



Evaluation of the Distribution of Heavy Metals in Soil around Electronic Dumpsite in Owutu, Ikorodu, Lagos State, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author HOS supervised, designed the study and performed the statistical analysis. Author FOO wrote the draft of the manuscript, managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

The soil from antiquity has been the primary repository of all wastes. Millions of tons of toxic e-waste from a variety of sources annually find their way into dumpsites. The assessment of the levels of Pb, Cr, Cd, Zn and Cu in soil from Owutu dumpsite in Ikorodu, Lagos State was performed using Atomic Absorption Spectroscopy. Control samples were also taken at 1 km away from the location. At the dumpsite, the concentration of Pb, Cr, Cd, Zn and Cu were found to range between 0.85 to 2261.15 mg/kg, 8.05 to 111.2 mg/kg, 1.05 to 46.6 mg/kg, 310.45 to 5443.7 mg/kg and 160.3 to 8246.3 mg/kg while that of the control sites range between 52.45 to 72.05 mg/kg, 18.1 to 20.80 mg/kg, 0.25 to 3.2 mg/kg, 126.55 to 140.7 mg/kg and 181.45 to 185.85 mg/kg respectively. Heavy metal concentrations at the dumpsite were found to be higher than those at the control site and that of the regulatory bodies. Assessment of the contamination level of the soils at the dumpsite was done by calculating the metal contamination factor and Geoaccumulation index. The results revealed that there is gross contamination of the dumpsite with heavy metals due to the e-waste disposed on the site.

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1. INTRODUCTION

The term e-waste, e-scrap or waste electrical and electronic equipment (WEEE) is used to describe any used electrical or electronic materials such as radio, Personal computers, home theater, pressing iron, hot plate, water heater, blenders, electric moppers, led bulb, heaters and many more electrical gadgets used both at home and offices. Electrical and electronic equipment (EEE) have contributed to the revolution witnessed in recent years which has immensely ease life and promote various sections of human face around the world. The communication sector have experienced a tremendous development as a result of availability of high technology equipment and connectivity. These impacts are not limited to particular section but extended to entertainment industry, transportation (air, land and water), educational system and health care sectors. The importation of so called used electrical electronic material from China, Europe and other advanced country to the less developing countries is like hazard or problem in disguise. Because these electronic materials have expired, the developing countries are just been used as a dumping ground [1,2].

Recent studies conducted by United Nation show that WEEE generated around the globe triple the solid waste generated both at commerce enterprise and at household level. The increase resulted from the strategies adopted by the manufacturing companies by producing more efficient, reliable and less energy consumption gadget to replace the old and non fashionable ones been used at homes and offices to stay updated and connected to the world. As a result of this, millions of tones of WEEE are generated within limited period of time globally. All these discarded and used WEEE landed in some of these developing countries like Nigeria and been bought by the larger number of people since only few rich people can afford to buy new electrical equipment [3].

The great concern of this practice is not only the utilization end of life electronic equipment but the improper collection, storage and disposal danger created by these materials in the environment which have great effect not only on human race but both the plant and animals in the general environment. Various laws, policies and regulations have been formulated to regulate

indiscriminate importation and disposal but not properly enforced and monitored to checkmate the effect attached to such activities. This would have been employment creation opportunity and economy boosting avenue if it can be dubiously supervised and monitored by the concerned enforcement agencies. The display and sales of these used electronic equipments affect majorly four states which can be characterized of having higher pollution and better economy in Nigeria. The states include Lagos estimated which is to have 67% of industries and having highest pollution as stated in the population census in Nigeria. The sequence followed by Rivers, Kaduna and Kano due to the curiosity of the inhabitant to stay connected to the world. It is of great concern that effect of open burning and dismantles of the circuit of the panel of some of these materials placed huge burden on the general environment. The pollutant released from this process contain heavy metals like Cadmium, Zinc, Lead, Chromium mercury which can bioaccumulate, persist and biomagnified when released into the environment for long period of time due to their poor collection, transportation and disposal. The term heavy metals are adopted for a group of metals and metalloids and their compounds because they evoke the concept of recalcitrance and toxicity in biological systems, aside contamination and persistence in the environment [4]. Some heavy metals are referred to as endocrine disruptors. These types of metals include mercury, arsenic, cadmium, zinc, copper etc. The aim of this research study is to evaluate the distribution of heavy metals in soil around Electronic Waste dump site. The determination will however be limited to heavy metals such as lead, chromium, zinc, cadmium, copper.

2. MATERIALS AND METHODS

2.1 Sample Location

Lagos State is located in the southwestern part of Nigeria, in West Africa. It is on coordinates 6°27'N/3°23'45'E and covers an area of 999.6 km². Ikorodu is a city in Lagos State, Nigeria. Ikorodu Division has a large Industrial area containing many factories. In Ikorodu Township alone, half of the twenty-five (25) registered banks by the Central Bank of Nigeria, (CBN) have branch offices. Ikorodu's relative closeness to sprawling Lagos conurbation makes it the fastest growing exurb near Lagos metropolis.

Owutu (Ikorodu) dumpsite serves as Satellite Sites for other three main landfill sites (Olusosun, Abule-Egba and Solous). The site is well known for the dismantling and sorting of solid wastes including EEE (Electronic Electrical Equipment) and receive an average waste of about 1,864.29 m³ per day. LAWMA (Lagos Waste Management Agency) runs services for the collection of wastes from commercial organizations, street cleaning, fly tipping, and municipal parks/grounds around Ikorodu West LGA, all being dumped at this dumpsite.

2.2 Sample Collection and Preparation

Study Duration: October 2017 to November 2018.

The dump site was divided into four radial transects and the samples were collected at two locations in each radial transects (A – H, Table 1). 2 soil Samples were also collected at about 1 km away from the locations and were referred to as control samples (Control A- B, Table 1). Total

samples collected were ten (10) at the dumpsites.

2.3 Sample Treatment

Collected samples were kept in polythene bags and transported to the laboratory. Samples were air dried in the laboratory for few days at room temperature until they were properly dried. Large objects (stone, sticks) were removed. Samples were gently ground with porcelain mortar and pestle, sieved through a 2 mm sieve and stored in small polythene bags for Soil pH and metal analysis.

Quality assurance and quality control were ensured by meticulously following the written procedures for sample handling both on the field and in the laboratory. Instruments and equipment used were calibrated. Quality control techniques were performed such as cleaning of apparatus, glassware and method blank determination. The apparatus used for the analyses were soaked overnight in detergent solution, rinsed many

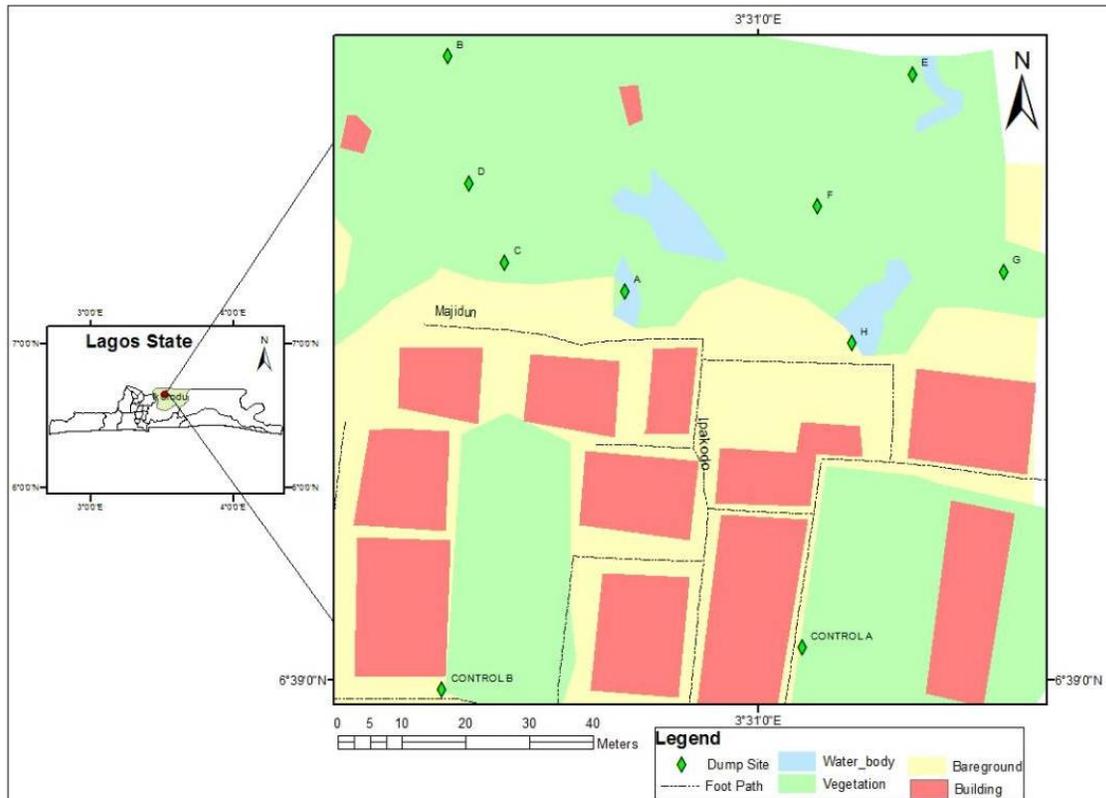


Fig. 1. Map of Ikorodu showing different sample points on the study areas represented by letters A to H and Control A

times with tap water and then soaked overnight in dilute HNO₃. The apparatus were rinsed many times with tap water until they were acid free and then finally rinsed with deionized water. This step was repeated in between analyses to avoid cross contamination. Standards were used to verify calibration accuracy. Analytical procedures were validated by carrying out duplicate analysis.

2.4 Soil Sample Analysis

The pH determination was done using pH meter which had been previously calibrated with buffer 4 and 7. Soil pH was measured in deionized water using 1:1 (w:v) soil/solution ratio. 10 g of the air dried and sieved soil sample was weighed into a 250 ml beaker and 10 ml of distilled water was added to it. The mixture was allowed to stand for 30 minutes while stirring occasionally with a glass rod. The electrode of the calibrated pH meter was inserted into the suspension and the pH was measured using Hanna (model H196107) pH meter.

2.5 Sample Analysis

2.5.1 Determination of heavy metals in soil

Approximately 1 g of the soil sample was weighed into centrifuge tubes and digested using a mixture of 5 ml of HNO₃ and 10 ml of HCl [5]. The mixture were heated over water bath for 2 hours and shaken at 20 min intervals. The solutions were filtered through Whatman number 42 filter paper into 100 ml volumetric flasks. The flasks were made up to mark with distilled water and the concentrations of heavy metals (Pb, Zn, Cu, Cr and Cd) were determined using Buck Scientific (model 210 VGP) Atomic Absorption Spectrophotometer. The data were analysed in duplicate and the mean concentration values were recorded.

3. ASSESSMENT OF CONTAMINATION LEVEL

The following factors were calculated to estimate extent of soil contamination by heavy metals.

3.1 Metal Contaminated Factor (CF)

The CF describes the ratio between the metal concentration in the polluted soil (C_s^i) and in the reference unpolluted soil [6] using the following equation:

$$CF_i = C_s^i / C_b^i$$

Where C_s^i represents the metal concentration in polluted soil and C_b^i represents the concentration of metal in unpolluted/ reference soil.

The intensity of contamination is reflected on a scale with zero indicating no contamination, 1 none to medium, 2 moderate, 3 moderate to strong, 4 strong, 5 strong to very strong and 6 high contamination [7].

3.2 Geoaccumulation Index (I_{geo})

The geoaccumulation index I_{geo} values were calculated for different metals [7] as follows:

$$I_{geo} = \log_2(C_s^i / 1.5C_b^i)$$

Where the number 1.5 is a background matrix correction factor which was used to characterize sedimentary features, petrogeology, and other influences. Muller proposed seven grades or classes of the geoaccumulation index with soil quality as follows:

- Class 0; $I_{geo} \leq 0$ = unpolluted
- Class 1; $0 < I_{geo} < 1$ = unpolluted to moderately polluted
- Class 2; $1 < I_{geo} < 2$ = moderately polluted
- Class 3; $2 < I_{geo} < 3$ = moderately polluted to highly polluted
- Class 4; $3 < I_{geo} < 4$ = polluted
- Class 5; $4 < I_{geo} < 5$ = highly polluted to very highly polluted
- Class 6; $5 < I_{geo} < 6$ = very highly polluted

The I_{geo} class 0 indicates the absence of contamination while the I_{geo} class 6 represents the upper limit of the contamination. The highest class 6 (very strong contamination) reflects 100 folds enrichment of the metals relative to their background values [7].

4. RESULTS AND DISCUSSION

The soil from antiquity has been the primary repository of all wastes [8]. Millions of tons of toxic e-wastes from a variety of sources annually find their way into dumpsites. The presence of heavy metals in the environment beyond acceptable limits calls for concern because of the deleterious effect of toxic metals on humans, animals and plants [9]. The heavy metals (zinc, copper, lead, chromium and cadmium) contents of the soil were evaluated to predict the concentration of the soil (Table 1). The risk assessment of heavy metals at the dumpsite is presented in Tables 2 and 3.

Table 1. Concentration of heavy metals in soil samples at various sampling points, control sites as well as the threshold values for the elements in the soil

Sampling points	Ph	Cu (mg/kg)	Zn (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Zn (mg/kg)
A	6.40	7177.1±202.23	824.05±40.52	BDL	2.8±0.85	793.35±11.53
B	7.49	7853.3±14.81	1895.65±77.71	111.2±5.09	5.25±1.34	1167.1±8.63
C	7.30	107.0±54.87	224.4±20.93	15.6±1.13	1.55±0.49	0.55±0.78
D	6.94	6048.3±54.87	5105.9±883.32	88.4±5.79	46.6±2.40	2219.7±8.34
E	6.60	8246.3±149.91	622.9±55.72	8.05±1.77	1.0±1.41	954.25±7.71
F	7.85	5822.3±344.22	1812.7±230.38	76.65±4.45	4.5±1.13	1836.2±149.62
G	6.45	160.3±11.31	310.45±33.87	29.15±0.35	1.05±0.35	0.85±1.20
H	7.25	5814.75±154.36	5443.7±87.96	75.25±3.61	23.35±3.32	2261.15±310.63
Control A	7.48	181.45±4.03	140.7±4.53	18.1±0.85	0.25±0.35	52.45±3.04
Control B	6.89	185.85±9.83	126.55±7.42	20.80±2.97	3.2±1.56	72.05±10.11
EU limit Value	7.70	100	200		1.5	100
USEPA					3.0	300

Table 2. Table showing Contamination Factor (CF) for all elements

Sample ID	Cu	Zn	Cr	Cd	Pb
A	39.55	5.85	BDL	11.2	15.12
B	43.28	13.47	6.14	21.0	22.25
C	0.58	1.59	0.86	6.2	0.01
D	33.33	36.28	4.88	186.4	42.32
E	45.44	4.42	0.44	4.00	18.19
F	32.08	12.88	4.23	18.00	35.00
G	0.88	2.20	1.61	4.20	0.01
H	32.04	38.69	4.15	93.40	43.11

Table 3. Geoaccumulation index for Owutu dumpsite soil

Sample ID	Geoaccumulation Index				
	Cu	Zn	Cr	Cd	Pb
A	14.40	0.82	BDL	0.18	0.53
B	15.76	1.92	0.22	0.35	0.78
C	0.21	0.22	0.03	0.10	3.67
D	12.14	5.12	0.17	3.11	1.48
E	16.54	0.62	0.10	0.06	0.63
F	11.68	1.81	0.15	0.30	1.22
G	0.32	0.31	0.05	0.07	5.68
H	11.66	5.46	0.15	1.56	5.51

The pH ranged from 6.40 -7.85 for all soil samples while the pH of the control sample was 7.5 (Table 1). The degree of acidity and/or alkalinity is considered a master variable that affects nearly all soil properties such as chemical, physical and biological while some organisms are unaffected by a rather broad range of pH values, others may exhibit considerable intolerance to even minor variation in pH [10]. It has been reported that most metals in the pH range 6.0-9.0 are not always in the free form, hence not likely to be available [11]. The

pH of all the soil samples investigated is within this range.

The concentration of lead in the soil samples ranged between 0.55 to 2261.15 mg/kg. Maximum concentration was observed in the soil sample collected in location H. At the control site, the concentration of lead ranged from 52.45 to 72.05 mg/kg (Table 1). The results revealed that the dump site contained significant amount of lead which could be a result of the presence of lead containing substances like cathode ray

tubes, batteries and solid at the site. Lead is found in E-Waste such as in cathode ray tubes, batteries and solders. Effects of exposure to lead include low intelligent quotient, muscle pain, anorexia, malaise, attention deficient, impairment of cognitive function and high level of lead exposure could cause brain damage and lead to death [12].

Concentration of chromium in the soil samples ranged between 0 to 111.2 mg/kg. The highest concentration of chromium was found in point B where point A chromium concentration falls below detected limit. The mean level of chromium in soil was BDL, 111.2 ± 5.09 mg/kg, 15.6 ± 1.13 mg/kg, 88.4 ± 5.79 mg/kg, 8.05 ± 1.77 mg/kg, 76.65 ± 4.45 mg/kg, 29.15 ± 0.35 mg/kg, 75.25 ± 3.61 mg/kg. The mean level when compared with the control was found to be higher with points B, D, F and H. At these points, chromium might have been introduced by chromium containing E-waste material into the soil. Major source of chromium in E-waste include hardener in plastics, and dye in pigments of some switches. Skin contact with some chromium VI compounds can lead to ulcers with allergic reaction and could result in redness and swelling of the skin. Chromium VI compound have also be noted to increase risk of lung cancer and also cause damage to DNA. The mean concentration of chromium in this study fall below the 100 mg/kg recommended by USEPA, 100.3 to 105.0 mg/kg by [13] but was found to be higher than 0.10 and 0.35 mg/kg as reported [5].

Zinc concentration was found to range between 224.4 to 5443.7 mg/kg. The highest concentration was found at point H while the lowest concentration was found at point C. Zinc concentration at control site was lower when compared with what was observed at the dumpsite. This indicates that increase in the zinc concentration at the dumpsite is greatly influenced by the release of zinc containing substance into the soil. The acceptable limit of zinc in the soil is 200-300 mg/kg. It was observed that except for zinc content at point C, all other zinc content did not fall within the save limit. Zinc is an essential element which is required in low quality for body development. However, excessive intake or exposure to zinc can cause dehydration, abdominal pain, electrolyte imbalance, lack of muscular co-ordination and vomiting 12.

The concentration of cadmium from this study was very high at point D (46.6 mg/kg) and the lowest value at point E (1.0 mg/kg). The mean

value when compared with control was found to be higher except at point E and G. The mean levels were also compared with the international threshold value and were found to be higher than soil criteria from some countries (Table 1). The difference in Cadmium concentration at the site and control samples suggest that increase in Cadmium concentration may be as a result of the released of cadmium from e-wastes containing electronic and electrical equipment such as batteries, PVC, aviation, corrosion resistant and light-sensitive resistors. Cadmium is a potentially long-term cumulative poison and toxic. Compound of Cadmium tend to accumulate in human body causing kidney and lung damage. It is also known to be carcinogenic to human health.

The concentration of copper in soil samples ranged between 107.0 to 8246.3 mg/kg. Maximum concentration was observed in soil sample collected in location E. At a distance of 1 Km away from the dumpsite, the concentration of Copper ranged between 181.45 to 185.85 mg/kg. The mean levels compared with the controls and were found to be higher by more than twenty folds except for point C and G where the values were lower than the control.

The average concentration of Heavy metals studies in the soil followed the order: Cu > Zn > Pb > Cr > Cd. The results suggest very serious anthropogenic influence which is connected with the dumpsite which receives all kinds of E-wastes. The concentration for Zn, Pb, Cr were higher than previous study on Abule-Egba (Pb: 146.30 ± 8.42 ; Cr: 26.40 ± 2.13 ; Cd: 27.83 ± 3.23 ; Zn: 211.46 ± 9.41), Olusosun (Pb: 328.40 ± 10.30 ; Cr: 30.80 ± 4.43 ; Cd: 31.40 ± 5.36 ; Zn: 306.94 ± 14.82) and Soluos (Pb: 152.30 ± 9.85 ; Cr: 23.94 ± 2.84 ; Cd: 24.86 ± 3.55 ; Zn: 268.20 ± 4.82) E-waste dumpsites in the previous study reported. Higher levels of metals could also be from fresh deposition of high metal content of E-waste on the dumpsite.

The contamination factors for most studied elements were above 6. This indicates a very high contamination of the site (Table 2) [7]. The higher contamination factor was observed for copper. This indicates that the soils were highly contaminated with copper. Soil samples collected at point C and G indicated low to medium contamination except for Cadmium which has a contamination factor of 6.2 and 4.2 suggesting high contamination of these sampling points with cadmium.

The geoaccumulation Index showed that the dumpsite was highly polluted with Copper; moderately to highly polluted with Lead; unpolluted with Chromium and moderately polluted with Zinc (Table 3). All the soil samples showed far higher concentrations for all metals investigated (except for Chromium) when compared to EU permissible level in soil.

5. CONCLUSION

Evaluation of the Distribution of Pb, Cu, Zn, Cr and Cd in soil samples within the vicinity of Owutu dumpsite in Ikorodu, Lagos, Nigeria was carried out to ascertain the extent of contamination of the dumpsite and dangers it can pose on human health. The concentrations of all metals for all soil samples collected were far higher than those at the background (control site) suggesting serious anthropic influence. Contamination factor and geoaccumulation index calculated revealed that continuous dumping of e-waste on this dumpsite would pose great danger to human health especially for those living in the surrounding environment (Tables 2 and 3). This is because owutu dumpsite is currently surrounded by residential neighborhood. People living around the dumpsite can be exposed to the harmful impact of the dumpsite in form of dust particle, contaminated water (due to run-off) ingestion etc. Awareness of the pollution state of the soil within the vicinity of the dumpsite needs to be urgently created especially among people living in the environment to avert health related problems. It is however recommended that:

- ✓ Government should keep the public aware of the pollution state of the soil within the e-waste dumpsite urgently and a policy relating to premises regulation need to be enforced to prevent erection of residence within the area to limit exposure of the hazard to the public.
- ✓ Risk based environmental guidelines and standards for dumpsite in Nigeria are established.
- ✓ Waste pickers should use protective equipment while scavenging on e-waste dumpsites.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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