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Evaluation of the heavy metals composition of soil at e-waste dumped sites

ABSTRACT

Electronic waste (e-waste) has become a subject of growing ecological concern in developing nationsdue to legal/illegal import of electronics from developed countries. Soil samples were collected from dumping sites (electronic waste (e-waste)in Arakale and Karakata, Akure, Ondo State, Nigeria. The samples were analysed for heavy metals with the aid of Atomic Absorption Spectroscopy. The mean concentrations of Cadmium, Lead, Chromium, Zinc and Copper from the two locations range from 4.24±0.31 to 9.73±0.39; 113.66±1.03 to 261.63±3.58; 21.42±0.27 to 56.92±0.53; 108.71±0.82 to 197.98±2.22 and 19.79±0.32 to 62.88±0.91 mg/kg respectively. There was a gradual decrease in heavy metals concentrations at various distances away from each e-waste site. Lead recorded the highest values, while the lowest were found for Cadmium in all the samples. The mean concentrations of metals observed in this study were found bellow the recommended standard limits of heavy metals in soil by United States Environmental Protection Agency, European Union, and the United State of America. However,Cadmium were found above the recommended standard limits of heavy metals in soil, thus their potential availability and possible effects on human, plants and the ecosystem at large.

KEYWORDS: E-waste; Heavy Metals; Pollution; Soil.

INTRODUCTION

Electronic waste has been defined as an electronic or electrical appliance that has been rejected by their original user's such as computers, televisions, cellular phones, telecommunications equipment among others (PPCC, 2006; Ogbomo *et al.,* 2012). E-waste products comprises of sophisticated blends of plastics and chemicals, which when not properly handled can be injurious to people and the environments (Leung *et al.,* 2006). The composition of e-waste is very diverse and varies in products across different kinds. It comprises different substances, which fall under ‘hazardous' and ‘non-hazardous' classes. The

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occurrence of components like lead, mercury, arsenic, cadmium, and selenium retardants beyond threshold quantities in e-waste classifies them as hazardous waste (Robinson, 2009).

It is estimated that 50 million tons of e-waste are produced annually (Sthiannopkao and Wong, 2012) of which75-80% is transported to countries in Asia and Africa for reprocessing and dumping. Only 25% of all the electronics produced and sold worldwide can be recycled or re-used, thus 75% will end up as a waste (Widmer *et al.,* 2005).In Asia and Africa countries, reprocessing of e-waste is accomplished with limited and often no ecological or worker health safeguards. Activities at these sites often stance detrimental coercions in the form of soil pollution prominent to polluted water and food as well as air pollutants affecting the well-being of the workers and children at these sites (Caravanos *et al.,* 2011).In countries, where ecological enforcement laws may not be efficient, high concentrations of trace metals can be discharged from e-waste, thus producing wide-spread environmental destruction to people and their immediate environment (Ademorati, 1996).

In recent years, with the improvement in the global economy, both type and content of heavy metals in the soil were triggered by human activities, resulting in the deterioration of the surroundings (Raju *et al.,* 2013; Prajapati and Meravi, 2014; Zojaji *et al.,* 2014; Izegaegbe and Oloye, 2017). The high absorption of heavy metals in soils is reflected by concentrations of metals in plants, water, animal, and human bodies (Oloye *et.al.,* 2013). Therefore, when contaminants from e-waste are washed into nearby water bodies by rain or flood, there will be an alteration in the level of heavy metal concentration and nutrient absorption of the water bodies (Asuquo *et al.,* 2004).

Environmental pollution by heavy metals is of important environmental concern. This is owed to the fact that they are not easily decomposable or metabolized, thus precipitating far-reaching effects on the biological system such as humans, animals, floras and soil biota (Yoon, 2003). In order to understand the mobility of heavy metals cause by e-waste and to enable the development of appropriate environmental guidelines in e-waste dismantling areas, concentrations of selective metals and other priority pollutants in soils in Arakale and Karakata were monitored by this study, aiming at evaluating the status of heavy-metal contaminations and their lateral mobility.

MATERIALS AND METHODS

Sample Location

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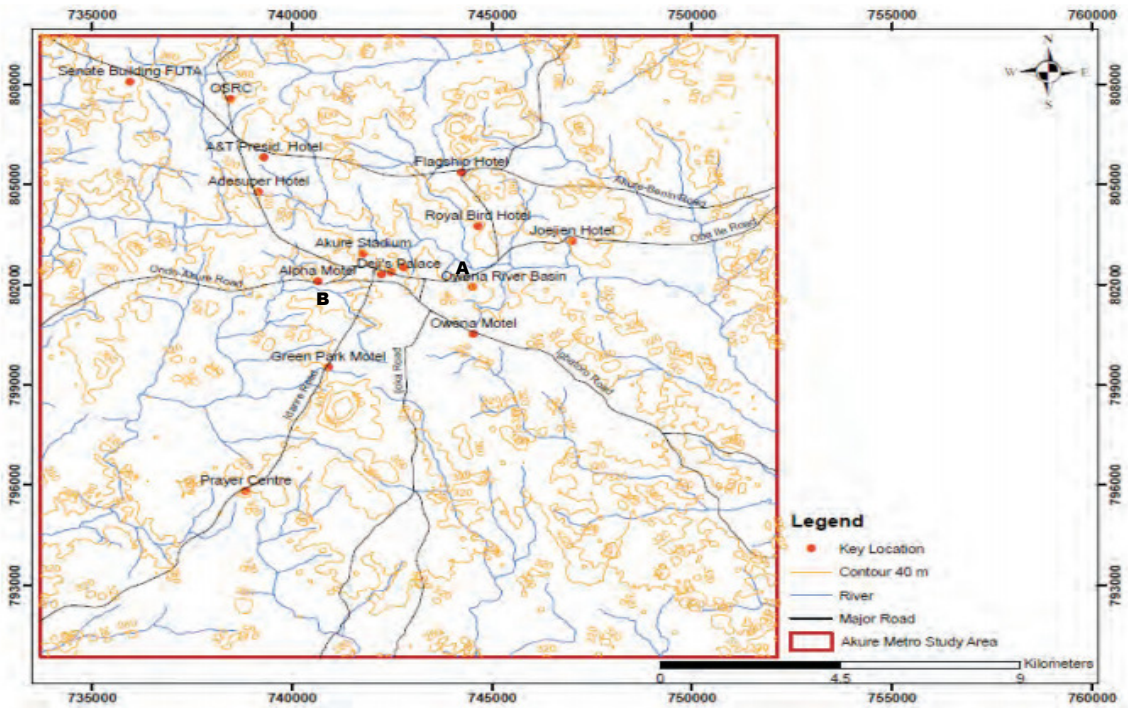

Figure 1: Map of Akure showing different locations and the study areas represented by letter A and B

Akure is a city in south-western Nigeria and the capital of Ondo State, it lies at latitude 70°15' north and longitude 50°15' east (figure 1). Akure is the trade midpoint for a farming region where cocoa, yams, cassava, corn, cotton, and tobacco are sold(Dorcas, 2016). Arakale and Karakata are one of the unique hubs of economic activity in Akure and it is an electronic and electrical materials hub which draws several patronages within Akure.

Sample Collection and Preparation

The top soil samples were collected from two locations (Arakale and Karakata) where e-wastes were constantly dumped and burnt. The samples were labeled as Arakale and Karakata. Other samples were taken at a distance of 20, 50 and 80m away from each site. Samples were stored in polyethylene bags (zip locks) and stored at ambient temperature until when required. The samples were sorted to; eliminate stones and other unwanted materials. Samples were then placed in desiccators to get rid of moisture and ground into fine powder. Dry samples were sieved with 2 mm sieve and homogenized.

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Soil Sample Analysis

The digestion method by Francek *et al.* (1994) was used for the extraction of metals in the study. The soil was crushed and 1g was perfectly 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 through No. 40 Whatman filter paper and then made up to 100 ml with 2% HNO_3. Determination of heavy metals (Cd, Cr, Cu, Pb, and Zn) in the soil samples were performed using the atomic absorption spectrometer (AAS) (Model 210 VGP) at the Central Laboratory of Federal University of Technology Akure, Ondo State, Nigeria. Data obtained for heavy metals concentrations were subjected to bar chart and analysis of variance using Statistical Package for Social Sciences (SPSS) version 22 to generate the mean and standard error.

Amounts of metal loss = Y - X

Where,

Y = Amounts of metal at the dumping site

X = Amounts of metal at a distance away from the site.

RESULTS

The results of the heavy metals composition from Arakale and Karakata soil samples as well as those of the samples at distances away from the sites are presented in Table 1. The soil sample from Arakale area had cadmium concentrations in the range of 5.24±0.13 to 9.73±0.39 mg/kg, while that of Karakata area range from 4.24±0.31 to 7.97±0.78 mg/kg. The highest values of cadmium were observed at Arakale (9.73±0.39). The concentrations of cadmium in all the two locations were found decreasing with an increase in the distance away from each e-waste sites.

Lead concentrations from Arakale range from 113.66±1.03 to 228.97±3.55 while that of Karakata range from 122.68±0.92 to 261.63±3.58. The highest values of lead were observed at Karakata (261.63±3.58). In all the two locations, the concentrations of lead were found decreasing with an increase in the distance away from each e-waste sites.

The experimental results of Chromium in the Arakale range from 21.42±0.27 to 50.57±0.56 while Karakata range from 22.53±0.42 to 56.92±0.53. The highest values of Chromium were

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observed at Karakata (56.92±0.53). Concentrations of Chromium were found decreasing with an increase in the distance away from each e-waste sites.

The Zinc concentrations result at Arakale range from 108.71±0.82 to 182.95±3.29 while Karakata range from 117.29±0.52 to 197.98±2.22. The highest values of Zinc were observed at Karakata (197.98±2.22). The concentrations of Zinc in all the two locations were also found decreasing with an increase in the distance away from each e-waste sites.

Experimental results of Copper at Arakale range from 22.38±0.71 to 58.59±2.31 while that of Karakata range from 19.79±0.32 to 62.88±0.91. The highest values of Copper were observed at Karakata (61.88±0.91). The concentrations of Copper in all the two locations were found decreasing with an increase in the distance away from each e-waste sites.

The mean concentrations of metals at Arakale, Karakata, and locations away from the two dumping sites are compared to standard limits of heavy metals in soil in mg/kg and presented in Table 2. The results of all the metals fell below the standard limits of heavy metals in soil according to the United States Environmental Protection Agency (USEPA), European Union (EU) and United State of America (USA) except for Cadmium that were found to be above the standard limits of heavy metals in soil.

Figure 1 and 2 shows the amounts of metal loss at distances away from Arakale and Karakata dumping sites, respectively. The concentrations of the metal loss increase as the distance away from each e-waste site increases. This is an indication that metals don't only leached horizontally alone, but as well do leached vertically (Ololade et. al. 2015).

Table 1: Mean concentrations of the metals from at e-waste sites with their respective control Samples

Metals	Cd	Pb	Cr	Zn	Cu
Arakale	9.73±0.39	228.97±2.55	50.57±0.56	182.95±3.29	58.59±2.31
20 m away	7.24±0.32	154.56±1.22	39.68±0.45	147.27±2.30	48.37±1.21
40 m away	6.04±0.23	132.72±1.11	28.23±0.33	120.61±1.06	30.31±0.52
60 m away	5.25±0.13	113.66±0.53	21.42±0.27	108.71±0.82	22.38±0.71
Karakata	7.97±0.78	261.63±2.58	56.92±0.54	197.98±2.22	61.88±0.91
20 m away	6.13±0.54	175.76±1.97	47.90±0.42	154.26±1.09	47.79±0.72
40 m away	5.03±0.24	142.24±1.23	33.42±0.53	122.17±0.67	29.18±0.63

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60 m away	4.24±0.31	122.68±0.92	22.53±0.42	117.29±0.52	19.79±0.32

Table 2: Standard limits of heavy metals in soil in Mg/kg

Metals	USEPA	EU	USA
Cd (Mg/kg)	3.00	3.00	3.00
Pb (Mg/kg)	300.00	300.00	300.00
Cr (Mg/kg)	100.00	150.00	180.00
Zn (Mg/kg)	300.00	300.00	200.00
Cu (Mg/kg)	250.00	140.00	80.00

USEPA= United States Environmental Protection Agency (1996), EU= European Union (2002), USA= United State of America

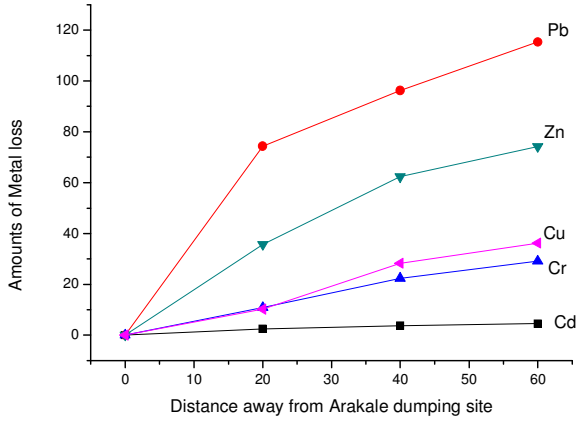

Figure 2: Amounts of metal loss when moving away from Arakale dumping site

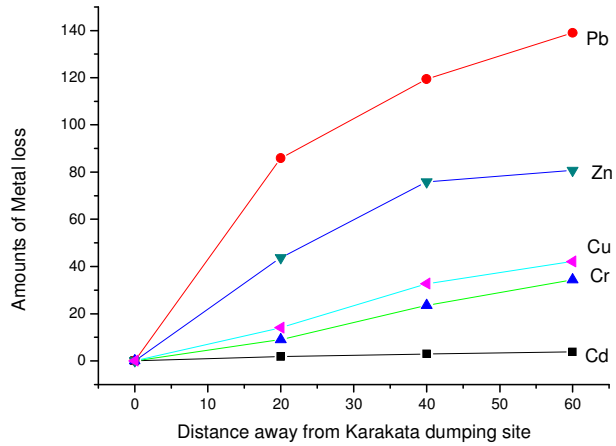

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Figure 3: Amounts of metal loss when moving away from Karakata dumping site

DISCUSSION

The mean concentrations of Cadmium in all the two locations (Arakale and Karakata) were found decreasing with an increase in the distance away from each e-waste sites. The decreasing in Cadmium concentrations with an increase in the distance away from each e-waste sites may be attributed to the released of Cadmium from e-wastes containing electrical and electronic equipment such batteries, resistant and light-sensitive resistors. Also, Fluorescent layers of cathode ray tube screens, printer ink, toners, and photocopying machines contain some elements of Cadmium.

The concentrations of Cadmium observed in this study were above the recommended standard limits of heavy metals in soil (3.0mg/kg) by the United States Environmental Protection Agency (USEPA), European Union (EU), and United State of America (USA). The concentrations of cadmium in this study range from 5.24±0.13 to 9.73±0.39 mg/kg (Arakale), 4.24±0.31 to 7.97±0.78 mg/kg (Karakata). The differences in the concentration of the cadmium from the two sites is connected to the age of the dumping site and the frequency of dumping waste at the site. The rate at which cadmium is amounts of cadmium reduced as we move away from dumping site varies from site to site ($y=1.802\ln(x)-2.923$ and $y=1.706\ln(x) - 3.292$, for Arakale and Karakata, respectively). This is greatly influenced by soil components. Hence, the soil component in Arakale may be different from that of Karakata. The results of cadmium contents in soil samples from this study were higher than 0.11 to 1.65 mg/kg recorded by (Akpoveta *et al.,* 2010) and agreed with the findings of (Adaramodu *et al.,* 2012) 1.80 to 19.00 mg/kg who reported that the soils of indoor dust and outdoor dust from Westminster electronic market in Lagos contained. The profile of the metal content of e-waste in this study were found in the order Lead>Zinc>Copper>Chromium>Cadmium. Exposure to Cadmium is triggered by closeness to hazardous waste sites and workshops and employees in the metal refining industry. The breathing of cadmium causes severe harm to the lungs and kidneys (Jarup, 1988). Cadmium is a possibly long-term cumulative poison and lethal compounds of Cadmium tend to gather in the human body triggering kidney and lung damage, it is known to be cancer-causing to human health (Odukoya *et al.,* 2001).

The mean concentrations of Lead in this study were found bellow the recommended standard limits of heavy metals in soil (300mg/kg). The concentrations decrease with an increase in the distance away from each e-waste site which could be as a result of the occurrence of lead-containing substances like cathode ray tubes, computer monitor glass, acidic batteries at these

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sites as reported by (Ofudje *et al.*,2014). The concentrations of lead in this study range from 113.66±0.55 to 228.97±2.55 (Arakale) and 122.68±0.92 to 261.63±2.58 (Karakata). The results observed in this finding were higher than 8.92 to 14.47 mg/kg, 2.20 to 12.50 mg/kg and 15.9 to 22.5 recorded by (Akpoveta *et al.,* 2010), (Anyakora *et al.,* 2013) and (Adaramodu *et al.,* 2012). Continous exposure to lead-containing substances could be deadly. Short-term exposure to high levels of lead can cause nausea, diarrhea, convulsions, unconsciousness, or even death (Ogunseitan *et al.,* 2009). Other symptoms are appetite loss, abdominal pains, constipation, fatigue, sleeplessness, irritability, and headache. Lead is mostly hazardous to young children because it readily affects their nervous systems (Awokunmi *et al.,* 2010).

The concentrations of chromium observed in this study fell below the recommended standard limits of heavy metals in soil (100mg/kg) by USEPA, (150 mg/kg) by EU and (180mg/kg) by the USA. The concentrations of chromium decreased with an increase in the distance away from each e-waste sites which could be as a result of major sources of chromium in e-waste, which include hardener in plastics and dye in pigments of some switches. The results of chromium observed range from 21.42±0.27 to 50.57±0.56 (Arakale) and 22.53±0.42 to 56.92±0.53 (Karakata). The results observed in chromium were higher than 0.24 to 2.20, 16.84 to 38.21, 10.51±0.01± to 19.65±0.55 recorded by (Anyakora *et al.,* 2013), (Akpoveta *et al.,* 2010) and (Ofudje *et al.,* 2014).

Chromium (VI) is simply absorbed by the human body and can produce numerous toxic effects within cells as chromium toxicity in the environs is relatively unusual, it still presents some hazards to human well-being as reported by (Oladunni *et al.,* 2012). Skin contact with some chromium (VI) compounds can lead to ulcers while hypersensitive reaction could result in redness and swelling of the skin. chromium (VI) compounds have also been well-known to increase the risk of lung cancer and can also cause damage to DNA. Chronic contact to chromium compounds can cause perpetual eye injury. chromium may also cause DNA damage.

The concentrations of zinc in all the two locations were also found decreasing with an increase in the distance away from each e-waste sites. The mean value of zinc concentrations for all the soil samples analyzed, fell below the recommended standard limits of heavy metals in soil (300 mg/kg) by USEPA, EU and (200-300 mg/kg) by the USA. The results of zinc observed in this study range from 108.71±0.82 to 182.95±3.29 (Arakale) and 117.29±0.52 to

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197.98±2.22 (Karakata) and it higher than 40.53±2.20 to 98.62±7.27 mg/kg and 54.15 to 97.21 observed by Ofudje *et al.,* 2014 and Akpoveta *et al.,* 2010, but fell below 213.0 to 295.5 detected in indoor dust and outdoor dust from Westminster electrical market in Lagos State as reported by Adaramodu *et al.,* 2012. Zinc is an essential element, which is required by human body for healthy development. However, excessively exposure to zinc as dust or fumes can result into a temporary disease known as metal fume fever (Adaramodu *et al.,* 2012). Persistent exposure to amounts greater than the acceptable upper intake level may subdue immunity, decrease high-density lipoprotein cholesterol levels, and cause copper deficiency (King *et al.,* 2006).

The mean concentrations of copper in all the two locations (Arakale and Karakata) were found decreasing with an increase in the distance away from each e-waste sites. The mean concentrations fell below the recommended standard limits of heavy metals in soil (250 mg/kg) by USEPA, (140 mg/kg) by EU and (280-200mg/kg) by the USA. The results of copper observed in this study range from 22.38±0.71 to 58.59±2.31 (Arakale) and 19.79±0.32 to 62.88±0.91 (Karakata). The results observed were higher than 2.20 to 6.60 and 14.22 to 34.21 recorded by (Anyakora *et al.,* 2013) and (Akpoveta *et al.,* 2010). Copper also is an important trace element that is required in enzyme systems which are accountable for countless metabolic processes required to sustain life. Too much of copper buildup in the human body can cause numerous ailments and health complications such as fatigue and exhaustion, headaches, migraines, arthritis, constipation and anorexia (Trumbo *et al.,* 2001).

CONCLUSION

This study revealed the level of concentrations of cadmium, lead, chromium, zinc and copper in two different locations (Arakale and Karakata, Akure, Ondo State, Nigeria) with respect to samples taken at different distances away from the e-waste sites. the nature of business around a dumping site determined the concentrations of the metals around the site. The age of the dumping site also has influence on the amount of the metal at the waste site. The results revealed that the concentrations of these heavy metals were high at each e-waste site and there is a decrease in the concentrations with an increase in the distance away from each e-waste site. The rate at which metal leached away horizontally is different from location to location, and is determined by the soil component. This concluded that regular dumping of e-waste at these locations will increase the concentrations of heavy metals in the soil, which may be dangerous to the health of people living around this area and ecosystem at large. The

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government should, therefore, provide better locations where e-waste can be dumped properly.

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