Moderately polluted to Strongly polluted
4	3-4	Strongly polluted
5	4-5	Strongly polluted to Extremely polluted
6	>5	Extremely polluted

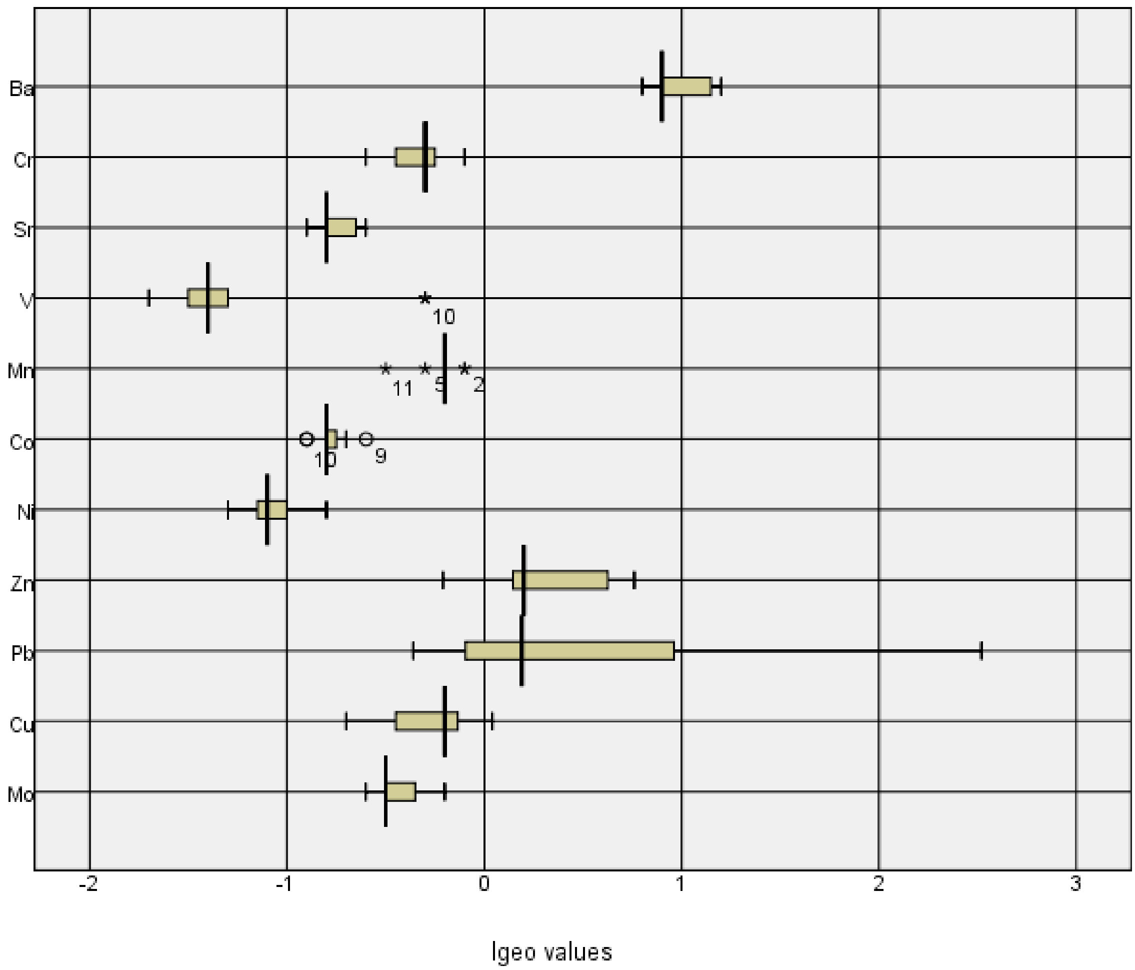

Fig. 1: Geo-accumulation Index Plot

Table 5: Enrichment Factor Classification (Simex and Helz, 1981)

Enrichment Factor	Qualification of samples
EF<2	Deficiency to minimal enrichment
EF= 2-5	Moderate enrichment
EF= 5-20	Significant enrichment
EF=20-40	Very high enrichment
EF>40	Extremely high enrichment

Table 6: Summary Table for Enrichment Factor of Soil Samples

	Soil Samples	
Metals	Range	Average Shale Content
Mo	0	2
Cu	0-1	50
Pb	1-621	20
Zn	1-6	90
Ni	0	80
Co	0	20
Mn	0-1	850
V	0-1	12
Sr	0-1	400
Cr	0-1	130
Ba	0-1	25

Table 7: Contamination Factor Classification (Hakanson et.al., 1980)

Classes	Ranges	Remarks
0	<1	Low Contamination
1	1≤cf<3	Moderate Contamination
2	3≤cf<6	Considerable Contamination
3	cf≥6	Very High Contamination

Table 8: Summary Table of Contamination Factor for Soil Samples

	Soil Samples	
Metals	Contamination Factor	Average Shale Content
Mo	1	2
Cu	1	50
Pb	89	20
Zn	4	90
Ni	0	80
Co	0	20
Mn	1	850
V	1	12
Sr	0	400
Cr	0	130
Ba	2	25

Table 9: Pollution Load Index Classification

PLI Values	Qualification (Geometric mean)
PLI<1	Perfection
PLI=1	Only baseline levels of pollutants are present
PLI>1	Deterioration of site quality

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