Environmental Impact of Heavy Metals in Soils from Electronic Waste Dumpsite in Southwest Nigeria

ABSTRACT

The massive influx of electronics into Nigeria has led to environmental challenges due to increase in the production of electronic waste, which causes serious health and pollution problems. This study investigated the level and impact of heavy metals in 30 soil samples from an electronic waste disposal site in southwest Nigeria, using appropriate standard methods. The range concentrations of the heavy metals were 1615 mg/kg Pb, 20 mg/kg Cr, 266.32 mg/kg Ni, 22.39 mg/kg Cd and 242.03 mg/kg Cu at depth 0-15cm while 1453.56 mg/kg Pb, 26.31 mg/kg Cr, 497.11 mg/kg Ni, 17.04 mg/kg Cd and 230.31 mg/kg Cu were observed at depth 15-30 cm. The concentrations of the heavy metals exceeded the allowable limits, except for Cr. The mean degree of contaminations, 18.15 and 14.35, were observed at depth 0-15and 15-30 cm respectively and indicated considerable and moderate degree of contamination by the heavy metals, respectively. The mean Potential index of 323.52 and 225.79 at depth 0-15 cm and 15-30 cm showed sever toxicity and moderate toxicity, respectively. The $I\text{-}geo$. of Pb at both depths indicated extreme contamination. This study reveals sever potential environmental and health hazards in the neighborhood, ecosystem, and community, and advices that the government should establish a national policy on e-waste and regulate testing of all electronics imported under the names of reuse, donation and recycling, which will halt the importation of e-scraps (e-waste).

KEY WORDS: Heavy metals, Electronic-waste disposal site, Contamination Factor, Potential Ecological Risk, index of geo-accumulation factor, Pollution Indices, Environmental Impact

INTRODUCTION

Rapid economic development, especially in ICT, has resulted in the production of newest and latest models and brands of computers, phones, washing machines, and other electronic gadgets. As the newest electronics flood the market, the old ones they replaced became obsolete and were therefore discarded by the owners. With time, these obsolete and discarded electronics, otherwise known as electronic waste (e-waste), find their way to the dumpsite, where scavengers either dismantle or burn off the plastic part to retrieve the parts that they can sell to make money. Mobile phones and computers are abundant in e-waste due to their short lifespan [1]. There are over 1,000 different substances in e-waste [2], including valuables substances such as: aluminum, copper, gold and steel [3]. However, most substances in e-waste are toxic and cause serious environmental pollution. These toxic substances include: heavy metals 9such as lead, cadmium, mercury, chromium, copper, chromium, beryllium, barium), polychlorinated biphenyls (PCBs), brominated flame retardants and polyvinyl chloride (PVC), which release dioxins under combustion [2]. Indiscriminate disposal of e-waste causes the release of these harmful substances, especially heavy metals into the environment; when dumped on land, heavy metals leach into the ground water but when burnt at the disposal site, the heavy metals fly ashes are released into the atmosphere and are deposited on soil, plants, buildings and may be inhaled by animal and man.

Heavy metals are defined as metals with a specific gravity of more than 5 g/cm3 when in their standard state [4,5]. These are then transferred from the soil and water to plants and animals. Over time, these heavy metals bio-accumulate in living tissues and can become hazardous to plants and animals, posing damaging traits to their tissues, organs and systems.

The transfer factor (TF) of heavy metals from soil to waterleaves in dumpsites has been studied and explained, given that there is significant accumulation of Cd, Cu, and Zn in vegetables [6]. They suggested that the consumption of vegetables grown on such sites could be dangerous to human health. These heavy metals have been found to negatively affect plants by reducing the yield and quality of agricultural products [7] but are also both carcinogenic and highly toxic to humans [8]. This study is aimed at determining the level and impact of pollution; via pollution indices such as Contamination Factor, Degree of Contamination, Potential Ecological Risk, Risk Index and Index of Geo-accumulation factor; caused by different heavy metals resulting from the dumping and burning of electronic waste at the study dump site.

MATERIALS AND METHODS

Sampling Site

The dumpsite under investigation is one of the dumpsites at Alaba-International Market, Ojoo, Lagos State, Nigeria. The dumpsite is about one and half building plots in size and has only been operational for about 7 years. Most of the e-wastes disposed of at this site range from CRT of TV, plastic casing of TV, circuit boards, Monitors, keyboards of computer, etc. Soil samples were collected randomly at the electronic waste disposal site located at the Alaba International Market, Ojoo local Government Area, Lagos State at 6^{O} 27′ 14″ N, 3^{O} 11′ 25″ E, shown in Figure 1.

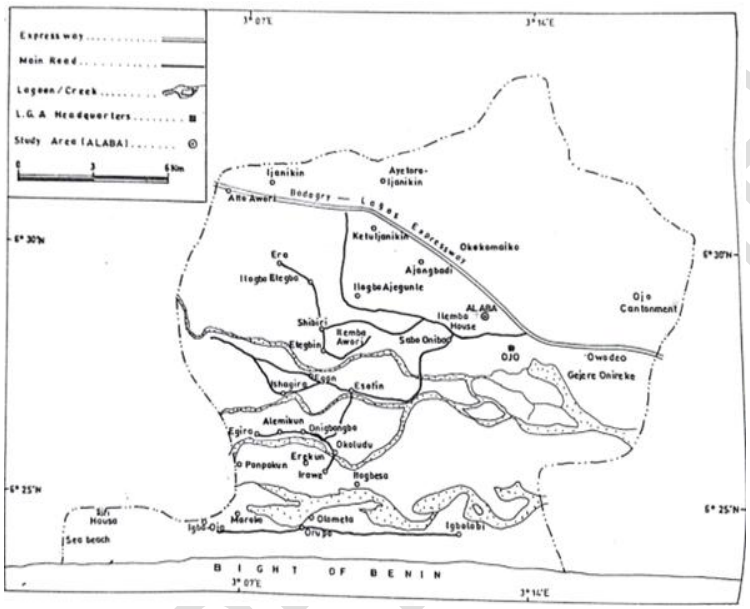

Fig. 1 Map of Ojoo Local Government Area showing the study area (Alaba) in Lagos State

Sampling

About 15 sampling spots were mapped randomly for sampling at the dumpsite and soils were collected at two depths, 0-15 and 15-30 cm, respectively, to obtain a total of 30 soil samples. All samples were stored in black polythene bags and labeled appropriately.

The control soil was sampled from a farmland under fallow for a year which was located far away from the road at Ago Palace way Okota in Lagos State, Nigeria, at 6^{O} 30′ 25″ N, 3^{O} 17′ 43″ E, where there was no pollution. The plot of land was divided into four quadrants; soil samples were collected from each quadrant at depth 0-15cm and 15-30 cm to give a total of 8 soil samples. All the surface soil samples were merged, so also, the sub-surface soil, to give a total of two sample.

Sample Preparation

The soil samples were spread on a new transparent waterproof placed on a drying table in a drying room and airdried for two weeks. To prevent metal contamination, the samples were pulverized using agate mortar and pestle that were previously soaked in 10 % trioxonitrate (V) acid solution and rinsed with deionized distilled water. Then, they were sieved using a 2 mm sieve and stored appropriately.

Sample Digestion

The method described in [1] was adopted for wet digestion of the soil samples. Approximately 2 g of the pulverized soil samples were weighed into previously washed centrifuge tubes, and approximately 10 ml of 2 M Trioxonitrate

(V) was added to the centrifuge tube and prepared in duplicate. The centrifuge tubes were placed in a beaker containing boiling water and were opened and shaken at 20 min intervals. Heating was carried out for approximately 2 h in a water bath, and thereafter, the solution was filtered using filter paper (Whatman No.1 filter paper). The filter paper was rinsed with deionized distilled water, and the filtrate/digest was made up to mark with deionized distilled water in a 25 ml standard flask. The digests were stored in well-labeled plastic containers and analyzed for metals using a Flame Atomic Absorption Spectrophotometer (AAS).

Total Heavy Metal Concentration

The total concentration of heavy metals in the studied profiles reflects both natural differences in soil genesis and the degree of contamination and was analyzed using an atomic absorption spectrophotometer (AAS). The actual metal concentrations of the samples (mg/kg) were obtained using Equation 1:

$$\text{Metal concentration (mg/kg)} = \frac{(A - B)}{D}\ x\ C \qquad (1)$$

Where:

A = concentration of the metal in the sample obtained from the instrument (mg/L).
B = Metal concentration in the blank obtained from the instrument (mg/L)
C = the final volume of the digest (ml)
D = the weight of sample digested (g)

Pollution indices

Indicators were used to assess and interpret the contamination status of each heavy metal in the contaminated soil. These indicators include the contamination factor, degree of contamination, ecological risk factor, potential ecological risk index, and index of geo-accumulation.

Contamination factor

The contamination factor is used to express the contamination of a given toxic substance [9] and is expressed as shown in Equation 2.

$$C_f^i = \frac{C_r^i}{C_R^i} \qquad (2)$$

Where:

C_f^i = contamination factor of single metal
C_r^i = measured the concentration of metal in the sample;
C_R^i = the background concentration of the soil according to DPR

Contamination factor is defined according to four categories [9]

Contamination values < 1 = low contamination factor,
1 ≤ Contamination factor value ≤ 3 = moderate contamination,
3 < Contamination factor value ≤ 6 = considerable contamination) and
Contamination factor value> 6 = very high contaminated)

Degree of contamination

The sum of the contamination factors of all the elements in the soil is termed the degree of contamination or sum of pollution, according to Hakanson [10] in [9], as expressed in Equation 3.

$$C_D = \sum_{i=1}^{n} C_f^i \qquad (3)$$

Where:

C_D = Degree of contamination
C_f^i = Contamination factor of a single element i
n = Count of the heavy metal

The four categories used in defining the degree of contamination are:

< 8 shows a low degree of contamination;
8-16 shows a moderate degree of contamination;
16-32 shows considerable degree of contamination and
>32 indicates a very high degree of contamination.

Potential Ecological risk factor

Potential ecological risk factor, E_f^i, is the determination of the extent of pollution in soils and sediments and assesses the potential harm of a given heavy metals in the sample as explained in Equation 4. The categories of the potential ecological risk factor and Index are presented in Table 1. The toxicity response factors of metals as: Cadmium, Cd = 30; Chromium, Cr = 2; Copper, Cu = Lead, Pb= Nickel, Ni= 5 [10]

$$E_f^i = T_f^i \, x \, C_f^i \qquad (4)$$

Where:

E_f^i = Potential ecological risk factor of single metal;
T_f^i = Toxicity response factor of a given metal; and
C_f^i = Contamination factor of single element i

The Potential Ecological risk index was calculated using Equation (5), which is a sum of the potential ecological risk of the single heavy metal in the sample from each spot and indicts the toxicity and environmental response of the heavy metals of interest [10].

$$RI = \sum_{(i=1)}^{n} E_f^i \qquad (5)$$

Where:

E_f^i = the potential ecological risk factor of single metal;
RI = the potential ecological risk index of many metals
n = Count of the heavy metal

Table 1: Categories of E_f^i and RI [20]

Ranges of Potential Ecological risk	Categories of Potential Ecological risk	Ranges of Potential risk index	Categories of potential risk index
< 40	Low	RI < 150	Low grade
$40 \leq E_f^i < 80$	Moderate	150 ≤ RI < 300	Moderate
$80 \leq E_f^i < 160$	Higher	300 ≤ RI <600	Sever
$160 \leq E_f^i < 320$	High	600 ≤ RI	Serious
$320 \leq E_f^i$	Serious		

Index of Geo-accumulation

The geo-accumulation index is used to assess the effects of heavy metal contamination on agriculture and man [11] or to determine the extent of metal pollution. It is expressed as stated in Equation 6.

$$I_{geo} = log_2 \frac{C_D^i}{1.5C_R^i} \quad (6)$$

Where:

C_r^i = measured the concentration of metal in the sample;
C_R^i = the background concentration of the soil (DPR)
I_{geo} = Index of geo-accumulation
1.5 is the correction factor for compensating for the background data as a result of lithogenic effects. The classifications of geo-accumulation index is presented in Table 2.

Table 2: Classification of geo-accumulation index

I_{geo} **Value**	**Class**	**Soil Quality**
≤ 0	0	Uncontaminated
0 – 1	1	From Uncontaminated to moderately contaminated
1 – 2	2	Moderately contaminated
2 – 3	3	From moderately contaminated to strongly contaminated
3 – 4	4	Strongly contaminated
4 – 5	5	From strongly contaminated to extremely contaminated
> 6	6	Extremely contaminated

RESULTS AND DISCUSSION

Metal Concentrations

The overall mean concentrations of Pb, Cr, Ni, Cd and Cu at depth 0-15 cm of the contaminated soil were: 1050.23±530.67, 12.98±5.67, 141.58±85,43, 7.40±6.06 and 175.16±77.62 mg/kg, respectively, while the overall mean concentrations for the metals at depth 15-30 cm were: 965.27±406.39 mg/kg Pb; 13.75±6.34 mg/kg Cr; 183.97±164.89 mg/kg Ni; 4.94±3.90 mg/kg Cd and 93.22±90.42 mg/kg Cu. The order of the mean concentration at depth of 0-15 cm was Pb > Cu> Ni> Cr> Cd, whereas that at depths of 15–30 cm was Pb> Ni> Cu> Cr> Cd. The overall mean concentrations of Pb were the highest at both depths studied whereas Cd concentrations at both depths, were the lowest of all the metals studied as shown in Figure 2. The mean Pb concentrations at both depths were significantly higher than those of the other metals analyzed. There was no significant difference between the concentrations of Cu and Ni at depth of 0-15 and 15–30 cm, as shown in Figure 2. The mean concentrations of Cu and Ni at depths 0-15 cm were significantly higher than the mean concentrations of Cd and Cr at that same depth while the mean concentrations of Ni at 15-30 cm was significantly higher than the concentration of Cr and Cd at the same depth. In addition, the surface soils of 0-15 cm had higher concentrations of Pb, Cd, and Cu; therefore, depth is a better indicator of metallic burdens.

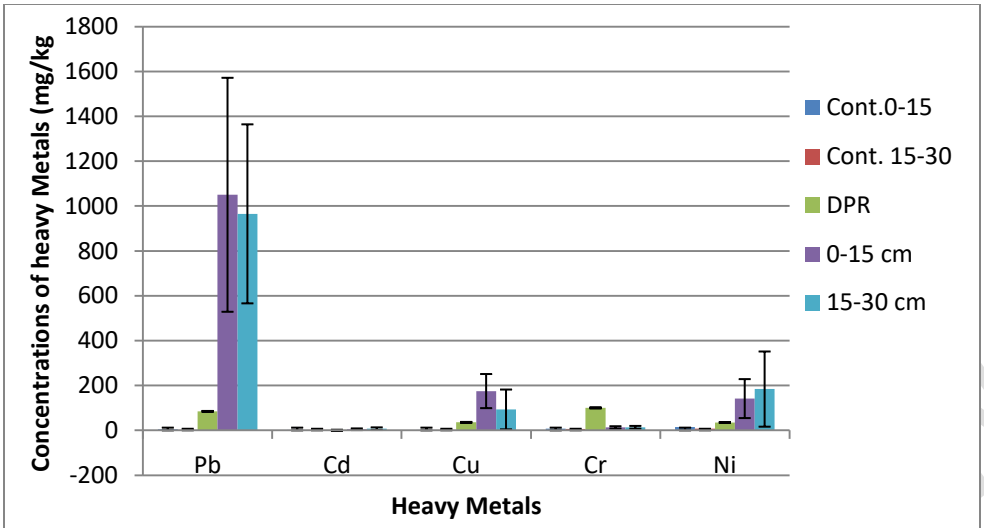

Figure 2: Overall Mean of the Heavy Metals with their Error bars

Pb Concentration

Pb was detected in all the soil samples analyzed, as shown in Figure 3(a). Its concentration at depth 0-15 cm ranged from 76.65 to 1692.30 mg/kg in S-4 and S-5, respectively, while the range at depth of 15-30 cm was 1453.56 mg/kg. The minimum and maximum concentrations of Pb at depth 15-30 cm were 24.55 and 1478.11 mg/kg respectively. The overall mean concentrations were 1050.23 mg/kg at depth 0-15cm and 965.27 mg/kg at depth 15-30 cm. The highest mean concentration at depth 0-15cm was 1679.07±18.72 mg/kg at S-4, followed by 1583.41±6.66 mg/kg at S-1, and thirdly, 1517.64±7.28 mg/kg at S-8 while 1472.49±7.96 mg/kg at S-11, 1449.15±19.02 mg/kg at S-6 and 1318.87±22.47 mg/kg at S-8 were the first three highest concentrations observed at depth 15 -30 cm. However, the lowest concentration of Pb at depth 0-15 cm was 78.71±2.91 mg/kg at S-5, seconded by 139.86±6.29 mg/kg at S-10 and thirdly, 352.95±21.14 mg/kg at S-14 while at depth 15-30 cm, the lowest concentration of Pb observed as shown in Figure 3(a), was 27.90±4.73 mg/kg at S-5, seconded by 406.37±7.72 mg/kg at S-14 and thirdly, 525.27±19.02 mg/kg at S-15. The mean concentration of Pb obtained from the control soil sample at depth 0-15cm was 4.71±0.36 mg/kg and 1.63±0.14 mg/kg at depth 15-30 cm.

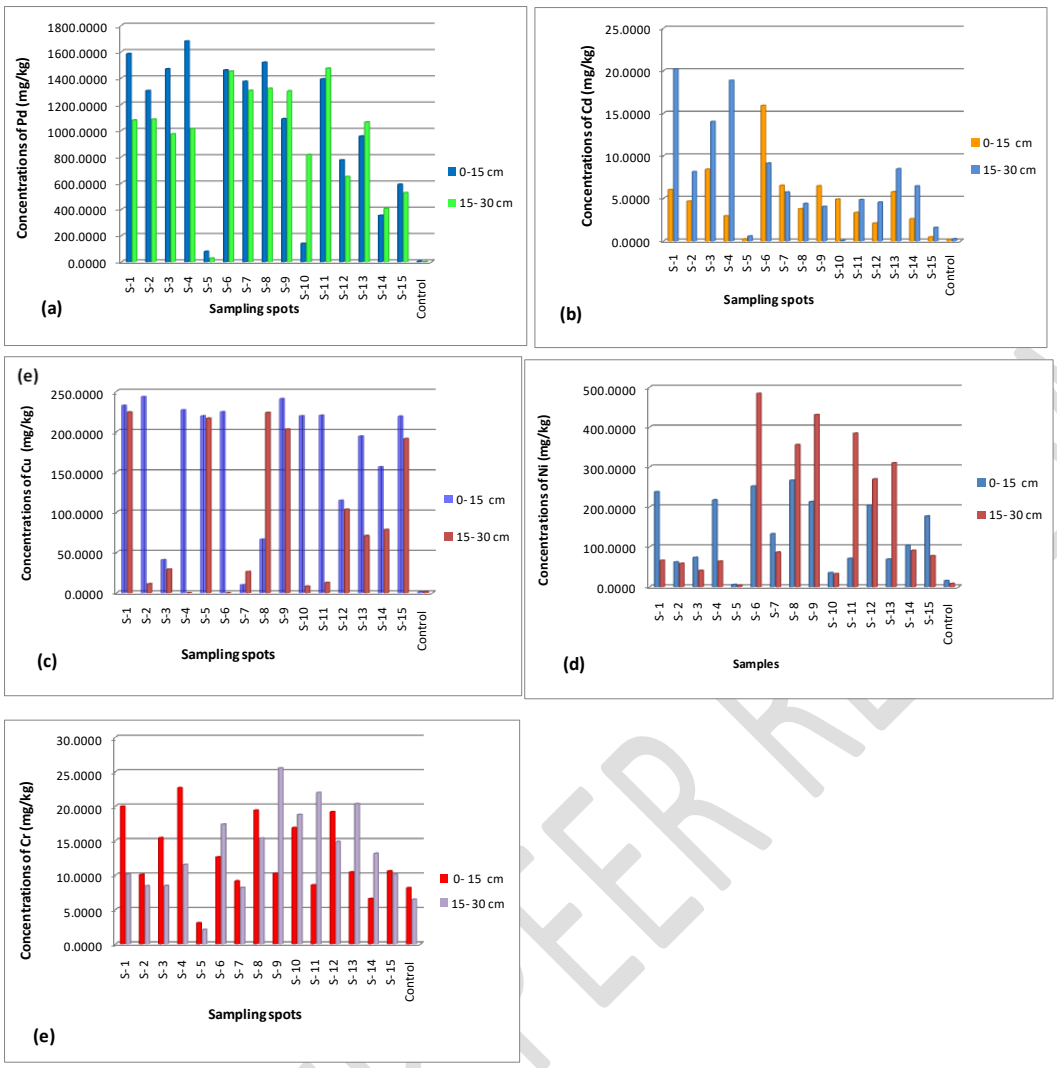

Figure 3: Concentrations of Heavy Metals in the soil from e-waste disposal site at depths 0-15and 15-30 cm

(a) Concentrations of Pb in S-1 to S-15 at both depths
(b) Concentrations of Cd in S-1 to S-15 at both depths
(c) Concentrations of Cu in S-1 to S-15 at both depths
(d) Concentrations of Ni in S-1 to S-15 at both depths
(e) Concentrations of Cr in S-1 to S-15 at both depths

The error bars in Figure 2 indicate that the overall mean Pb concentrations at depth of 0-15 and 15-30 cm were significantly higher than the overall mean concentrations of all the other metals and the Pb concentrations observed at the surface and sub-surface of the soil from the control site. It also surpassed the background Pb concentration set by the DPR in Nigeria, as shown in Figure 2. However, there was no significant different between the Pb mean concentration at depth 0-15 cm and 15-30 cm. The concentration of Pb in the soils from the control site at both depths was significantly lower than that set by DPR.

In this study, high Pb concentrations of 1692.30 mg/kg at 0-15cm and 1478.11 mg/kg at 15-30 cm were observed to be higher than 86 and 333 mg/kg from Kronum and Amakom dumpsites [13], respectively; 0.40 mg/kg [14]; 262.53 mg/kg [15]; 13.14 mg/kg Pb [16], 219.51 mg/kg [17]; 79.55 mg/kg [9]; 826.13 Pb; [5]; 896 mg/kg [18], 0.41 mg/kg [19], 97 mg/kg [20], 32.47 mg/kg [21] and 102 mg/kg Olayinka et al (2014). However, the Pb concentration was lower than Pb concentrations of 3630 mg/kg [22]. 49,022 mg/kg [23]. However, it exceeded the normal concentration of Pb allowable by the WHO and surpassed the maximum allowable concentration of Pb, as detailed

by the Department of Petroleum Resources [24] reported by [9]. However, the concentrations of Pb in the control soil samples at both depths were very low compared with the maximum allowable concentration in [24].

The high concentrations of Pb observed in the e-waste soil samples could be due to the burning of electric wires, light bulbs, printed circuit boards, cathode ray tubes and batteries [12] at the dump site, which caused the release of high levels of Pb into the soil environment. High Pb concentrations in soils reduce soil productivity, urease, catalase, invertase [25] and interrupt water balance, enzyme activity and mineral nutrition [26]. The metabolic functions of organisms in the soil are abnormal due to high concentrations of Pb [27]. It also causes abnormal plant metabolism, morphophysiological features, plant growth & productivity and decrease chlorophyll biosynthesis [28]. Consuming plants grown or planted on this disposal site could lead to damaging effects on the kidney, nervous, blood, and reproductive systems and can affect the development of the children's brain [3, 29].

Cadmium Concentration

The range of Cd concentration in the contaminated soil samples at depth 0-15cm was 22.39 mg/kg and 14.04 mg/kg at depth 15-30 cm. The results shown in Figure 3(b) represent the mean of duplicate samples analyzed from different locations in the e-waste disposal site. It was observed that Cd was not detected in approximately 6.67 % of the surface and sub-surface soils of the spots analyzed because their concentrations were below the detection limit of the instrument used. The maximum and minimum concentrations of Cd at the surface soil of the e-waste disposal site was 22.39 and 0.10 mg/kg, respectively while at sub-surface soil, 17.04 and 0.04 mg/kg, respectively.

The overall mean Cd concentration at depths of 0–15 cm was 7.40 mg/kg and 4.94 mg/kg at depth 15-30 cm. The highest mean concentration at the surface soil as shown in Figure 3(b), was 15.91±1.61 mg/kg at S-6, followed by 8.42±0.60 mg/kg at S-3, and thirdly, 6.52±1.315 mg/kg at S-7 while the highest at depth 15-30 cm was 20.20±3.10 mg/kg at S-1, followed by18.86±.45 mg/kg at S-4 and thirdly, 14.02±0.86 mg/kg at S-3. The lowest mean concentration of Cd at depth 0-15 cm was 0.23±0.13 mg/kg at S-5, followed by 0.46±0.26 mg/kg at S-15 and thirdly, 2.10±1.44 mg/kg at S-12 while at depth 15-30 cm, 0.06±0.02 mg/kg at S-10, 0.58±.18 mg/kg at S-5 and 1.58±.75 mg/kg at S-15 were the first three lowest concentrations observed. It was also observed that S-5 had very low concentrations of Cd at both depths. The following mean Cd concentrations were observed at the control site: 0.19±0.13 mg/kg and 0.25±0.09 mg/kg at depth 0-15 and 15-30 cm, respectively.

The results displayed in Figure 2 indicate that the overall mean concentration of Cd at both depths did not show any significant differences. At 95 % confidence level, the overall mean concentration of Cd, at both depths in the soil from the e-waste disposal site were significantly higher than the Cd concentrations from the 0-15 and 15-30 cm of the control soil. The concentrations were also significantly higher than the set concentration by the DPR. From this study, the highest mean, 15.91±1.61 mg/kg at surface and 20.20±3.10 mg/kg at sub-surface, exceeded the limit set by WHO [30]. These concentrations were higher than the concentrations displayed in some literatures: 0.36 mg/kg [31]; 3.99 mg/kg [32], 7.51 mg/kg [17]; 0.32 mg/kg [14], 6.5 mg/kg from Amokom dumpsite [13]; 0.011 mg/kg [9]; and 1.40 mg/kg [33]. However, it was lower than the maximum concentrations of: 209 mg/kg from Kronum dumpsite [13]; 531 and 21 mg/kg [34, 22], respectively.

Some of the parts of electronics that contain cadmium include: batteries, printed circuit boards, semiconductor chips, cathode ray tubes, printer's drum with toner SMD chip resistors, etc. [29, 35]. The dismantling and indiscriminate burning of these electronics parts on the disposal site may have caused the release of such high mean Cd concentrations seen in the results displayed in Figure 3(b). Exposures to high concentrations of Cadmium is related to different types of cancer [36]; could cause the irritation of the respiratory system, persisting in the lungs and may cause kidney disease [29]; affect neonatal weight and length [37]. Itai-itai disease which is characterized by the malfunctioning of the renal tubular, connected to softening of the bones (osteomalacia) and atrophic kidney, occur due to exposures to extreme concentrations of Cd [38], this happened when Cadmium was released into Jinzu River basin by a zinc mine [39], as Liu *et al*., [40] explained that prenatal cadmium exposure could affect the cognitive development of offspring.

Copper Concentration

Copper was discovered in all the spots at depth 0- 15cm but was not detected in about 13 % of the spots at depth 15-30 cm because their concentrations at this depth were below the detection limit of the instrument used. The mean concentrations of the duplicate soil samples analyzed are shown in Figure 3(c). The range for Cu was 242.03 and 230.31 mg/kg at depth 0-15cm and 15-30 cm, respectively. The minimum and maximum concentrations of Cu detected were 9.64 and 251.67 mg/kg at depth 0-15 cm, respectively and 0.00 and 230.31 mg/kg respectively at depth 15-30 cm. From the result shown in Figure 3(c), the highest mean concentration of Cu at depth 0-15 cm was 243.11±1.05 mg/kg from S-2, followed by 240.66±4.19 mg/kg from S-9 and thirdly, 232.41±8.06 mg/kg from S-1 while the lowest concentration at this depth was 9.84±0.28 mg/kg at S-7, seconded by 40.82±1.80 mg/kg at S-3 and thirdly, 66.41±0.84 mg/kg at S-8. At depth 15-30 cm, the highest mean concentration as displayed in Figure 3(c) was 224.15±8.72 mg/kg at S-8, seconded by 223.60±8.71 mg/kg at S-1 and the thirdly lowest was 216.38±10.98 mg/kg at S-5. Also, the lowest mean concentration of Cu observed from Figure 3(c) 0.01±0.01 mg/kg S-4, followed by 0.01±0.01 mg/kg at S-6 and thirdly, 8.23±0.73 mg/kg at S-10. The mean concentration of Cu in the control soil sample was 1.21±0.33 mg/kg at depth 0-15 cm and 1.63±0.74 mg/kg at depth 15-30 cm.

Figure 2 shows that there was no significant difference between the Cu concentrations from these two depths of the control site. The overall mean concentration of Cu in the surface soil sample was 175.16 and 93.22 in the sub-surface soil as shown in Figure 2. Hence, there was no significant difference between the mean concentration of Cu in the contaminated soil at depth 0-15and 15-30 cm. The mean concentration of Cu at depth 0-15cm was significantly higher than the Cu concentration limit set by DPR. However, the concentrations of Cu observed in the soil samples from the control site were significantly lower than those observed in contaminated soil at both depths. However, there was no significant difference between the Cu concentration at depths 15-30 cm and the concentration limit set by DPR [24]. The mean Cu concentrations at both depths of the soils from control site were significantly lower than the set value of the DPR. The highest concentration of Cu, 251.67 mg/kg at 0-15cm and 230.31 mg/kg at 15-30 cm were lower than the concentration in some literature such as: 4850 mg/kg [22] and 858.97 mg/kg [17], 2395 mg/kg from Amakom dumpsite [13] and 130 mg/kg from Kronum dump site [13]. However, this concentration of Cu was higher than 59.10 mg/kg [9]; 17.83 mg/kg [5]; 57.80 mg/kg [23], 69.2 [20] and 3.38 mg/kg [6].

The high concentrations of Cu released at the dumpsite as shown in Figure 3(c), indicate Cu contamination from the crude and unfriendly environmental practices at the e-waste disposal site by the scavengers who burn and used acid-baths on copper containing parts of the electronic waste such as the cables, wires and Printed-Circuit-Boards [41, 42]. High Copper concentrations in soil could cause: reduction of the height and fresh weight of plants, resulting to low yield and quality of crops [43, 44]; decrease in the availability of soil nitrogen and Sulphur needed for crop production [25]; the death of crops since plants rarely survive in soils rich in Cu [5]. Consuming cash and food crops that are contaminated with Cu could cause health hazards such as headaches, dizziness and irritation in the eye, nose and mouth [45]. Cu at high concentrations is linked with hepatic disorder, neurodegenerative especially when Cu homeostasis is disrupted [46] but its long-term accumulation causes liver, kidney or central nervous system toxicity (Taylor *et al.*, 2020). Ferenci and Ott [47] reported that the Hepatic ATP7B protein controls Copper content in the entire body by mediating its excretion into bile or irreversible incorporation into ceruloplasmin. Hence, the dysfunction of the ATP7B protein leads to inability to excrete copper, resulting to its accumulation in the liver and extra hepatic tissues, causing Wilson's disease, which could be fatal when overlooked but curable when diagnosed [47]. However, Cu intake has not been linked to Cancer and Arthritis [48]

Nickel Concentration

Nickel was detected in all the soil sample of the spots analyzed and showed a range of 266.32 mg/Kg at depth 0-15 cm and 497.11 mg/Kg at depth 15-30 cm. The mean concentrations of Ni for the duplicate soil samples analyzed are displayed in Figure 3(d). The maximum and minimum concentrations of Ni at the surface soil of the disposal site were 271.32 and 5.00 mg/kg, respective while those of the sub-surface soil were 500.61 and 3.50 mg/kg respectively, as shown in Figure 3(d). From the result displayed in Figure 3(d), the highest and lowest mean concentrations of Ni were 266.91±6.24 and 5.74±1.04 mg/kg for the surface soil samples and 484.06±23.41 and 4.14±0.90 mg/kg for the sub-surface soil samples. Interestingly, S-5 also yielded the lowest concentrations of Ni at depth 0-15 and 15-30 cm. The mean concentration of Ni in the control soil was 15.33±1.17 at depth 0-15 cm and 8.25±1.05 mg/kg at depth 15-30 cm.

The overall mean of Ni concentrations in this study were 141.58 and 183.97 mg/kg for depths 0-15 cm and 15-30 cm, respectively as shown in Figure 2. There was no significant difference between the overall mean concentrations of Ni at depth 0-15and 15-30 cm. The overall mean concentration of Ni in the surface soil was significantly higher than the concentration set by DPR and those of the control soils at both depths. However, the Ni concentration at sub-surface soil was significantly higher than the concentrations at both depths of the control soil but had no significant difference with that set by DPR. The mean concentrations of Ni from both depth of this study exceeded the mean concentrations of Ni obtained in the literature of some dumpsite: 49.49±0.12 mg/kg [16], 6.419 ± 0.26 [15] and 87.29±16.75 & 44.70±13.28 mg/kg of Ni [49]. The maximum concentrations, 271.32 and 500.61mg/kg from the surface and sub-surface, respectively of this study exceeded the highest concentrations of 69 and 60 mg/kg Ni from Kronum and Amakom dumpsites respectively [13]. 4.18 mg/kg [9] and 3.21 mg/kg [5]. This indicates that the dumpsite is contaminated.

The indiscriminate burning of electronic parts that contain nickel; such as: Nickel-Cadmium batteries and cathode ray tubes [45] and printed circuit boards [50]; must have contributed to the high concentrations of Ni released at the soil of the dumpsite. Accumulations of high levels of Ni can cause: allergy; cardiovascular and kidney diseases [47]; dermatitis of the fingers, hands and forearms [51, 52]; respiratory distress such as lung fibrosis, lung and nasal cancer [53-55]; bronchial asthma [56] especially during dismantling of e-waste at the disposal site. More so, non-cancer respiratory, gastrointestinal [36, 52] and reproductive effects [52] may result at high exposures.

Chromium Concentration

The concentration of Cr in the surface soil sample ranged from 2.75 to 23.43 mg/kg while the concentration at the subsurface ranged from 1.25 to 27.56 mg/kg. All the soil sample of the spots analyzed showed the presence of Cr in them. The overall mean concentrations of Cr in the analysis were 12.98 and 13.75 mg/kg for surface and sub-surface soil samples respectively. The results displayed in Figure 3(e) shows Cr mean concentration of the duplicate soil samples analyzed and studied. Also, the highest and lowest mean concentrations observed at depth 0-15 cm were 22.66±1.10 and 3.04±0.41 mg/kg, respectively from S-4 and S-5 respectively. Meanwhile, at depth 15-30 cm, the highest and lowest mean concentrations of Cr detected were 25.53±2.87 and 2.10±1.20 mg/kg respectively from S-9 and S-5 respectively as shown in Figure 3(e). At both depths analyzed, S-5 had the lowest concentrations of Cr. The mean concentration of Cr in the control soil sample was 8.15±0.73 mg/kg at depth 0-15cm and 6.47±1.54 mg/kg at depth 15-30 cm.

The mean Cr concentrations at the surface and sub-surface soils of the e-waste disposal site were significantly higher than the concentrations obtained in the soils form the control site but were significantly lower than the concentration limit set by DPR as shown by the error bars in Figure 2. Also, the Cr concentrations in the control soil samples were significantly lower than the concentration limit set by DPR [24]. However, there was no significant difference between the Cr concentration at depth 0-15 cm and that at depth 15-30 cm. The highest concentrations of 23.43 and 27.56 mg/kg at depth 0-15 cm and 15-30 cm, respectively were lower than the concentrations 94.82 mg/kg published by [17]; 43.523±0.36 mg/kg [15]; 48.9 mg/kg [23]; 564.00±89.21 and 46.23±12.00 released by Ojiego *et al.*, [49] but higher than 10.15 mg/kg [9]; 9.91 mg/kg [5];10.97 mg/kg [57].

The literature has identified the use of Chromium as anti-corrosion coatings and pigments in many electrical and electronic products; in the production of data tapes and disk, [58, 59]. The indiscriminate open burning of these products would be expected to release Cr into the environment and may cause detrimental effects to plants and man. High level of Chromium in plants restricts the uptake of nutrients in soil by the roots via the formation of insoluble compounds [60], suggesting that Cr disturbs the nutrient balance [61]. Cr inhibits the biosynthesis of chlorophyll [62] and as such reduces the accumulation of the pigment in the leaves of plants [61]. Also, its toxicity results in oxidative stress by targeting cellular membranes and biomolecules resulting in retarded plant growth, induction of chlorosis and wilting of leaves [61]. Human exposures to Cr can cause dizziness, damage to nasal mucosa, stomach ulcer, convulsion and kidney damage [63]; respiratory tract irritations and increase the risk of lung, nasal, and sinus cancer [60, 64]; cause mild to severe liver abnormalities and lead to cardiovascular collapse and hematological toxicity; may induced DNA damage, gene mutation, sister chromatid exchange, chromosomal aberrations in a number of targets, including animal cells in vivo and animal and human cells in vitro [64]; and liver damage, weakened immune systems [60].

***Contamination factor and degree of contamination at* depth 0-15cm**

The calculation of the contamination factor and degree of contamination of the soils in this study at depth 0-15cm and 15-30 cm are presented in Table 3. At depth 0-15cm, the maximum contamination factor of Pb was 0.34 from S-4 while the minimum was 0.02 from S-5 with a mean contamination factor of 0.21.

Table 3: Contamination factor and degree of contamination for heavy metals at depth 0-15 and 15-30 cm

Sampling Spots	Contamination factor										Degree of contamination	
	Pb		Cr		Ni		Cu		Cd			
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
S- 1	0.32	0.22	0.20	0.10	6.80	1.89	6.46	6.23	25.25	7.54	39.03	15.98
S- 2	0.26	0.22	0.10	0.08	1.78	1.68	6.75	0.31	10.16	5.84	19.05	8.13
S- 3	0.29	0.19	0.15	0.08	2.10	1.17	1.13	0.81	17.52	10.52	21.19	12.77
S- 4	0.34	0.20	0.23	0.12	6.22	1.83	6.3	0.00	23.58	3.68	36.67	5.83
S- 5	0.02	0.01	0.03	0.02	0.16	0.12	6.09	6.01	0.73	0.29	7.03	6.45
S- 6	0.29	0.29	0.13	0.17	7.21	13.83	6.24	0.00	11.42	19.88	25.29	34.17
S- 7	0.27	0.26	0.09	0.08	3.79	2.48	0.27	0.73	7.17	8.15	11.59	11.70
S- 8	0.30	0.26	0.19	0.15	7.63	10.18	1.84	6.21	5.49	4.70	15.45	21.50
S- 9	0.22	0.26	0.10	0.26	6.10	12.32	6.69	5.64	5.05	8.10	18.16	26.58
S- 10	0.03	0.16	0.17	0.19	1.01	0.94	6.09	0.23	0.07	6.13	7.37	7.65
S- 11	0.28	0.29	0.09	0.22	2.04	10.99	6.11	0.35	6.06	4.17	14.58	16.02
S- 12	0.15	0.13	0.19	0.15	5.83	7.72	3.18	2.88	5.70	2.62	15.05	13.50
S- 13	0.19	0.21	0.10	0.20	1.98	8.87	5.40	1.97	10.59	7.21	18.26	18.46
S- 14	0.07	0.08	0.07	0.13	2.97	2.60	4.34	2.17	8.06	3.26	15.51	8.24
S- 15	0.12	0.11	0.11	0.10	5.07	2.22	6.08	5.31	1.98	0.57	13.36	8.31
Mean	0.21	0.19	0.13	0.14	4.05	5.26	4.86	2.59	9.26	6.18	18.51	14.35
Max.	0.34	0.29	0.23	0.26	7.63	13.83	6.75	6.23	25.25	19.88	39.03	34.17
Mini	0.02	0.01	0.03	0.02	0.16	0.12	0.27	0.00	0.07	0.29	7.03	5.83
Control	0.00	0.00	0.08	0.06	0.44	0.24	0.03	0.05	0.31	0.23	0.86	0.58

The contamination factor of Lead in the control site was 0.00. From the categories, Lead was generally found to have low contamination. The mean contamination factor of Chromium was 0.13, with maximum and minimum values of 0.23 and 0.03 respectively. The contamination factor of the chromium in the control site was 0.08. Thus, chromium level in the contaminated and control site were categorized as low contamination. The maximum and the minimum contamination factor of Ni were 7.63 and 0.16 found at S-6 and S-5 respectively, with a mean contamination of 4.05; implying that the e-waste dump site was considerably contaminated. The control site, which had a mean Ni contamination factor of 0.44, was categorized as having low contamination. Copper had maximum and minimum contamination factor of 6.75 and 0.27 from S-2 and S-7 respectively; with a mean value of 4.86, so, Cu was considered to have moderately contaminated the e-waste dump site. The control site had Cu contamination factor of 0.27 and was considered to have low contamination at this site. Lastly, the Cadmium contamination factor of the control site was 0.07, and hence the site has low contamination of cadmium. For the e-waste dump site, the maximum and minimum contamination factor values were 25.25 and 0.07 from S-1 and S-10, respectively but had a

mean contamination factor of 9.26, hence the e-waste dumpsite was considered to have been very highly contaminated with Cadmium. Therefore, the contamination factors for the heavy metals follow this trend: Cd> Cu > Ni >Pb> Cr for depth 0-15cm.

From Table 3, the mean degree of contamination, 18.15, of the heavy metals at depth 0-15cm indicated considerable contamination. About 6 % of the sampled spot each fell within the range of moderate and considerable degree of contamination. However, S-5 and S-10 had low degree of contamination while S-1 and S-4 were of high degree of contamination.

***Contamination factor and degree of contamination at* depth 15-30 cm**

The calculation of the contamination factor and degree of contamination of the soils in this study at depth 15-30 cm is shown in Table 3. The maximum and minimum contamination factors of the heavy metals were: 0.29 and 0.01 for Pb, 0.26 and 0.02 for Cr, 13.83 and 0.12 for Ni, 6.23 and 0.00 for Cu and 19.88 and 0.29 for Cd as shown in Table 3. The mean contamination factors of Pb, Cr, Ni, Cu and Cd at depth 15-30 cm of e-waste dump site was 0.19, 0.14, 5.26, 2.59 and 6.18 respectively. Categorizing their contamination factors; the contamination by Pb and Cr were low; Cu was found to have moderately contaminated the dump site while the contaminations by Ni and Cd were of considerable contamination. Therefore, the contamination factor values for the heavy metals in the dump site follow this trend: Cd> Ni> Cu >Pb> Cr for depth 15-30 cm. The contamination factor of the heavy metals in the control site were low.

The degree of contamination at depth 15-30 cm is displayed in Table 3. The Table showed that only sampling S-6 had a very high degree of contamination, 34.17, though this same spot was considerably contaminated at depth 0-15 cm, indicating that the heavy metals leached into the lower layer of the soil. Yet, samples S-8, S-9, S-11 and S-13 showed considerable degree of contamination, S-1, S-2, S-3, S-7, S-12, S-14 and S-15 showed moderate degree of contamination while S-4, S-5, and S-10 showed low contamination. Generally, the degree of contamination for depth 15-30 cm of the e-waste dump site showed moderate degree of contamination as the mean degree of contamination of the site was 14.35, implying that the dump site was moderately contaminated by the heavy metal studied.

Potential Ecological risk factor of Heavy Metals at Depth 0-15cm

The potential risk factor and potential risk index for the heavy metals at depth 0-15 cm are presented in Table 4. The maximum and minimum potential ecological factor of the different heavy metals were 1.70 and 0.10 for Pb; 0.46 and 0.06 for Cr; 38.15 and 0.80 for Ni; 33.75 and 1.35 for Cu and 757.50 and 2.10 for Cd.
The following metals: Pb, Cr, Ni and Cu were of low potential ecological risk factor while Cd had high potential harm to the soil environment. S-1, S-3, S-4, and S-6 had serious potential ecological risk of Cadmium. The mean potential ecological factor of Pb, Cr, Ni, Cu and Cd at 0-15cm were 1.05, 0.26, 20.23, 24.32, and 277.66, respectively while that of the control was 0.00, 0.16, 2.2, 0.15, and 9.6 for Pb, Cr, Ni, Cu and Cd, respectively. Meanwhile, the highest potential ecological risk index of the heavy metals in the different spots of the e-waste disposal site was 825.80 at S-1, followed by 772.16 at S-4 and thirdly by 543.50 at spot S-3. The lowest potential ecological risk index was 38.09 at S-10. However, the potential risk index of the control was 12.11.

At 0-15 cm, the ranges of the Potential Ecological risk for Pb, Cr, Ni and Cu for all the spots were < 40 while only S-5 and S-10 also had range of < 40 for Cd. This implies that these metals at those spots had low Potential Ecological risk. However, at S-15, cadmium had Potential Ecological risk of 59, indicating that the Potential Ecological risk is moderate. Meanwhile, only S-9 had a value of 151.50 for Cd, which lies between $80 \leq E_f^i < 160$, and the Potential Ecological risk is categorized high. In addition to this, S-2, S-7, S-8 and S-11 to S-14 for Cd showed higher Potential Ecological risk was within $160 \leq E_f^i < 320$ range. The Potential Ecological risk factor for every other Spot was in the range of $320 \leq E_f^i$ implying that the risk factor is serious.

Table 4: Potential Ecological risk factor and Index for depth 0-15 and 15-30 cm

	Potential Ecological risk factor										Potential Ecological risk Index	
	Pb		Cr		Ni		Cu		Cd			
Sampling spots	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
S-1	1.60	1.10	0.40	0.20	34.00	9.45	32.30	31.15	757.50	226.20	825.80	268.10
S-2	1.30	1.10	0.20	0.16	8.90	8.40	33.75	1.55	304.80	175.20	348.95	186.41
S-3	1.45	0.95	0.30	0.16	10.50	5.85	5.65	4.05	525.60	315.60	543.50	326.61
S-4	1.70	1.00	0.46	0.24	31.10	9.15	31.50	0.00	707.40	110.40	772.16	120.79
S-5	0.10	0.05	0.06	0.04	0.80	0.60	30.45	30.05	21.90	8.70	53.31	39.44
S-6	1.45	1.45	0.26	0.34	36.05	69.15	31.20	0.00	342.60	596.40	411.56	667.34
S- 7	1.35	1.30	0.18	0.16	18.95	12.40	1.35	3.65	215.10	244.50	236.93	262.01
S- 8	1.50	1.30	0.38	0.30	38.15	50.90	9.20	31.05	164.70	141.00	213.93	224.55
S- 9	1.10	1.30	0.20	0.52	30.50	61.60	33.45	28.20	151.50	243.00	216.75	334.62
S-10	0.15	0.80	0.34	0.38	5.05	4.70	30.45	1.15	2.10	183.90	38.09	190.93
S-11	1.40	1.45	0.18	0.44	10.20	54.95	30.55	1.75	181.80	125.10	224.13	183.69
S-12	0.75	0.65	0.38	0.30	29.15	38.60	15.90	14.40	171.00	78.60	217.18	132.55
S-13	0.95	1.05	0.20	0.40	9.90	44.35	27.00	9.85	317.70	216.30	355.75	271.95
S-14	0.35	0.40	0.14	0.26	14.85	13.00	21.70	10.85	241.80	97.80	278.84	122.31
S- 15	0.60	0.55	0.22	0.20	25.35	11.10	30.40	26.55	59.40	17.10	115.97	55.50
Mean	1.05	0.96	0.26	0.27	20.23	26.28	24.32	12.95	277.66	185.32	323.52	225.79
Maxi.	1.70	1.45	0.46	0.52	38.15	69.15	33.75	31.15	757.50	596.40	825. 80	667.34
Mini	0.10	0.05	0.06	0.04	0.80	0.60	1.35	0.00	2.10	8.70	38.09	39.44
Control	0	0	0.16	0.12	2.2	1.2	0.15	0.25	9.6	6.9	12.11	8.47

From Table 4, the calculated potential risk index ranged from 38.09 to 825.80, showing that the Potential Risk Index, (RI) of the soil passed through the entire categories of the RI. However, the mean RI of the surface soil, 323.52, of the contaminated soil, fell within $300 \leq RI < 600$, thus, indicating sever toxicity to the environment caused by the heavy metals and was found also to be higher than the mean RI for the control soil. The RI for S-5, S-10, and S-15 were of low-grade, as their RI values were within < 150 while about six spots from depth 0-15 cm had potential risk index ranging $150 \leq RI < 300$, indicating that they had moderate potential risk index. However, S-2, S-3, S-6 and S-13 were of sever Potential Risk Index as they were between the range of $300 \leq RI < 600$. The spots with serious potential risk index were S-1 and S-4 as their potential risk index were greater than 600. The high levels of the potential risk index were majorly contributed by the high Potential Ecological risk factor of cadmium in the contaminated soil

Potential Ecological risk factor of Heavy Metals at Depth 15-30 cm

The Potential Ecological risk factor, E_f^i, of the heavy metals at depths 15-30 cm are displayed in Table 4. For Pb, its E_f^i in the contaminated soil ranged from 0.05 to 1.45, with a mean value of 0.96, hence, it was within low Potential Ecological risk factor. The Potential Ecological risk factor of Pb in the control soil was zero and was less than the minimum Pb Potential Ecological risk factor of the contaminated soil. In addition, the Potential Ecological risk factor of Cr for all the spot were also low since the values were <40, ranging from 0.04 to 0.52. From Table 4,

Nickel showed low potential harm in all the spots analyzed except about 33.33 % which was between $40 \leq E_f^i < < 80$ with moderate Potential Ecological risk. The range for Ni Potential Ecological Risk ranged from 0.60 – 68.15. Similarly, the Potential Ecological risk of Cu in the contaminated soil ranged from 0.00 – 31.15, with low Potential harm. All the metals analyzed showed a range within <40 for the control soil and indicates that the metals had low potential harm to the environment. On the contrary, the range for Cd Potential Ecological risk factor ranged from 8.70– 596.40; where two spots, S-5 and S-15 had low potential harm; Only S-12, with Potential Ecological risk factor of 78.60 and moderate Potential harm to the soil environment. However, S-4, S-8 and S-11 were within $80 \leq E_f^i < 160$ with high Potential Ecological risk. Nonetheless, every other spot had higher Potential Ecological risk for Cd in the contaminated soil except S-6 with serious Potential harm of 596.40.

The Potential Ecological Risk Index of soil from 15-30 cm ranged from 39.44 – 667.34, cutting across all the categories and were majorly contributed by the Potential Ecological risk factor of Cd in the contaminated soil, as was also observed in the Potential Ecological risk Index for spots collected from 0-15cm. The second highest Potential Ecological risk Index was 334.62, followed by 326. 61. From Table 4, only about 13.33 % of the spots had sever Potential Ecological risk index with a range of $300 \leq RI < 600$. More so, about 46.67 % of the spots analyzed were between the $150 \leq RI < 300$, with moderate environmental toxicity. The ranges of Potential Ecological risk Index of <150 were occupied by about 33.33 % of the spots, with low grade Potential Ecological risk Index or toxicity. The Ranges of Potential Ecological risk factors of the heavy metals of interest in the control soil were within <40 indicating a low toxicity. The Potential Ecological Risk Index of the control soil was 8.47, which were < 150, with a low-grade Potential Ecological risk Index.

The Geo-accumulation Index of heavy metals

In this study, the essence of geo-accumulation index, $I\text{-}geo$, was to assess the effects of the contamination of the heavy metals of interest on agriculture and was done by comparing the concentration of the heavy metal content of the e-waste contaminated soil with that of the background concentration as stated by DRP in Nigeria; the index is shown in Table 5.

The metals of interest Pb, Cr, Ni, Cu and Cd showed maximum, minimum and mean of geo-accumulation index of 48.98, -0.43 and 26.95; -2.73, -5.62 and -3.69; 2.35, -3.19 and 0.98; 2.17, -2.46 and 1.37; 4.07, -4.45 and 1.82, respectively, at depth 0-15cm. However, at depth 15-30 cm the maximum, minimum and mean of the calculated geo-accumulation index were: 40.76, -0.48 and 23.35 for Pb; -2.55, -6.16 and -3.64 for Cr; 3.21, -3.67 and 1.0 for Ni; 2.05, -13.40 and -1.61 for Cu and 3.73, -2.38 and 1.50 for Cd, respectively. The maximum $I\text{-}geo$. of all the metals were positive at both depths except Cr with negative maximum $I\text{-}geo$., -2.73 at depth 0-15cm and -2.55 at 15-30 cm. Pb had the highest calculated maximum $I\text{-}geo$. at both depths. The maximum $I\text{-}geo$. at depth 0-15cm was 48.98 from Pb and about 80 % of the spot had $I\text{-}geo$. values >6. While at depth 15-30 cm the maximum $I\text{-}geo$., was 40.76 and about 86.67 % of the spots had $I\text{-}geo$. value >6. The maximum calculated $I\text{-}geo$., showed an order of: Pb > Cd> Ni> Cu > Cr at both depths. The metal with the least positive calculated maximum $I\text{-}geo$. was Cu at both depths.

The minimum $I\text{-}geo$. of all the metals showed negative $I\text{-}geo$. at both depths, with an order of: Pb > Cu> Ni> Cd > Cr at depth 0-15cm and Pb> Cd> Ni> Cr> Cu at depth 15-30 cm. At depth 0-15cm, the mean $I\text{-}geo$. of the metals of interest were all positive except Cr, -3.67 while at depth 15-30 cm, it showed positive for Pb, Ni and Cd and negative for Cr and Cu. The metal with the highest positive and negative mean calculated $I\text{-}geo$. were Pb and Cr, respectively, at both depths with their order as: Pb > Cd> Cu> Ni > Cr. The $I\text{-}geo$. values of the metals were: >6 for Pb at both depths, ≤0 for Cr at both depths, 0-1 for Ni at both depths, 1-2 at depth 0-15cm and ≤0 at depth 15-30 cm for Cu and 1-2 for Cd at both depths.

The $I\text{-}geo$. classes and soil quality as shown in Table 5 were: 6 and extremely contaminated for Pb at both depths; 0 and uncontaminated for Cr at both depths and Cu at depth 15-30 cm; 1 and moving from uncontaminated to moderately contaminated for Ni at both depths, lastly, 2 and moderately contaminated for Cd at both depths and Cu at depth 0-15cm. The calculated $I\text{-}geo$. of the control soil was negative for all the metal at both depths, with their order as: Pb> Ni> Cd> Cr> Cu and their $I\text{-}geo$. values as ≤ 0, class 0 at both depths and indicates uncontaminated soil quality.

Table 5: The Geo-accumulation Index of heavy metals in e-waste disposal site

Geo-accumulation Index of the Heavy Metals

Samples	Pb		Cr		Ni		Cu		Cd	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
S- 1	45.14	26.05	-2.91	-3.89	2.18	0.33	2.11	2.05	4.07	2.33
S- 2	34.24	26.28	-3.90	-4.15	0.25	0.16	2.17	-2.27	2.76	1.96
S-3	40.59	22.35	-3.28	-4.15	0.49	-0.35	-0.40	-0.88	3.55	2.81
S- 4	48.98	23.72	-2.73	-3.70	2.05	0.29	2.07	-13.40	3.97	1.29
S- 5	-0.49	-0.48	-5.62	-6.16	-3.19	-3.67	2.02	2.00	-1.05	-2.38
S- 6	40.23	39.86	-3.57	-3.11	2.26	3.21	2.06	-13.40	2.93	3.73
S- 7	36.93	34.28	-4.04	-4.20	1.34	0.73	-2.46	-1.05	2.26	2.44
S- 8	42.53	34.87	-2.95	-3.29	2.35	2.76	0.30	2.05	1.87	1.65
S- 9	26.42	34.15	-3.87	-2.55	2.02	3.04	2.16	1.91	1.75	2.43
S- 10	0.15	17.14	-3.15	-3.0	-0.57	-0.67	2.02	-2.71	-4.45	2.03
S- 11	37.60	40.76	-4.14	-2.77	0.44	2.87	2.03	-2.09	2.01	1.47
S- 12	15.81	11.94	-2.97	-3.34	1.96	2.36	1.09	0.94	1.93	0.80
S- 13	21.80	25.53	-3.85	-2.88	0.40	2.56	1.85	0.39	2.82	2.27
S- 14	4.07	5.33	-4.52	-3.51	0.98	0.79	1.53	0.54	2.43	1.12
S- 15	10.22	8.415	-3.83	-3.89	1.76	0.57	2.02	1.82	0.40	-1.40
Max.	48.98	40.76	-2.73	-2.55	2.35	3.21	2.17	2.05	4.07	3.73
Min	-0.43	-0.48	-5.62	-6.16	-3.19	-3.67	-2.46	-13.40	-4.45	-2.38
Mean	26.95	23.35	-3.69	-3.64	0.98	1.0	1.37	-1.61	1.82	1.50
I-geo. Value	>6	>6	≤0	≤0	0-1	0-1	1- 2	≤0	1-2	1-2
I-geo. Class	6	6	0	0	1	1	2	0	2	2
Control	-0.18	-0.08	-4.20	-4.54	-1.78	-2.67	-5.48	-5.05	-2.29	-2.70

CONCLUSION

The presence of heavy metals at any location represents one of the most important environmental hazards. Knowledge of the total concentration of these metals through soil analysis could be considered a starting point for evaluating the degree of pollution as investigated in the present study. Generally, heavy metal concentrations in the soils investigated were mostly at a critical level, exceeding the set limits by DPR and from all indications, the e-waste dumpsite is polluted and correct strategies should be implemented to stop dumping and burning of e-waste at the site. Consequently, indiscriminate disposal of e-waste has caused metal pollution of soil at the disposal site. These metals could leach into ground water making it unfit for human consumption. Also, policy should be put in place to stop out rightly the importation and dumping of e-waste as reuse materials in the country through Lagos

ports. In addition, measures should be adopted to remediate the polluted soil. Therefore, it is imperative that the heavy metal concentrations in soils of electronic waste dumpsites be monitored regularly to avoid toxicity.

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