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Assessment of Heavy Metals Concentrations in Dumpsites Soils in Benin City, Edo State, Nigeria

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Abstract: *Heavy metal concentrations of soil in four dump sites were studied. The dump sites are located in Iguosa, Oluku, Otofure 1 and Otofure 2 communities, near Benin City, Edo State, Nigeria. The heavy metals analysed were Pb, Cd, Cr, Ni, Fe, Zn, Cu and Mn. Sampling of soils at 0 – 15 cm depth was done in March, June and October, in all the dump sites. Atomic Absorption Spectrophotometry (AAS) was used to analyze heavy metal concentrations in soils and the results obtained were Pb (24.66 – 57.89 mg/kg), Cd (3.49 – 7.02 mg/kg), Cr (4.66 – 7.58 mg/kg), Ni (12.20 – 19.84 mg/kg), Fe (8580.56 – 11072 mg/kg), Cu (4.59 – 8.12 mg/kg), Zn (91.52 – 208.42 mg/kg) and Mn (173.96 – 235.67 mg/kg). The Analysis of Variance (ANOVA) showed no significant (p<0.05) difference among the metals except Cadmium (p<0.05). Degree of soil contamination was in this order Iguosa>Oluku>Otofure 1>Otofure 2. Soil metal concentrations obtained from the analysis indicated that Cd concentrations were above the permissible limit.*

Keywords: *Contamination, Dumpsites, Heavy Metals, Pollution, Soils.*

I. INTRODUCTION

Pollution studies in recent years have identified heavy metals as one of the major pollutants of aquatic and terrestrial environments. Soil and water being receptacles of materials have been abused by man especially in the developing countries where "collect and throw or dump concept" is a common practice. Contamination and subsequent pollution of the environment by heavy metals has become an issue of global concern due to their sources, widespread distribution and multiple effects on the ecosystem [1]. Heavy metals cannot be degraded, and are released into the environment through natural and anthropogenic processes. Naturally, they occur in soil, water, and air, through volcanic eruption and forest fires. Most alarming is the anthropogenic processes which include agricultural practices, energy production, mining and smelting, secondary metal production and recycling operations, urban and industrial complexes.

Generally, heavy metals uses are widespread. They are common in industrial applications such as in the manufacture of pesticides, batteries, alloys, electroplated metal parts, textile dyes, steel, etc [2]. A handful of heavy metals are essential to plant metabolism in trace amounts. At very low concentration, some of them are nutritionally essential for healthy life. These include zinc, iron, copper, nickel, boron, manganese, molybdenum, cobalt etc and are referred to as trace elements or micronutrients, because they are only required in small amounts. Others such as lead, cadmium, arsenic, mercury, chromium etc play little or no role in plant development though, naturally present in the environment because of their various sources. However, at high concentrations, they can lead to poisoning. Human exposure at higher concentration can cause serious health effects, including reduced growth and development, organ and nervous system damage and in extreme cases, death [2].

Studies have revealed that dumpsites are one of the major sources of contaminants such as heavy metals in the environment. In the global world, various kinds of activities, including industrial, transportation and most importantly, agriculture produce a large amount of wastes. In developing countries including Nigeria, open and unregulated dumps are still the predominant method of waste disposal. These dump sites comprise wastes from homes, markets, industries and agricultural production. Moreover, they comprise large amount of organic materials, including considerable proportions of plastics, papers, metal rubbish and batteries which are known to be real sources of heavy metals [3][4][5].

Oviasogie *et al*. [6], studied the distribution of heavy metals in refuse dump soils in Akure, South – West Nigeria and reported maximum concentrations of 23.00, 2.91, 9.00 and 24.00 mg/kg in soil for Pb, Cd, Cr and Ni respectively. They observed that Cadmium in soil was consistent with the critical value for agricultural soils, while the concentrations of other metals were much higher than their critical values. Ebong *et al*. [7], examined soil quality of refuse dump sites in Uyo, Nigeria, and reported high concentrations of Pb, Cd, Ni, Fe and Zn. Similarly, Okoronkwo *et al*. [8], studied dump sites contamination of soil in Umuahia, South – East Nigeria and reported high accumulation of heavy metals such as Pb, Ni, Cr, Cd and As. Oyedele *et al*. [9], studied waste dumpsites of various ages and observed that the older a dump site is, the higher the concentrations of heavy metals in that soil. However, Akinola *et al*. [10], attributed the variability to locations of the dumpsites. They studied four dump soils in Lagos and reported higher concentrations of heavy metals in the dump sites close to a busy highway than the dumpsites located in a less vehicular traffic roads. Akinola *et al*. [10] agreed with [11] who studied dumpsite soils and showed that heavy metals concentration is high in dumpsites located near high traffic density areas. Ukpebor and Unuigbe [12], studied three waste dump soils in Benin City and observed that the concentrations of most of the metals such as Cd, Cr, Cu, Pb, Mn and Ni decreased with increased distance from the dump sites which suggested that the dump sites contributed significantly to the level of these metals in that environment. The concentration of cadmium was higher than other metals with the exception of Cu, Mn and Cr. They further reported that the sites were unsuitable for agricultural activity and residential location due to possible ingestion via food chain and direct inhalation.
Therefore, it is imperative to monitor and inform ourselves about the concentrations of these metals in the environment. The current study aims to assess the concentrations of heavy metals in dumpsite environments.

II. Materials And Methods

2.1 THE STUDY AREA

This study was carried out in Otofure (lat N6^0 27.759', long E5^0 35.861'), Oluku (lat N6^0 27.371', long E5^0 35.744') and Iguosa (lat N6^0 26.765', long E5^0 35.781') communities, near Benin City, in Ovia North East Local Government Area of Edo State, Nigeria. The general language spoken in all the communities is Bini. The communities experience two seasons, the rainy and dry seasons. The rainy season is between May and October while the dry season is between November and climaxes in April.

Otofure is predominantly inhibited by rural dwellers whose occupation is farming and petty trading. The community is blessed with land resources that the dwellers utilize for their farming activities. There is a major express road through the community to other towns. Two dump sites were studied in Otofure denoted as Otofure 1 and 2. Otofure 1 is a very large dump site located close to the express road and it is managed by the Government of Edo State. Heterogeneous wastes such as wastes from homes, offices, factories, industries, markets, etc, collected from Benin City by authorised agents are disposed at this site, and the dump site is occasionally incinerated. The second dump site (Otofure 2) is a small-sized refuse site that is used by the rural dwellers only, and it is a bit close to a highway however, Otofure 1 is closer. There are farms around this dump site and wastes disposed constituted household wastes, farm produce wastes and fire wood ash. Oluku and Iguosa are semi urban centres. The inhabitants are people of different income class. There are visible industrial activities such as hotels and business for artisans and petty traders in the two communities. The dumpsite studied in Oluku is an abandoned dump site that was used and managed by the community. It is close to Benin/Lagos highway. Wastes disposed at the dumpsite were mainly household wastes such as wastes from the market, condemned electronics, dead batteries used for non-rechargeable torchlight and radio sets. In Iguosa, spent oil is discharged into the dumpsite as it is located at a mechanic workshop close to Benin/Lagos highway. Although all the dumpsites are close to major express roads, Otofure 1 is the closest, followed by Iguosa and Oluku dumpsites while Otofure 2 is farthest from the highway when compared to other sites.

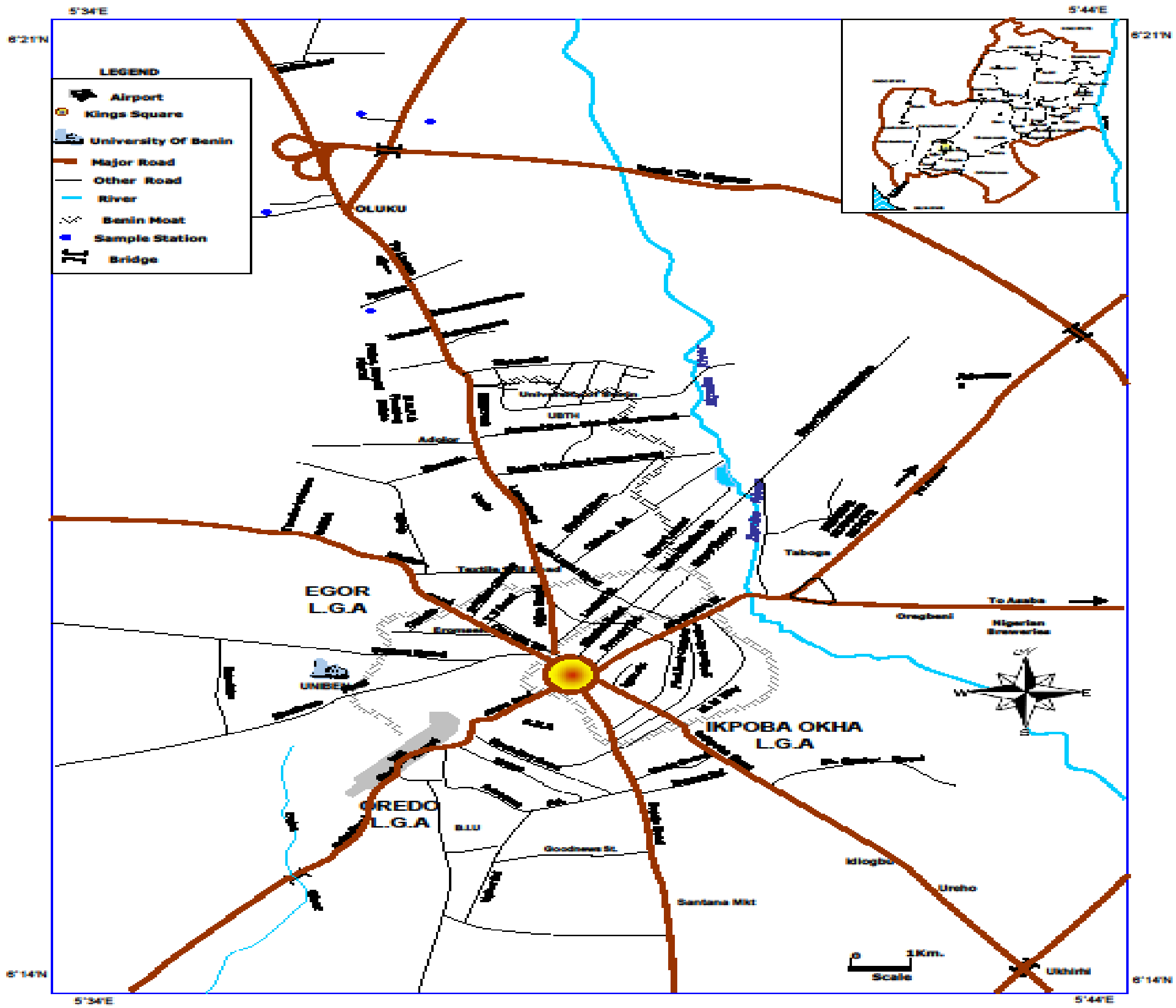

FIG. 1. MAP OF BENIN METROPOLIS SHOWING SAMPLE STATIONS

2.2 SOIL SAMPLES COLLECTION

Soil samples were collected from the four stations at 0-15 cm depth and 100 meters away from each dump site as control using soil Auger. A total of thirty six (36) samples were collected in all. In all cases, soil samples were kept in clean polyethylene bags and carefully labelled for easy identification and to reduce the effect of contamination. Thereafter, samples were transported to the laboratory and were air-dried at room temperature, crushed and passed through 2 mm mesh sieve and later stored in clean plastic bags with proper labelling. Soil samples were analysed for the following parameters Pb, Cd, Ni, Cr, Fe, Cu, Zn and Mn.

2.3 CHEMICAL ANALYSIS

Soil samples (1 g) each was introduced into digesting tubes following the addition of 10 ml concentrated HNO_3. The samples were placed in the digester for 8 h at 96^{o}C with intermittent stirring. Upon complete digestion, the samples were filtered into 100 ml volumetric flasks using Whatman no. 42 filter paper. The samples were made up to the 100 ml mark in the volumetric flask using distilled or deionised water. The concentrations of Pb, Cd, Cr, Ni, Fe, Zn, Cu and Mn in the supernatant solutions were determined using atomic absorption spectrophotometer (AAS). All the analyses were done in duplicates.

Concentration of heavy metal (mg/kg) = Instrument Reading x Slope Reciprocal x Volume of Extract…Equation 1
Weight of sample.

2.4 STATISTICAL ANALYSIS

Means, standard deviations and Analysis of Variance (ANOVA) as well as Duncan multiple range test of the heavy metals in soil were calculated. Geoaccumulation Index (I_{geo}) was calculated to determine the degree of contaminations of the dumpsites by heavy metals. $I_{geo} = Log2 (Cn/1.5 \times Bn)$ ……………………………..Equation 2; Where Cn = Concentration of heavy metals in the studied soil, Bn = Background concentration (control soil) of heavy metal and 1.5 is the background correction factor.

Table 1: Normal Range of Heavy Metals Concentrations in an unpolluted Tropical Soils (mg/kg)

Metal	Soil	
Pb	2 – 164®	2 – 200
Cd	0.1 – 3®	0.1 – 3.00*
Cr	5 – 100®	5 – 3000
Ni	10 – 70®	10 – 1000
Fe		7,000 – 38,000#
Cu	2 – 100®	2 – 100
Zn	10 - 420®	10 – 300*
Mn		100 – 4,000

Source: NESREA® [13][14][15]*[16]#

III. RESULTS AND DISCUSSION

3.1 RESULTS

Table 2: Summary of Heavy Metals Concentrations in Soils collected from four Dumpsites

	Pb	Cd	Cr	Ni	Fe	Cu	Zn	Mn
Otofure 1	24.66±5.44ᵃ	3.49±1.77ᵇ	4.66±4.51ᵃ	16.1±6.52ᵃ	8800.84±3840.76ᵃ	4.59±2.88ᵃ	97.64±25.56ᵃ	187.91±127.36ᵃ
Otofure 2	28.7±8.06ᵃ	4.54±1.3ᵃᵇ	5.59±3.72ᵃ	12.2±6.45ᵃ	11072.72±3528.94ᵃ	8.12±2.78ᵃ	176.88±174.55ᵃ	173.96±143.21ᵃ
Oluku	34.86±16.7ᵃ	7.02±2.03ᵃ	6.23±8.46ᵃ	19.84±12.47ᵃ	8580.56±6923.89ᵃ	7.04±2.83ᵃ	208.42±169.19ᵃ	204.87±14.43ᵃ
Iguosa	57.89±41.1ᵃ	4.14±0.67ᵃᵇ	7.58±6.63ᵃ	18.47±10.11ᵃ	9906.63±4189.5ᵃ	5.35±1.14ᵃ	91.52±33.83ᵃ	235.67±41.94ᵃ

Mean ± S.D across the columns with different superscript were significantly different at 5% with a>b>c. Mean separation done by Duncan multiple range test.

Table 3: Assessment of Heavy Metals in four Dump Sites using Geoaccumulation Index (I_{geo})

Location	I_{geo}							
	Pb	Cd	Cr	Ni	Fe	Cu	Zn	Mn
Otofure 1	1.93	1.11	0.24	1.16	3.68	1.69	0.42	1.93
Otofure 2	1.73	1.68	0.96	0.26	3.22	3.65	1.15	1.66
Oluku	2.01	2.6	2.53	2.79	3.14	3.34	1.6	2.32
Iguosa	2.34	1.48	2.98	2.41	3.51	2.25	-0.31	2.64

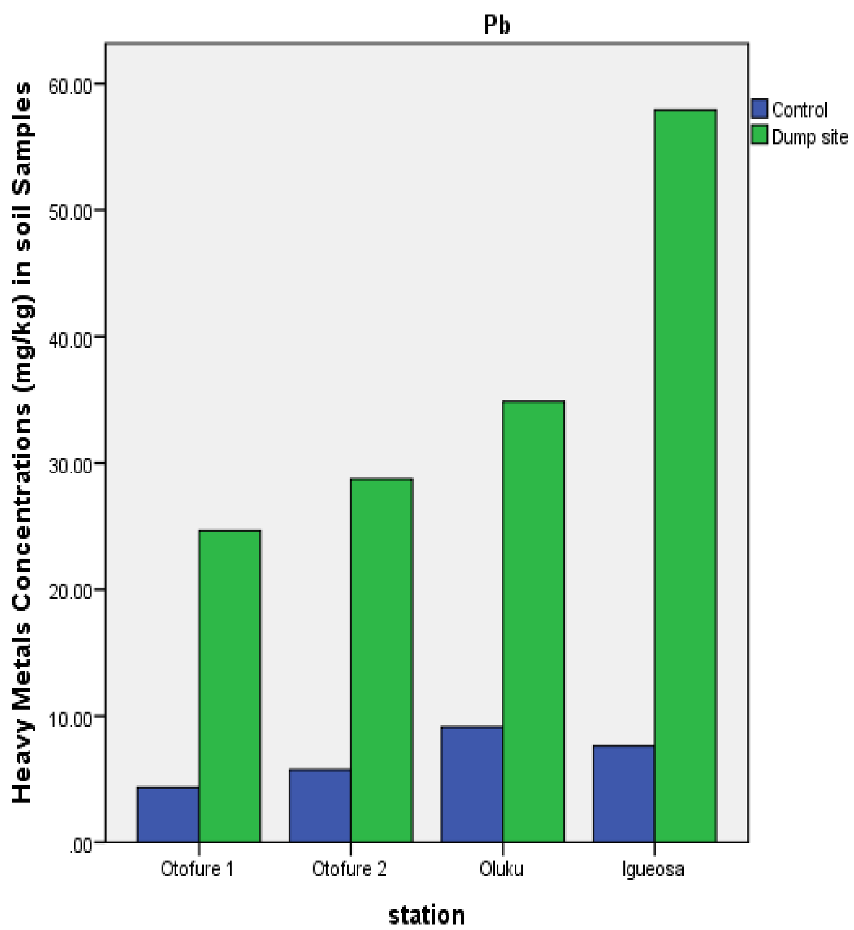

Figure 2: Pb concentrations in dumpsites and control soils across the four stations

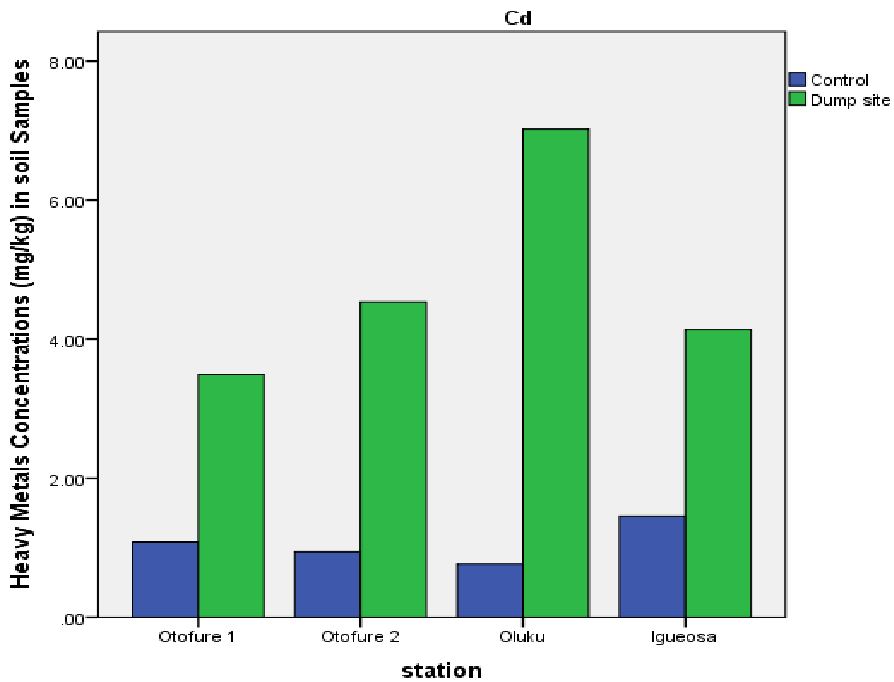

Figure 3: Cd concentrations in dumpsites and control soils across the four stations

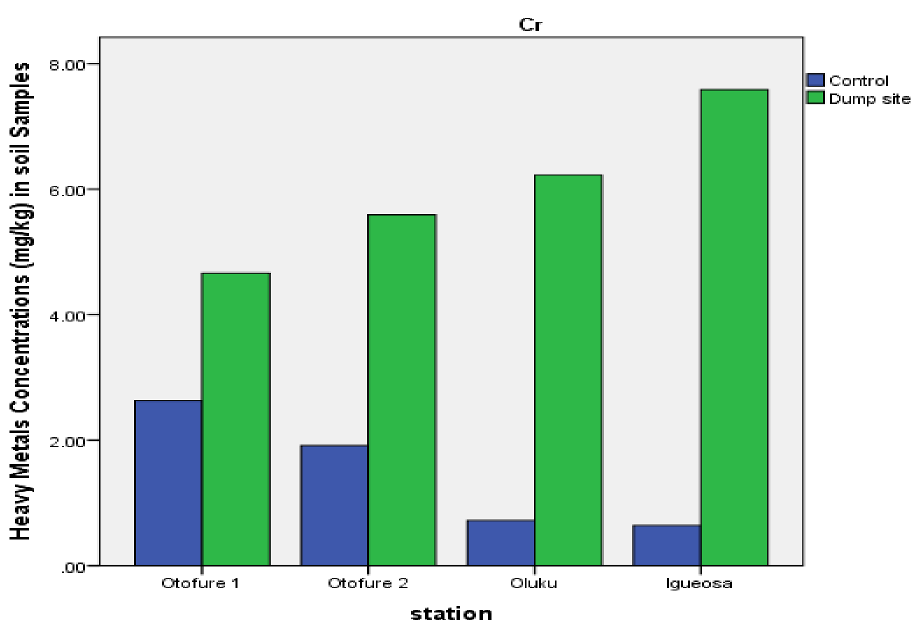

Figure 4: Cr concentrations in dumpsites and control soils across the four stations

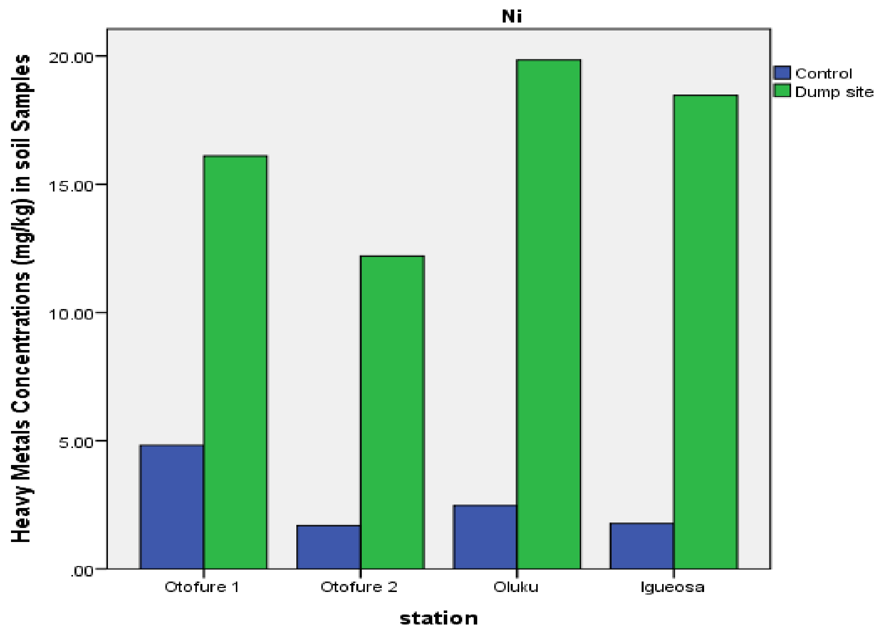

Figure 5: Ni concentrations in dumpsites and control soils across the four stations

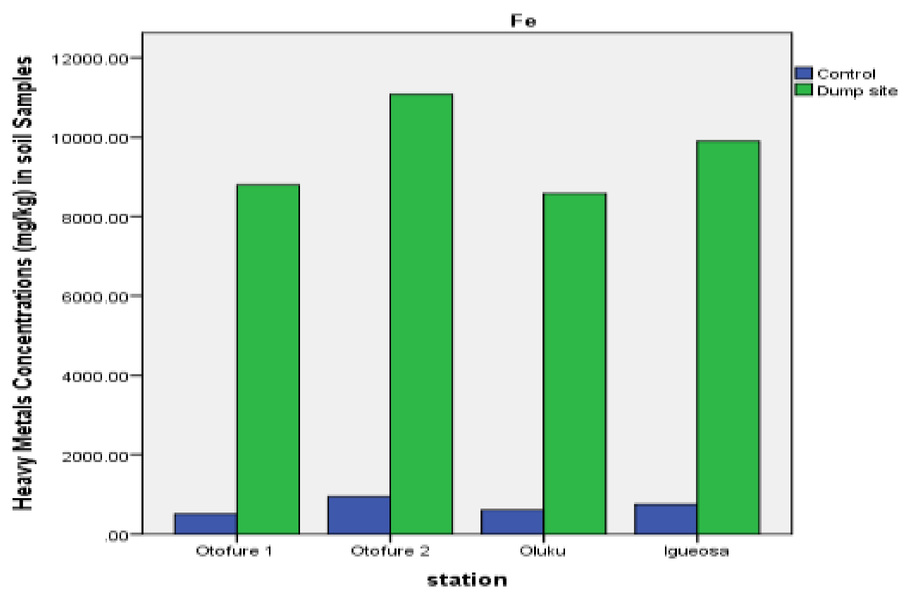

Figure 6: Fe concentrations in dumpsites and control soils across the four stations

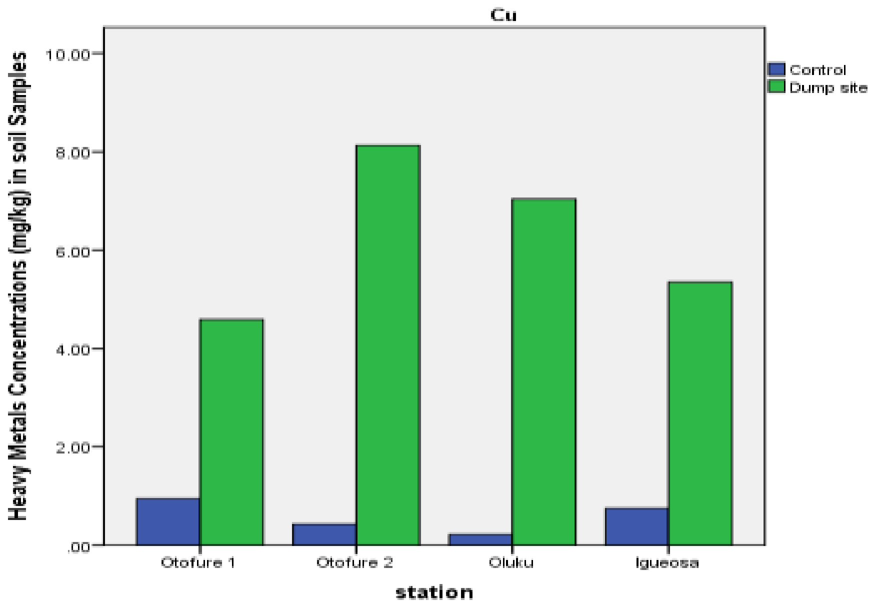

Figure 7: Cu concentrations in dumpsites and control soils across the four stations

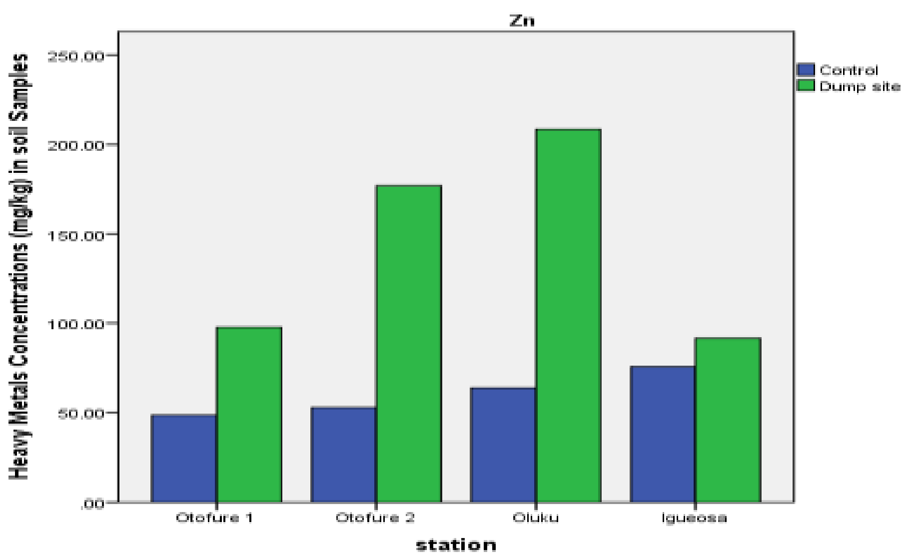

Figure 8: Zn concentrations in dumpsites and control soils across the four stations

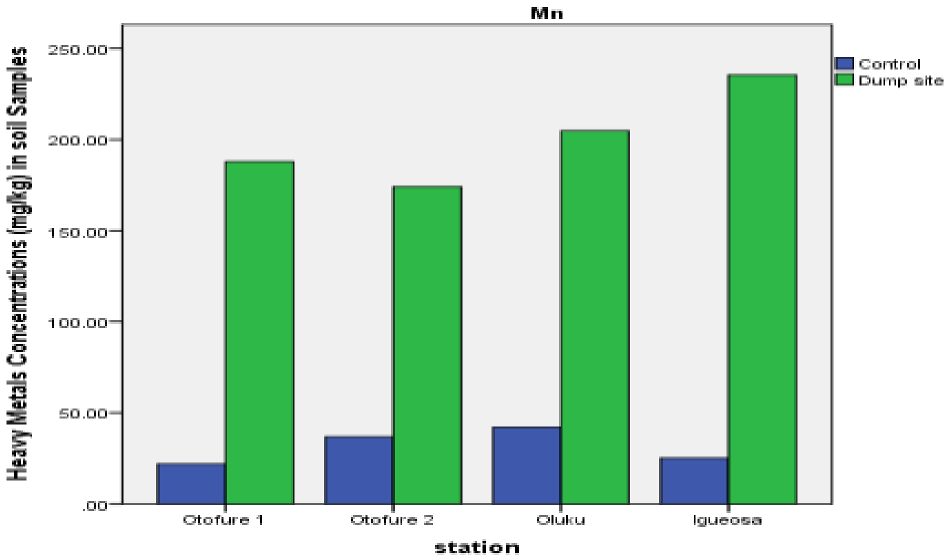

Figure 9: Mn concentrations in dumpsites and control soils across the four stations

3.2 DISCUSSION

The World Health Organisation does not have soil quality guidelines or standards for heavy metals in soil. Therefore, comparisons made in this study were based on concentrations of the control soils, National Environmental Standard and Regulatory Agency (NESREA) Soil Quality Standards enshrined in Schedule XII, and universally accepted safe range for tropical soils (TABLE 1).

3.2.1 Lead

The range of Pb obtained in this study (24.66 – 57.89 mg/kg) was higher than the control soil (4.31-9.11 mg/kg) (Fig 2) but within the permissible limit of Pb in soil (TABLE 1). Pb concentration was particularly high in the studied stations probably because of the dump sites proximity to highway roads. Akinola *et al*. [10], and [11], studied similar sites close to major high ways in Lagos, Nigeria and Madrid, Spain respectively and reported high concentrations of metals particularly Pb than those farther away from the roads. Although the concentrations of Pb obtained in this study are within the permissible limit in tropical soils (TABLE 1), it is undesirable to humans because of its health hazards. A notable serious effect of lead toxicity is its tetratogenic effect [17]. Lead poisoning also causes inhibition of the synthesis of haemoglobin, dysfunctions in kidney, joints and damage to the central nervous system [18].

3.2.2 Cadmium

The range of Cd obtained in the dump sites (3.49 – 7.02 mg/kg) was higher than the range obtained in the control (0.77 – 1.45 mg/kg) (Fig. 3). The range of Cd obtained in the dump sites exceeded the permissible limit (0.1 – 3.00 mg/kg) in tropical soil as well as NESREA soil standards (TABLE 1). Following this finding, the studied environment is considered to be highly contaminated with Cd according to [12]. Consequently, humans who would have had contact with the soil either directly through skin or ingestion at the time of this study might have ended up with cadmium contamination. Cd load was high in all the dump sites but Oluku dump site had the highest (TABLE 2). This was expected because, used batteries from cars, torch light and condemned television and radio sets were disposed at this dump site. Cd is a key component in battery production [19] and its oxides is used in black and white television phosphors [20]. Other sources of Cd in the environment include fossil fuel combustion, phosphate fertilizers, cement production and solid waste incineration. These sites may be considered unsuitable for agricultural activities because of likely contamination by Cd. Although, the range of Cd obtained in this study exceeded the permissible limit in tropical soil and NESREA soil standards, it is below the range (7.30 – 29.00 mg/kg) reported by [12]. Cadmium is a metal with unknown essential function in higher plants [21] and animals. Long term exposure to Cd either through inhalation or ingestion has been reported to be highly toxic to humans especially kidney and bones and with the potential to cause cancer of the lungs [22].

3.2.2 Iron

Fe had very high concentrations in all the stations irrespective of the month of sampling. This finding is not out of hand because, Fe is the most common element (by mass) forming much of Earth's outer and inner core. More so, Fe has been reported to occur in high proportion in Nigerian soil environment [17]. However, its high concentrations obtained in this study in all the stations (TABLE 2) calls for serious concern. Excessive exposure to Fe can cause serious health problems such as vomiting, upper abdominal pain, pallor, cyanosis, diarrhea, dizziness, shock, heamochromatosis, diabetes, liver, lungs and kidney diseases, haepatoma and cardinomyopathy [7][23][18].

3.2.3 Chromium, Nickel, Copper, Zinc and Manganese

The ranges of Cr, Ni, Cu, Zn and Mn concentrations obtained in the dump sites were generally higher than ranges obtained in the control (TABLE 2) however; both ranges were within the permissible limits in tropical soil (TABLE 1). Although the concentrations of these metals obtained across the stations were low (Figs 4, 5, 7, 8 and 9 respectively), it is crystal clear that dump sites contributed to the overall increase in the metal concentrations vis a vis the concentrations obtained at control stations. Nickel for example, is a potent skin sensitizer which implies that, it could cause allergic reaction in human [22], while exposure to excess copper can cause anemia, liver and kidney damage, stomach and intestinal irritations in man [24].

3.3 Geoaccumulation Study of the Stations

Geoaccumulation Index was used to assess the degree of heavy metals contamination of the studied environment. Based on Forstner [25] classification, the degree of contamination in all the stations may be classified between uncontaminated, moderate and strongly contaminated (TABLE 3). In general, Iguosa dump site had the highest degree of contaminations by most of the heavy metals studied followed by Oluku, Otofure 1 and Otofure 2 respectively (TABLE 3). This finding may be due to the homogeneity and small quantity of wastes disposed at Otofure 2 dump site by rural dwellers compared to the content of wastes disposed at Iguosa, Oluku and Otofure 1. This finding can also be attributed to the fact that Otofue 1, Iguosa and Oluku dump sites are closer to high traffic density areas than Otofure 2 dump site. The same trend was observed by [26] in Ghana who assessed the soil quality of four dump sites and reported that the dump site in a rural community had the lowest degree of contamination. Akinola *et al.* [10] in Lagos, Nigeria and Hernandez *et al.* [11] in Madrid, Spain studied similar sites close to major high ways and reported high concentrations of heavy metals than those farther away from the roads.

IV. Summary and Conclusion

The results obtained in this study showed that the four dump sites had measurable changes in the soil qualities. The concentrations of heavy metals: Pb, Cd, Ni, Cr, Fe, Cu, Zn and Mn analysed in soil decreased as distance increased from the study stations indicating anthropogenic source of contaminations. More so, it was revealed that the contents and locations of the dump sites determined heavy metals concentrations. These findings are in agreement with Hernandez *et al.* [11] in Spain, Oyedele *et al.* [9] in Ile – Ife, Akinola *et al.* [10] in Lagos, Nigeria and Agyarko *et al.* [26] in Ghana.

In conclusion, the study revealed that waste dump sites are sources of heavy metals contamination of the environment. The concentrations of Cd obtained in this study exceeded its threshold in soil hence, it will be very necessary to monitor heavy metals concentrations in dump sites to avoid fauna and flora contamination via food chain.

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