Original Research

Heavy Metals Contamination of Water, Soil, and Plants around an Electronic Waste Dumpsite

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Abstract

Electronic waste (e-waste) has become a subject of growing environmental concern in developing countries due to legal/illegal import of electronics from developed nations. In this study, concentrations of heavy metals in and around the largest e-waste dumping site in Nigeria, Alaba International Market in Lagos, was investigated. Concentrations of five heavy metals, namely: cadmium (Cd), chromium (Cr), lead (Pb), nickel (Ni), and zinc (Zn) in soil, water, and plant samples during the wet and dry seasons were measured using atomic absorption spectrometry (AAS). Samples were collected between October 2011 and May 2012 and digested using standard wet digestion methods. Pb recorded the highest values, while the lowest were found for Cd in all the samples during the dry season. Heavy metal concentrations were generally lower during the wet season due to increased aeration and dilution from rainfall.

Results show that the total mean concentrations of the heavy metals decreased with depth in soil samples and distance from the dumpsite. Possible sources of contamination were also discussed. A noteworthy observation was that the concentrations of most of the heavy metals under investigation exceeded maximum permissible levels.

Keywords: Nigeria, E-waste dumpsite, heavy metals, environmental pollution, Alaba International Market

Introduction

Electronic waste (e-waste) may be defined as discarded computers, office electronic equipment, entertainment device electronics, mobile phones, television sets, and refrigerators [1]. This definition includes used electronics that are destined for reuse, resale, salvage, recycling, or disposal. Developed countries have replaced massive amounts of obsolete electronic equipment and home appliances with newer versions, creating a huge e-waste problem for the global environment. Uncontrolled burning, disassembly, and disposal cause a variety of environmental problems such as groundwater contamination, atmospheric pollution, or even water pollution either by immediate discharge or due to surface runoff. Men, women, and children are employed in the highly polluting, primitive recycling technologies of extracting metals, toners, and plastics from computers and other e-waste [2]. Developing countries utilize methods that are more harmful and more wasteful such as open burning of electronic equipment in order to melt plastics and to recover metals. This leads to the release of carcinogens and neurotoxins into the air, contributing to smog.

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In these countries, where environmental enforcement laws may not be sufficient, high concentrations of trace metals can be discharged from e-waste, thus causing widespread environmental damage to people and their immediate environment [3]. Only 25% of all the electronics produced and sold worldwide can be recycled or re-used, thus 75% is waste [2]. Alaba International Market in Lagos is a dumping ground for electronic appliances and equipment that come from home and abroad. Some electronics contain heavy metals such as mercury found in fluorescence tubes and flat screen monitors, cadmium in rechargeable batteries and resistors, and lead in lead batteries and cathode ray tubes, just to mention a few. A statement from an environmental report reveals that about 75% of the heavy metals found in landfills come from e-wastes [4]. When the compost from an e-waste dumpsite is used as manure, some heavy metals are being subject to bioaccumulation and may cause risk to human health when transferred to the food chain. Exposure to heavy metals may cause blood and bone disorders, kidney damage, decreased mental capacity, and neurological damage [5-7].

Human exposure to heavy metals occurs through three primary routes, i.e. inhalation, ingestion and skin absorption. Pb is a particularly dangerous metal that has no biological role and negatively affects children in significant ways [5]. The environmental problem with heavy metals is that they are unaffected during breakdown of organic waste and have toxic effects on living organisms when they exceed a certain concentration. The high concentration of heavy metals in soils is reflected by concentrations of metals in plants, water, animal, and human bodies. Consequently, when pollutants from e-waste are washed into surrounding water bodies by rain or flood, there will be a change in the level of heavy metal concentration and nutrient concentration of the water bodies [6].

This work was able to establish a basic understanding of the extent of contamination of heavy metals and generate baseline data on the concentration of heavy metals from e-waste on soil, water, and plants on the dump site. The information obtained from this study will help to advocate for the preservation of the environment through environmentally sound e-waste management in Nigeria [6].

Materials and Methods

Our study was carried out within Alaba International Market in Lagos State. Lagos State is located in Southwestern Nigeria on the geographic grid reference longitude of 3º10´E and latitude 6º28´N. It has a tropical climate characterized by rainfall in the wet season (WS) April-October and in the dry season (DS) October-May.

Soil, water, and plant samples were collected at various points on and around the e-waste dumpsite between April-October, 2011. This was repeated in October-May 2012. Composite samples were taken to give a true representation of the area. The major soil types in the region were identified using a semi-detailed soil map of central western Nigeria produced by Smyth and Montgomery [8]. Samples of soil were taken from the dumpsite and designated distances: 100 m, 150 m, and 200 m from the dumpsite. The identified soil types were sampled using a Dutch soil auger to collect core samples at 0-to-15 and 15-to-30 cm soil depths. For each soil series, 10 core samples, randomly taken, were homogenized and a composite sample was taken.

The homogenized composite samples were air-dried, crushed, and sieved using a 2 mm sieve. The samples were kept in a polyethylene bag and labeled accordingly. Well and tap water were sampled on the dumpsite and from residences 100 m and 200 m from the dumpsites, and composite samples were taken to give a true representation of each point. The samples were collected in plastic containers previously cleaned by washing in non-ionic detergent. It was rinsed with tap water and later soaked in 10% HNO_3 for 24 hours and further rinsed with deionized water before use. The samples were stored in a refrigerator at 4ºC prior to analysis to inactivate bacteria and prevent any change in volume that may be caused due to evaporation.

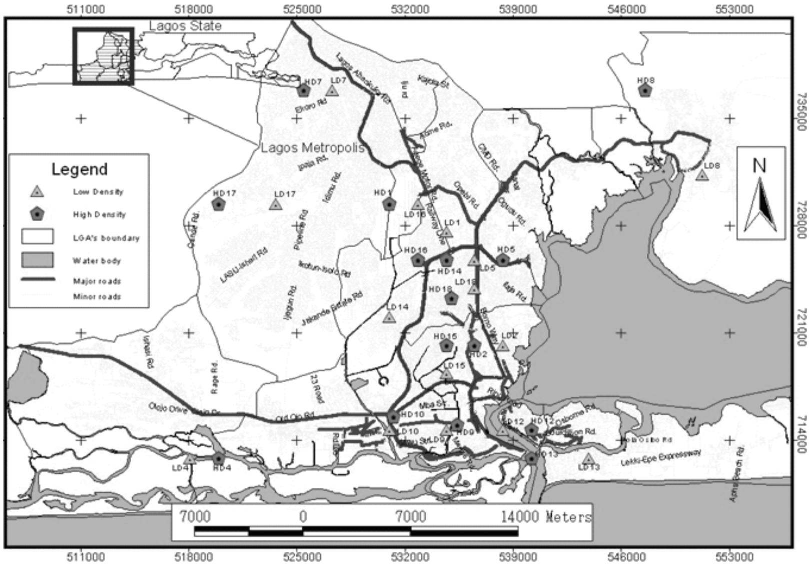

Fig. 1. Map of Lagos metropolis.

Table 1. Total elemental concentrations (mg/L) of heavy metals in water samples during the wet (WS) and dry (DS) seasons.

(mg/L)	Pb	Cd	Zn	Cr	Ni
Tap, market (WS)	1.360±0.98	0.002±0.09	0.400±2.01	0.290±0.03	0.920±0.26
Tap, (DS)	1.200±1.00	0.006±0.02	0.680±0.22	0.350±0.01	0.970±0.04
Tap, residence 100 m from market (WS)	0.033±1.09	0.003±0.25	0.004±0.01	0.004±0.01	0.001±0.01
Tap, residence 100 m from market (DS)	0.015±0.11	0.006±0.54	0.020±0.01	0.030±0.33	0.004±0.73
Tap, residence 200 m from market (WS)	0.029±1.04	0.025±0.01	0.004±0.01	0.031±0.03	0.001±0.01
Tap, residence 200 m from market (DS)	0.011±0.01	0.005±0.54	0.001±0.01	0.012±0.01	0.002±0.02
Well, residence 100 m from market (WS)	0.430±0.07	0.004±0.23	0.350±0.04	0.020±0.21	0.005±0.03
Well, residence 100 m from market (DS)	0.510±0.02	0.004±0.11	0.500±0.02	0.050±0.01	0.005±0.12
Well, residence 200 m from market (WS)	0.422±0.01	0.002±0.01	0.210±0.02	0.020±0.01	0.005±0.01
Well, residence 200 m from market (DS)	0.320±0.02	0.035±0.10	0.220±0.01	0.051±0.01	0.003±0.02
Well, market (WS)	1.800±0.01	0.006±0.01	0.841±0.02	0.250±0.12	1.230±0.04
Well, market (DS)	2.770±0.02	0.012±0.12	0.948±0.12	0.520±0.01	1.450±0.05

Fig. 1 shows the map of Lagos Metropolis showing the low and high density areas, Local government area boundaries, water boundaries, and major and minor roads.

Amaranthus spinosus (spiny spinach), a plant found growing on the refuse dump was randomly uprooted, packed into plastic bags, and washed with distilled water to remove debris and insects, and partitioned into parts (leaf, stem, fruit, and root) prior to analysis in the laboratory.

Laboratory Analysis

All reagents used were of analytical grade and from which standard solutions were prepared. Glassware was thoroughly washed with detergent and rinsed with distilled water.

Soil Sample Analysis

The digestion method by Francek et al. [9] was adopted for the extraction of trace metals in the study. The soil was crushed and 1g was accurately weighted and digested with 10 ml of 1:1 concentrated HNO_3. The mixture was evaporated to near dryness on a hot plate and cooled, and the procedure repeated with 1:1 concentrated HCl (15 ml). The extracts were filtered with No. 40 whatman filter paper and then made up to 100 ml with 2% HNO_3.

Water Sample Analysis

2.5 ml concentrated HNO_3 was added to 50 ml of the sample and digested until a colorless solution was obtained. The digested sample was filtered to remove insoluble materials and the volume of the digested sample made to 50 ml with distilled water [10].

Vegetable Sample Analysis

The already partitioned *Amaranthus caudatus* (spinach) was dried in the oven at 60ºC for 10 hours, then ground and powdered with a mortar. The powdered sample (1 g) was digested using a mixture of concentrated nitric and perchloric acids [10].

Digestion was carried out in triplicate for all the analysis. Determination of heavy metals (Cd, Cr, Ni, Pb, and Zn) in the soil, water, and vegetable samples were performed using the atomic absorption spectrometer (AAS) (200A Model) at the Centre for Energy Research and Development of Obafemi Awolowo University, Ile-Ife, Nigeria.

Discussion of Results

Water

Heavy metal concentrations in water samples are presented in Table 1. The heavy metal concentrations in the water samples were higher in dry season compared to those of the wet season. This may be the result of slow currents of water in dry season. This gives room for the heavy metals to settle down and accumulate in water without turbulence. The mean concentrations (mg/L) of Pb, Cr, Ni, Zn, and Cd in tap water at residences close to the dumpsite in the wet and dry seasons were generally lower. For the well water, the mean concentrations (mg/L) in the dry season were generally higher for all the heavy metals studied. Figs. 2 and 3 show highest concentrations of heavy metals in well water from the market. This is of particular concern due to the strategic location of the well water and its use in diverse forms by humans and domestic animals. The elevated level of metals in the well water further implicates the magnitude of metal input from leachates resulting from e-wastes that leached from the dumpsite. In fact, significant levels of Pb and Ni were found in well and tap water at the residences and dumpsite, although the concentrations of heavy metals in the sample decreased when the sampling distances from the dumpsite increased. The level of Pb in the study is high and is call for concern. More than 50% of samples from well and tap water some meters from the dumpsite exceeded WHO maximum permissible limits for heavy metals in water [11]. Thus, adverse effects of heavy metals pollution may result from domestic use of the water and its use for livestock and aquaculture. Pb toxicity studies conducted on female animals revealed mostly miscarriages and potent mortality [12]. High Pb concentration in drinking water may result in metallic poisoning that manifests in symptoms such as tiredness, lassitude, slight abdominal discomfort, irritation, and anemia [13]. Pb is a cumulative poison and a possible human carcinogen [14]. In comparison with a study where a concentration of 0.1 mg/L had resulted in the development of neurological problems in fetuses and children, the results obtained in this study definitely require urgent attention by the citizenry [15].

Ni occurs at elevated concentrations in the wells and tap water on and around the dumpsite, although the heavy metals concentrations of Ni in water decreased as the sampling distances away from the dumpsite increased. This may be due to its presence in electronic wastes in diverse forms, especially in Ni-Cd batteries and electric guns in cathode ray tubes. Nickel may have leached through soil into ground water. Ni causes skin damages and asthma symptoms in about 10 to 20% of the population that has direct contact with it [16]. Workers exposed to dust containing Ni suffer bronchitis and lung damage. There is evidence that many Ni compounds such as nickel hydroxide are carcinogens. One of the air routes of exposure to Ni is through the burning of e-wastes on dumpsites [16].

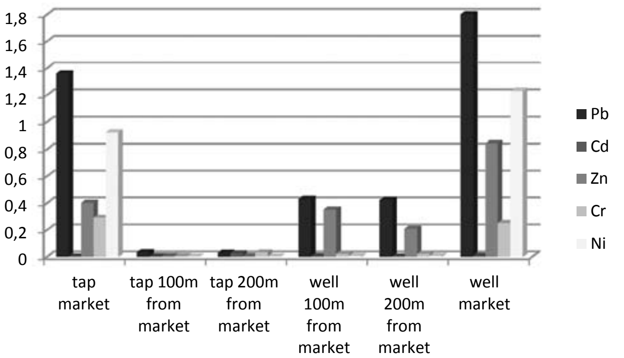

Fig. 2. Total elemental concentrations (mg/L) of heavy metals in water samples in the wet season.

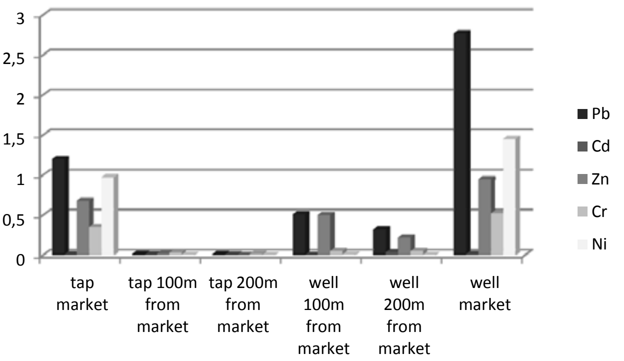

Fig. 3. Total elemental concentrations (mg/L) of heavy metals in water samples in the dry season.

Zn concentrations in the boreholes are lower in the wet season when compared with the dry season. This is at variance with some findings [17]. These discrepancies in research results may be due to variations in the geology of the different study areas as well as dissimilar anthropogenic activities occurring in areas under investigation. The study showed consistency in Zn concentrations in water for both the wet and dry seasons with the present study [18, 19]. However, Zn concentrations in all the boreholes are all within the WHO acceptable limit for drinking water for both the wet and dry seasons [11]. Zn is essential to plant and animal physiology, but excessive levels in water can cause problem of bitter, astringent taste and opalescent appearance [16]. Zn in e-waste is usually in the form of ZnS used in monitor glass. Exposure to this heavy metal may be from burning and dismantling of computer monitors. Direct critical exposure is corrosive to the skin and lungs and ingestion can be very harmful [20].

The heavy metals concentrations of Cd and Cr were generally low in tap and well water analyzed on the dumpsites and distances away from the dumpsite. Cd metal can be found in chip resistors, infrared detectors, and semiconductors. Old monitors contain around 5 to 10 grams of Cd and some batteries are made of Ni-Cd. Cd exposure commonly occurs when cadmium enters the environment through many electronic components [21]. Low Cd in water may be due to reuse of chip resistors, infrared detectors, and semiconductors at the market. Therefore, few of the items containing Cd and Cr may be burned or discarded to e-waste dumps. Exposure to Cd may be from inhalation and ingestion of food or contaminated water.

The heavy metals concentrations of Cd and chromium Cr were generally low in tap and well water analyzed on the dumpsites and distances away from the dumpsite. Cd metal can be found in chip resistors, infrared detectors, and semiconductors. Old monitors contain around 5 to 10 grams of Cd, and some batteries are made of Ni-Cd. Cd exposure commonly occurs when cadmium enters the environment through many electronic components [21]. Low Cd in water may be due to reuse of chip resistors, infrared detectors, and semiconductors at the market. Therefore, few of the items containing Cd and Cr may be burned or discarded to e-waste dumps. Exposure to Cd may be from inhalation and ingestion of food or contaminated water. Chromium VI is the toxic form of Cr and this is used as a protective layer on some electronic equipment components. Exposure to chromium over an elevated period causes high blood pressure and kidney and DNA damage, and has been linked to asthma and bronchitis [21]. The major pathways are through landfill leachates or from fly ash generated when materials containing chromium VI are incinerated. In comparison with this study, environmental pollution, resulting from unregulated e-waste recycling activities contributed to elevated heavy metals, especially Cd in neonates born in Guiyu, China, and threatened health [21]. This implies that prolonged consumption of water polluted with heavy metals will create health risks over time. High concentrations of some of the metals observed in the wet season samples could be an indication that the

Table 2. Total elemental concentrations (mg/kg) of heavy metals in the soil surface (15 to 30 cm) (n=9) during the wet and dry seasons.

mg/kg	Pb	Cd	Zn	Cr	Ni
100 m from dump, (WS)	257.00±0.05	4.55±0.12	44.75±0.09	23.32±0.01	62.68±0.07
100 m from dump, (DS)	288.35±1.20	4.61±0.01	46.46±0.03	24.60±0.01	69.55±0.06
150 m from dump, (WS)	232.55±0.02	3.78±0.34	36.54±1.09	24.84±0.37	56.68±0.07
150 m from dump, (DS)	245.00±0.09	4.56±0.01	40.15±1.13	21.20±0.01	60.05±0.04
200 m from dump, (WS)	200.90±0.40	2.55±0.12	32.08±0.01	19.62±0.37	35.45±0.37
200 m from dump, (DS)	214.00±0.01	2.83±0.76	35.59±0.01	19.11±0.01	46.81±0.53
Dumpsite, (WS)	428.12±0.01	7.28±0.02	60.32±0.02	32.84±0.02	80.24±0.75
Dumpsite, (DS)	569.07±0.11	9.63±0.07	73.21±1.03	37.16±0.01	82.70±0.06

Table 3. Total elemental concentrations (mg/kg) of heavy metals in the soil surface (0 to 15cm) (n=9) during the wet and dry seasons.

mg/kg	Pb	Cd	Zn	Cr	Ni
100 m from dump, (WS)	263.00±0.03	4.62±0.12	48.98±0.12	22.54±0.01	61.22±0.01
100 m from dump, (DS)	300.35±1.01	4.79±0.01	50.22±0.02	26.98±0.05	70.88±0.03
150 m from dump, (WS)	248.55±0.06	3.92±0.34	47.35±0.01	30.23±001	58.68±0.01
150 m from dump, (DS)	291.00±0.03	4.60±0.01	50.52±0.01	27.64±0.02	62.03±0.02
200 m from dump, (WS)	226.90±0.23	2.79±0.12	31.54±0.03	22.98±0.03	35.15±0.01
200 m from dump, (DS)	233.00±0.11	2.99±0.76	45.37±0.04	29.22±0.01	47.51±0.03
Dumpsite, (WS)	502.12±0.12	7.82±0.02	66.90±0.01	32.65±0.02	84.24±0.12
Dumpsite, (DS)	630.07±0.01	9.99±0.07	54.66±0.01	46.58±0.02	85.43±0.02

soluble forms of the metals are either present in the environment or produced after chemical reactions have occurred.

Soils

Tables 2 and 3 summarize the mean concentrations of heavy metals (Pb, Cd, Zn, Cr, and Ni) in soils at various depths and distances away from the dumpsite in the wet and dry seasons. The concentrations of the heavy metals were found to be higher in the dry season when compared with the wet season, which can be attributed to the leaching of the cations down the profile by rainfall [22, 23]. Heavy metal concentrations in soils were generally higher for lead and lowest for cadmium metal in this study. The concentrations of all heavy metals concentrations at a depth of 0-15 cm (top soils) were higher than the concentrations of heavy metals found in a depth of 15-30 cm (sub soils). It can be assumed that the subsoil is considerably less influenced by soil-forming processes and anthropogenic supply than the top soil. The concentrations of heavy metals also decreased as the soil sampling distance from the dump increased. This was in accordance with other studies [23-27]. High concentrations of Pb in the e-waste dump may be due to the disposals of cathode ray tubes, computer monitor glass, printed wiring boards, and lead-acid batteries. A typical 15-inch cathode ray tube may contain 1.5 pounds of lead [29]. Short-term exposure to high levels of lead can cause vomiting, diarrhea, convulsions, coma, or even death [28]. Other symptoms are appetite loss, abdominal pains, constipation, fatigue, sleeplessness, irritability, and headache. Lead is particularly dangerous to young children because it readily affects their nervous systems [29].

In the dry season, Ni concentrations in soils ranged from 35.45±0.01 mg/kg at a depth of 15-30 cm in the wet season to 85.43±0.02 at a depth of 0-15 cm in the dry season (Figs. 6 and 7). The concentration levels were above the critical value for most countries. This study agrees with the study by some researchers [30, 31] who found Ni to range between 18-335 mg/kg at the surface layer of soil for all the dumpsites investigated. Nickel content in soil can be as low as 0.2 mg/kg or as high as 450 mg/kg, although the average is usually about 20 mg/kg [16]. The UK soil and herbage survey found total nickel concentrations in the range of 1.16 to 216 mg/kg for rural UK soils, with a mean value of 21.1 mg/kg. Urban UK soils were found to contain nickel concentrations in the range 7.07 to 102 mg/kg with a mean value of 28.5 mg/kg. The concentration values of the heavy metals in the soils were above the permissible values for heavy metals in the environment [32]. Global input of nick-

Table 4. Total elemental concentrations of heavy metals in *Amaranthus caudatus* (spinach) (mg/kg) (n=9) during the wet and dry seasons.

mg/L)	Pb	Cd	Zn	Cr	Ni
ROOT (WS)	83.05±0.05	0.60±0.21	23.35±0.43	2.23±0.28	12.35±0.07
ROOT (DS)	86.35±1.28	1.21±0.01	29.20±0.01	2.59±0.77	16.35±0.02
STEM (WS)	50.90±0.03	0.37±0.03	15.90±0.01	1.94±0.03	08.43±0.01
STEM (DS)	68.10±0.01	1.03±0.01	21.95±0.02	2.24±0.23	11.10±0.05
LEAF (WS)	37.25±0.11	0.13±0.13	10.20±0.65	1.82±2.91	05.40±0.01
LEAF (DS)	41.20±0.02	0.99±0.11	19.85±0.15	2.04±1.67	07.35±0.02

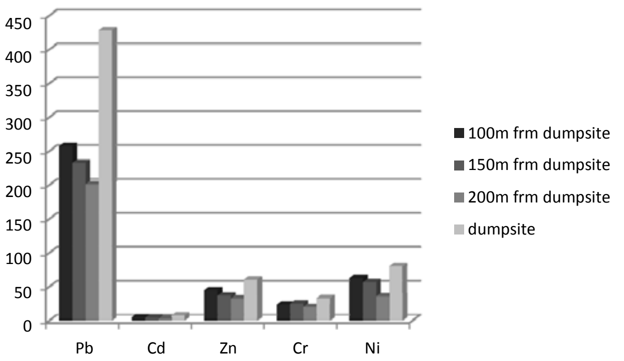

Fig. 4. Total elemental concentrations (mg/kg) of heavy metals in the soil surface (15 to 30 cm) (n=9) in the wet season.

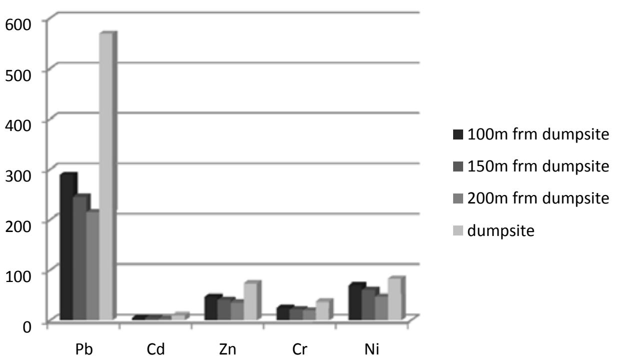

Fig. 5. Total elemental concentrations (mg/kg) of heavy metals in the soil surface (15 to 30 cm) (n=9) in the dry season.

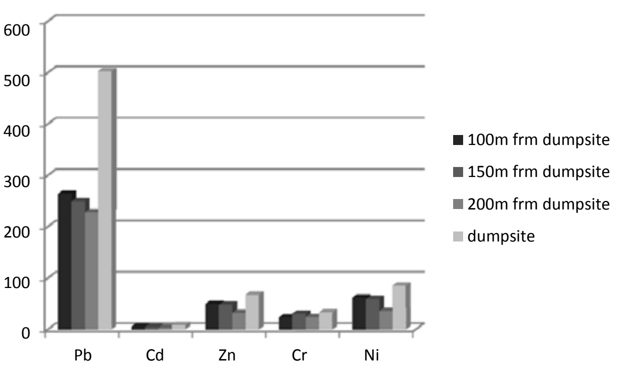

Fig. 6. Total elemental concentrations (mg/kg) of heavy metals in the soil surface (0 to 15 cm) (n=9) in the wet season.

el to the human environment from e-waste sources is mostly from nickel batteries and magnets, as an alloying metal in steel, and in the production of pigments and magnetic tapes [33].

The results in Tables 2 and 3 further showed the significant differences in the distribution of Zn in soils. This could be attributed to leaching conforming to observations of earlier studies by [23, 34, 35]. Although zinc is an essential trace element, an excess of zinc intake in the human diet can lead to copper deficiency, immune system disorders, fatigue, nausea, hair loss, mental apathy, and reproductive and growth disorders. Zinc in electronics is usually found in the interior of cathode ray tube screens as zinc sulphide [36]. The concentrations of Cd decreased with increasing soil depth (Figs. 4 and 5). This shows an indication of low mobility of the heavy metal. This result is in accordance with earlier studies [29, 30]. The concentration of Cd was the lowest for all the heavy metals investigated. This may be due to the ban of Cd-Ni batteries in most countries where electronics are manufactured, for instance the sale of Cd-Ni batteries has been banned in the European Union except for medical use [37]. When not properly recycled, Cd can leach into the soil, harming microorganisms and disrupting the soil ecosystem. Exposure to Cd is caused by proximity to hazardous waste sites and factories and workers in the metal refining industry. The inhalation of cadmium causes severe damage to the lungs and kidneys [38]. Fluorescent layers of cathode ray tube screens, printer ink, toners, and photocopying machines contain some elements of Cd. Acute exposure to Cd fumes causes flu-like symptoms of weakness, fever, headache, chills, sweating, and muscular pain. The primary health risks of long-term exposure are lung cancer and kidney damage. Cd is a non-essential heavy metal and causes pulmonary emphysema and bone disease (osteomalacia and osteoporosis) [39].

The concentrations of chromium in soils at various depths is also shown in Tables 2 and 3 The concentration of Cr in soil decreased as the depth of soil increased, which is in accordance with studies conducted by various researchers [23, 14-16]. The concentration of Cr analyzed in soils in this study is above the allowable limits for heavy metals in soils. Cr and its oxides are widely used because of their high conductivity and anti corrosive properties.

While some forms of chromium are non-toxic, Chromium (VI) is easily absorbed in the human body and can produce various toxic effects within cells. Most chromium (VI) compounds are irritating to eyes, skin, and mucous membranes [40]. Chronic exposure to chromium compounds can cause permanent eye injury. Chromium may also cause DNA damage. Although Cr toxicity in the environment is relatively rare, it still presents some risks to human health [40].

Vegetable Plant (*Amaranthus spinosus*)

Generally, the investigation of the analyses of heavy metals in plants on the soils of Alaba International market showed the following trends (Table 4). Heavy metals concentrations in vegetables were lower in the wet season when compared to the dry season. Pb showed the highest level of heavy metals concentrations in the roots of the plant (Figs. 8 and 9). This study confirms the investigation of heavy metals in vegetables conducted by some researchers [16, 41, 42]. Cr, Cd, Ni, and Zn are beneficial to people at low concentrations, since they are integral parts of important physiological activities of certain enzymes, where it is essential for their activity. These metals have been suggested as essential trace/heavy metals in nutrition, whose functions include regulation of apoptosis, activation of depressed immune systems, and as cofactors for metalloenzymes. Ni is involved in fat metabolism and aids fat deposition. The concentration level of Pb is generally higher than those of Cd, Cr, Ni, and Zn, and is of toxicological significance since Pb has no known biological importance [16]. From the results, all vegetable samples analyzed had high concentrations of the heavy metals. The nutritional implication is that consumers may be exposed to heavy metal toxicity if bioaccumulation results due to regular consumption [43]. Though vegetables may be cooked before consumption, the heavy metals are non-degradable. The toxicity of Pb at high a level of exposure is well known, and the gradual accumulation of heavy metals in humans can lead to adverse health effects [44].

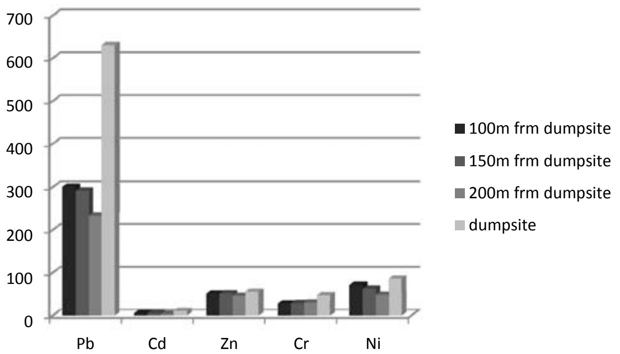

Fig. 7. Total elemental concentrations (mg/kg) of heavy metals in the soil surface (0 to 15 cm) (n=9) in the dry season.

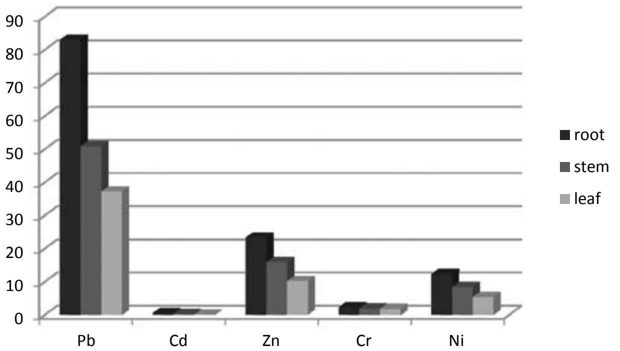

Fig. 8. Total elemental concentrations of heavy metals in *Amaranthus caudatus* (spinach) (mg/kg) (n=9) in the wet season.

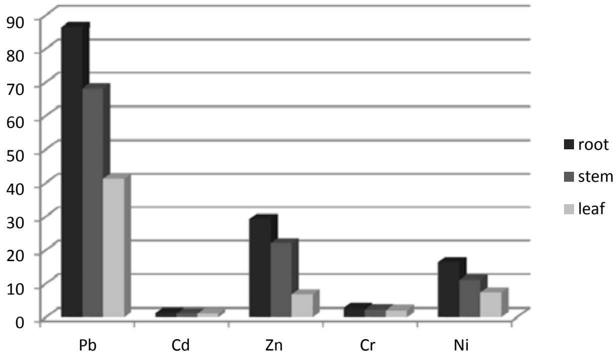

Fig. 9. Total elemental concentrations of heavy metals in *Amaranthus caudatus* (spinach) (mg/kg) (n = 9) in the dry season.

Conclusion

The study has shown that heavy metals pollution of groundwater, soil, and plants is an issue of environmental concern, especially when e-waste is involved. The concentration levels of heavy metals were noted to be affected by change in season, depth of soil, sampling distance, and plant part. The results from this study revealed the presence of significant concentrations of Cd, Cr, Zn, Pb, and Ni in water, soils, and plants in the e-waste dumpsites and residences in and around Alaba International Market, Nigeria. It also revealed the potential use of *Amaranthus spinosus* as a plant for environmental monitoring and soil remediation. Consumption of the vegetables with elevated levels of heavy metals may cause related health disorders. Frequent monitoring of the quality of groundwater, soil, and plants will be necessary to know the changes in chemistry of the environment and possibly initiate remedial measures. Education and legislation on management of e-wastes in electronic villages should be intensified to forestall the effects of waste-related problems. The culture of reduce, reuse, and recycle should be inculcated in the populace and the government should place a ban on the importation of used/damaged electronics into the country. Modern waste disposal facilities should be acquired by relevant authorities and appropriate waste disposal sites be chosen to avoid the injurious effects of indiscriminate disposal of wastes, and residential buildings should be sited farther away from areas of pollution.

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