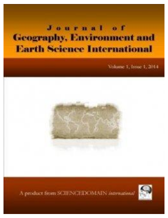

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# Heavy Metal Concentration and Physicochemical Parameters in Soil and Plants near Unengineered Dumpsites in Port Harcourt, Nigeria

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Author OOE designed the study, performed the statistical analysis, wrote the protocol and wrote the draft of the manuscript. Authors GJU and ICO supervised the study. All authors read and approved the final manuscript.*

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## ABSTRACT

Cross sectional study was conducted around two unengineered dumpsites in Port Harcourt, Nigeria on heavy metal concentrations and physicochemical parameters in soil and plants. Physicochemical parameters studied include pH, Total Dissolved Solids (TDS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Electrical Conductivity (EC), Nitrite ion, Phosphate ion, Sulphate ion, Chloride ion and heavy metals (Cd, Pb, Zn, Fe, and Cu). The result shows that edible plants were observed to have recorded one variety of metal or the other; and a relatively higher concentration of metals were found in the soil than in plant which indicates possible gradual movement of metals from the soil samples into the plants. Chloride ion concentration was negligible in all edible plants, but traces of other anions were recorded in both plants. Both

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dumpsites have contamination factor (CF) ranging from low to very highly polluted for different metals. Contamination degree (CD) at the dumpsites showed that both sites have very high degree of contamination. Pollution Load Index (PLI) of 4.64 in S1 (Soil sample from Choba dumpsite) and 4.19 in S2 (Soil sample from Ada-George dumpsite) show that there is progressive deterioration of the two sites. Index of geoaccumulation ($I_{geo}$) values obtained show that Zn was the only metal that did not enrich the soil with Zero (0) values (S1 = -0.04, and S2 = -2.00); which indicate that it originated from natural processes or crustal materials alone, and not from anthropogenic sources. Other metal concentrations ranged from unpolluted to moderately polluted and to extremely polluted. Bioaccumulation Factor (BAF) showed that all the dumpsites are excluders and are not effective accumulators of metals and anions from the soil into the plants. Urgent attention has to be given to the dumpsites to prevent further degradation of the soil and possible bioaccumulation of metals in edible plants.

*Keywords: Heavy metals; physicochemical; unengineered dumpsites; leachate; underground water; borehole water.*

## 1. INTRODUCTION

In developed countries, the disposal of most wastes in landfills is done after proper waste management processes such as recycling, reuse; sources reduction and treatment operation have been completed [1]. Cunningham et al. [2] reported that the practices mentioned above are not common in developing countries. This results to the development of unengineered dumpsites of different materials ranging from perishable food wastes to hazardous chemicals which pollute the environment. Landfilling is one of the less expensive methods of disposal of solid waste playing an important role in integrated solid waste management [3]. It is reported that about 90% of municipal solid waste (MSW) is disposed in open dumps and landfills in a crude manner creating problems to public health and the environment [4]. The emitted liquid known as ‘Leachate’ may contain several organic and inorganic contaminants which have detrimental effects on water, and soil environment [5].

Rapid population growth and development in Nigerian states has resulted in environmental health hazards [6]. Wastes are generated from human activities and in most cases not properly managed in most Nigerian cities [6,7]. This leads to low environmental quality which accounts for 25% of all preventable ill health in the world [8]. In most cases, wastes are collected and disposed of in uncontrolled or unengineered dumpsite sites near residential buildings. These wastes are heaped up and/or burnt, polluting the environment [9,10]. Waste generally leads to proliferation of pathogenic microbes and heavy metals which can transfer significantly to the environment [11]. Leachates from dumpsites constitute a source of heavy metal pollution to both soil and aquatic environments [12]. This may have serious effects on soils, crop and human health [13].

Many unengineered dumpsites located in various parts of Port Harcourt and its environment are located at or close to streams, valleys, open fields, water lands and in abandoned ‘borro’ pits. In Port Harcourt today, wastes generated and gathered at source are disposed of in communal bins or communal collection points stipulated by the Government. Most of these wastes appear to come from domestic sources and are characterised mostly by household waste. Generally, the practices in the unengineered dumpsites are unrestricted to different sources of wastes. Dumpers do have access to the site at any time of the day, which increase dumping of restricted materials, such as car batteries and metals. Scavengers have free access to the dump, and they scatter the waste to recover valuable material. Some scavengers even pitch their tent in and around the unengineered dumpsites.

Dumpsite leachate is a major source of soil contamination which is caused by the presence of chemicals or other alteration in the natural soil environment. Concern over soil contamination stems primarily from health risks from direct contact with the contaminated soil, vapours from the contaminants, and from secondary contamination of water supplies within the soil [14]. High potential risk may result from infiltration of hazardous chemicals in the soil into groundwater aquifers used for human consumption. Agriculture in these areas faces major problems when pollutants and heavy metal are transferred into crops and subsequently into the food chain.

Several metals are essential at low concentrations for normal growth and development in either plants or animals, but become toxic at higher cellular concentrations [15,16,17]. Other trace metals (e.g. lead, mercury) are apparently never required and must be regarded as only having potentially negative effects. Trace metal uptake by plants is generally limited and usually shows saturation characteristics. However, phytotoxicity thresholds (lowest concentration at which decreased plant growth occurs) are generally higher than tissue toxicity thresholds for those animals consuming them. Risks for plants are therefore of a lower order than for animals, thus facilitating bioaccumulation and exacerbating problems of trace metal transfer along the food chain.

A key route for entry of metals into the food chain is via uptake by plants from the soil or as a result of accumulation in fish tissues. Uptake by plants is affected by soil pH and salinity, with cadmium and lead uptake being enhanced by chloride complexation of the metals in materials such as leachate [18]. General toxicity effects of contamination on plant physiology are depressed root growth (with consequent drought symptoms) and foliar discolouration (chlorosis) resulting from membrane damage and enzyme inhibition [19]. However, major interactions occur between different trace metals [20], with many metals inducing copper deficiency symptoms.

This study is therefore set to assess heavy metal concentration and physiochemical parameters in soil and plants near unengineered dumpsites in Port Harcourt, Nigeria.

## 2. METHODS

Cross-sectional study of selected unengineered dumpsite was conducted to assess the concentrations of heavy metal and physiochemical parameters in the soil and plants near unengineered dumpsites in Port Harcourt, Nigeria. Port Harcourt is the capital and largest city in Rivers State, Nigeria. It is located in the Niger-Delta region; and at the southernmost part of Nigeria between longitude 7° 00′ and 7° 15′ East of the Greenwich meridian and Latitude of 4° 30′ and 4° 47′ North of the equator (See Fig. 1). The average temperature throughout the year in the city is relatively constant, showing little variation throughout the year. Its average temperature is between 25°C – 28°C.

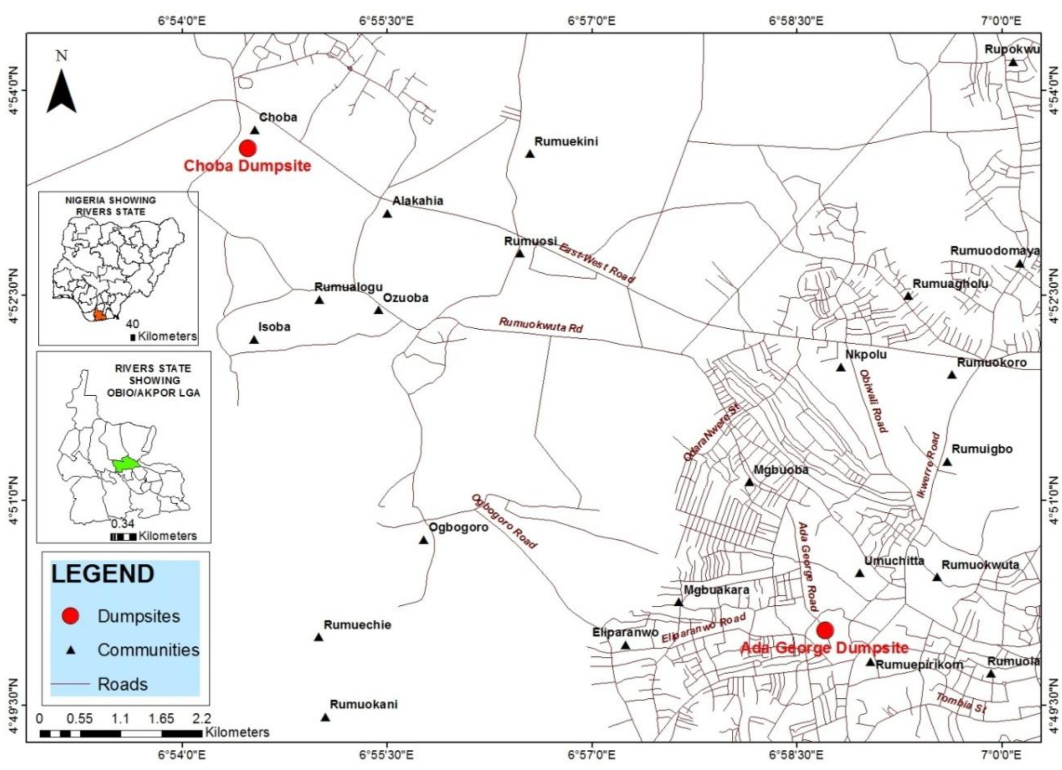


**Fig. 1. Map of study area**

Cross-sectional study was conducted to assess Heavy Metal Concentration and Physiochemical Parameters in Soil and Plants near Unengineered Dumpsites in Port Harcourt, Nigeria. The study covered two major open unengineered dumpsites; Ada George Road and Choba. Samples of soil and plants were collected around two unengineered dumpsites in Port Harcourt, Rivers State Nigeria for laboratory analysis. Parameters tested include Nitrite ($NO_3^-$), Phosphate ($PO_4^{3-}$), Chloride ($Cl^-$), Sulphate ($SO_4^{2-}$), Cadmium (Cd), Lead (Pb), Zinc (Zn), Iron (Fe), Copper (Cu). Geomorphological study of the region indicates that most of the area where the unengineered dumpsites were located was found to have deep pediments, with shallow and buried pediments in other parts.

Four samples of soil and edible plants (Pawpaw and Potatoes) each were collected around two unengineered dumpsites in Port Harcourt, Nigeria for laboratory analysis. Attempts were made to minimise changes in the chemistry of the samples. Preservation methods such as refrigeration and protection from light were adopted to assist in maintaining the natural chemistry of the samples. These conditions were maintained until the samples were received at the laboratory. Samples are stored in refrigerator at 4°C. Sampling plan was coordinated with the laboratory so that appropriate sample receipt, storage, analysis, and custody arrangements were provided.

## 2.1 Assessment Tools

Five quality tools/indices were applied for interpretations of data. These are:

- Contamination Factor (CF)
- Contamination Degree (CD)
- Pollution Load Index (PLI)
- Index of Geoaccumulation ($I_{geo}$)
- Bioaccumulation Factor (BAF)

### 2.1.1 Contamination Factor (CF)

Contamination factor is used to determine the concentration status of the sediment in the present study. Contamination factor was calculated by comparing the mean of trace metal concentration with average shale or background concentration given by Turekian and Wedepohl [21], which is used as global standard reference for unpolluted sediment. The CF is the single element index. CF for each metal was determined according to Thomilson et al. [22] by the following equation:

$$\text{Contamination Factor (CF)} = \frac{\text{Mean Metal Concentration at Contaminated Site}}{\text{Metal Average Shale Concentration}}$$

Hakanson [23] classified CF values into four grades, i.e.,

a) CF < 1 = low CF,
b) 1 $\leq$ CF < 3 = moderate CF,
c) 3 $\leq$ CF < 6 = considerable CF and
d) CF > 6 = very high CF.

### 2.1.2 Contamination Degree (CD)

Contamination degree is used to determine the degree of overall contamination or concentration status in the sampling site. CD is the sum of all CF values of a particular sampling site [23,24].

$$\text{CD} = \sum_{i=I}^{i=n} (\text{CF})$$

Where n is the number of analysed elements and CF is the contamination factor.

Ahdy and Khaled [25] classified CD in terms of four grade ratings of sediments, i.e.

CD < 6 shows low CD,
6 $\leq$ CD < 12 shows moderate CD,
12 $\leq$ CD < 24 shows considerable CD and
CD $\geq$ 24 shows very high CD.

### 2.1.3 Pollution Load Index (PLI)

Pollution severity and its variation were determined with the use of pollution load index. Pollution load index for each site was determined by the method proposed by Thomilson et al. [22]. It is used for detecting pollution which permits a comparison of pollution levels between sites and at different times. The PLI was obtained as a concentration factor of each heavy metal with respect to the background value in the soil. The PLI for a single site is the nth root of n number multiplying the factors (CF values) together. PLI for each site was determined by the following equation:

$$\text{PLI} = (\text{n}\sqrt{(\text{CF1 X CF2 X CF3 X} \ldots\ldots \text{CFn})}$$

Where

**CF** is the contamination factor and
**n** is the number of parameters.

#### 2.1.4 Index of Geo-Accumulation ($I_{geo}$)

A common approach to estimating the enrichment of metal concentrations above background or baseline concentrations is to calculate the index of geoaccumulation ($I_{geo}$) as proposed by Müller [27]; Abrahim and Parker [28]. $I_{geo}$ is used to quantify the extent of heavy metal contamination associated with soils. This index is basically a single metal approach to quantify metal pollution in sediments when the concentration of toxic heavy metal is 1.5 or more times greater than their lithogenic background values [29]. Geo-accumulation index is calculated using the following equation:

$$\mathrm{Igeo} = \log 2 \frac{\mathrm{Cn}}{1.5\mathrm{Bn}}$$

Where

- **Cn** is the measured concentration of the element n in the soil tested,
- **Bn** is the geochemical background value of the element n in average crust (average shale concentration has been given by Turekian and Wedepohl [21]; Taylor and McLennan [30]; and Wedepohl [31].
- **1.5** is the factor used to compensate possible variations in background data (correction factor), which may be attributed to lithogenic effect (30).

A geochemical background value of Fe was taken from Turekian and Wedepohl [21]. The others were taken from Aksu et al. [24] and Reimann et al. [32]; as: Cu: 17 ppm, Zn: 65 ppm, Pb: 8.5 ppm Cd: 0.003 ppm.

The $I_{geo}$ factor is not comparable to other indices of metal enrichment due to the nature of the $I_{geo}$ calculation; it involves a log function and a background multiplication of 1.5. It is composed of seven grades (0–6) indicating various degrees of metal enrichment above the average shale value ranging from unpolluted to very high polluted sediment quality. Table 2.

#### 2.1.5 Bioaccumulation factor

BAF was calculated by:

$$\mathrm{BAF} = \frac{\mathrm{Cplant}}{\mathrm{Csoil}}$$

$C_{plant}$ and $C_{soil}$ are metals concentration in the plant shoot (mg/kg) and soil (mg/kg), respectively. Ma et al. [33]; and Cluis [34] categorised BAF further as

Excluder = BAF<1
Effective Accumulator = BAF=1
Hyperaccumulators = BAF>1

**Table 1. Categories of the sediment quality according to PLI**

| Pollution load index | Categories |
|---|---|
| PLI < 1 | Perfection |
| PLI = 1 | indicate only baseline levels of pollutants present and |
| PLI > 1 | indicate progressive deterioration of sites |

*(After [26])*

**Table 2. Classification of sediment grade based on $I_{geo}$ Index [27]**

| $I_{geo}$ value | Class | Category |
|---|---|---|
| $I_{geo} \leq 0$ | 0 | Unpolluted |
| $0 < I_{geo} \leq 1$ | 1 | From unpolluted to moderately polluted |
| $1 < I_{geo} \leq 2$ | 2 | Moderately polluted |
| $2 < I_{geo} \leq 3$ | 3 | From moderately to strongly polluted |
| $3 < I_{geo} \leq 4$ | 4 | strongly polluted |
| $4 < I_{geo} \leq 5$ | 5 | From strongly to extremely polluted |
| $I_{geo} > 5$ | 6 | extremely polluted |

## 3. RESULTS AND DISCUSSION

The average result of physicochemical parameters and heavy metals obtained in the soil and edible plants are recorded in Table 3.

### 3.1 Concentration of Metals in Soil and Edible Plants (in mg/kg)

Concentrations of metals obtained from the two dumpsites include S1 (Cd=14.60, Pb=21.30, Zn=94.70, Fe=154.20, Cu=66.60), and S2 (Cd=1.80, Pb=0.9, Zn=24.30, Fe=103.30, Cu=43.30). This result shows that soil at Choba dumpsite (S1) receives more metallic waste than Ada-George dumpsite (S2). Cd and Pb are lower in the soil samples than other metals which indicate that there are fewer dumping of batteries, fluorescent lamps, photographic materials and petroleum compounds than other metallic sources.

Tables 3 and 4; shows that all the plants have taken up one form of metal or the other. Zn and Fe are the most absorbed metals with 21.20 mg/kg and 18.70 mg/kg respectively. Edible plants at Ada-George dumpsite were free of Cd and Pb, while edible plants at Choba dumpsites have absorbed all the forms of metal analysed. This can be linked to the fact that Ada-George dumpsite is relatively free of any source of Cd and Pb like batteries, radiographic materials etc. The result also shows a gradual transition of concentration from the soil samples to the two edible plants. Chlorine was negligible in the edible plants sampled, but traces of metals were found in them, which indicate possible absorption from the soil and leachate.

**Table 3. Average sampling result (in mg/kg)**

| Parameter | S1 | S2 | Paw 1 | Paw 2 | Pot 1 | Pot 2 |
|---|---|---|---|---|---|---|
| Cd | 14.60 | 1.80 | 1.08 | <0.001 | 1.00 | <0.001 |
| Pb | 21.30 | 0.90 | 2.10 | <0.001 | 2.90 | <0.001 |
| Zn | 94.70 | 24.30 | 8.10 | 21.20 | 13.70 | 10.50 |
| Fe | 154.20 | 103.30 | 18.70 | 6.90 | 4.00 | 1.60 |
| Cu | 66.60 | 43.30 | 4.30 | 1.90 | 5.60 | 0.80 |
| $NO_3^-$ | 410.30 | 16.30 | 2.10 | 0.10 | 0.98 | 0.30 |
| $PO_4^{3-}$ | 21.80 | 4.30 | 2.20 | 0.30 | 1.40 | 0.80 |
| $Cl^-$ | 146.50 | 42.60 | <0.01 | <0.01 | <0.001 | 0.002 |
| $SO_4^{2-}$ | 110.60 | 69.30 | 0.90 | 1.20 | 3.60 | 1.90 |

*Where: S1 = Soil sample from Choba dumpsite, S2 = Soil sample from Ada-George dumpsite, Paw 1 = Pawpaw plant from Choba dumpsite, Paw 2 = Pawpaw plant from Ada-George dumpsite, Pot 1 = Potato plant from Choba dumpsite, Pot 2 = Potato plant from Ada-George dumpsite*

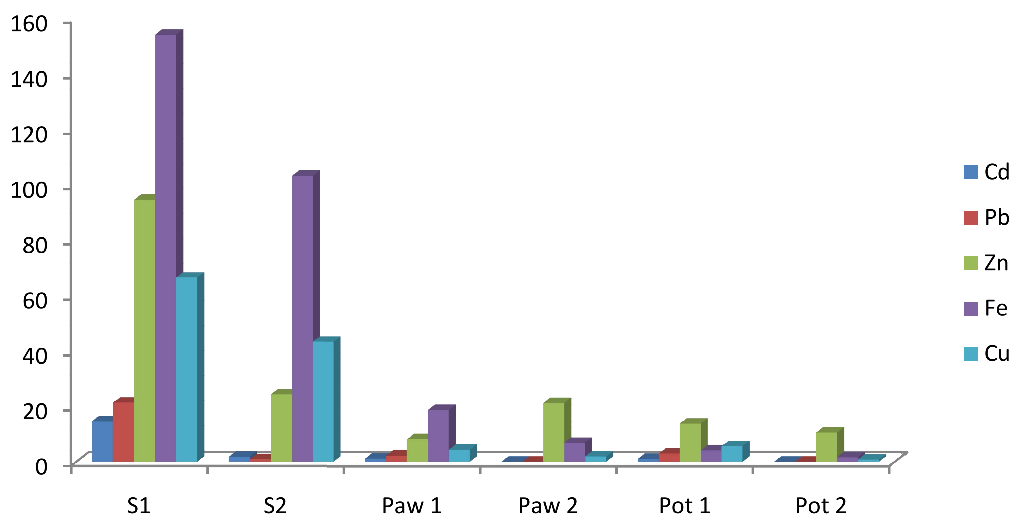


**Fig. 2. Average concentration of metals in the soil and edible plants**

**Table 4. Average concentration of metals in the soil and edible plants (in mg/kg)**

| | Cd | Pb | Zn | Fe | Cu |
|---|---|---|---|---|---|
| S1 | 14.6 | 21.3 | 94.7 | 154.2 | 66.6 |
| S2 | 1.8 | 0.9 | 24.3 | 103.3 | 43.3 |
| Paw 1 | 1.08 | 2.1 | 8.1 | 18.7 | 4.3 |
| Paw 2 | 0.001 | 0.001 | 21.2 | 6.9 | 1.9 |
| Pot 1 | 1 | 2.9 | 13.7 | 4 | 5.6 |
| Pot 2 | 0.001 | 0.001 | 10.5 | 1.6 | 0.8 |

**Table 5. Average concentration of anion in soil and edible plants (in mg/kg)**

| | $NO_3^-$ | $PO_4^{3-}$ | $Cl^-$ | $SO_4^{2-}$ |
|---|---|---|---|---|
| S1 | 410.3 | 21.8 | 146.5 | 110.6 |
| S2 | 16.3 | 4.3 | 42.6 | 69.3 |
| Paw 1 | 2.1 | 2.2 | 0.01 | 0.9 |
| Paw 2 | 0.1 | 0.3 | 0.01 | 1.2 |
| Pot 1 | 0.98 | 1.4 | 0.001 | 3.6 |
| Pot 2 | 0.3 | 0.8 | 0.002 | 1.9 |

## 3.2 Concentration of Anion in Soil and Edible Plants

Table 5 and Fig. 3 shows the concentration of anions in the soil at the unengineered dumpsites. As in other parameters, S1 recorded relatively highest concentrations than S2. (S1: $NO_3^-$ = 410.30, $PO_4^{3-}$ = 21.80, $Cl^-$ = 146.50, $SO_4^{2-}$ = 110.60; and S2: $NO_3^-$ = 16.30, $PO_4^{3-}$ = 4.30, $Cl^-$ = 42.60, $SO_4^2$- = 69.30). $NO_3^-$ was highest in S1 indicating that the dumpsite at Choba contains components that are organic in nature.

Chloride ion concentration was negligible in all edible plants as it was hardly absorbed by them. Traces of other anions were however recorded in both Pawpaw and Potatoes. (Paw 1: $NO_3^-$ = 2.10, $PO_4^{3-}$ = 2.20, $Cl^-$ = <0.01, $SO_4^{2-}$ = 0.90; and Paw 2: $NO_3^-$ = 0.10, $PO_4^{3-}$ = 0.30, $Cl^-$ = <0.01, $SO_4^{2-}$ = 1.20. Pot 1: $NO_3^-$ = 0.98, $PO_4^{3-}$ = 1.40, $Cl^-$ = <0.01, $SO_4^{2-}$ = 3.60, and Pot 2: $NO_3^-$ = 0.30, $PO_4^{3-}$ = 0.80, $Cl^-$ = <0.01, $SO_4^{2-}$ = 1.90. The result shows a relatively higher concentration in the soil than in the plant. This might be as a result of addition of cation to the anion forming compound before they are absorbed by the root of those edible plants. It shows that the higher the concentrations in the soil, the more likely it is the plants will absorb the anions.

## 3.3 Data Analysis

The tools for the analysis of data are

1. Contamination Factor (CF)
2. Contamination Degree (CD)
3. Pollution Load Index (PLI)
4. Index of Geoaccumulation ($I_{geo}$)
5. Bioaccumulation Factor (BAF)

The result in Table 6 shows that Zn having the lowest CF with 1.46 in S1; and the highest was recorded in Cd with 4,866.67. Others in descending order are Fe (30.84), Cu (3.92) and Pb (2.51). This shows that the soil in S1 is from moderately polluted to very highly polluted (i.e low CF to high CF). S2 however has lowest CF in Pb and Zn with 0.11 and 0.37 respectively. Others in ascending order are Cu (2.55 – moderate CF), Fe (20.66 – very high CF) and Cd (600.00 – very high CF). CF for Cd and Fe are very high in the two dumpsites. This shows that there is increase in the quantity of batteries and metallic products dumped into the unengineered dumpsites. S1 also recorded relatively higher CF than S2. CD at S1 was 4,905.4, and S2 was 623.69; which shows that both sites have very high degree of contamination. Pollution Load Index of 4.64 was recorded in S1 and S2 has 4.19 for PLI, which shows that there is progressive deterioration of the two sites. $I_{geo}$ obtained for S1 include the following in order of decreasing values: Cd (11.66), Fe (4.36), Cu (1.38), Pb (0.74) and Zn (-0.04). The result shows that the most polluted metal in S1 is Cd (extremely polluted), and the least polluted metal is Zn (which indicates unpolluted). S2 has the same order with the highest at Cd (8.64, indicating extremely polluted), followed by Pb (3.84), Fe (3.78), Cu and Zn (with 0.77 and -2.00 falling in the range of unpolluted).

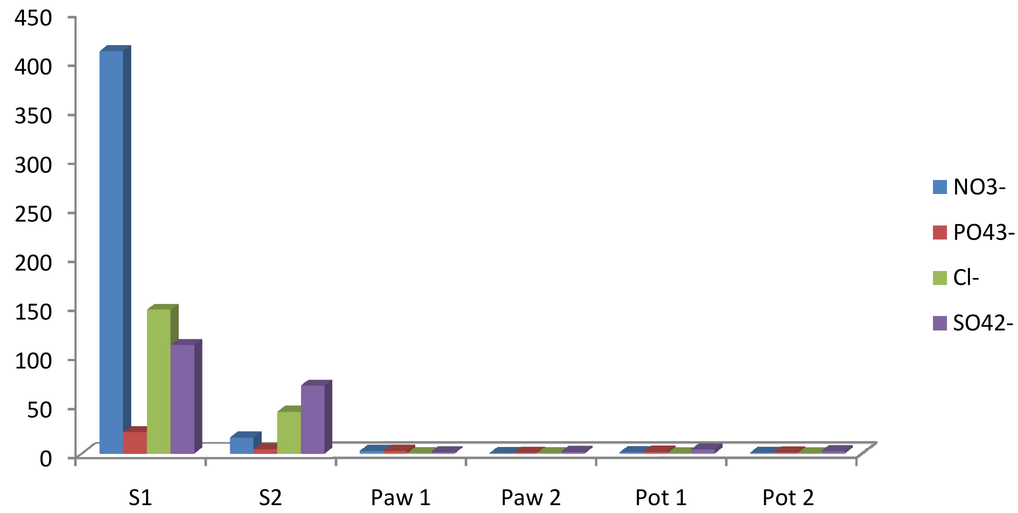


**Fig. 3. Average concentration of anion in soil and edible plants**

**Table 6. CF, PLI, CD, $I_{geo}$ of metals for soil**

| Parameter n = 5 | S1 | | | | S2 | | | |
|---|---|---|---|---|---|---|---|---|
| | Data | Conc. (Bn) | CF | $I_{geo}$ | Data | Conc. (Bn) | CF | $I_{geo}$ |
| Cd | 14.60 | 0.003 | **4,866.67** | **11.66** | 1.80 | 0.003 | **600.00** | **8.64** |
| Pb | 21.30 | 8.5 | **2.51** | **0.74** | 0.90 | 8.5 | **0.11** | **-3.84** |
| Zn | 94.70 | 65.0 | **1.46** | **-0.04** | 24.30 | 65.0 | **0.37** | **-2.00** |
| Fe | 154.20 | 5.0 | **30.84** | **4.36** | 103.30 | 5.0 | **20.66** | **3.78** |
| Cu | 66.60 | 17.0 | **3.92** | **1.38** | 43.30 | 17.0 | **2.55** | **0.77** |
| **CD** | | | **4,905.4** | | | | **623.69** | |
| **PLI** | | | **4.64** | | | | **4.19** | |

**Table 7. Analysis of $I_{geo}$ for soil at Choba dumpsite**

| Parameters | Conc. in soil | Bn | $I_{geo}$ | Remark |
|---|---|---|---|---|
| Cd | 14.60 | 0.003 | **11.66** | Extremely polluted |
| Pb | 21.30 | 8.5 | **0.74** | From unpolluted to moderately polluted |
| Zn | 94.70 | 65.0 | **-0.04** | No pollution |
| Fe | 154.20 | 5.0 | **4.36** | Strongly to extremely polluted |
| Cu | 66.60 | 17.0 | **1.38** | Moderately polluted |

$I_{geo}$ test was conducted to estimate the enrichment of metal concentrations above background or baseline concentrations. The result in Table 6 shows that Zn was the only metal that did not enrich the soil with values less than 0 (S1 = -0.04, and S2 = -2.00). However, S2 recorded a Pb value less than 0 (-3.84). Other results range from unpolluted to moderately polluted, and to extremely polluted. S1 = Cd (11.66), Pb (0.74), Zn (-0.004), Fe (4.36) and Cu (1.38). S2 = Cd (8.64), Pb (-3.84), Zn (-2.00), Fe (3.78) and Cu (0.77). Generally, Index of Geoaccumulation showed that Zn and Pb may have originated from natural processes or crustal materials alone, and not from anthropogenic sources. However, moderate pollution of Pb was recorded for Choba dumpsites. There is gradation from strongly polluted with Fe to extremely polluted with Cd in both dumpsites. This shows that they may have originated from anthropogenic sources and not natural processes or crustal materials alone. This implies that urgent attention has to be given to the dumpsites to avoid or prevent further degradation of the soil.

**Table 8. Analysis of $I_{geo}$ for soil at Ada-George dumpsite**

| Parameters | Conc. in Soil | Bn | $I_{geo}$ | Remark |
|---|---|---|---|---|
| Cd | 1.80 | 0.003 | **8.64** | Extremely polluted |
| Pb | 0.90 | 8.5 | **-3.84** | No pollution |
| Zn | 24.30 | 65.0 | **-2.00** | No pollution |
| Fe | 103.30 | 5.0 | **3.78** | Strongly polluted |
| Cu | 43.30 | 17.0 | **0.77** | From unpolluted to moderately polluted |

**Table 9. Bioaccumulation factors at Choba dumpsites**

| Parameter | S1 | Paw 1 | BAF | Pot 1 | BAF |
|---|---|---|---|---|---|
| Cd | 14.60 | 1.08 | 0.07 | 1.00 | 0.07 |
| Pb | 21.30 | 2.10 | 0.10 | 2.90 | 0.14 |
| Zn | 94.70 | 8.10 | 0.09 | 13.70 | 0.14 |
| Fe | 154.20 | 18.70 | 0.12 | 4.00 | 0.03 |
| Cu | 66.60 | 4.30 | 0.06 | 5.60 | 0.08 |
| $NO_3^-$ | 410.30 | 2.10 | 0.01 | 0.98 | 0.00 |
| $PO_4^{3-}$ | 21.80 | 2.20 | 0.10 | 1.40 | 0.06 |
| $Cl^-$ | 146.50 | <0.01 | 0.00 | <0.001 | 0.00 |
| $SO_4^{2-}$ | 110.60 | 0.90 | 0.01 | 3.60 | 0.03 |

**Table 10. Bioaccumulation factors at Ada-George dumpsites**

| Parameter | S2 | Paw 2 | BAF | Pot 2 | BAF |
|---|---|---|---|---|---|
| Cd | 1.80 | <0.001 | 0.00 | <0.001 | 0.00 |
| Pb | 0.90 | <0.001 | 0.00 | <0.001 | 0.00 |
| Zn | 24.30 | 21.20 | 0.87 | 10.50 | 0.43 |
| Fe | 103.30 | 6.90 | 0.07 | 1.60 | 0.02 |
| Cu | 43.30 | 1.90 | 0.04 | 0.80 | 0.02 |
| $NO_3^-$ | 16.30 | 0.10 | 0.01 | 0.30 | 0.02 |
| $PO_4^{3-}$ | 4.30 | 0.30 | 0.07 | 0.80 | 0.19 |
| $Cl^-$ | 42.60 | <0.01 | 0.00 | 0.002 | 0.00 |
| $SO_4^{2-}$ | 69.30 | 3.60 | 0.05 | 1.90 | 0.03 |

Tables 9 and 10 shows that all the dumpsites did not have BAF up to 1, i.e all BAF are less than 1, it shows that all are excluders and are not effective accumulators of metals and anions from the soil into the plants.

## 4. CONCLUSIONS AND RECOMMENDATIONS

Heavy metal and physiochemical contamination on soil and plants around unengineered dumpsites was evaluated in this study using various indices. Most of the indices revealed that the study area was seriously affected by different metals and anions. Index of geoaccumulation results shows that metals with high concentrations in the studied soils may have originated from the dumpsites and leachates, and not from the natural environment/earth crust. The result also indicated that the dumpsite is producing many potent metal and anions to the environment. Proper treatment and safe disposal of Municipal solid waste are recommended, prior to construction of modern landfill system.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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