Evaluation of the Chemical Composition of Soil at E-waste Blazing Sites in Computer Village, Ikeja, Lagos, Nigeria

Edwin Andrew Ofudje[1*], Olubunmi Kolawole Akiode[2], Gabriel Opeoluwa Oladipo[3], Adebusayo Emmanuel Adedapo[4] and Lateefah Olanike Adebayo[5]

[1]*Department of Chemical Sciences, College of Natural and Applied Sciences, McPherson University, Sariki-Sotayo, Ogun State, Nigeria.*
[2]*Chemistry Unit, Institute for Human Resources Development, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria.*
[3]*Department of Science Laboratory Technology, D. S. Adegbenro ICT Polytechnic, Ogun State, Nigeria.*
[4]*Department of Chemistry, College of Science and Technology, Covenant University, Ota, Ogun State, Nigeria.*
[5]*Department of Chemical Sciences, Crescent University, Abeokuta, Ogun State, Nigeria.*

Authors' contributions

This work was carried out in collaboration between all authors. Author EAO designed the study, wrote the protocol and wrote the first draft of the manuscript. Author OKA performed the statistical analysis. Authors GOO, AEA and LOA managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

ABSTRACT

The evaluation of open blazing of electronic waste on the chemical composition of three different soil where e-waste were regularly being burnt with control samples at various distances away from each blazing site at computer village, Ikeja, Lagos, Nigeria was carried out using Atomic Absorption Spectroscopy. The mean concentrations of Pb, Cr, Zn, Cd and Cu from the three locations were

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Corresponding author: E-mail: ofudjeandrew4real@yahoo.com;

found to be 120.3±0.4, 18.7±1.3, 90.3±0.4, 16.4±0.5 and 60.3±2.0 mg/kg respectively. There was gradual decrease in heavy metals concentrations at various distances away from each blazing site as the distances increase which suggested that there were leaching of these heavy metals from e-waste containing substances. Pearson correlation revealed that some of the heavy metals showed both positive and negative correlations with each other. When compared with standard values, only cadmium exceeded the tolerable limit recommended by European Union and USEPA. Thus, open blazing of e-waste contributed to the concentrations of these heavy metals in the soils.

Keywords: Contaminants; e-waste; metal toxicity; open blazing; soil.

1. INTRODUCTION

Immense technological advancement and aggressive market strategies in recent time have resulted in the lifespan of most electrical and electronic devices which shorten sharply. As new products are being formed, the existing once are also be displaced and then discarded which then generate large amount of electronic waste (e-waste). Electronic waste or e-scrap may be defined as discarded electrical and electronic equipment (EEE) which includes computers, entertainment devices, television sets, office electronic equipment, mobile phones, cathode ray tubes (CRTs) and refrigerators [1,2,3,4]. This definition may also include the destination of such electrical and electronic devices such as salvage, recycling, reuse, resale, or disposal [2,3]. As defined in the waste electrical and electronic (WEE) directive of the European Union (2002/96/EC), EEE consist of equipment that are dependent on electric currents or electromagnetic field in order to work properly, and include equipment for generation, transfer and measurement of such currents and fields [5,6]. The Environmental Protection Agency estimates that only 15-20% of e-scrap is recycled, while the rest of these electronics go directly into landfills and incinerators [7]. According to a report by UNEP, the amount of e-waste being produced from mobile phones and computers could rise by as much as 500 percent over the next decade in some developing countries, such as India [8] and Nigeria is not in exception.

Nigeria is presently undergoing rapid development in information and communication technology (ICT) with very important part of ICT users depending on secondhand equipment from developed countries, primarily from Europe and North America due to the poor economic status of many Nigerians. It was estimated that about 400,000 units of second hand desktop computers (PCs or CRTs) are imported into Nigeria every month [9]. Fig. 1 shows the open blazing of cable wires in other to recover some precious components. Traders from Nigeria and other Africa countries come to Lagos to buy secondhand computers and their accessories as well as other electronic devices particularly from computer village. Many who work in this industry are migrant laborers who disassemble the waste by hand, open fires, acid baths, and broilers to extract precious metals such as copper, gold, silver and other valuable metals [10]. All these techniques discharge toxic substances such as fumes and liquid waste causing health problems for the worker and severe environmental degradation to the surrounding area. Once the waste has gone through the disassembly process and when the valuable materials have been successfully removed, the unusable parts are dumped which may result in the leaching of heavy metals and other toxins into the water system and this may cause environmental pollution [10].

Fig. 2 shows the results for the trace products which showed the share of the tracer products from household appliances based on the survey carried out by Olakintan et al. [6] on the amount of household appliances installed, the total percentage tracer products from category 1 is 34.9%, category 2 is 5.1%, category 3 is 41.1%, while category 4 is 69.3%. Category 4 is the highest and this may be as a results appliances such as TVs (flat and CRT), MP3, radios, stereos, game console and DVD players.

Cathode ray tubes (CRTs) in television and computer monitor screens for instance, contain about 1.5 to 6 pound of lead depending on the size and manufacturing year [11] and due to its high lead content, it is considered hazardous substance. Printed circuit board which can be dismantle by the removal of computer ship, open acid burning and acid bath can lead to the emissions of air as well as discharge into rivers of glass dust, tin, lead, brominated dioxin, beryllium cadmium, and mercury [12]. Also, Chips and other gold plated components which

can be scavenge by chemical stripping using nitric and hydrochloric acid and burning of chips can cause the release of heavy metals, hydrocarbons and brominated substances directly into rives causing the acidification of fish and flora [3,12]. Plastics from printers, keyboards, monitors and computer wires which are scavenge through shredding and low temperature melting or open burning can result in the emissions of brominated dioxins, hydrocarbons and heavy metals into the soil, air and river [3,12]. There has been report on cytotoxicity and genotoxicity effects of some chemicals from e-waste, which have been shown to inhibit cell proliferation, cause cell membrane lesion, DNA single-strand breaks, and elevate reactive oxygen species (ROS) levels [13]. According to our previous work [4], the concentrations of heavy metals at dumpsites were found to be higher than what was observed in the dust samples at the dismantling sites. Also, the control samples showed lower concentration when compared with the dismantling sites and that of the dumpsites. The result showed that e-waste contributes to the concentration of heavy metals in the soil samples where e-waste are being disposed. According to Oladuni et al. [14], the report of the study of the concentrations of heavy metals in and around the largest e-waste dumping site in Nigeria, Alaba International market in Lagos, showed that the mean concentrations of the heavy metals decreased with depth in soil samples and distance from the dumpsite. They concluded that the dumping of e-waste into the soil had lead to an increase in the concentrations of heavy metals in the soil with the concentrations of the heavy metals investigated exceeding the maximum permissible levels. To this end, this study was designed to evaluate the impact of open blazing of e-waste on the chemical compositions of heavy metals such as Pb, Cr, Zn, Cd and Cu. There concentration values were compared with control samples taken at several distances away from the burn sites as was with standard references.

2. MATERIALS AND METHODS

2.1 Sample Location

Lagos state is one of the smallest states in Nigeria but has one of the highest populations of 17.5 million as reported by the Lagos state government [15]. It lies at latitude 6º27'// north and longitude 3º23'45'' east. Lagos has been home to a number of different ethnic groups over the years playing home to significant international populations including Lebanese, Indian and British communities and all and sundry. Computer village is one unique center of economic activity in Lagos and it is an ICT hub which attracts several patronages within Nigeria and indeed West Africa. It grew from a mini computer market to a huge market that now provides employment, as well as opportunities for private enterprise and investment and computer education with over 3,000 small businesses. The used electronics refurbishing sector in Lagos generates $50.8 million per year, which is equivalent to 0.015% of Nigeria's gross domestic product and it was estimated that Lagos' State Government received up to a summed of $419,000 annually as taxes from refurbishing enterprises [16]. Fig. 3 shows the schematic map of Lagos State with an inscribed arrow indicating the study location.

2.2 Sample Collection, Preparations and Metal Analysis

Top soil samples were collected from three locations where e-waste were constantly being burnt at computer village in Ikeja, Lagos, Nigeria and they were labeled as location one (LC_1), location two (LC_2), and location three (LC_3) respectively. Control samples were also taken at a distance of 10, 20, 50, 100 and 150 m away from each site. The samples were air dried for 21 days and sorted to remove unwanted materials. The samples were then crushed using mechanical grinder and seized for fine particle require. The method described by Adaramodu et al. [17] was adopted and modified. Briefly, a homogeneous solution of nitric acid and perchloric acid in the ratio 2:1 strength was prepared. 1 g of the dried powdered samples of each soil was added to this solution in a Kjeldahl flask. The contents of the flask were heated on a hot plate at 130ºC until the volume was reduced to 3 ml. The solution was cooled and filtered with Whitman no. 1 filter paper. The filtrate was there after diluted up to the mark in a volumetric flask. All the sample solutions were analyzed for the presence of Pb, Cr, Zn, Cd and Cu using Buck Scientific model 210VGP Atomic Absorption Spectrophotometer. Three replicate samples were collected from the same site and analysed separately before the standard deviation and other statistical tools were performed.

3. RESULTS AND DISCUSSION

The results of the elemental compositions of different soil samples as well as those taken as control samples are as presented in Table 1. The pH values of the soil samples collected from LC_1 and LC_2 were found in acidic medium with the burnt sites having lower acidic pH, while the soil samples from LC_3 were observed to be in alkaline medium. The pH ranges from 4.6 to 6.5, 4.8 to 5.7 and 7.4 to 8.5 in LC_1, LC_2 and LC_3 respectively. It was observed that the acidic properties of the soil samples at LC_1 and LC_2 decreases with an increase in the distance away from the burnt sites. On the contrary, an anomalous behaviour was noticed at LC_3 where there was no particular order in the pH values.

The low acidic nature observed at LC_1 and LC_2 may be as a result of the burning of e-waste containing acidic substances such as Pb or Cd/Ni batteries which increases the acidic contents of the soil, while the alkaline nature of LC_3 may be as a result of the natural background of the soil. According to McBride [18], the mobility of metals in soil depends on the soil pH with most metals in their free ionic state being mobile in acidic pH. Richard et al. [19] reported that metals complexation with dissolved organic matter at higher pH can ensure solubility which can also ensure metal mobility. The pH results from LC_1 and LC_2 were in agreement with the findings of Buszewski et al. [20], while those from LC_3 were in agreement with the observations of Ofudje et al. [21] and Akpoveta et al. [22]. This might be as a result of the release of acidic substances from e-waste such as lead/cadmium batteries into the soil.

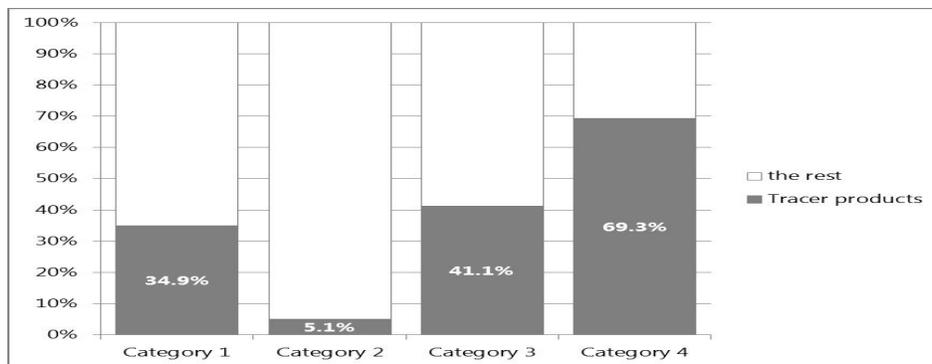**Fig. 1. Open blazing of WEE to recover metal components [6]**

Fig. 2. Weight based share of tracer products from all installed appliances in Nigerian households (Adapted from [6])
Note: category 1: fridges, air conditioners, category 2: irons, kettles, category 3: PCs, laptops, mobile phones and category 4: TVs (CRT and flat panel), radios, stereos

Fig. 3. Map of Lagos state with an arrow inscription showing the location of computer village

Table 1. Metal concentration at burn sites with their respective control samples

	pH	Pb	Cr	Zn	Cd	Cu
LC_1	4.6	180.4±3.1	30.4±2.0	150.4±3.2	2.8±0.5	30.4±0.8
10 m away	5.2	160.0±1.5	25.1±0.8	130.6±2.5	2.4±0.3	26.2±1.3
20 m away	5.5	144.8±2.3	20.2±0.4	122.1±1.0	2.3±0.7	20.2±1.5
50 m away	6.0	112.0±4.2	19.6±0.2	102.8±0.7	1.9±0.4	16.3±1.2
100 m away	6.3	98.2±5.0	14.9±0.6	70.5±5.3	1.5±0.8	13.0±0.8
150 m away	6.5	70.2±3.8	10.2±0.8	50.2±0.3	1.1±0.2	11.4±0.3
LC_2	4.8	30.2±2.7	22.4±0.9	40.0±2.2	18.2±0.7	47.2±3.0
10 m away	5.1	25.3±1.4	19.3±0.4	30.4±0.5	16.5±1.3	38.5±1.4
20 m away	5.3	20.2±0.7	15.5±0.1	29.7±1.2	13.9±0.4	30.0±0.8
50 m away	5.7	16.3±0.5	12.5±0.8	32.8±1.9	10.2±0.7	22.7±1.5
100 m away	6.4	14.2±0.8	9.8±0.4	10.2±0.5	5.8±0.1	16.6±0.3
150 m away	6.7	10.0±0.6	4.7±0.2	19.8±1.6	2.1±0.1	11.2±0.6
LC_3	7.5	150.4±3.2	3.3±0.5	80.4±0.8	28.2±4.8	100.2±4.8
10 m away	7.9	142.8±1.8	2.5±0.1	66.0±0.5	22.1±1.4	77.5±0.4
20 m away	7.4	133.5±0.4	2.0±0.3	60.1±2.8	16.0±0.8	61.8±0.9
50 m away	7.6	118.6±4.1	1.9±0.4	40.4±1.6	12.1±0.2	40.3±0.6
100 m away	8.5	82.9±3.6	0.8±0.1	31.2±2.0	11.3±0.5	31.4±2.3
150 m away	8.4	50.0±0.5	0.5±0.2	21.4±0.3	10.2±0.4	24. 8±0.9

The soil from different sampling locations including control samples contained different concentrations of all the metals analyzed as presented in Table 1. The soil from LC_1 area had Pb concentrations in the range of 70.2±3.8 to 180. 4±3.1 mg/kg, while that of LC_2 and LC_3 areas range from 10.0±0.6 to 30.2±2.7 and 50.0±0.5 to 150.4±3.2 mg/kg respectively. The highest value of Pb was observed at LC_1, while the least value was observed in LC_2 burn site. In all the three locations, the concentrations of Pb were found decreasing with an increase in the distance away from each burn site. The decreasing in Pb concentrations from each burn site may be attributed to the burning of Pb containing e-waste substances such as CRT, rechargeable batteries and printed wiring boards. Lead concentrations in all the sites analyzed were found below the safe limit recommended by USEPA [23] and European Union [24]. Continuous exposure to Pb may cause harmful effects in the human body. Short-term exposure to Pb could result in diarrhea, vomiting, convulsion or coma, while long term exposure could result in kidney and nervous damage, cause brain and blood disorder and could leads

to death [25]. The results from this study were found to be higher than 2.1 to 12.50 mg/kg and 0.21 to 0.42 mg/kg reported by Anyakora et al. [26] and Opaluwa et al. [27] respectively but agree well with 99±7.18 to 151±29.86 mg/kg and 68.46±5.02 to 120.45±9.42 mg/kg recorded by Atayese et al. [28] and Ofudje et al. [21].

Chromium concentrations from LC_1 were found to range from 10.24±0.8 to 30.4±2.0 mg/kg, 4.7±0.2 to 22.4±0.9 mg/kg for LC_2 and 0.5±0.2 to 3.3±0.5 mg/kg for LC_3 samples. Although, the level of chromium in the soil samples were low, the gradual decrease in chromium concentration as the various distances away from the burnt sites increases, clearly showed the contribution of blazing e-waste in these areas. This inferred that there were interactions between the e-waste and soil samples as a result of the leaching from chromium containing e-waste substances such as data tapes and floppy-disks. The mean value of chromium concentration for all the soil samples analyzed fell below the value recommended by USEPA [23] and European Union [24]. The results of this study were higher than 0.10 to 0.35 mg/kg and 0.46 to 2.20 mg/kg reported by Adaramodu et al. [17] and Anyakora et al. [26], but lower than 89.10±0.15 reported by Abdallah et al. [29] and agree well with 10.51±0.01± to 19.65±0.55 and 16.84 to 38.21 mg/kg as reported by Ofudje et al. [21] and Akpoveta et al. [22] respectively. Owing to the high conductivity and anti corrosive properties of chromium and its oxide, they are widely applied in the manufacture of electrical and electronics substances. However, chromium can be easily absorbed in human body which could cause irritation to skin, eyes and membrane, while chronic exposure could cause damage to DNA, cancer and permanent eye injury [30].

The experimental results of zinc concentration at LC_1 range from 50.2±0.3 to 150.4±3.2 mg/kg, 19.8±1.6 to 40.0±2.2 mg/kg for LC_2 and 21.4±0.3 to 80.4±0.8 mg/kg in LC_3. The increasing order of the Zn concentration from the burnt sites is given as $LC_1 > LC_3 > LC_2$. At a distance of 10, 20, 50, 100 and 150 m away from the burnt site, the concentration of Zn at LC_1 and LC_3 was observed to be decreasing, while there was an anomalous behavior in the concentration of Zn at LC_2. The high concentration of Zn at the burnt site compared with the control sites could be as a result of the release of Zn from Zn containing e-waste substances like cables, small motors and reading or writing devices of drives into the soil of the burnt site. The values of Zn in all the burnt

soil and control samples fell below the recommended value by USEPA [23] and EC [24]. The results were however lower then 213.00 to 295.50 mg/kg observed in indoor dust and outdoor dust from Westminster electronic market in Lagos State as reported by Adarmodu et al. [17] but fell within the range of 40.53±2.20 to 98.62±7.27 mg/kg in soil dust from e-waste dismantling sites at computer village, Lagos as observed by Ofudje et al. [21]. Zinc is an essential element which is required by human body for healthy development. However, too much exposure to zinc as dust or fumes can results into a short-term disease known as metal fume fever [17]. Too much absorption of Zn can also leads to electrolyte imbalance, abdominal pains, vomiting and dehydration [31].

All the soil samples from the locations contained different concentrations of cadmium with soil samples from LC_1 ranging from 1.1±0.2 to 2.8±0.5 mg/kg, while that of LC_2 and LC_3 areas had Cd concentrations in the range of 2.1±0.1 to 18.2±0.7 and 10.2±0.4 to 28.2±4.8 mg/kg respectively. Although, a gradual decrease in Cd concentration with an increase in distance away from the burnt sites was observed, the concentration of Cd from LC_1 were very low and fell below the standard limit of 3.0 mg/kg stipulated by USEPA [23] and EC [24], while that from LC_2 and LC_3 exceeded this limit. The low concentrations of Cd observed at LC_1 may be as a result of the burning of less Cd containing e-waste substances, while the high level of Cd observed at LC_2 and LC_3 may be as a result of the blazing of Cd containing e-waste materials such as rechargeable Ni-Cd batteries, fluorescent layer (CRT screen), printer inks and tonners, printer drum in photocopier etc. It should be noted that some of these materials were seen at LC_1 and LC_2. Adaramodu et al. [17] reported that the soils of indoor dust and outdoor dust from Westminster electronic market in Lagos contained 19.00 and 1.80 mg/kg Cd concentration which agrees well with the findings of this study. Also, Anyakora et al. [26], observed that Cd concentration ranged between 0.56 to 4.20 mg/kg recorded in the soil samples from highly industrialized Lagos environment. Inhalation of excess Cd could damage the reproductive lungs, DNA, kidney and could be carcinogenic [32]. Cadmium can also cause deficit in learning, cognition, behavior and neuromotor skills in children [33].

The soil samples from different locations contained different concentrations of copper in

the range of 11.4±0.3 to 30.4±0.8, 11.2±0.6 to 47.2±3.0 and 24.8±0.9 to 100.2±4.8 mg/kg for soil samples at LC_1, LC_2 and LC_3 respectively with the burnt site having high concentrations of copper which all fell below the values stipulated by USEPA [23] and European Union [24]. The results of Cu contents in soil samples from this study were higher than 2.20 to 6.67 mg/kg recorded by Anyakora et al. [29] and agree well with 42.09±0.01 to 88.50±0.10 mg/kg and 26.80 mg/kg reported by Omoloye [34]. Copper is an essential trace element with the human body containing copper at a level of about 1.4 to 2.1 mg/kg of the body mass. Although, the human body can handle large quantity of copper concentrations, too much of copper accumulation can cause several ailments and health problems such as irritations of eyes, nose and skin, headache, dizziness, vomiting, diarrhea, damage the liver and kidney, and can as well leads to death [35].

Figs. 4 and 5 show the mean concentrations of heavy metals from site 1 and 2 including the control samples at different distances away. As seen from Fig. 1, the concentrations of all the metals decreased as the distance away from the blazing site increases. The decreasing order of the elements is given as Pb>Zn>Cr>Cu>Cd. From Fig. 5, it can be observed that while there was a decrease in the concentrations of Pb, Cr, Cu and Cd as the distances away from the blazing sites increases, there was an anomaly in the behaviour in the concentration of Zn at 50 m and 150 m away. This may be as a result of the discharge of Zn from other contaminants or natural background of Zn at these sites. There was an increase at 50 m and 150 m away from the blazing site. The decreasing is Cu>Zn>Pb>Cr>Cd.

As indicated in Table 2, the mean concentration of Pb from this study was higher than what was recorded by other researchers except for Ofudje et al. [21]. All other metals except Cd and Cu in some locations had metal concentrations below the recommended safe limit by USEPA and United Kingdom regulation.

Statistical analysis performed using Pearson correlation was considered significant at the 0.05 level (2-tailed with n = 5) and the values obtained are presented in Tables 3, 4 and 5. From Table 3, except for Zn versus Pb, Cr and Cu versus Zn which displayed negative correlations with each other, all other showed very strong positive correlations with each other. From Table 4, Cr showed very strong positive correlations with Pb, while Zn displayed negative correlation with Pb and positive correlation with Cr. Cadmium displayed strong positive correlation with Pb and Zn and negative correlation with Cr. Cu showed a positive correlation with Cr and Cd and then negative correlation with Pb and Zn.

Table 2. Comparative heavy metal contents in mg/kg in soil samples with other works in literature and standard values

Metal	This study	Adaramodu et al. 2012 [17]	Akpoveta et al. 2010 [22]	Anyakora et al. 2013 [26]	Ofudje et al. 2014 [21]	USEPA [23]	EC [24]
Pb(mg/kg)	120.3±0.4	15.9-22.5	8.92-14.47	2.20-12.50	120.45±9.42	300	300
Cr(mg/kg)	18.7±1.3	0.35–0.10	16.84-38.21	0.24-2.20	19.65±0.55	100	150
Zn(mg/kg)	90.3±0.4	213.0-295.5	54.15-97.21	ND	98.62±7.27	300	300
Cd(mg/kg)	16.4±0.5	1.8–19.00	0.11-1.65	0.56-4.10	17.91±3.04	3.0	3.0
Cu(mg/kg)	60.3±2.0	ND	14.22-34.21	2.20-6.60	ND	250	140

Note: ND = not detected

Table 3. Correlation coefficient of metals at LC_1

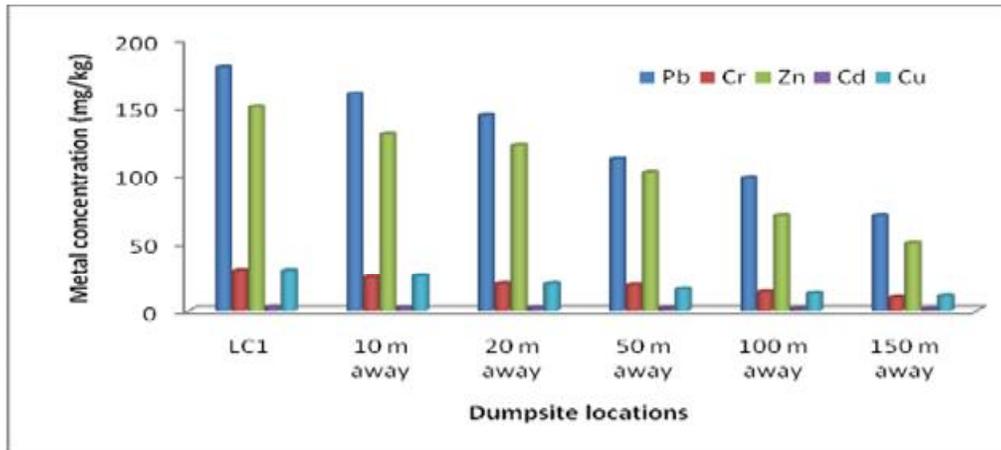|	Pb	Cr	Zn	Cd	Cu
Pb	1.00				
Cr	0.97	1.00			
Zn	-0.48	-0.62	1.00		
Cd	0.88	0.95	0.95	1.00	
Cu	0.74	0.55	-0.82	0.67	1.00

Fig. 4. Metal concentrations from different locations in dumpsite 1

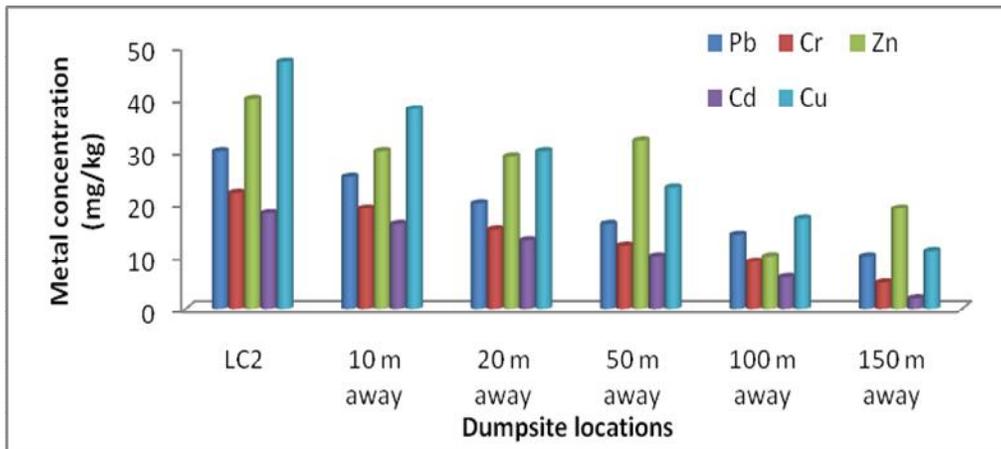**Fig. 5. Metal concentrations from different locations in dumpsite 1**

Table 4. Correlation coefficient of metals at LC$_2$

	Pb	Cr	Zn	Cd	Cu
Pb	1.00				
Cr	0.93	1.00			
Zn	-0.86	0.74	1.00		
Cd	0.83	-0.69	0.87	1.00	
Cu	-0.44	0.78	-0.57	0.84	1.00

Table 5. Correlation coefficient of metals at LC$_3$

	Pb	Cr	Zn	Cd	Cu
Pb	1.00				
Cr	0.85	1.00			
Zn	0.32	-0.27	1.00		
Cd	-0.89	0.96	0.48	1.00	
Cu	-0.68	0.73	0.93	-0.83	1.00

The correlation of metals at LC_3 as presented in Table 5 showed that Cr displayed strong positive correlation with Pb, Zn with Pb but negative correlation with Cr. Cd showed positive correlation with Cr but negative correlation with Pb, while Cu displayed positive correlation with Cr and Zn but negative correlation with Pb and Cd. Positive correlations among metals in soil could be attributed to the leaching of heavy metals from the same source which is open blazing of e-waste substances such as cable and copper wires, Pb or Cd containing rechargeable batteries etc. On the hand, the negative correlations among metals could indicate contamination of one metal in soil which does not necessarily indicate contamination of other element. This may infer different or uncommon source of contamination.

4. CONCLUSION

This study examined the role of open blazing of e-waste on the concentrations of Pb, Cr, Zn, Cd and Cu in three different locations with respect to control samples taken at different distances away from the e-waste blazing sites at computer village, Ikeja, Lagos, Nigeria. The results revealed that the concentrations of these heavy metals were high at each blazing site with the corresponding samples at several distances away from blazing site decreasing gradually. This inferred that regular open blazing 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. It will therefore be important for the government to restrict the open blazing of e-waste around these areas, while better locations should be provided to suit these purpose.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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