

Heavy Metals Concentration at Electronic-Waste Dismantling Sites and Dumpsites in Lagos, Nigeria.

Abstract

The importation and refurbishing of second-hand electrical and electronic equipment (EEE) is a major concern all over the world and Nigeria is not in exception owing to the generation of e-wastes. The assessment of the levels of Pb, Cr, Ni, Cd and Zn in the dust of dismantling sites and soil of dumpsites from Lagos municipal was performed using Atomic Absorption Spectroscopy. Control samples were also taken at 1km away from each site. At the dismantling sites, the concentration of Pb, Cr, Ni, Cd and Zn were found to ranged between 99.63 to 141.90 mg/kg, 14.80 to 21.88 mg/kg, 30.41 to 55.68 mg/kg, 10.55 to 23.56 mg/kg and 57.61 to 111.48 mg/kg, while that of the control site ranged between 44.31 to 73.33 mg/kg, 6.62 to 13.42 mg/kg, 16.44 to 34.13 mg/kg, 5.86 to 14.40 mg/kg and 20.35 to 60.73 mg/kg respectively. At the dumpsites, the contents of Pb, Cr, Ni, Cd and Zn were found to ranged between 152.30 to 328.40 mg/kg, 23.94 to 30.80 mg/kg, 53.75 to 64.81 mg/kg, 24.86 to 31.40 mg/kg and from 211.46 to 306.94 mg/kg, while that at the control sites range between 74.60 to 162.90 mg/kg, 11.43 to 16.52 mg/kg, 36.91 to 41.43 mg/kg, 10.91 to 20.84 mg/kg and 116.90 to 178.31 mg/kg respectively. Heavy metals concentrations at the 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. Thus, e-waste contributes to the concentration of heavy metals in the soil and dust sample where e-waste are being dismantled and the dumpsites where the unused electrical and electronic equipment are being disposed.

Keywords: Dismantling sites, Dumpsites, E-Waste, Heavy Metals.

1.0.Introduction

The production and sale of electronic appliances has skyrocketed all over the world owing to rapid development of technology. As new versions of existing products are being launched, existing versions are constantly being relegated to the back and subsequently being replaced and disposed. This has resulted in the pollution of the environment with electronic-waste. The term e-waste, e-scrap or waste electrical and electronic equipment (WEEE) is used to described any discarded electrical or electronic devices such as computers, mobile phones, television sets, refrigerators, entertainment devices, office electronic equipment to mention but a few [1, 2, 3]. Rapid changes in technology, changes in existing versions and planned obsolesce have resulted in a fast growing surplus of WEEE all over the globe. According to the Environmental Protection Agency, it's only about 15 to 20% of e-waste that is being recycled, while the remaining goes directly into landfills and incinerators [4]. An estimated amount of about 50 millions tons of e-waste are produced annually [5].

Lagos is gradually emerging as one of the top city in Nigeria that is been regarded as the home ground for all sort of electronic wastes and other toxic chemicals [5]. According to the report of Basel Action Network (BAN), over 500 shipping containers containing about 175, 000 large TV sets or 400, 000 computer monitors are being imported to Lagos on monthly basis [6]. About 75% of such shipments are classified as e-waste [6, 7, 8]. The disposal, distribution, recycling as well as parts salvaging of the discarded electronic devices are sources of social, environmental and public health challenge in Nigeria [8]. The process of disposing and dismantling of WEEE in developing countries like Nigeria caused a lot of environmental impact such as the release of liquid and atmospheric hazardous substances which end up in the bodies of water, groundwater, soil and air which affects land and sea animals, crops and human beings [1, 9].



Fig. 1: E-waste Scavengers at work at Olushosun dumpsite in Lagos (source: E-waste Country Assessment Nigeria, 2012).

Furthermore, e-waste salvagers are exposed to lead fumes as a result of cooking circuit boards over open flames or in swallow pans [10]. Acid baths are often used to extract gold from circuit board chips, spewing even more toxic gases into the air [11] and these process release heavy metals such as cadmium, lead and mercury into the air, water and soil [12]. Some of the hazardous substances found in e-waste are presented in Table 1.

55 **Table 1:** Hazardous substances in e-waste, their sources and health effects.

Hazardous Substances	Sources	Health effects	References
Mercury	It is found in fluorescent tubes, flat screen monitors, mechanical doorbells and thermostats.	Sensory impairment, memory loss, muscle weakness. In-uterus exposure leads to serious deficits in motor functions and verbal domain	[1, 13]
Americium	Found in smoke alarms	It is carcinogenic	[1]
Lead	CRTs, batteries, solder and formulated PVC.	It lowers intelligent quotient, attention deficits, and cognitive function impairment and causes behavioral disturbances, malaise, anorexia and can also damage some important organs such as kidney, liver, hearth and leads to death.	[1, 13, 17]
Cadmium	It is found in light-sensitive resistors, batteries, aviation and marine corrosion resistant alloys.	It damages the kidneys, lungs when inhaled. It can also leads to reduction in learning, behavior, cognitive and motor skills in children.	[1, 13, 16]
Brominated Flame Retardants (BRF)	It is used as flame retardants in plastics in electronics.	Thyroid problem, liver problem, nervous system impairment.	[1, 17]
Sulphur	Acid batteries.	It causes damage to kidney, liver, heart and causes throat irritation.	[1]

56 It's obvious that e-waste not properly dismantled and recycled pose a serious threat to both
57 human health and the environment. For instance, electronic cables which contain heavy metals
58 are burned in open air and release toxic furans and dioxin. Also, cathode ray tubes (CTRs) are
59 dismantled with hammers so as to remove copper but this process release toxic phosphor dusts
60 into the atmosphere. While there is agreement that the number of discarded electronic appliances
61 is on the increase, there is considerable disagreement about the relative risk and strong

disagreement also that curtaining trade in used electronic will improve the state of contamination. It is to this end this research work was conducted to assessed the level of some heavy metals in the dust and soil where these WEEE are being dismantled and the dump sites where the unused components are disposed. Control samples were also taken 1km away from each site.

2.0.Materials and Methods

2.1. Sample Locations

Traditionally, Lagos State is inhabited by the Aworis subgroup of the Yoruba people but due to high level of commercialization and industrialization, many people from different nationalities work and live within the territory boundary of Lagos State. The National Population Commission 2006 put Lagos population at 17.5 million inhabitants and the newest report put the population at about 21 million. Lagos is the second fastest growing city in Africa and the seventh fastest growing city in the word. The three dumpsites are located at Abule-Egba, Olushosun and Soluos in Lagos State of Nigeria. They are designated dumpsites by the Lagos State Waste Management Agency and with a capacity of about 63.67 hectares of land. The Olushosun dumpsite is one of the largest in Aafrica and was established in 1992. It covers about 42 hectares of Land which receives about 2,400 metric tones of waste every day. The soluos dumpsites has a capacity of about 2,250 metric tones of waste with about 350 to 500 individuals involved in the picking of waste materials.

Ikeja computer village opened business in 1995/96 in the sales of new electrical and electronic equipment. But around year 2000, the market commenced the sales of second-hand electronic devices such as mobile phones, computers, TV sets e.t.c. It has a size of about 1.1km² and occupies over 3,000 businesses in both new and used electrical and electronic equipment. The Ojota scrap market is well known for the dismantling and sorting of solid wastes including EEE. It is located along Lagos-Ikeja axis. Part of this market is used to dispose and incinerates waste. Burning of cables is a normal routine in this market. Alaba International market is the largest refurbishing cluster in West Africa. The metal-containing wastes are sold to collectors who then dismantled and sort out the useful parts. Cables are burn in open fire at some locations very close to this market.

2.2. Sample Collection

Three sets of samples were collected randomly at different locations between December 2012 and March 2013 during the dry season. First, surface dust samples were collected from four sites where electronic waste are being dismantled by sweeping the surface and this was referred to as dust sample (DS). Secondly, top soil between 0 to 10cm samples were randomly collected from three e-wastes dumpsites where the unused components are being dumped after dismantling and removal of important parts and this was referred to as soil sample (SS). Finally, samples were also collected about 1km away from the locations where the dust samples and the soil samples

were collected and it was referred to as control sample (CS). The samples were collected in 500ml sample bottles which has been previously washed with detergents and rinsed with distilled water and transported into the Laboratory for preparation. A total number of three samples were collected from each site.

2.3. Sample Preparation and Metal Contents Analysis

The samples were sun dried for 15 days and thereafter placed in an oven for 2 hours at a temperature of 80°C. The samples were homogenized using a mechanical grinder and sieved through a mesh size of 2mm and kept in air-tight plastic sample bottles prior to analysis. The homogenized samples were then digested by using a mixture of 5ml of HNO₃ and 10ml of HCl in a kjeldahl flask that contained 1g of the sample. The contents of the flask were digested until the brown fumes of nitroxide ceased to appear. The solution was then filtered through Whatman number 42 filter paper into a 100 ml volumetric flask and made up to the mark with deionized water. The concentrations of Pb, Cr, Ni, Cd and Zn were analyzed using Buck Scientific model 210VGP Atomic Absorption Spectrophotometer. The data were analyzed in triplicate and the mean values were recorded.

3.0. Results and Discussions

Table 2: Heavy Metal Concentration at Various Dismantling Sites

Locations	pH	Pb(mg/kg)	Cr(mg/kg)	Ni(mg/kg)	Cd(mg/kg)	Zn(mg/kg)
Odo-Iya Alaro	8.42	114.31	10.24	38.76	11.21	86.31
Control*	7.22	50.70	4.33	27.81	9.64	48.71
Alaba Int. Mkt.	9.66	141.90	21.88	55.68	23.56	111.48
Control**	8.83	73.33	13.42	34.13	14.40	60.73
Computer Village	8.32	120.45	19.65	43.24	17.91	98.62
Control***	8.26	68.46	10.51	21.52	6.80	40.53
Ojota Scrap Mkt	8.11	99.63	14.80	30.41	10.55	57.61
Control****	8.01	44.31	6.62	16.44	5.86	20.35

Table 3: Heavy Metal Concentration at Various Dumpsites

Locations	pH	Pb(mg/kg)	Cr(mg/kg)	Ni(mg/kg)	Cd(mg/kg)	Zn(mg/kg)
Abule-Egba	8.65	146.30	26.40	64.81	27.83	211.46
Control°	7.81	74.60	12.60	36.91	10.91	116.90
Olushosun	9.93	328.40	30.80	73.94	31.40	306.94
Control°°	9.64	162.90	16.52	41.43	20.84	178.31

Soluos	8.59	152.30	23.94	53.75	24.86	268.20
Control^{ooo}	8.35	90.40	11.43	38.94	15.20	149.90

Table 4: Correlation between the levels of metals in dusts versus soil samples.

	Pb-soil	Cr-soil	Ni-soil	Cd-soil	Zn-soil
Pb-dust	0.74	0.68	-0.41	0.68	0.15
Cr-dust	0.36	0.82	-0.87	0.52	-0.28
Ni-dust	-0.58	0.19	-0.23	0.57	-0.45
Cd-dust	0.71	0.24	0.43	0.96	0.32
Zn-dust	-0.46	0.22	0.37	0.11	-0.14

The relative increase in the concentrations of heavy metals at e-waste dumpsites and dismantling sites compared with those in the soil and dust samples from 1km away (control samples) in respective sites indicate the impact of e-waste in these areas which greatly influence and contribute to the high metal contents observed. The results of heavy metals analysis of the various dust sites as well as their respective controls are presented in Table 2; while that of the soil samples and its control counterparts are presented in Table 3. The range of the concentration of lead in the dust samples ranged between 99.63 to 141.90 mg/kg. Maximum concentration of 141.90 mg/kg was observed in the dust sample collected from Alaba International Market, followed by computer village (120.45 mg/kg), then by Odo-Iya Alaro (114.31 mg/kg), while Ojota scrap market showed the least value of 99.63 mg/kg. At a distance of 1km away from each site, the concentration of lead ranged between 44.31 to 50.70 mg/kg. From Table 3, it can be seen that the concentration of lead in the three e-waste dumpsites ranged between 146.3 to 328.4 mg/kg with Olushosun dumpsite having the highest value of 328.4 mg/kg, followed by Soluos (152.3 mg/kg) and the least value was observed in the soil sample at Abule-Egba dumpsite. At 1km away from the various dumpsites, the lead concentration ranged between 74.6 to 162.9 mg/kg. Except for the lead contents at Olushosun dumpsite, other sites fall below the save limit of 300 mg/kg proposed by USEPA [18] and the normal range of 2-200 mg/kg reported by Ebong *et al.*, [19]. The results agree well with what had been observed by previous reports [20, 21, 22]. However, the results were higher than the range of 1.34 to 1.693 mg/kg reported by Aluko *et al.*, [23] and 9.40 to 22.5 mg/kg observed by Adaramodu *et al.*, [8]. The results revealed that both the dumpsites and dismantling sites contained significant amount of lead which could be as a result of the presence of lead containing substances like e-waste at these sites. It is worthy to note that continues exposure to lead containing substances could be deadly. Lead is found in e-wastes such as in cathode ray tubes, batteries and solders. Effects of exposure to lead includes low intelligent quotient, muscle pains, anorexia, malaise, attention deficit, impairment of cognitive function and high level of lead exposure could cause brain damage and leads to death [11,13, 14, 15].

Chromium concentrations from the samples of dust from various sites are shown in Table 2. As indicated in the Table, sample from Alaba International market had the highest concentration of 21.88 mg/kg, followed by 19.65 mg/kg at computer village, then by 14.80 mg/kg at Ojota scrap market while the least value of 10.23 mg/kg was found in Odo-Iya Alaro market. Also, the results of 1km away showed that the mean concentrations of Alaba International market, computer village, Ojota scrap market and Oja-Iya Alaro were found to be 13.42, 10.51, 6.62 and 4.33 mg/kg respectively. From Table 3, chromium concentration of 30.80, 26.40 and 23.94 mg/kg were found at Olushosun, Abule-Egba and Soluos dumpsites respectively with Olushosun having the highest value and Soluos dumpsite showed the lowest value. Chromium contents of control samples from the dumpsites ranged between 11.43 to 16.52 mg/kg. It was observed that the mean concentration of chromium (27.03 mg/kg) in dumpsites was higher than the mean concentration (16.64 mg/kg) in the dust of dismantling sites. This is to say that there is more interaction between chromium with the soil of the dumpsites than the dust of the dismantling sites. It was also observed that the values of the control (1km away) were lower than what were observed at the dismantling sites and dumpsites. This suggests that chromium might have been introduced by chromium containing e-wastes materials into the soil and dust samples. Major sources of chromium in e-waste include hardener in plastics and dye in pigments of some. Skin contact with some chromium (VI) compounds can lead to ulcers while allergic reaction could result in redness and swelling of the skin [24]. Chromium (VI) compounds have also been noted to increase the risk of lung cancer [8] and can also cause damage to DNA [17]. The mean concentration of chromium in this study fall below the 100 mg/kg recommended by USEPA, 100.3 to 105.0 mg/kg reported by Gitimoni and Krishna [24] but was found to be higher than 0.10 and 0.35 mg/kg reported by Adaramodu *et al.*, [8].

The concentration of cadmium from this study is very high. The maximum mean value of 23.56 mg/kg was observed in the dust samples of Alaba International market and the minimum value of 10.55 mg/kg was obtained in the sample of Ojota scrap market as shown in Table 1. However, at 1km away, cadmium concentration ranged between 5.86 to 14.40 mg/kg for the dust samples. From Table 3, Olushosun dumpsite showed the highest concentration (31.40 mg/kg) followed by Abule-Egba (27.83 mg/kg) and the least value was obtained at Soluos dumpsite (24.86 mg/kg). At 1km away, cadmium concentration ranged between 10.91 to 20.84 mg/kg. The difference in the cadmium concentration at various dumpsites, dismantling sites and control samples suggests that increase in cadmium may be as a result of the released of cadmium from e-wastes containing electrical and electronic equipment. Batteries, PVC, aviation corrosion resistant and light-sensitive resistors are the major source of cadmium in e-waste [1, 10]. Cadmium is a potentially long-term cumulative poison and toxic compounds of cadmium tend to accumulate in the human body causing kidney and lung damage [1, 8], it is known to be carcinogenic to human health [25]. The level of cadmium from this study exceeded the 3.00 g/kg proposed by USEPA but agree with the findings of Abdallah *et al.*, [22] in the range of 5.19 to 45.49 mg/kg. The cadmium level from this study were however lower than 0.009 and 0.42 mg/kg, 0.04 to 0.08 mg/kg reported by Umoh and Etim [26].

Zinc concentration was found to range between 57.61 to 111.48 mg/kg for the dust samples and between 20.35 to 60.73 mg/kg for the control samples in the dismantling sites. Maximum zinc concentration (111.48 mg/kg) was observed at Alaba International market while the least value (57.61 mg/kg) was obtained from the dust samples at Ojota scrap market. Also, zinc concentrations at various dumpsites were found to range between 211.41 to 306.94.37 mg/kg and between 116.90 to 178.37 mg/kg for the control samples. For the dumpsites, maximum zinc concentration (306.94 mg/kg) was observed at Olushosun and the least values (211.46 mg/kg) were found in the soil sample at Abule-Egba. Zinc concentration at control sites were lower when compared with what was observed at the dumpsites and dismantling sites. This indicate that increase in the zinc concentration at the dismantling sites and dumpsites is greatly influenced by the released of zinc containing substances into the soil. The acceptable limit of zinc in the soil is 10-300 mg/kg. It was observed that except for zinc contents at Olushosun dumpsite, all other zinc contents from the study areas as well as that of the control sites fall within the save limit. Odkoya *et al.*, [25] reported that the concentration of zinc in Abeokuta dumpsites was found to be between 100.80 to 226.00 mg/kg while that of the control samples ranged between 51.25 to 71.43 mg/kg which is in agreement with results of this study. Also, Adaramodu *et al.*, [8] found out that zinc concentration in dust and out dust present at west minister electronic market in Lagos was 295. 50 and 213.00 mg/kg respectively, while that of the control sample was 78.00 mg/kg which also conform to the finding of this study. Zinc is a good essential element which is required in low quantity for body development. However, excessive intake or exposure to zinc can cause dehydration, abdominal pain, electrolyte imbalance, lack of muscular co-ordination and vomiting [26, 27].

The concentration of nickel in dust sample was obtained to range between 30.41 to 55.68 mg/kg and between 16.44 to 34.13 mg/kg for the control sites. For the dumpsites, nickel concentration was obtained to range between 53.75 to 73.94 mg/kg and between 36.91 to 41.43 mg/kg for the control soil samples. Nickel concentration in the control sites were lower than what was observed in the dust and soil samples from dismantling sites and dumpsites respectively. This shows that the e-waste contribute significantly to nickel concentration in both the dust samples and the soil samples. The concentration of nickel in the soil and control samples fall within the world average for nickel contents in the soil (40 mg/kg) [26, 28] except for the dust sample which was obtained from Alaba International market. The results from this work fall within the values observed by Gitimoni and Krishna [24] (48.9 to 50.1 mg/kg). Although, nickel is an essential element, it is also known to be harmful if inhaled in excess. Nickel at higher concentration is carcinogenic and when inhaled in large amount, it can cause damage to the brain, liver, muscle and kidney [29]. The pH of the study areas were found to range between 8.11 to 9.66 mg/kg for the dust sample at the dismantling sites and from 7.22 to 8.83 for the control samples.

On the analysis of the pH of the dumpsites, the pH ranged between 8.59 to 9.93 mg/kg and from 7.81 to 9.64 for the control sites. The solubility of metals ions in the soil could affect metal

availability in a particular soil. This will in turn affect the mobility of the metal in the soil. According to Smith *et al.*, [30], metal mobility decreases proportionally with the pH of the soil due to the formation of carbonates or insoluble organic complex and the precipitation of hydroxides.

Table 4 shows the results of the statistical analysis of the correlation between metals in the dust and metals in the soil samples. The correlation was performed at $\alpha = 0.05$ (two tail) and for $n = 7$. The results indicated that Pb-dust displayed positive correlation with Pb-soil, Cr-soil, Cd-soil and Zn-soil, while Cr-dust displayed positive correlation with Pb-soil, Cr-soil and Cd-soil. Ni in the dust sample displayed positive correlation with Cr-soil and Cd-soil; Cd-dust also showed positive correlation with Pb-soil, Cr-soil, Ni-soil and Zn-soil. Also, Zn-dust displayed positive correlation with Cr-soil, Ni-soil and Cd-soil. Negative correlation was observed between Pb-dust with Ni-soil, Cr in dust showed negative correlation with Ni and Zn in the soil. Negative correlation was also observed between Ni-dust with Pb, Ni and Zn-soil, while Zn-dust displayed negative correlation with Pb and Zn in the soil samples. The positive correlation that was observed may indicate that the concentration of metals in the samples of the dust may have come from the same origin as that of the soil samples and in this study, the e-waste. On the other hand, the negative correlation may indicate that the concentration of metals in the soil and dust were from different source. This implies that for negative correlation, the natural background concentration of individual metals in the soil might be responsible for the high concentration observed and not necessarily from the e-waste.

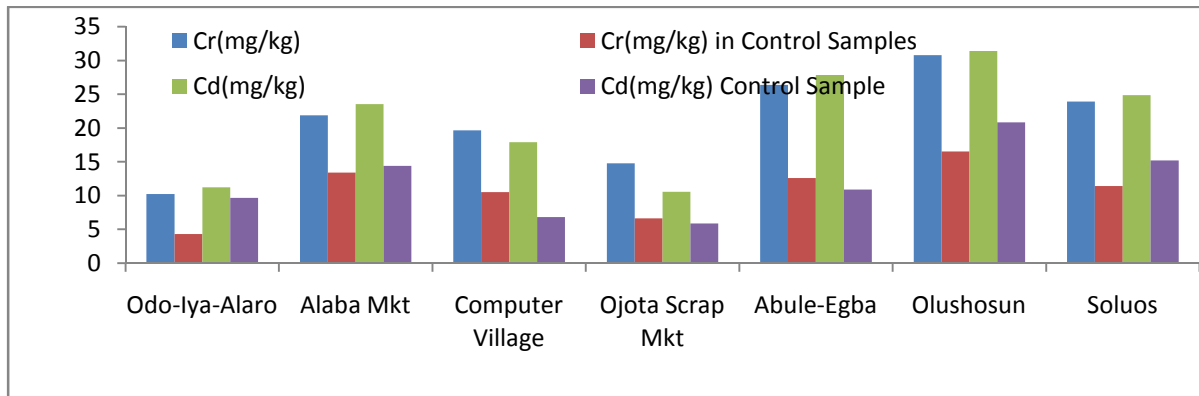


Fig.2: Comparative mean concentration of Cr and Cd (mg/kg) in dumpsites and dismantling sites with control samples.

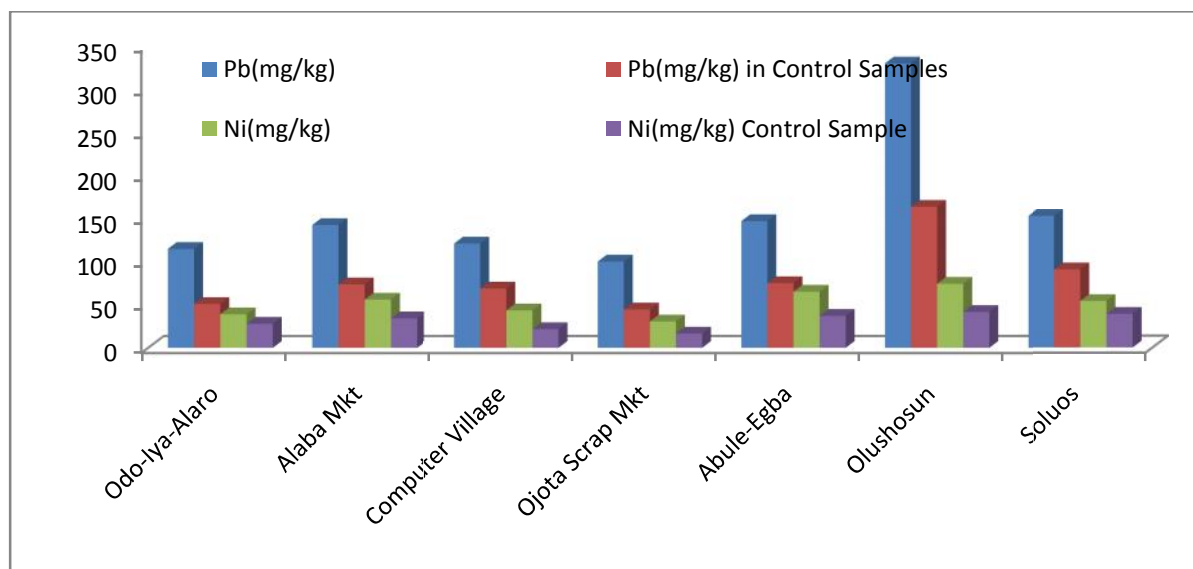


Fig.3: Comparative mean concentration of Pb and Ni (mg/kg) in dumpsites and dismantling sites with control samples.

Figures 2 and 3 showed the comparative mean concentration of heavy metals (mg/kg) in dumpsites and dismantling sites with control samples. It's obvious from the plots that there were great significant difference between the concentration of heavy metals in the soil samples, dust samples and that of the control samples. In each case, the concentrations of heavy metals in the control samples were lower indicating that the heavy metals concentration in the control site might be as results of natural sources or other means of contamination. This shows that the concentration of heavy metals at the dumpsites and dismantling sites is contributed by the presence of e-waste containing heavy metals.

4.0. Conclusion

This study focuses on the analysis of the level of heavy metals concentrations in the dust and soil samples of e-waste dismantling sites and dumpsites. Dust sample were collected from four locations in Lagos where electrical and electronic equipment are regularly being dismantled, while the soil samples were collected from three e-waste dumpsites in Lagos as well. Control samples were equally taken at 1km away from each site. It was observed that dust samples from Alaba International market and that of the control site had comparatively higher heavy metals concentrations in comparison with other sites. This could be as a result of the large quantity of electrical and electronic equipment activities around this area. Alaba International market is known to be the home to electronic of all kinds in Nigeria. It was also observed that the concentration of heavy metals analyzed at various sites were higher than what was observed at the control sites for both the dismantling sites and the dumpsites. For the soil samples in the dumpsites, Olushosun and the control samples had the highest contents of heavy metals in comparison with other sites. High levels of positive correlation exist between the dumpsites and

dismantling sites showing common source of pollution. Thus, there is urgent need to pay more attention to the chemical composition of e-wastes dismantling sites and dumpsites.

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