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Toxic Metals in Oyo Dumpsite Soils as Potential Hazards to Residents Within Dumpsite Catchment Areas, Southwestern Nigeria

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Abstract— *Heavy metals constitute indispensable raw materials in industries, agriculture, medicine and technology contributing to socio-economic life of man. Though heavy metals are elements required by plant and animals, the toxic level of the metals in soil and water can create serious threats to human health and his environment. The focus of this study is to examine the possible dangers that arbitrary dumping of refuse within residential areas could cause to the environment and the people. Fifteen (15) active dumpsites located between Latitude N07^o 47^l to N07^o 52^l and Longitude N003^o 47^l to E003^o 58^1 were sampled at 10cm depth to the surface. They were air- dried in the laboratory, sieved to 75µm size and pulverized for geochemical analysis using the Atomic Absorption Spectrophotometric (AAS) method. Results show average values of metal concentration in the soils as Fe (49,032.68ppm), Pb (73110.21ppm), Mn (63.57ppm), Cu (21.20ppm), Ni (6.39ppm), Co (0.04ppm), Zn (28.19ppm), Cd (0.05ppm) and Cr (3.61ppm). Heavy metal pollution in the soils were assessed using geoaccumulation index (Igeo), enrichment factor (EF), contamination factor (Cf), and pollution load index (PLI). Results show that the soils are extremely contaminated with Pb but moderately contaminated in Fe while Mn, Cu, Ni, Co, Zn, Cd and Cr all show low level of contamination. The pollution load index of Fe and Pb show high values. The overall results indicated that Fe and Pb are major source of potential hazards in the study area.*

Keywords— *Heavy metals, waste dumpsite, contamination, human exposure, toxicity, hazards.*

I. INTRODUCTION

Indiscriminate refuse disposal without regards for neither environmental pollution nor health implication to residents in the dumpsite catchment areas is a common future in many urban cities in Nigeria. Expectedly, population growth and economic development are major contributors to solid waste generation in developing communities in particular (Verge and Rowe, 2013 and Singh et al., 2011). Minimizing uncontrolled waste disposal habits in urban cities is a matter of serious concern to government and stakeholders if the millennium goal of a healthy environment and sustainable living will be achieved (MDG7, 2005)

Soil is the unconsolidated mineral matter or organic material on the immediate surface of the earth and a natural medium for plant growth, supporting plants and animal existence. Waste discharges can be a major source of anthropogenic contamination to soils especially hazardous wastes that can be a source of different metals in soils from where they can be transferred to plants through several processes (Akinbile and Yusoff, 2012). Heavy metals when present in soil, eventually ends up as contaminants in underground shallow water through percolation and leaching.

Heavy metals are elements with high atomic weights and high density which are naturally occurring in the earth crust. Although heavy metals are naturally occurring elements in the earth crust, most environmental contamination and human exposure results from anthropogenic activities like mining and smelting operations, industrial production, domestic and agricultural use of metals and metal-containing compounds and arbitrary refuse disposal. All these are potential channels where these metals infiltrates into shallow groundwater thereby becoming pollutants. Heavy metal pollution in soils and water could also be geogenic (Grützmacher *et al.*, 2013) as in weathering of rocks and volcanic eruptions.

The factors that determines the toxicity of heavy metals includes the dosage, route of exposure, chemical species, and more importantly, age, gender, genetics, and nutritional status of an exposed individual. Cadmium (Cd), Chromium (Cr), Lead (Pb) and Mercury (Hg) have high degree of toxicity and are classed among priority metals that are of public health concern by WHO (Brathwaite and Rabone, 1985).

Heavy metals occur as trace elements in the earth crust (ppb range to less than 10ppm) and the bioavailability of these metals are influenced by physical, chemical and biological factors among which are temperature, phase association and adsorption, factors influencing speciation at thermodynamic equilibrium, complication kinetics, species characteristics and biochemical/physiological adaptation (Rieuwerts, *et al., 1998*)

II. MATERIALS AND METHODS

Fifteen (15) active dumpsites located within residential areas in Oyo town, delineated by latitude N07^o 47^l to N07^o 52^l and Longitude N003^o 47^l to E003^o 58^l in the Southwestern Basement Complex terrain of Nigeria were sampled (Fig.1).

The surface soil sample were strategically collected at a depth of 10cm close to each waste dumpsite using the hand auger, hand trowel and stored in standard sample bags. The lithology of each location were also studied and recorded. The samples were latter air dried in Ajayi Crowther University (ACU) geology workshop.

The samples were sieved and weight retained on 75µm sieve grounded, pulverized and geochemically analyzed for Fe, Pb, Mn, Cu, Ni, Co, Zn, Cd, and Cr using Atomic Absorption Spectrometry (AAS) Method.

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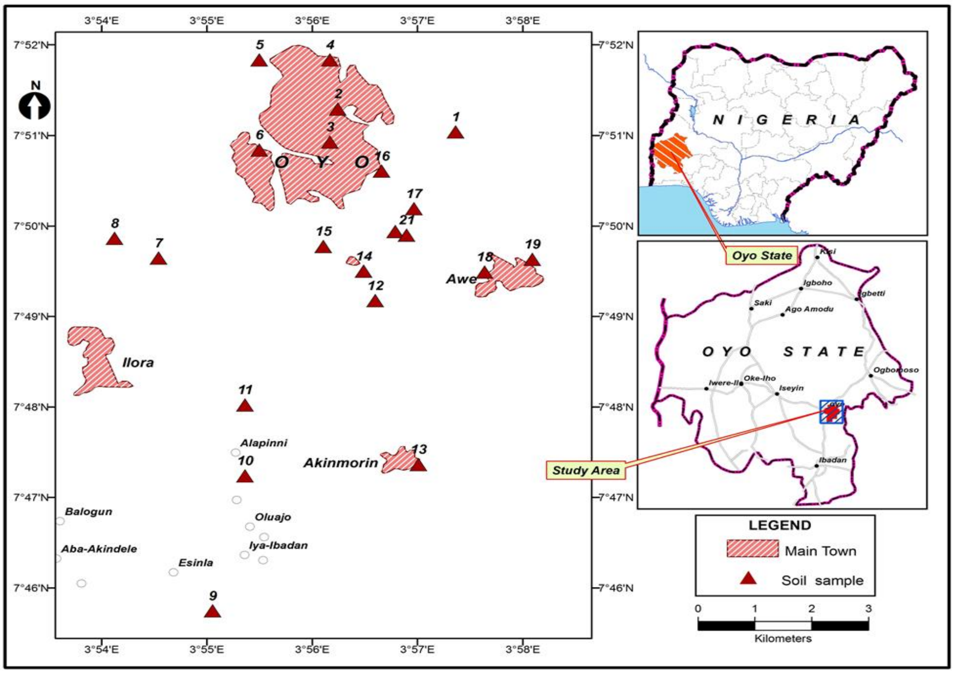

Fig. 1. Sample location map of the study area

Statistical analysis of the geochemical results were done using Microsoft excel 2013 programs. The range of the values, mean and standard deviation were calculated and pollution indices in each dumpsite soil sample assessed on the basis of the geo-accumulation index (I_{geo}) by Muller (1969), enrichment factor (EF) by Ergin et al. (1991), contamination factor C_f by Hakanson (1980) and pollution load index (PLI) by Tomlinson *et al.* (1980).

2.1 Geo-accumulation Index (Igeo)

The Geo-accumulation index (Igeo) proposed by Muller (1969) was calculated by computing the base 2 logarithm of the measured concentration of the metal content over its background concentration using:

$$I_{geo} = \log_2 (C_n/1.5Bn)$$

where, C_n == the measured concentration of metal in the soil sample; B_n = the geochemical background value/average shale concentration and 1.5 is a constant factor neutralizing possible lithological variations of the background data. Muller, (1969) characterizes I_{geo} into 6 class, with varying values and specific contamination level (Table 1).

TABLE 1. Classes of geo-accumulation Index (I_{geo}) for soil after Muller, (1969)

Igeo class	Igeo value	Contaminated level
0	1 geo ≤0	Uncontaminated
1	0<Igeo≤1	Uncontaminated or moderately contaminated
2	1<Igeo≤2	Moderately Contaminated
3	2<Igeo≤3	Moderately or strongly contaminated
4	3<Igeo≤4	Strongly contaminated
5	4<Igeo≤5	Strongly or extremely contaminated
6	Igeo>5	Extremely contaminated

2.2 Enrichment Factor

The enrichment factor (EF) is a calculated value for determining anthropogenic input of metals in soils as proposed by Ergin *et al*. (1991) (Table 2). It is a tool for differentiating crustal from non-crustal origin of metals in soils (Galuszka and Migaszewski, (2011). This is expressed by the relationship:

$$EF = (M/Fe)_{sample}/ (M/Fe)_{background}$$

where $(M/Fe)_{sample}$ = ratio of metal and Fe concentration in the sample and $(M/Fe)_{background}$ = ratio of metal and Fe concentrations of the background.). Values >10 are indicative of non-crustal origins. Soils were categorized into seven levels based on the EF value. Zonta *et al. (*1994), calculated enrichment Factor Percentage (EF %) using the relationship :

$$EF (\%) = (C – C_{min}/C_{max} - C_{min}) \times 100$$

TABLE 2. Enrichment Factor (after Mohsen and Alireza, 2014)

Level	Value	Categorization
I	EF<1	No enrichment
II	EF=1-3	Minor enrichment
III	EF=3-5	Moderate enrichment
IV	EF=5-10	Moderately severe enrichment
V	EF=10-25	Severe enrichment
VI	EF=25-50	Very severe enrichment
VII	EF>50	Extremely severe enrichment

2.3 Contamination Factor (CF)

The soils from the dumpsites are assessed using the contamination factor (C^i_f) and the degree of contamination (C_d). Contamination factor is the ratio of the mean content of metals from at least five sample sites to the pre-industrial concentration of the individual metal and this is calculated using the relationship:

$$C^i_f = C^i_s/C^i_n$$

where C^i_f = contamination factor for ith metal; C^i_s = ith metal concentration in the soil sample; C^i_n = background concentration of ith metal taken from uncontaminated soil . Table 3 below showed the different class of contamination factor and the levels of contamination after Hakanson (1980).

TABLE 3. Contamination factor (C^i_f) for soils (after Hakanson, 1980)

$C^i f$ class	Contamination factor level
$C^i_f<1$	Low contamination factor indicating low contamination
$1<C^i_f<3$	Moderate contamination factor
$3\geq C^i_f<6$	Considerable contamination factor
$6\leq C^i_f$	Very high contamination factor

2.4 Pollution Load Index (PLI)

Tomlinson *et al*. (1980) defines pollution load index as the nth root of the product of the values of contamination factor (CF).

$$PLI = \sqrt[n]{(CF1 \times CF2 \times CF3 \times \ldots\ldots\ldots CFn)}. \quad (1)$$

values of PLI > 1 imply heavy metal pollution otherwise, there is no heavy metal pollution.

III. Results And Discussion

The geochemical results of the nine toxic metals analyzed from each dumpsite soil are shown in Table 4. These results showed average and range of values of the metals. Fe (71519; 27099 – 73859)ppm, Pb (61,111; 26863- 59269)ppm, Mn (95.348; 48- 78)ppm, Cu (31.149; 13.20 - 33.80)ppm, Ni (9.581; 2.46 - 13.78)ppm, Co (0.0579; 0.012 - 0.28)ppm, Zn (42.279; 22.30- 35.29)ppm, Cd (0.077; 0.02 - 0.11)ppm and Cr (5.422; 1.45 - 11.47)ppm. In figure 2, the metal concentrations in the dumpsite soils are presented graphically indicating that lead and iron have elevated values in all the locations (Osman *et al.;*(2015).

TABLE 4. Geochemical results of heavy metals in dumpsite soils from the study area (ppm)

	Fe	Pb	Mn	Cu	Ni	Co	Zn	Cd	Cr
S1	28,679.20	30,394.41	62.97	21.35	9.75	0.017	25.29	0.02	2.58
S2	30,394.41	33,944.39	48.32	18.99	9.01	0.021	27.24	0.05	1.45
S3	37,901.40	34,097.72	63.38	19.42	8.41	0.016	29.76	0.04	1.86
S4	39,029.24	32,993.73	61.44	16.74	6.10	0.020	28.25	0.05	2.01
S5	52,057.74	37,596.99	54.02	18.24	6.58	0.012	28.79	0.06	2.02
S6	46,274.78	31,845.39	63.93	19.42	6.58	0.028	28.78	0.03	2.86
S7	68,568.14	59,268.75	74.53	22.86	13.78	0.045	34.69	0.11	11.47
S8	27,099.26	26,863.13	69.29	18.03	5.12	0.025	25.43	0.05	2.34
S9	37,568.14	35,170.48	68.45	18.67	5.12	0.019	27.46	0.07	4.92
S10	42,154.86	38,853.34	56.55	14.70	5.61	0.022	29.35	0.06	3.21
S11	63,004.25	57,429.43	62.66	13.20	3.85	0.015	22.30	0.02	2.86
S12	56,237.22	42,901.14	57.82	22.64	3.90	0.009	30.78	0.04	2.35
S13	59,057.40	48,503.76	67.77	32.94	2.46	0.012	24.26	0.03	1.79
S14	73,859.38	56,239.17	77.57	20.49	6.83	0.038	35.29	0.09	7.72
S15	53,301.10	45,004.42	64.78	33.80	2.71	0.28	25.12	0.05	4.78
Average	71518.65	61110.62	95.348	31.149	9.581	0.0579	42.279	0.077	5.422
Max	73,859.38	59,268.75	77.57	33.80	13.78	0.28	35.29	0.11	11.47
Min	27,099.26	26,863.13	48.32	13.20	2.46	0.01	22.30	0.02	1.45
STDEV	14634.93	10415.24	7.577	5.742	2.960	0.067	3.594	0.025	2.718

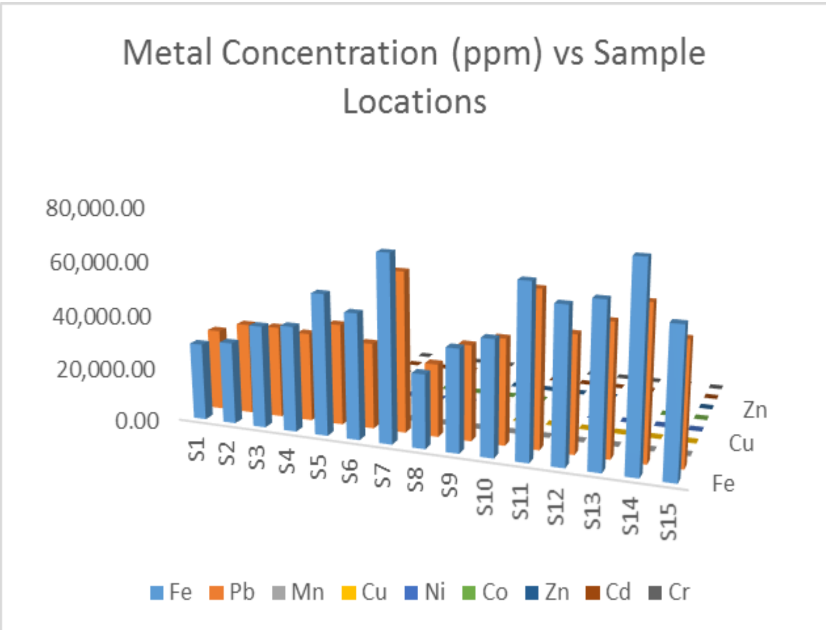

Fig. 2. Metal Concentrations in the soil around the dump site

3.1 Geo-accumulation Index (I_{geo})

The calculated geo-accumulation Index (I_{geo}), the mean and range of values is as presented in Table 5. Fe (-0.892; -0.194 to -1.643), Pb (10.879; 10.321 to 11.462), Mn (-4.514; -4.210 to -4.921), Cu (-2.163; -1.415 to -2.775), Ni (-4.197; -2.932 to -5.442), Co (-10.656; -7.065 to -12.024), Zn(-1 .909;

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-1.573 to -2.237), Cd (-2.291; -1.035 to -3.506), Cr (-8.808; -6.880 to -9.863).

These results showed elevated value of Igeo for Pb (11.462- 10.321) while Igeo values for Fe, Mn, Cu, Ni, Co, Zn, Cd and Cr falls below Igeo < 0 indicating that the dumpsite soils are uncontaminated with these metals. According to Muller, (1969), the geo-accumulation Index (I_{geo}) greater than 5 (Igeo>5) represents an extremely contaminated soil,. So the dumpsite soils from the study area could be considered to be extremely contaminated. The bar charts (Figs.3 to 17) presents the graphical expression of these values for each sample location:

TABLE 5. Geo-accumulation index of dumpsite soil from the study area

Sample no	Fe	Pb	Mn	Cu	Ni	Co	Zn	Cd	Cr
S1	-1.56	10.499	-4.506	-2.077	-3.442	-11.107	-2.058	-3.506	-9.031
S2	-1.477	10.658	-4.921	-2.244	-3.556	-10.802	-1.948	-2.171	-9.862
S3	-1.158	10.665	-4.506	-2.217	-3.643	-11.194	-1.821	-2.498	-9.504
S4	-1.114	10.617	-4.539	-2.426	-4.107	-10.873	-1.894	-2.171	-9.392
S5	-0.698	10.805	-4.756	-2.307	-4.011	-11.609	-1.867	-1.91	-9.384
S6	-0.87	10.566	-4.506	-2.217	-4.011	-10.387	-1.867	-2.91	-8.883
S7	-0.302	11.462	-4.265	-1.977	-2.932	-9.702	-1.599	-1.035	-6.88
S8	-1.643	10.321	-4.38	-2.321	-4.38	-10.552	-2.046	-2.171	-9.172
S9	-1.171	10.709	-4.38	-2.272	-4.38	-10.946	-1.937	-1.685	-8.1
S10	-1.002	10.853	-4.68	-2.617	-4.237	-10.735	-1.841	-1.91	-8.716
S11	-0.422	11.417	-4.539	-2.775	-4.795	-11.287	-2.237	-3.506	-8.883
S12	-0.588	10.996	-4.643	-1.994	-4.756	-12.024	-1.771	-2.498	-9.166
S13	-0.516	11.173	-4.411	-1.45	-5.442	-11.609	-2.114	-2.91	-9.559
S14	-0.194	11.386	-4.21	-2.139	-3.943	-9.947	-1.573	-1.321	-7.45
S15	-0.664	11.065	-4.473	-1.415	-5.321	-7.065	-2.064	-2.171	-8.142
Aver.	-0.892	10.879	-4.514	-2.163	-4.197	-10.656	-1.909	-2.291	-8.808
Max.	-0.194	11.462	-4.21	-1.415	-2.932	-7.065	-1.573	-1.035	-6.88
Min	-1.643	10.321	-4.921	-2.775	-5.442	-12.024	-2.237	-3.506	-9.862

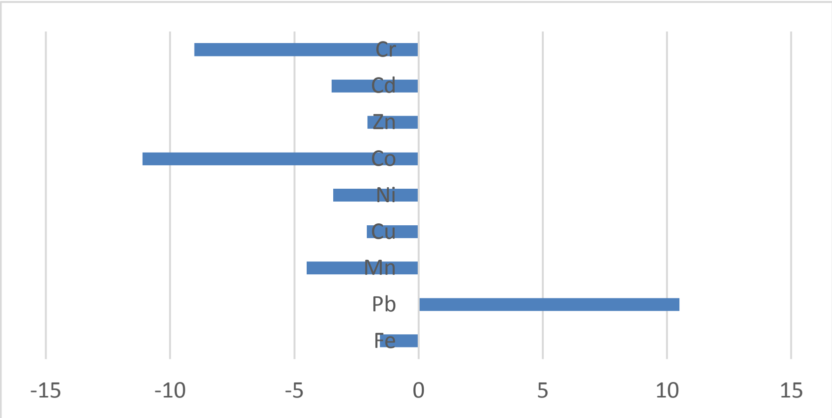

Fig. 3. Bar chart showing the range of Igeo values obtained for each metal in location 1

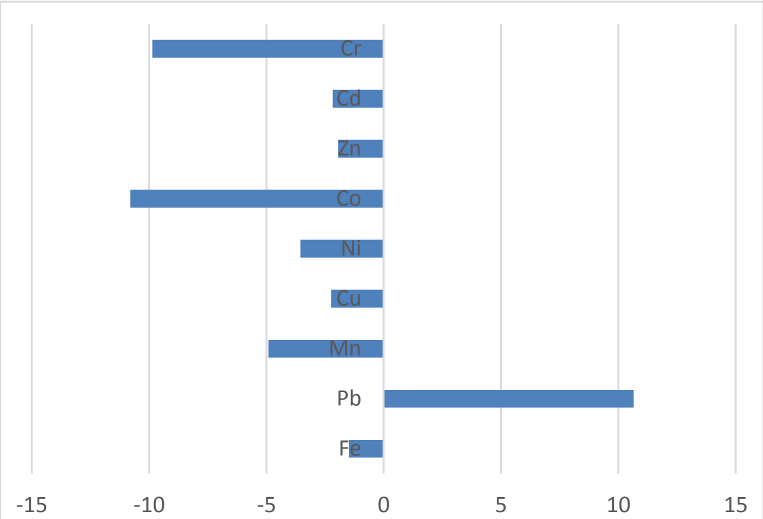

Fig. 4. Bar chart showing the range of Igeo values obtained for each metal in location 2

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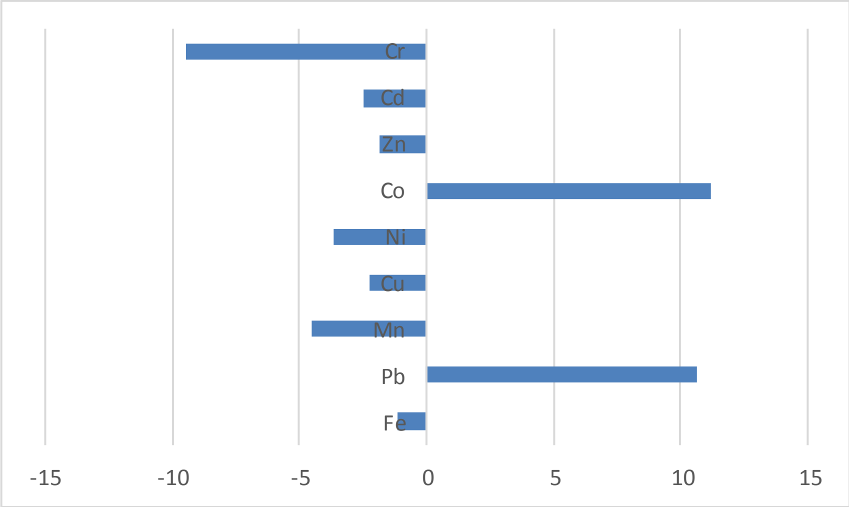

Fig. 5. Bar chart showing the range of Igeo values obtained for each metal in location 3

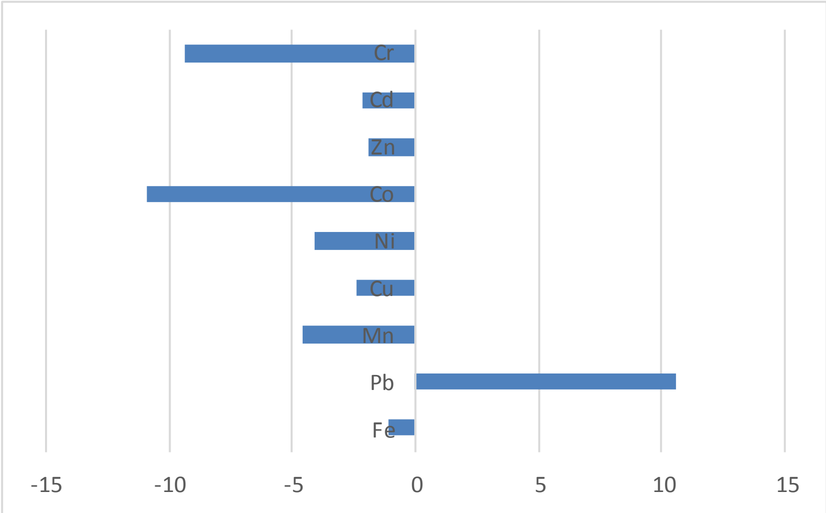

Fig. 6. Bar chart showing the range of Igeo values obtained for each metal in location 4

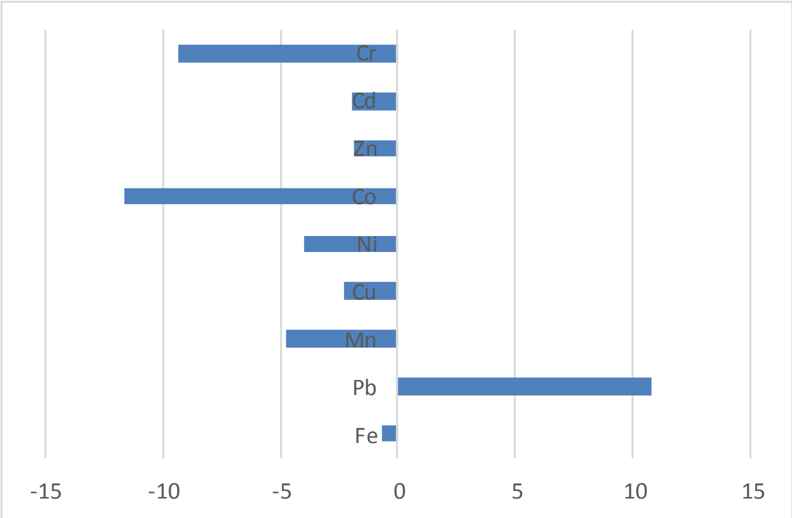

Fig. 7. Bar chart showing the range of Igeo values obtained for each metal in location 5

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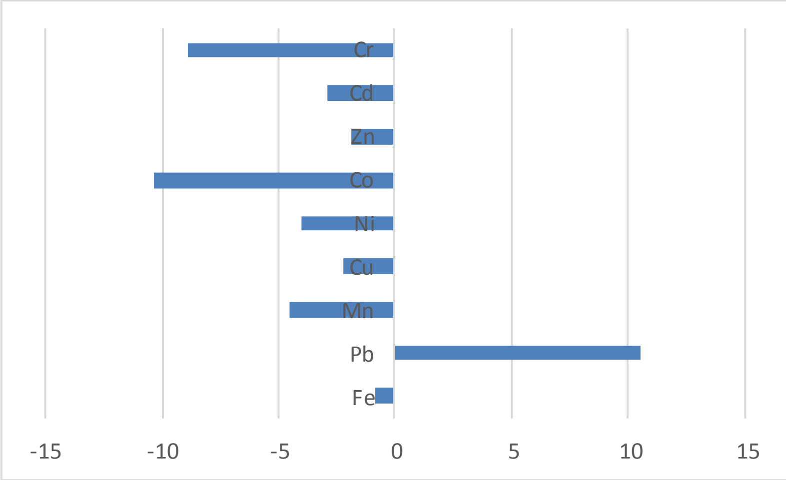

Fig. 8. Bar chart showing the range of Igeo values obtained for each metal in location 6

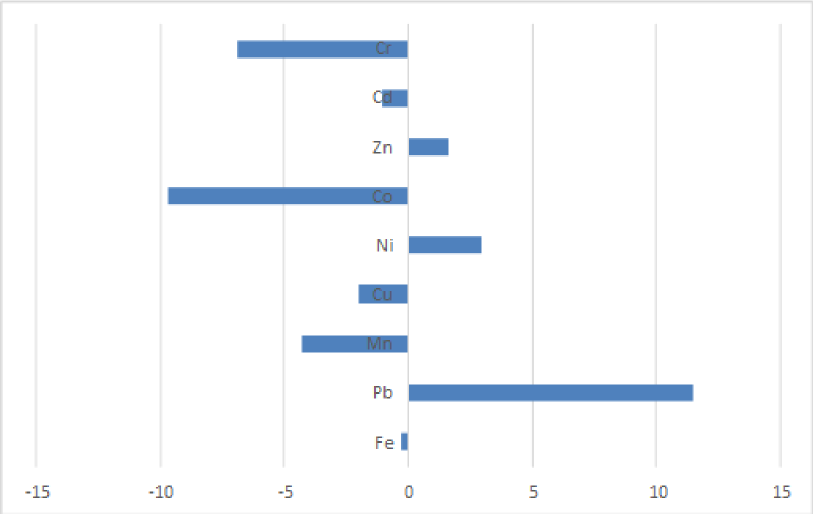

Fig. 9. Bar chart showing the range of Igeo values obtained for each metal in location 7

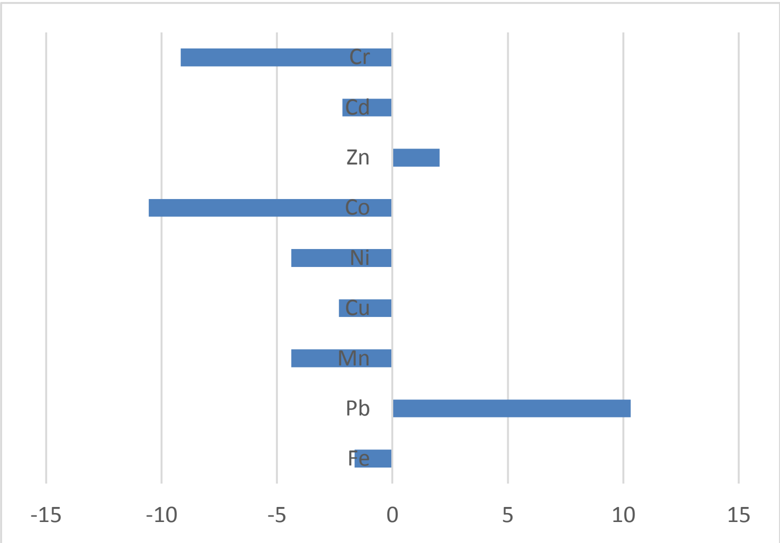

Fig. 10. Bar chart showing the range of Igeo values obtained for each metal in location 8

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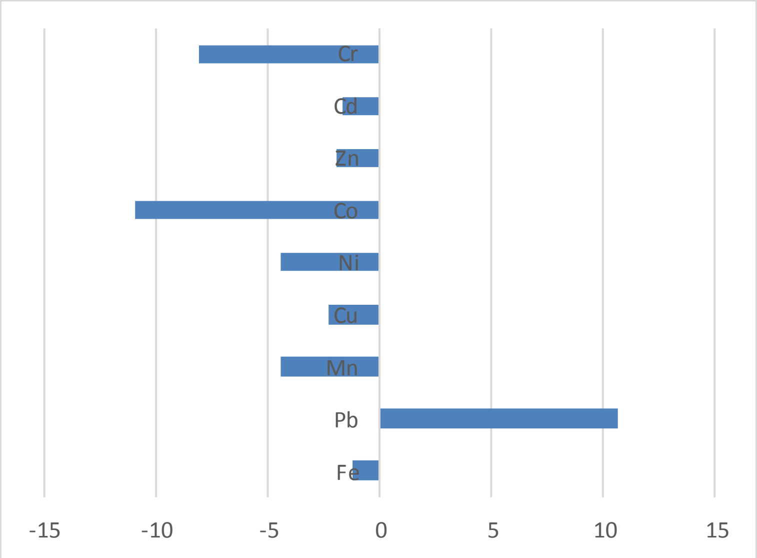

Fig. 11. Bar chart showing the range of Igeo values obtained for each metal in location 9

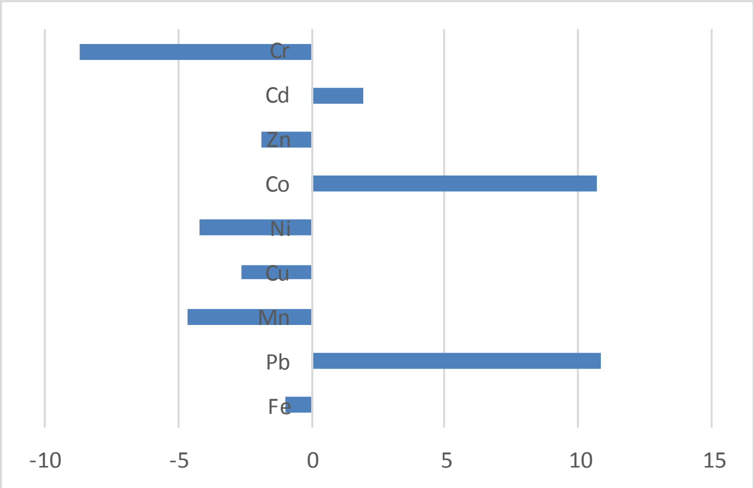

Fig. 12. Bar chart showing the range of Igeo values obtained for each metal in location 10

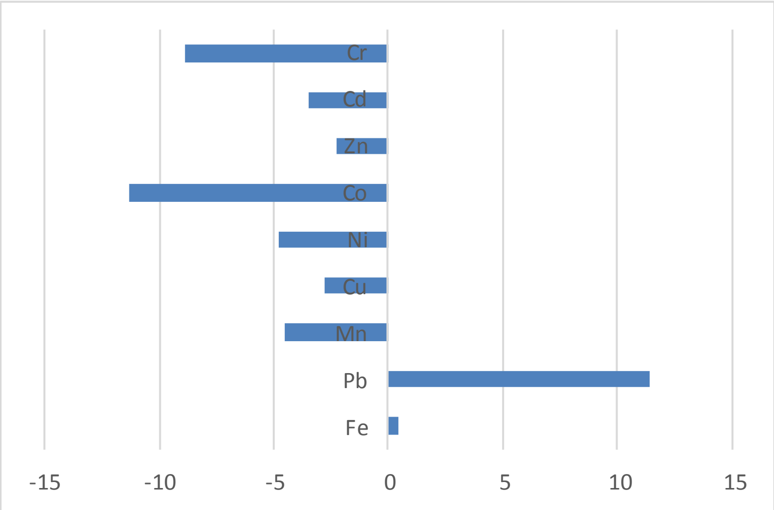

Fig. 13. Bar chart showing the range of Igeo values obtained for each metal in location 11

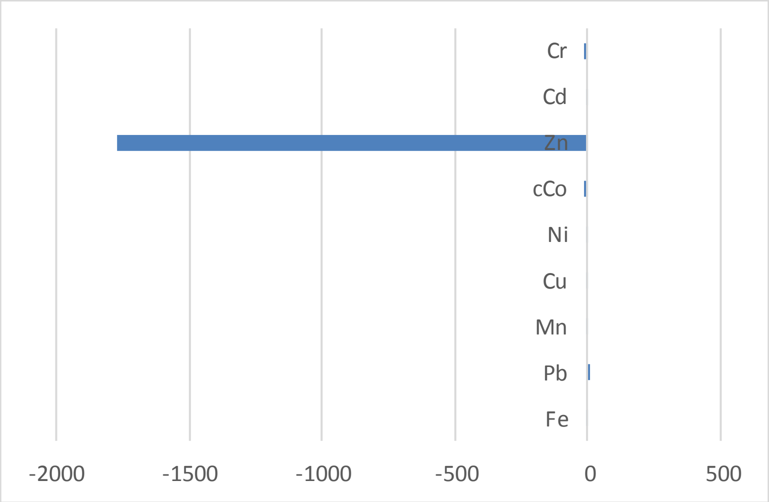

Fig. 14. Bar chart showing the range of Igeo values obtained for each metal in location 12

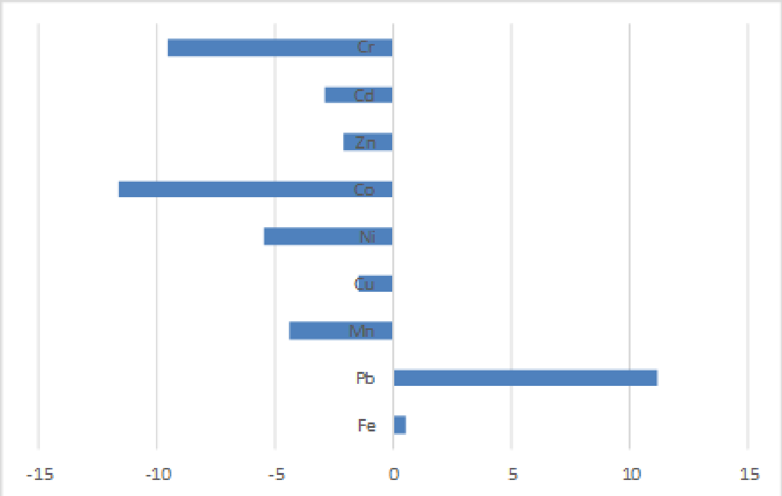

Fig. 15. Bar chart showing the range of Igeo values obtained for each metal in location 13

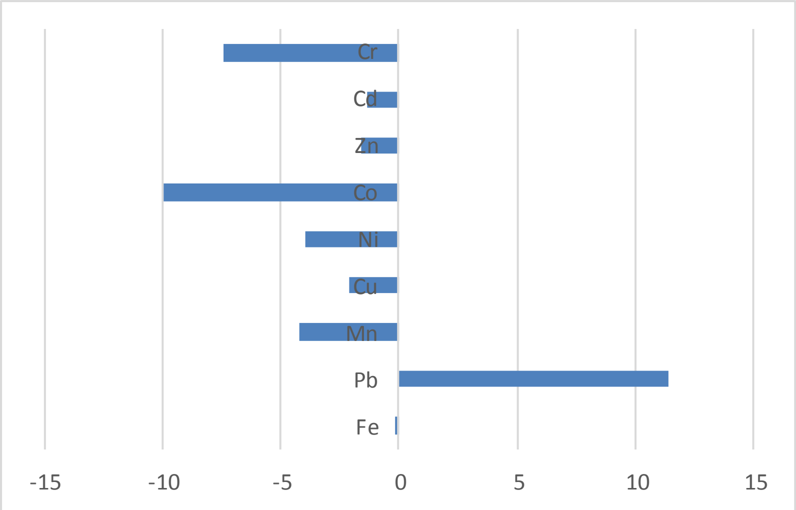

Fig. 16. Bar chart showing the range of Igeo values obtained for each metal in location 14

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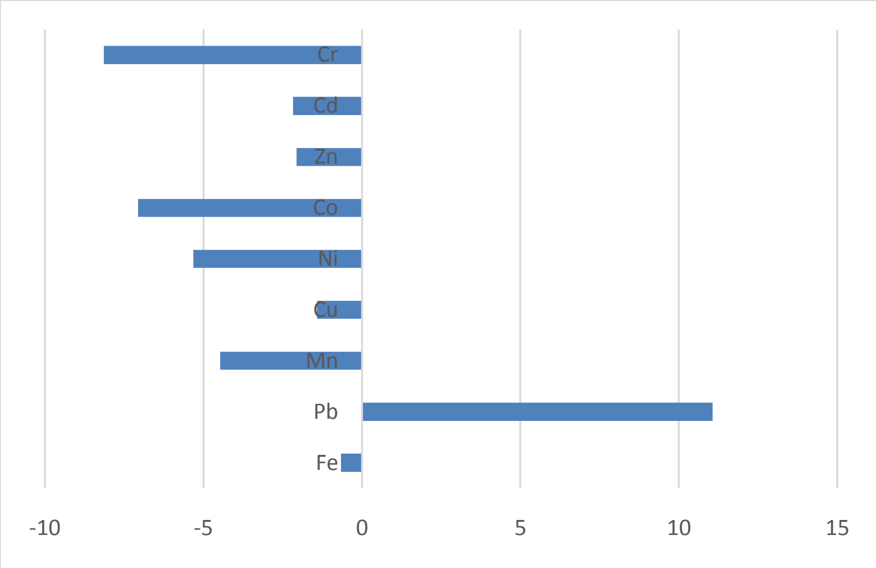

Fig. 17. Bar chart showing the range of Igeo values obtained for each metal in location 15

3.4 Enrichment Factor

The enrichment factor (EF) of soil as proposed by Ergin *et al*. (1991), is a calculated value for determining anthropogenic from geogenic contributions to metal concentrations in soils and basically, it is a tool for differentiating crustal from non-crustal origins of metals in soils. The values of Enrichment Factor of the investigated dumpsite soils is presented in Table 6.

Mohsen and Alireza, (2014) proposed the range of values that categorizes soil enrichment factor between minor to extremely severe enrichment. In this work, except lead (Pb) with values of enrichment factor (EF) ranging between 2.078 to 0.762 and average of 1.295 which falls in the minor enrichment category, Mn, Cu, Ni, Co, Zn, Cd and Cr all falls within EF<1 suggesting that the dumpsite soils are not enriched in these metals. In fig.16, the variation of enrichment factor of each metal by location is presented.

3.5 Contamination Factor (Cf) and Pollution Load Index

Contamination factor was calculated from the mean values of each metal content in the 15 sample sites and the pre-industrial concentration of the individual metal. Clarke value of each of the heavy metal ware used as the pre-industrial concentration of the metal. The contamination factor of Iron (Fe) indicates moderate contamination but Mn, Cu, Ni, Co, Zn, Cd, Cr, all have low contamination factor (Table 7). However, Pb has a very high value of contamination factor which is an indication that the dumpsite soils are highly contaminated in Lead.

The pollution load index (PLI) as defined by the nth root of the multiplications of the concentrations of the metals in the soil, i.e. PLI = $^{n}\sqrt{}$(CF1 × CF2 ×CF3 ×………CFn) and a value of PLI > 1 indicates the existence of heavy metal pollution in the soil while values of PLI < 1 indicates a non-polluted soil (Tomlinson et al., 1980). The values for pollution index for dumpsite soils investigated are presented in table 10 bellow.

TABLE 6. Enrichment factor for dumpsite soils from study area

Soil sample	Pb(ppm)	Mn(ppm)	Cu(ppm)	Ni(ppm)	Co(ppm)	Zn(ppm	Cd(ppm)	Cr(ppm)
S1	1.963	0.13	0.698	0.227	0.001	0.709	0.261	0.049
S2	1.855	0.094	0.587	0.199	0.001	0.721	0.618	0.026
S3	1.485	0.099	0.48	0.148	0	0.631	0.396	0.027
S4	1.442	0.093	0.402	0.104	0.001	0.582	0.48	0.028
S5	1.08	0.061	0.328	0.084	0	0.444	0.432	0.021
S6	1.216	0.081	0.393	0.095	0.001	0.5	0.243	0.034
S7	0.821	0.064	0.312	0.134	0.001	0.406	0.602	0.092
S8	2.078	0.151	0.624	0.126	0.002	0.754	0.692	0.047
S9	1.498	0.107	0.466	0.091	0.001	0.587	0.699	0.072
S10	1.336	0.079	1.335	0.089	0.001	0.559	0.534	0.042
S11	0.893	0.058	0.196	0.04	0	0.284	0.119	0.025
S12	1	0.06	0.377	0.046	0	0.44	0.266	0.023
S13	0.953	0.068	0.523	0.027	0	0.33	0.19	0.016
S14	0.762	0.062	0.26	0.061	0.001	0.384	0.457	0.057
S15	1.056	0.072	0.595	0.034	0.011	0.379	0.352	0.049
Mean	1.295867	0.085267	0.505067	0.100333	0.0014	0.514	0.422733	0.040533
Max.	2.078	0.151	1.335	0.227	0.011	0.754	0.699	0.092
Min.	0.762	0.058	0.196	0.027	0	0.284	0.119	0.016

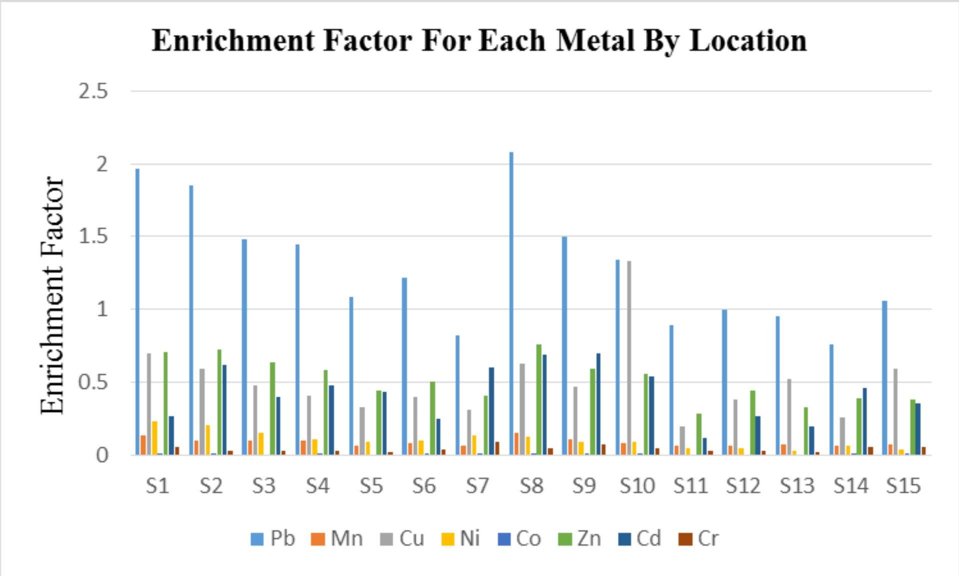

Fig. 16. Enrichment Factors for each metal by location

TABLE 7. Contamination factor ($C^i f$) and pollution load index (PLI) for metals in the study area

Contamination Factor (C^i_f)			**Pollution Load Index (PLI)**		
Metals	Values	Status	metals	Pollution load index	Metal Pollution
Fe	1.270	Moderate contamination factor	Fe	3.04	Polluted
Pb	4365.04	Very high contamination factor	Pb	3.63	Polluted
Mn	0.100	Low contamination	Mn	1.2×10^{-8}	No pollution
Cu	0.519	Low contamination	Cu	3.79×10^{-3}	No pollution
Ni	0.114	Low contamination	Ni	1.5×10^{-8}	No pollution
Co	0.002	Low contamination	Co	0	No pollution
Zn	0.603	Low contamination	Zn	0.01	No pollution
Cd	0.513	Low contamination	Cd	3.88×10^{-3}	No pollution
Cr	0.053	Low contamination	Cr	5.14×10^{-14}	No pollution

The results revealed that the PLI for Fe and Pb in the dumpsites investigated are far above the PLI > 1 recommended pollution load index showing that these soils are polluted in these metals.

IV. CONCLUSION

The Igeo results revealed that the dumpsite soils from the study area have elevated value for Pb while values for Fe, Mn, Cu, Ni, Co, Zn, Cd and Cr moderately lower indicating that the dumpsite soils are uncontaminated with these metals but contaminated with Pb. The bar charts in Figs.3 to 17) presents the graphical expression of these values for each sample location. The calculated enrichment factor (EF) of 1.295 for Pb suggests that this metal in the dumpsite soils is partially anthropogenic and partially crustal in origin. The Pollution Load Index (PLI) for Fe and Pb from the dumpsite soils investigated showed that these soils are polluted in these metals.

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