Research Journal of Environmental Toxicology

ISSN 1819-3420

Academic
Journals Inc.

www.academicjournals.com

Research Journal of Environmental Toxicology 9 (6): 342-349, 2015
ISSN 1819-3420 / DOI: 10.3923/rjet.2015.342.349

Heavy Metal Contents in Plants and Soils in Abandoned Solid Waste Dumpsites in Port Harcourt, Nigeria

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ABSTRACT

A study of heavy metal contents in plants and soils in two abandoned solid waste dumpsites alongside the controls located along East-west road (site 1) and Eastern by-pass (site 2) was conducted. A systematic sampling approach was used comprising total of 9 sample plots of 4 m^2 each located on 3 line transects. The soil samples were collected at each plot using a soil auger at the depth of 0-15 cm. Dominant plant species were selected, uprooted and collected from each sample plot. Both plants and soil from each sample plot were analyzed for heavy metals [Zinc (Zn), Iron (Fe), Cadmium (Cd) and Lead (Pb)]. The results showed that there was an increase in the concentration of heavy metals in the two dumpsite soils than that of the soils at the control sites. The heavy metal (Fe and Zn) contents in the plants were higher at the dumpsites than control sites while the concentrations of Pb and Cd in the plants were higher at the dumpsite than control at site 1 (East-West road) and higher at the control site than dumpsite at site 2 (Eastern By-Pass) respectively. The level of heavy metals transfer for site 1 was in the order: Fe>Pb>Cd>Zn while for site 2 was Fe>Cd>Pb>Zn. Therefore, abandoned solid waste dumpsites contained high concentrations of heavy metals which are later absorbed and accumulated by plants growing at such sites.

Key words: Zinc, east-west road, eastern by-pass, iron, hyper-accumulation

INTRODUCTION

Urban areas known for high level of industrial activities generate more pollutants and therefore subject to the menace of resultant indiscriminate disposal of both domestic and industrial wastes. A typical example of such urban centres is Port Harcourt city located in the heart of the oil-rich Niger Delta of Nigeria. There are reports that its suburbs are loaded with toxic heavy metals and certain trace elements resulting from poor waste management programme (Obute *et al*., 2001; Wegwu *et al*., 2002).

Nearly all human activities generate waste and the way in which this is handled, stored, collected and disposed of, can pose risks to the environment and to public health (Zhu *et al*., 2008). Earth is very good at recycling waste, but when the amount of wastes generated is far more than the earth can cope with; it poses a big threat to lives, a phenomenon called pollution. Pollution occurs at different levels and affects all lives ranging from plants, animals to man (Skye, 2006). The decay of these solid wastes releases substances that can affect the soil nutrients content, increase the concentration of heavy metals in the soil, altering the natural balance of nutrients available for plant growth and development thereby affecting species diversity and agricultural productions.

Heavy metals are natural components of the Earth's crust. They can neither be degraded nor destroyed. To a small extent they enter our bodies via food, drinking water and air

(Helmenstine, 2014). Heavy metals can enter a water supply by industrial and consumer wastes, or even from acidic rain breaking down soils and releasing heavy metals into streams, lakes, rivers and groundwater (Lenntech, 2014).

Heavy metals are dangerous because they tend to bioaccumulate which means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment (Helmenstine, 2014).

Some metals, such as Mn, Cu, Zn, Mo and Ni, are essential or beneficial micronutrients for microorganisms, plants and animals. Their absence may cause deficiency diseases but at high concentrations all have strong toxic effects and pose an environmental threat. Some heavy metals such as Cd and Pb have been known to have no known biological importance. Heavy metals have received the attention of researchers all over the world, mainly due to their harmful effects on plants and other living organisms (Tahar and Keltoum, 2011).

Heavy metal content of soils is a critical measurement for assessing the risks of refuse dumpsites. Since these contaminants affect the environmental qualities in and around such open dumpsites, monitoring of soil qualities especially heavy metal content in dumpsite becomes necessary which can facilitate to recommend suitable remedial measures (Biswas *et al*., 2010). Hence, this study is aimed at determining the contents of heavy metals in soil and plants in abandoned solid waste dumpsites. It is expected that results obtained from the study will widen our knowledge on the environmental risks associated with solid waste dumps in terms of heavy metal toxicity and the suitability of such site for plant cultivation.

MATERIALS AND METHODS

Site description: Two abandoned solid waste dumpsites located in two Local Government Areas, Obio-Akpor (East-west road) and Port Harcourt city (Eastern by pass) were used and two nearby sites with no knowledge of contact with refuse were used as the controls. The dumpsite on East-west road, designated as site 1 is located at geographical coordinates of latitude 4.88774°N and longitude 6.92296°E and the control site is on the other side of the road with latitude 4.88778°N and longitude 6.92272°E. The Eastern by-Pass, designated as site 2 is located at geographical coordinates of latitude 4.729281°N and longitude 7.01638°E and the control site is at latitude 4.79078°N and longitude 7.01782°E (Fig. 1).

Sample collection: The starting point (10 m away from the road) was cleared using a cutlass and marked with a carved wooden peg. Then the field was slightly cleared to create a footpath. At each of the dumpsite and control, a study site of 15×30 m was measured with a measuring tape, demarcated with wooden pegs and rope. A systematic sampling approach comprising three line-transects of 5 m intervals was used. Within each of the line transect, three sample plots of 10 m interval were located. A total of nine sample plots of 2×2 m were used for the exercise in each study site. The soil samples were collected at each plot using a soil auger at the depth of 0-15 cm. Dominant plant species from each sample plot were uprooted, washed in distill water to remove soil particles from the root. They were put in black polyethene bags, tied and labeled with a masking tape and marker. The soil and plant samples were taken to the laboratory for heavy metals [Zinc (Zn), Iron (Fe), Cadmium (Cd) and Lead (Pb)] analysis.

Heavy metals analysis: Using wet-digestion, for the analysis of Cd, Zn, Fe and Pb; 5.0 g of 2 mm sieve size air dried soil was weighed into a 100 mL teflon beaker. Twenty milliliter of 1.0 M HCl acid was added and transferred unto the hot plate and vigorously heated to near

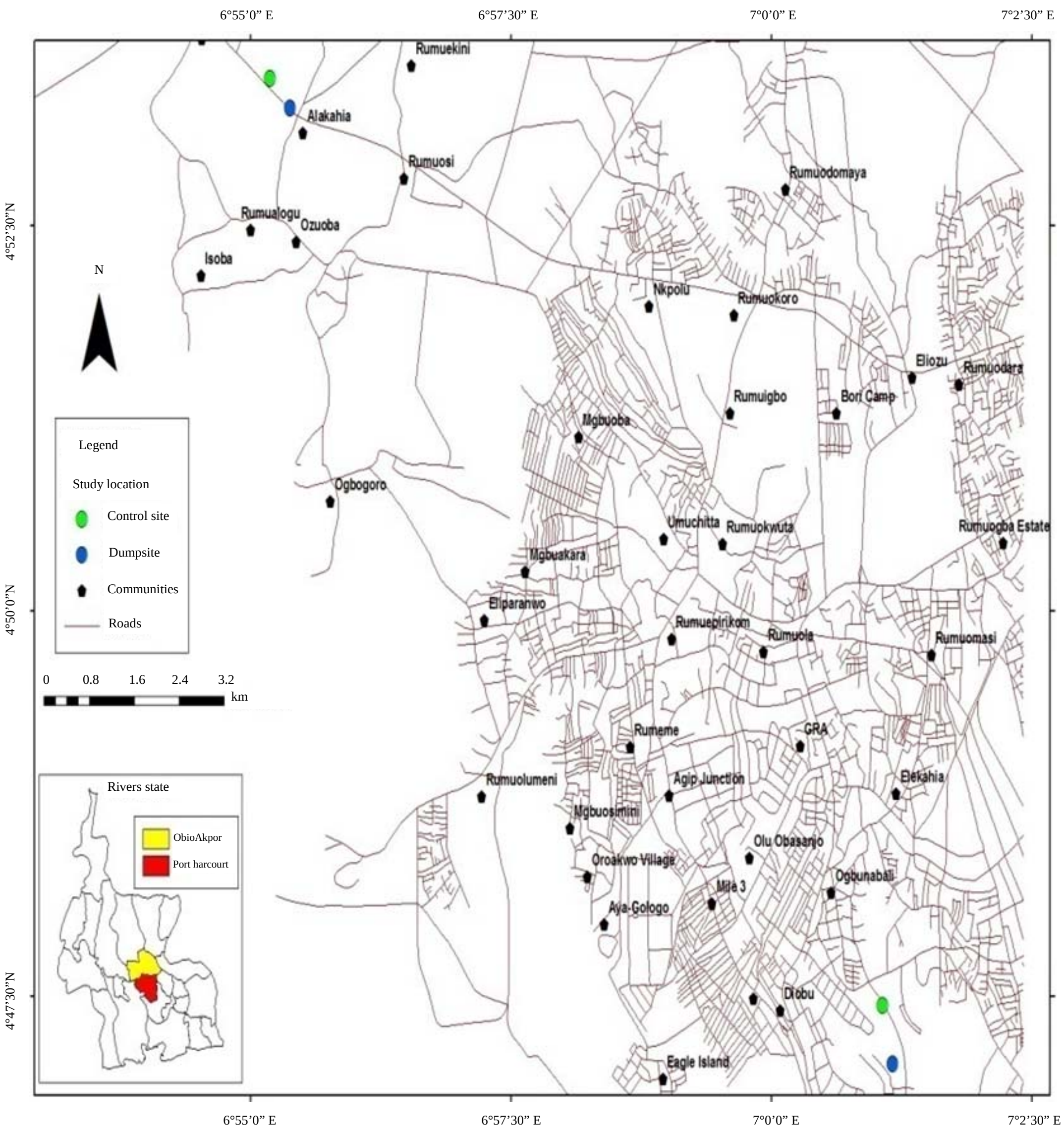

Fig. 1: Map showing study area

dryness. The acid digest/leachate was filtered into 50 mL measuring cylinders via a filter paper-laced filter funnel. The residue was rinsed thoroughly to allow for further washing through of the minerals/elements in the extract. The volume of the filtrate in the measuring cylinder was made up to 50 mL with distilled water.

The heavy metals (Zn, Fe, Cd and Pb) were then analyzed by Atomic Absorption Spectrophotometry (AAS) according to the method of Allen *et al*. (1974).

Plant samples were analyzed by first rinsing it with distilled water and oven-dried at 100°C for 48 h. The plant materials were ground to fine powder. One gram of the powder was digested as described above and analyzed for heavy metals using Atomic Absorption Spectrophotometer (AAS).

Data generated were subjected to statistical analysis such as mean, standard error mean and Analysis of variance. Means were separated using Least Significance Difference (LSD) according to Ogbeibu (2005).

RESULTS

The results for heavy metals in plants are presented in Fig. 2a-d while that of soil are presented in Fig. 3a-d.

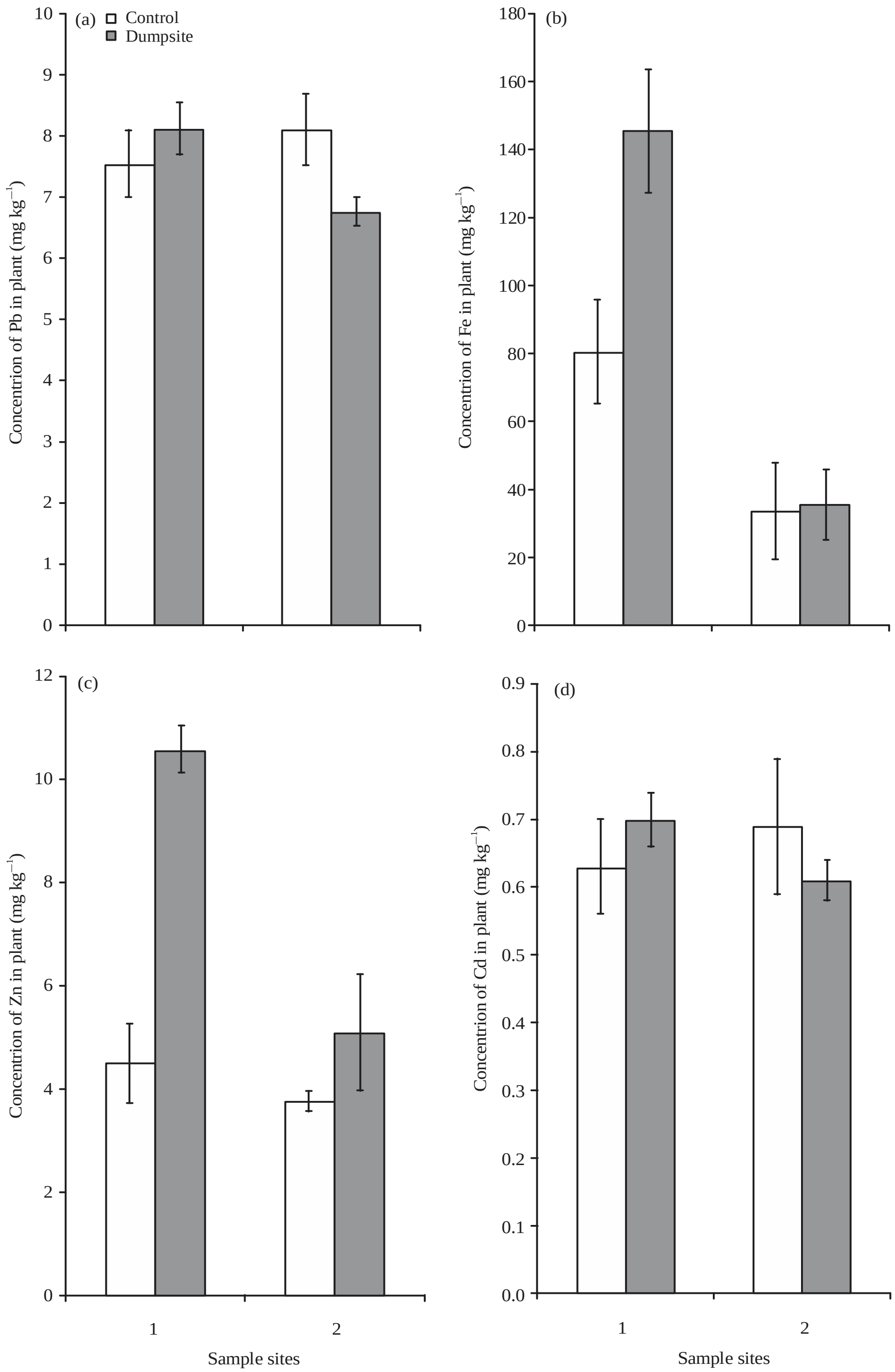

Fig. 2(a-d): (a) Pb, (b) Fe, (c) Zn and (d) Cd content of plants in the different sites

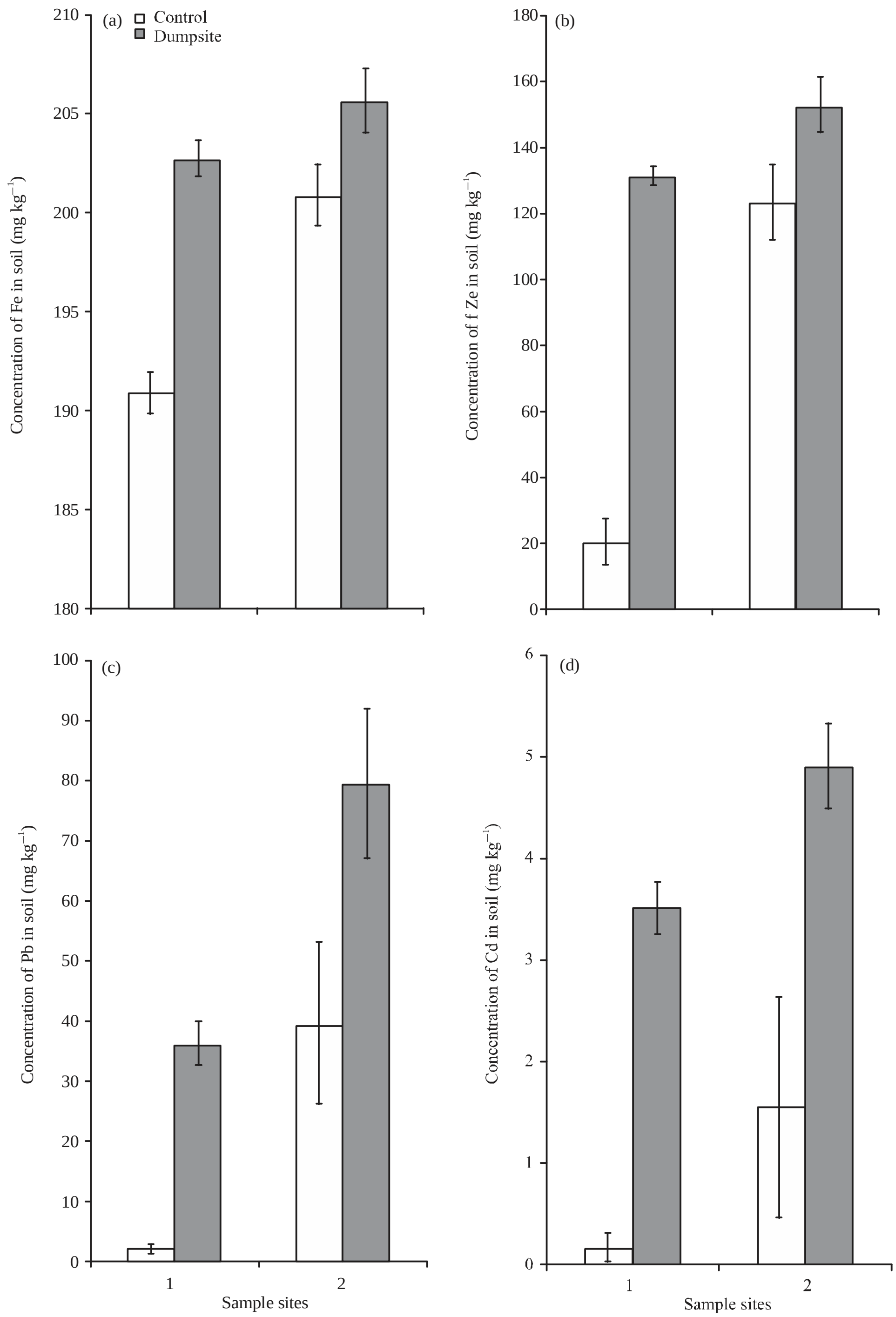

Fig. 3(a-d): (a) Fe, (b) Zn, (c) Pb and (d) Cd content of soil in the different sites

Heavy metals accumulation in plants: Figure 2a showed the concentration of lead in plants in site 1 and site 2. Results showed that plants in the dumpsite significantly accumulated higher lead (Pb) than the ones in the control of site 1 (East west road). The reverse was the case in site 2 (Eastern Bypass). Between site 1 and 2, dumpsite 1 plants had higher lead concentration than those in dumpsite 2. It was also observed that there was no significant difference (p = 0.05) in the level of Pb accumulation in the two control sites.

The dumpsites recorded a very high level of Fe in the plants growing there. The level of Iron (Fe) in plants was significantly higher at the dumpsite of site 1 than the control. In site 2, there was no significant difference in concentration of Fe in plants between the dumpsite and control site. Plants in dumpsite 1 recorded the highest Fe level in the study (Fig. 2b).

The concentration of zinc accumulated by the plants at the control site of site 1and 2 were significantly less than their respective dumpsites (Fig. 2c). The result also showed that the accumulation of zinc was substantially highest at the dumpsite of site 1 than all the other sites studied and lowest at the control site of site 2.

The concentration of cadmium accumulated by the plants in the study areas were below 1 mg kg^{-1}. The Cd level in plants at the study areas followed the same pattern as Pb concentration in plants. At site 1 (East-West road), the dumpsite recorded higher level of Cd in plants than it control site but at site 2 (Eastern By-pass), the reverse was the case showing a higher Cd level in it control site plants than the dumpsite plants. The dump site of site 1 showed the highest level of Cd accumulation than all the sites studied while the dumpsite 2 showed the least level of Cd accumulation by the plant (Fig. 2d).

Heavy metal concentration in soil: Results showed that the concentrations of heavy metals (Fe, Zn, Cd and Pb) in the soil at the two dumpsites were significantly (p = 0.05) higher than the controls (Fig. 3(a-d)). Highest concentration of heavy metals was recorded at dumpsite 2 and least at control site 1. For the Fe, the concentration in the soil at the two study sites were above 150 mg kg^{-1} with the highest concentration at dumpsite 2 (Fig. 3a). Similar results were obtained for soil Zn (Fig. 3b) and Pb (Fig. 3c) concentration levels in which the dumpsite 2 showed the highest level while the control site 1 recorded the least. No significance difference (p = 0.05) was observed in the Zn and Pb levels between dumpsite 1 and control site 2. The Cd contents in the soil in the study sites were low when compared to Fe, Zn and Pb levels. It was observed to be below 6 mg kg^{-1}. There were significant (p = 0.05) difference in the Cd content in the different sites in the order: Dumpsite 2>dumpsite 1>control site 2>control site 1 (Fig. 3d).

DISCUSSION

Solid wastes in abandoned dumpsites altered the physico-chemical parameters of the soil as well as increasing the concentration of heavy metals such as Lead (Pb), Iron (Fe), Cadmium (Cd) and Zinc (Zn). It also determined the type of plants growing in these environments (depending on their susceptibility and tolerance). In a similar study, Ndukwu *et al*. (2008) had report that physico-chemical changes occurred in the soils and plants associated with refuse dumps. The alteration of the physico-chemical properties of the soil is therefore expected to affect the survival of certain species and hence their diversity. Usman and Ayodele (2002) and Ebong *et al*. (2008) reveal the influence of plant species on the rate of uptake of various metal species in line with earlier reports of Kabata-Pendias and Pendias (1984). The uptake and accumulation of substances such as heavy metals by plants have public health implications especially when the plants are edible to man and livestock. Obute *et al*. (2001) report high levels of lead (Pb) in *Telfairia occidentalis* planted in soils treated with the metal and highlighted the hazardous implications of the trend. Excessive waste in soil may increase heavy metal concentration in the soil and underground water. Heavy metals may have harmful effects on soil, crops and human health (Nyle and Ray, 1999; Smith *et al*., 1996).

The results showed that the concentration of heavy metals in the soil increased at the dumpsites than the control sites for all the metals (Fe, Pb, Cd and Zn). This indicates that the solid waste deposited at the site had a high amount of substances containing heavy metals. This is in agreement with Adelekan and Alawode (2011) who reported that the levels of Pb at dumpsites were higher than the levels at the control samples. High level of Pb can cause inhibition of enzyme activities, water imbalance, alterations in membrane permeability and disturbs mineral nutrition (Sharma and Dubey, 2005). Awokunmi *et al.* (2010) report cadmium levels of 219-330 mg kg^{-1} at the surface layer of dumpsites and none at 200 m away. The results were similar to those of Amusan *et al.* (2005) for soils of Obafemi Awolowo University central refuse dumpsite. Magaji (2012) in a study on effects of waste dump on the quality of plants cultivated around mpape dumpsite FCT Abuja, Nigeria reported that the quantity of Zn, Fe and Cd were higher at the dumpsite than at the control site.

The heavy metal (Fe and Zn) content in the plants were higher at the dumpsites than control sites while the concentration of Pb and Cd were higher at the dumpsite than control on site 1 and higher at the control site than dumpsite at site 2. This result could have been influenced by the materials dumped at each site and the hyperaccumulation potentials of the species at the site. The level of heavy metals transfer for site 1 was in the order: Fe>Pb>Cd>Zn while for site 2 was Fe> Cd>Pb>Zn. The presence of heavy metals in the soil sample is an indication that there is appreciable contamination of the soil by leachate migration from an open dumping site (Kanmani and Gandhimathi, 2013).

CONCLUSION

The generation of waste is on the increase due to the rapid increase in human population which mounts pressure on production in order to meet the needs of the populace. The indiscriminate dumping of these solid wastes in the environment has caused great harm to our ecosystem through the release of pollutants such as heavy metals which in a high concentration in the soil can be harmful to humans if ingested directly or indirectly and plants which depend on the nutrient from the soil for their growth and development. It can therefore be concluded that the solid waste deposited at the site contained materials with high heavy metal contents; hence, adequate refuse disposal mechanism should be put in place. Waste sorting into biodegradable and non-biodegradable ones before deposition should be encouraged. Also proper remediation work should be done on such site found to contain high level of heavy metals before it can use for the cultivation of edible food crop in order to avoid heavy metal poisoning through biomagnification.

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