

Assessment of Soil Heavy Metal Concentration in Ori-Ile Village Battery Waste Dumpsite and its Environs, Ibadan, Southwest, Nigeria

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Abstract

Heavy metal polluted environments are threats to human health due to their bioaccumulation. Consequently, there is a need to constantly monitor and evaluate their concentrations in residential area soils. Ori-Ile village in Egbeda Local Government Area of Ibadan, which was formally a battery waste dumpsite, is currently a residential area. Soil samples from the battery waste dumpsite and its environs were analyzed for Lead, Cadmium, Manganese, Zinc and Copper concentrations using Atomic Absorption Spectrophotometer (AAS). Results showed that the mean metal concentration values were Pb (15,701.05 mgkg⁻¹), Cd (7.63 mgkg⁻¹), Mn (405.68 mgkg⁻¹), Zn (85.45 mgkg⁻¹) and Cu (88.80 mgkg⁻¹). Using Enrichment Factor, the soils were classified as deficient (1.0) to extremely highly enriched with Pb (3320.5), Cu (65.1) and Zn (37.7) while they were deficient to minimally enriched with Cd (1.9) and Mn (1.1). Calculated Geo-accumulation index (Igeo) showed the soil to be unpolluted (Igeo < 0) to moderately polluted (1 ≤ Igeo < 2) for the metals analyzed. The Contamination/Pollution Index (C/PI) placed the soil as slightly contaminated (0.1-0.3) to excessively polluted with Pb (733.6) and Cd (25.6); moderately contaminated to severely contaminated with Cu; and slightly contaminated to slightly polluted with Mn and Zn. To a large extent, the mean concentration value of Pb in Ori-Ile village was above the international guideline value for environmental quality criteria and hence, the soil should not be used for agricultural and residential purposes.

Keywords: Heavy Metal, Soil, Ori-Ile Village, Dumpsite, Environmental Pollution

1. Introduction

One of the key global difficulties facing the biosphere in recent times is environmental pollution. According to [1], indiscriminate disposal of industrial wastes due to man's lack of consideration for his environment has culminated into uncontrolled contamination of the environment. Pollution of the ecosystems by untreated industrial wastes is often connected with the occurrence of heavy metals [2]. According to [3], heavy metal is the generic term for metallic elements having an atomic weight higher than 40.4 (the atomic mass of Calcium). Many industrial activities, including automobile battery production have often resulted in the accumulation of noxious metals in the environment [4,5,6] and the discharge of heavy metals as a by-product of these activities has been accompanied by large scale soil pollution [7].

Heavy metals tend to persist in the environment indefinitely [8] and get accumulated

over time in soils and plants. Hence, they could have a negative influence on physiological activities of plants, determining the reductions in plant growth, dry matter accumulation and yield [9]. Excessive accumulation of heavy metals in agricultural soils often lead to elevated heavy metal uptake by crops, and thus affect food quality and safety [10]. One of the important pathways for the entry of toxic pollutants into the human body is via food chain contamination [11] and the consumption of heavy metal-contaminated food can seriously deplete some essential nutrients in the body that are further responsible for decreasing immunological defences, intrauterine growth retardation, impaired psycho-social faculties, disabilities associated with malnutrition and high prevalence of upper gastrointestinal cancer rates [12,13].

Some of the heavy metals such as Pb and Cd are toxic to plants and animals, even in low concentrations [14]; and exposure to some of them is normally chronic due to food chain transfer [15].



Pb and Cd have been found to inhibit plant growth, disturb ion uptake and transport as well as inhibit enzyme activation and photosynthesis [16,17].

Ori-Ile Village Battery Waste Dumpsite in Ikumapaiyi area of Olodo, Ibadan, Southwest, Nigeria is one of the several areas used as open dump by the waste contractors of the now closed lead acid battery manufacturing company, known as West African Battery Industry [18]. The allocation of these previously used open waste dumps for housing development has presented series of environmental challenges to the inhabitants [19]. The residents of Ori-Ile Village and the environs, predominantly grow maize for both human and animal consumption while some of them utilize their harvested maize seeds for constituting feed for their domestic animals.

Heavy metal polluted environments are threats to ecosystems, hence the need to regularly assess their concentrations in residential and agricultural soils. Therefore, this study was aimed to determine the concentration of some heavy metals (lead, cadmium, manganese, zinc, and copper) in the soil using selected pollution indices.

2. Materials and Methods

Description of Study Area

The study area is a semi-urban residential and agricultural area located on latitudes 7°24'28.1"N, longitudes 4°00'52.2"E and elevation 176m respectively. It contained a waste dumpsite located at Ori-Ile village in Ikumapaiyi Area of Olodo community, northwest of Egbeda Local Government Area, Ibadan, Oyo-State. It is popularly referred to as Ori-Ile Waste Dumpsite. The study site is a large and bare expanse of land of about 2 hectares, characterized with scanty vegetation. The most abundant group of vegetation on and around the waste dumpsite were the grasses, some of which included *Panicum clandestinum* (corn grass), *Muhlenbergia emersleyi* (bull grass) and *Echinopogon ovatus* (hedgehog grass). *Panicum clandestinum* were most abundant in areas surrounding the study site. The area has a bimodal rainfall pattern with peaks in June and September. The site was used as an unapproved waste dumpsite for battery wastes from the now closed down company called West African Battery Industry, who used to produce the battery known as 'Exide Battery'. It was also used as an informal lead recovery site by informal and local Used Lead Acid Battery operators. The area

surrounding the waste dumpsite is inhabited by people who are mostly peasant farmers and traders [18].

The study was conducted in four areas: Ori-Ile village (the main polluted site), Majue 1, Majue 2 and Ogungbade-Egberi village - the control site, as shown in Figure 1.

Enrichment Factor (EF)

The degree of soil polluted by heavy metal can be assessed by computing Enrichment Factor (EF) [20]. Enrichment Factor can be calculated according to the equation described by [21] and [22] as:

$$EF = \frac{\text{Mean Concentration of Heavy Metal in Soil}}{\text{Background Concentration}}$$

Where EF = Enrichment Factor and Background concentration = Concentration at the control site. Enrichment Factor is explored to distinguish between pollution due to nature and man-made causes as well as evaluating amount of human impact. Increase in Enrichment Factor value implies a corresponding increase in the contribution of human activities [23].

Geo-accumulation Index

The amount of metal pollution or contamination in the soil can similarly be assessed using geo-accumulation index [24]. This is computed using the formula: $I_{geo} = \log_2 C_{\text{metal}} / 1.5 C_{\text{metal}}(\text{control})$. C_{metal} is the concentration of heavy metal in sample while $C_{\text{metal}}(\text{control})$ is the concentration of metal in the uncontaminated control. 1.5 is presented to reduce the influence of conceivable alterations in the control values which may be ascribed to lithogenic change in the soil [25].

Contamination/Pollution Index (C/PI)

[26] defined contamination/pollution index (C/PI) as the quantity of metal in soil/target value. The target value is a recommended quantity of metallic elements as gotten via set table framed by Division of Petroleum Resources of Nigeria (DPR) for the highest permissible quantity of metals in soil [27]. DPR target values used in this study include Cd (0.8 mgkg⁻¹); Cu (36 mgkg⁻¹); Pb (85 mgkg⁻¹); Mn (437 mgkg⁻¹) and Zn (146 mgkg⁻¹). C/PI value not up to one defines contamination ranges whereas figures more than one define pollution [26].



Soil Sampling and Determination of Heavy Metal Concentration

A total of 96 soil samples were collected, with 24 samples from each site, at 0-15cm depth using soil auger (plate 1). The samples were kept in clean polythene bags without heavy metals contamination and were well covered while being moved from the sampling sites to the laboratory. The soil samples were thoroughly mixed and pulled together [28] for heavy metal analysis. The concentration of heavy metals and soil pH was done according to the method reported by [29] at the Department of Agronomy, University of Ibadan, Ibadan. The soil samples were air-dried for 24 hours and after drying, they were sieved first with 2.0mm sieve and then with 0.5mm sieve. The 0.5mm sieve was obtained from the 2.0mm sieved soil. The sample was weighed into a beaker and between 5mls and 10mls of an acid mixture of perchloric acid and concentrated nitric acid in ratio 2:1, was added and the beaker content was placed on a digesting heating mantle at 105°C for one hour. There was a colour change from brown to

colourless. The digest was allowed to cool and after cooling, it was made up to 25mls with distilled water. The concentration of heavy metals (Pb, Cd, Cu, Mn, and Zn) was read on bulk scientific Atomic Absorption Spectrophotometer (AAS) Model 210/211 VGP at various wavelengths [29].



Plate 1: Soil Auger used for soil sample collection



Figure 1: Map of Oyo State and extracted Egbeda Local Government Area showing the sampling sites.



3. Results

Table 1 shows the mean metal concentration (in mgkg^{-1}) of soil samples across the four study sites. The mean Lead concentration in the soils examined was $15,701.05 \text{ mgkg}^{-1}$ and ranges from $31.20 - 54856.5 \text{ mgkg}^{-1}$. The mean Lead concentration for soils of each site is plotted in Figure 2. Table 2 shows the Enrichment Factor of soil heavy metals from the four different study sites. The Enrichment Factor for Pb of soils from Ori-Ile site is 3320.5, indicating extremely high enrichment, Majue 1 had EF value of 7.60, indicating significant enrichment, while Majue 2 and Ogunbade-Egberi sites have EF for Pb not up to 2, representing deficiency to minimum enrichment. Table 3 shows the Index of Geo – accumulation of Heavy Metals from the different study areas. The C/P index for Pb ranges from 0.5 in Majue 2 to 733.6 in Ori-Ile (Table 4), interpreted as moderate contamination to excessive pollution.

The average Cadmium content in the soils evaluated is 7.63 mgkg^{-1} and varies from $0.40 - 20.50 \text{ mgkg}^{-1}$ in the soil samples (Table 1). The mean Cadmium value for soils of each location is plotted in Figure 3. The results indicated that the average Cadmium content in Ori-Ile site (20.50 mgkg^{-1}) was above WHO and UKEA limits but was below NESREA and USEPA limits for Cd in soil (Table 5). The EF for Cd of soils from Ori-Ile site is 1.9 (Table 2) representing deficiency to minimum enrichment, while the EF for Majue 1, Majue 2 and Ogunbade-Egberi are all below 1.9. The C/P index for Cd ranges from 5.1 in Majue 1 to 25.6 in Ori-Ile (Table 4), interpreted as severe pollution to excessive pollution.

The mean Manganese concentration examined is 405.68 mgkg^{-1} and varies from $373.6 - 462.9 \text{ mgkg}^{-1}$ in the soil samples (Table 1). The mean

concentration for soils of each site is plotted in Figure 4. The results showed that the mean Mn concentration in all the sample sites exceeded the NESREA limit for Mn concentration in soil (Table 5). The EF for Mn of soils from all the sites is not up to 2, displaying scarcity to least enrichment (Table 2). The C/P index for Mn varies from 0.8 in Ogunbade-Egberi to 1.1 in Ori-Ile (Table 4), deduced as very severe contamination to insignificant pollution.

The mean Copper concentration evaluated is 88.80 mgkg^{-1} and ranges from $5.2 - 334.8 \text{ mgkg}^{-1}$ in the soil samples (Table 1). The mean Copper value for soils of each location is plotted in Figure 5. The results indicated that the average Copper content in Ori-Ile site (334.8 mgkg^{-1}) with the highest Cu concentration, was above NESREA, WHO and UKEA limits for Cu in soil (Table 5). The EF for Cu of soils from Ori-Ile site is 65.1 (Table 2) indicating extremely high enrichment, while the EF for Majue 1, Majue 2 and Ogunbade-Egberi are all below 2, specifying deficiency to minimum enrichment. The C/P index for Cu ranges from 0.1 in Majue 1 to 9.3 in Ori-Ile (Table 4), interpreted as very insignificant contamination to very severe pollution.

The mean Zinc concentration examined is 85.5 mgkg^{-1} and ranges from $12.0 - 291.6 \text{ mgkg}^{-1}$ in the soil samples (Table 1). The mean Zn value for each site is plotted in Figure 6. The EF for Zn of soils from Ori-Ile site is 37.7 (Table 2) indicating very high enrichment, while the EF for Majue 1, Majue 2 and Ogunbade-Egberi are all below 2, indicating deficiency to minimum enrichment. The C/P index for Zn ranges from 0.1 (in Majue 1, Majue 2 and Ogunbade – Egberi) to 2.0 in Ori-Ile (Table 4), interpreted as very insignificant contamination to insignificant pollution.



Table 1: Metal Concentration (in mgkg⁻¹) in Soil Samples (Mean ± S.D) Across the Four Study Sites

Locations	Pb	Cd	Mn	Cu	Zn
Ori-Ile	54856.5 ±31058.6**	20.5 ±8.6*	462.9 ±269.8	334.8 ±203.6*	291.6 ±253.6*
Majue 1	7846.6 ±21730	4.0 ±3.4	394.8 ±60.0	9.4 ±3.6	18.6 ±14.9
Majue 2	69.9 ±110.6	0.4 ±0.2	373.6 ±288.3	5.2 ±5.1	19.6 ±21.0
Ogunbade-Egberi	31.2 ±26.3	5.6 ±5.1	391.4 ±149.3	5.8 ±2.7	12.0 ±4.9

Mean values are significantly different from the control site (Ogunbade-Egberi) at *p<0.05.

Table 2: Enrichment Factor of Soil Heavy Metals from the Four different Study Sites

Study location	Pb	Cd	Mn	Zn	Cu
Ori-Ile	3320.5	1.9	1.1	37.7	65.1
Majue 1	7.6	0.7	1.2	1.2	0.02
Majue 2	1.7	0.8	1.3	1.0	1.2
Ogunbade-Egberi	1.0	1.0	1.0	1.0	1.0

High Pb EF at Ori-Ile indicated increased contribution of human activities to the degree of pollution.

Table 3: Index of Geo-accumulation of Heavy Metals from the different Study Areas

Location	Pb	Cd	Mn	Cu	Zn
Ori-Ile	0.5	0.3	0.02	1.1	0.7
Majue 1	0.2	0.2	0.02	-0.4	0.3
Majue 2	0.2	0.2	0.02	0.3	0.2
Ogunbade-Egberi	0.1	0.2	0.02	0.3	0.2

Table 4: Contamination/Pollution Index (C/PI) Values of Soil Samples from the different Study Sites (Target values = DPR Values)

Study Location	Pb	Cd	Mn	Cu	Zn
Ori-Ile	733.6	25.6	1.1	9.3	2.0
Majue 1	8.2	5.1	0.9	0.1	0.1
Majue 2	0.5	6.1	1.0	0.2	0.1
Ogunbade-Egberi	0.6	6.7	0.8	0.3	0.1

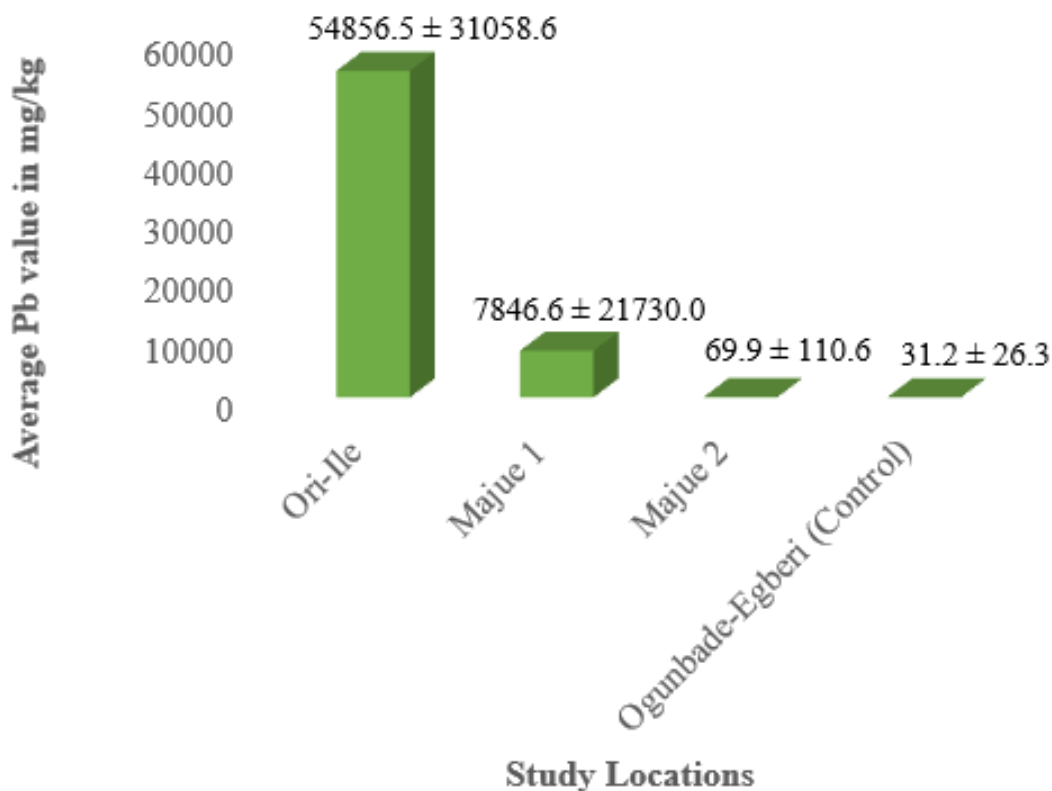
C/PI values indicated Ori-ile site to be severely polluted with Pb and Cd



Table 5: Contrast of Average Concentration (in mgkg⁻¹) of Metals in Soil Samples from the different Study Locations with National and International Limits for Heavy Metals in Soil

Heavy metal	Present study				NESREA limit	WHO limit	USEPA limit	UKEA limit
	Ori-Ile	Majue 1	Majue 2	Ogunbade-Egberi (Control)				
Pb	54856.5	7846.6	69.9	31.2	164.0	0.1	400.0	450.0
Cd	20.5	4.0	0.4	5.6	50.0	0.01	70.0	10.0
Mn	462.9	394.8	373.6	391.4	5.0	-	-	-
Cu	334.8	9.4	5.2	5.8	1.0	1.5	270.0	-
Zn	291.6	18.6	19.6	12.0	1.0	15.0	2200.0	-

(Sources: [30; 31]) Ori-Ile and Mahue 1 sampling sites exceeded all the national and international limits for heavy metals in soil, and hence not safe for habitation

**Figure 2:** Average Lead value in soil across the study locations.

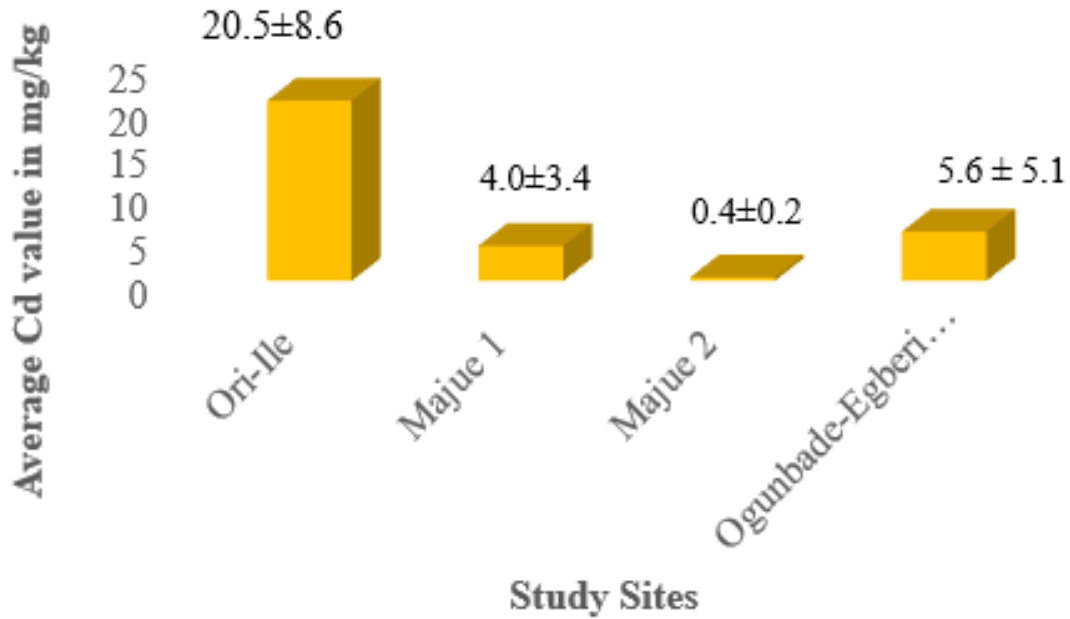


Figure 3: Average Cadmium value in soil across the study sites.

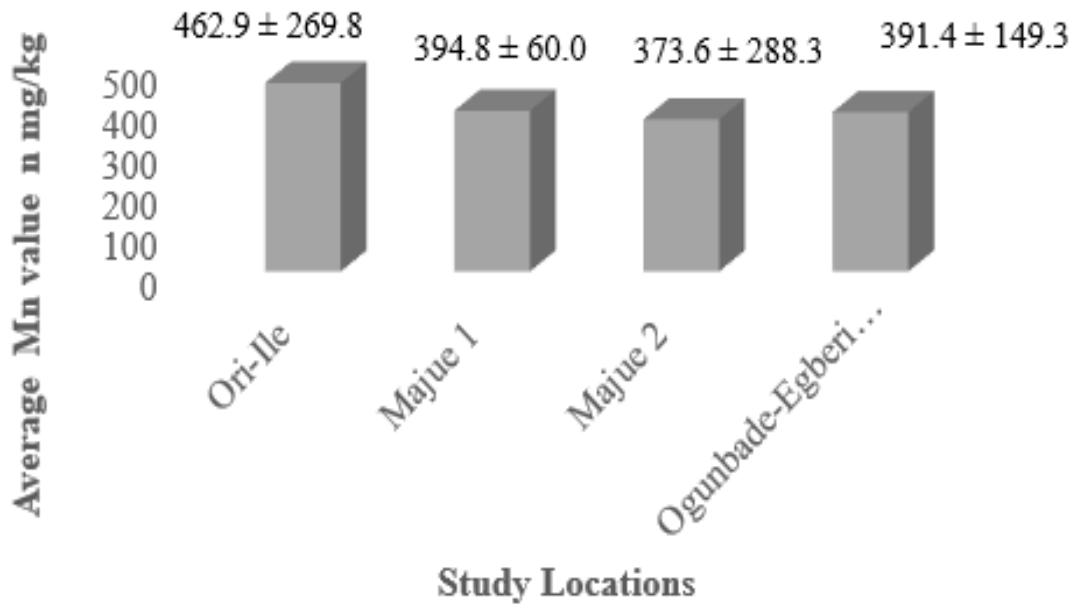


Figure 4: Average Manganese value in soil across the study sites.

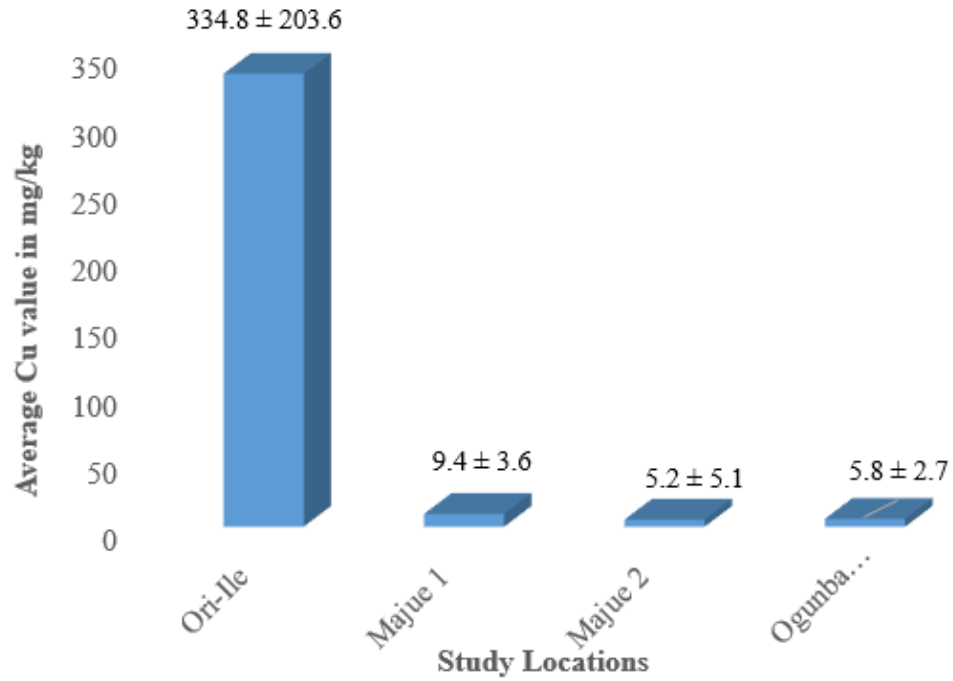


Figure 5: Average Copper value in soil across the study sites.

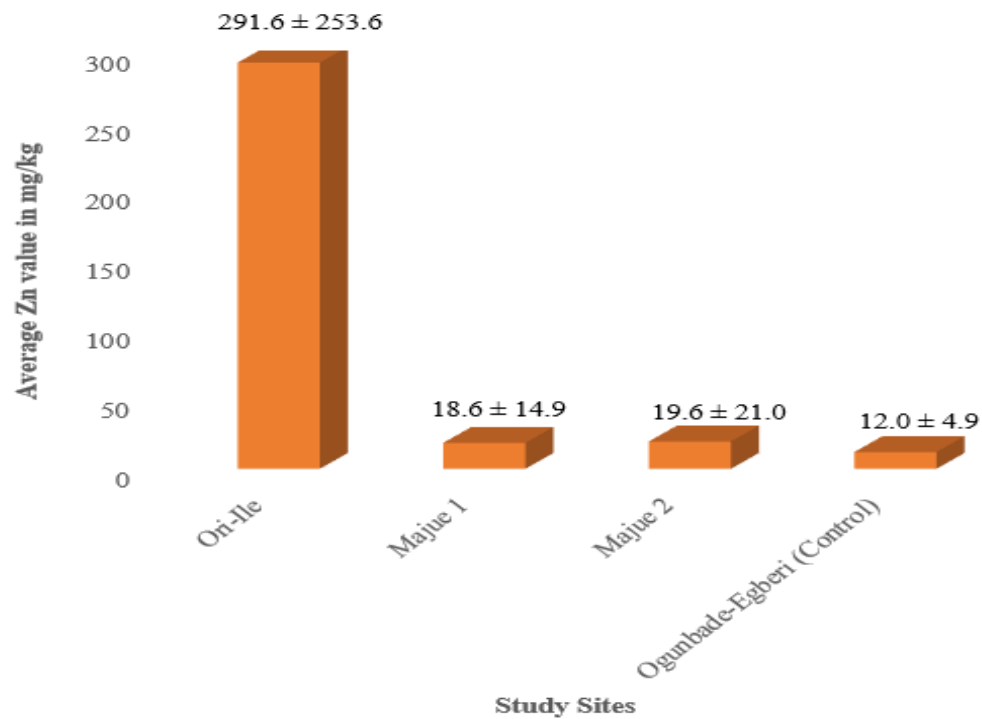


Figure 6: Average Zinc value in soils across the study sites.

4. Discussion

This study has shown that Pb, Cd, Mn, Cu and Zn concentrations in the soil of the waste dumpsite (Ori-Ile) and those of distances from the waste dumpsite (Majue 1 and Majue 2) were significantly higher than the values obtained from the control site (Ogunbade-Egberi). The metal concentrations decrease with increase in distance away from the dumpsite. Pb and Cd concentrations obtained were several folds higher than the maximum permissible limit of 164mg/kg and 50mg/kg respectively [32].

According to [33] and [34], Pb occurs naturally in all soils in concentrations ranging from 1 to 200 mg/kg with a mean of 15 mg/kg but the values obtained in this study for Ori-Ile soil and those of Majue 1 and Majue 2, 400m away from the waste dumpsite were several times beyond this range. [35] reported that normal concentrations of Pb in soil range from 15 to 30 mg/kg but this study Pb values were much higher than this value. Pb concentrations obtained were at very high concentrations than the maximum tolerable levels proposed for agricultural soils, 90 – 300 mg kg⁻¹ [36,37]. This shows a very high level of Pb contamination of the soil of the study site. [38], in their study on lead contamination of topsoil in the vicinity of a battery factory in Nigeria, reported the mean lead level of 50 - 2000 mg/kg in the topsoil studied. However, this study Pb values exceeded this range reported. In the study of Adie and [39] on soil polluted by slag from an automobile battery manufacturing plant in Nigeria, a range of 243 - 126000mg/kg was reported for Pb concentration. The mean values obtained in all the samples on and within the vicinity of the dumpsite were within this range and thus compare significantly with the result reported. The range of 419.54 - 10630.04mg/kg was reported in the studies conducted by [19] on impact assessment and safety status of the excavated waste site at Olodo, Ibadan, Nigeria. This also corroborates the values obtained in this study.

[40] reported that the median Cd concentration in soil of areas not known to be polluted ranges from 0.2 - 0.4 mg/kg. The cadmium concentrations obtained in this study were far higher than these stated values. The range of 1.95 - 32.83 mg/kg obtained by [19] in their studies on battery waste polluted areas was much less than the values obtained for Cd concentration in this study.

The Igeo value obtained in this study implied that the degree of pollution of the study sites varies from uncontaminated to moderately contaminated. The EF values obtained in this study revealed that the high value of lead, zinc, copper, and cadmium observed in Ori-Ile site, largely results from the effect of human activities rather than natural means. This could also be due to the dumping of battery waste at the site. [41] stated that Contamination/Pollution Indices (C/PI) are accumulative factors that are computed for metals in soils and used as the basis for deducing state of the soil. According to [26], C/P index value not up to one defines contamination ranges while values more than one define pollution. The calculated C/PI of the soils from the different sites in this study, gives a clear picture of the trend of the level of metal contamination/pollution in the soil. The results obtained in this study showed that Ori-Ile had the greatest value for all metals considered in this research. Lead is seen to have the highest C/PI value. This finding aligns with the observation of [42] in their research which revealed lead as having substantial contamination in soils of Shiraz area. The high C/PI value found in Ori-Ile indicated that the site is highly polluted. This could not be unconnected with the direct deposition of battery wastes on the site.

Conclusion

Heavy metal accumulation in soils is of increasing concern due to the potential human health risks [43; 44]. This eventually often leads to food chain contamination which is one of the important pathways for the entry of these toxic pollutants into the human body [45; 46]. Therefore, according to [10] the extreme build-up of heavy metals in soils can lead to higher heavy metal uptake by plants, and this can affect the quality and safety of food. This may result in several unpleasant health effects, if bioaccumulated. In view of this, the remediation of the polluted soils of Ori-Ile battery waste dumpsite and its surroundings is highly recommended.

Further research work in this village should focus on phytoremediation. More so, research should be conducted to study the effects of heavy metals on the inhabitants of Ori-Ile village to ascertain the quantity of heavy metals in their systems and possible detection of early damage to their cells, tissues, organs, and systems before they become so detrimental.



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