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ORIGINAL RESEARCH ARTICLE

ASSESSMENT OF SOME HEAVY METAL POLLUTION ON SOIL VIA E-WASTE DUMPING ACTIVITIES AND UNPOLLUTED SOIL IN ABRAKA, DELTA STATE, NIGERIA

O. B. Eyenubo*, O. Peretomode, F. Egharevba and S. A. Osakwe
Department of Science Laboratory Technology, Delta State University, Abraka, Nigeria
**Corresponding author's email address: eyenokero2013@gmail.com*

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ABSTRACT

This research investigated the concentration of heavy metals pollution of soil via e-waste dumping in Abraka community. Two soil samples were obtained and analyzed through digestion and the use of Atomic Absorption Spectrophotometer (AAS). The concentration of cobalt (Co), chromium (Cr) and manganese (Mn) on the polluted soil were higher than the control soil at depths 0 – 10 cm and 10 – 20 cm (25.55 and 22.65 mg/kg, 10.19 and 8.65 mg/kg, 78.15 and 51.16 mg/kg) and lower in depth 20 – 30 cm (10.82, 6.55 and 41.98 mg/kg). While the concentration of iron (Fe) on the polluted soil is higher than that of the control and also decreased across depths (1096.60, 652.02 and 420.43 mg/kg). The concentration of antimony (Sb) and arsenic(As) shows no much difference across the depths. Statistically, there was a much difference between the six metals ($t = 0.595$, $p = 3.020$) for cobalt, ($t = 0.222$, $p = 1.440$) for chromium, ($t = 0.969$, $p = 25.42$) for manganese, ($t = 0.092$, $p = 71.15$) for iron and ($t = 0.038$, $p = 0.020$) for both antimony and arsenic respectively. It was observed that concentration of the metals under study were lower than Dutch optimum and action values, except for Co in depths 0-10 cm and 10-20 cm. The mean and median of cobalt, chromium, manganese and iron show relatively close differences on the polluted soil at depths 0 – 10 cm and 10 – 20 cm, while at depth 20 – 30 cm, there is no relative closeness .The reverse is the case for control soil, except for antimony and arsenic which shows no pollution effects. The contamination factors for Co showed $1 < CF \leq 3$ (10-20 cm and 20-30 cm) and $1 < CF$ (0-10 cm), while Cr, Sb, Mn, Fe and As also show $1 < CF$ (0-10 cm). There is clear evidence of pollution when the concentrations of polluted and unpolluted soils were compared. As such an effort should be made by the government to monitor the indiscriminate dumping of e-waste in the community in order to avoid such pollution level.

1.0 Introduction

Obsolete electrical electronic equipment, referred to as e-waste are randomly dumped in our environments in both developing and developed nations, based on the trend of technology of this present day. Developing countries like Nigeria, India and other are facing concurrent flow of e-waste through domestic generation and illegal import (Vats and Singh, 2014). These generation and illegal import are as a result of globalization, transfer of technology, concurrent change in technology, affordable price of sensitive equipment and illegal dumping (Vats and Singh, 2014).

The huge amount of e-waste generated globally, pose a lot of threat to the waste treating agencies due to the hazardous metals, inorganic and organic compounds generated by them. E-waste are made up of different components like glass, metals, plastics and ceramics that contain hazardous compounds, such as polychlorinated biphenyls (PCBs) and brominated flame retardants (BFRs), Jinhui et al., 2011). The also contain a lot of heavy metals, such as chromium (Cr), found in floppy disk, magnetic tape etc, arsenic (As), found in light emitting diodes, manganese (Mn), found in battery, beryllium (Be), found in silicon-controlled rectifiers, antimony (Sb), found in flame retardant, additives in plastics and resins, copper (Cu), found in printed circuit board, wires and cables etc (Wu et al., 2008, Furlani et al., 2009, Jinhui et al., 2011).

Soil is regarded as contaminated when the concentration of the heavy metals present in that horizon exceed the permissible limit values for an uncontaminated soil (Proust et al., 2013, Salman et al., 2019). In fact, soil pollution has adverse effect on food safety, thereby increasing health risk (Salman et al., 2016a, Salman et al., 2019). It has been reported that heavy metal pollution on soil surface from an e-waste dismantling site poses a potential risk to human and the environment (Jinhui et al., 2011). Arsenic is known to exhibit toxicity symptoms of resisting seed germination, altering the height of plant, reducing the root and shoot growth, decreasing grain and fruit production and probably leads to death sometimes (Abedin et al., 2002, Jahan et al., 2003, Salman et al, 2019). It has been reported that chronic inhalation of too much concentration of iron oxide fumes have led to benign pneumoconiosis, known as siderosis which is seen as an x-ray change (Adaramodu et al., 2012) . Chromium has been known to cause skin rashes, kidney and liver damage, as well as carcinogens (Adaramodu et al., 2012). Studies have also shown that its bioaccumulation in organisms generates biomagnifications in the food chain leading to endocrine disruption as a result of leaching of polychlorinated biphenyls (PCBs) from e-waste (Deng et al., 2007, Richard et al., 2013). Heavy metal pollution in soil as a result of e-waste is persistent in the soil, accumulative in plants, animals and humans through food chain exposure to them. They also cause problems to our nervous system and genitourinary system (CDPHE, 2008, Richard et al., 2013).

Gases such as chlorofluorocarbon (CFCs) have been released into the environment as a result of landfill with obsolete e-waste such as freezers, refrigerator and air conditioning unit containing ozone depleting gases (Scheutz et al., 2014, Richard et al., 2013). Recent times, much attention has been paid to e-waste recycling site and surface dust, but none or little attention has been given to e-waste dumpsites without burning or any other waste mixed up with it. This study therefore focuses on the assessment of pollution generated by e-waste dump site.

2.0 Materials and Methods

2.1 Study Area

Abraka, a University town in Ethiope East Local Government Area of Delta State, is one of the most developed communities in the state . The geographical location of the sampling point is Latitude 06.23’01 45°N and Longitude 007.73’09 80° E. It has a level surface area with poor drainage system and also with heavy amount of rainfall during rainy season, mainly as from May - September .

Corresponding author’s e-mail address: eyenokero2013@gmail.com

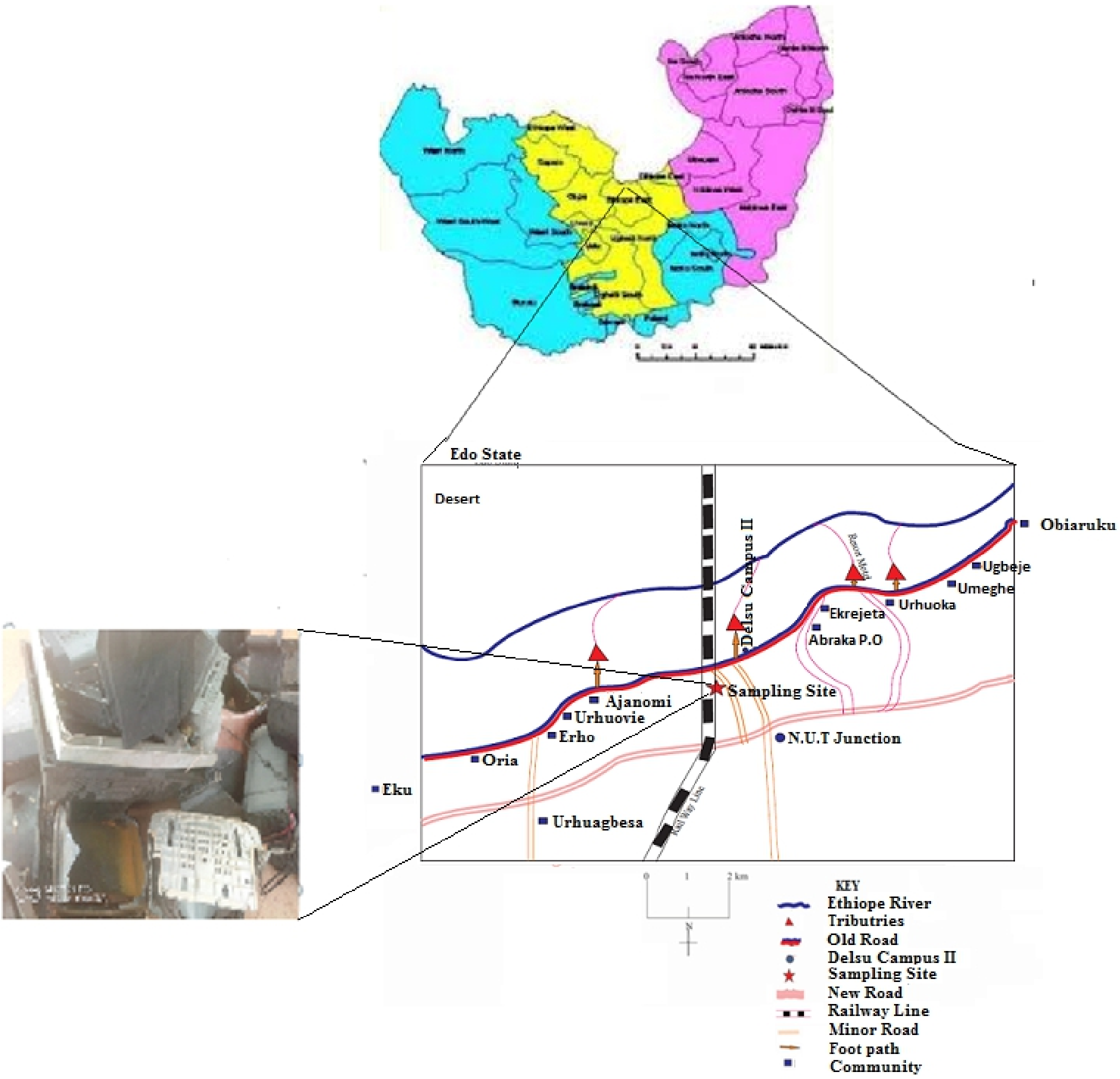

Figure. 1: Map of Delta state /Abraka showing the sampling site

2.1.1 Soil Sampling and Preparation

The soil samples were collected during raining season from two different site (polluted and unpolluted soils), at three different depths (0 - 10 cm, 10 – 20 cm and 20 – 30 cm). The unpolluted which serve as control samples were collected from reserved area used by a peasant farmer, having only foot path as the access road to it, far away from the community and has no history of fertilizer, herbicide or pesticide application. The samples were taken from six spots from each site and were mixed to form composite sample of three each from both sites. The samples were collected with soil auger into a black polythene bag and conveyed into the laboratory immediately, they were spread on white sheets of paper for air drying at room temperature, for five days. Thereafter, they were pulverized with mortar and pestle and sieve with 2mm mesh sieved to separate the coarse particle from the fine particle prior to digestion.

Figure 2: E-waste dump site in Abraka.

2.1.2 Laboratory Analysis

The soil samples were digested according to the method used by Adaramodu et al. (2012), the digests were analyzed for heavy metal concentration using Atomic Absorption Spectrophotometer (AAS) (model: Perkin Elmer 1100).

2.1.3 Contamination Factors (CF) and Degree of Contamination

The CF is determine using the following equation

$$C_f^i = \frac{C_{0-1}^i}{C_n^i} \quad (1)$$

Where C^i_f is the contamination factor of the element under study, $C^i_{0-1}$is the concentration of the element in the sample, and C^i_n is the background value or the continental crustal average as was used by Taylor and McLennan (1985). The categories of its definition are as follow; CF < 1 = low contamination, 1 < CF ≤ 3 = moderate contamination, 3 < CF ≤ 6 = considerable contamination, and CF > 6 = very high contamination. The degree of contamination can as well be determined by this equation, $C_{deg} = \sum C_f^i$, which is the sum total of the contamination factors of all the element under study. Its categories definitions are as follow; $C_{deg} < 8$ = low degree of contamination, $8 \leq C_{deg} < 16$ =moderate degree of contamination, $16 \leq C_{deg} < 32$ = considerable degree of contamination and $C_{deg} \geq 32$ = very high degree of contamination.

2.1.4 Data Analysis

The data were computed using Microsoft excel of windows 10 version and tested with one tailed t-test at 95% confidence level.

3.0 Results and Discussion

Table 1 reveals the mean ± SD concentration of heavy metals results obtained for both polluted and unpolluted soil, while Table 2 presents the median concentration results for both the polluted and the unpolluted soil across depths.

Table 1 : Mean ± SD concentration of heavy metals for both soil (mg/kg) across depths.

Metals	Mean ± SD (mg/kg)						DUTCH (mg/kg)	
	POLLUTED SOIL			UNPOLLUTED SOIL			Optimum	Action
	0-10 cm	10-20cm	20-30cm	0-10 cm	10-20cm	20-30cm	Optimum	Action
Co	21.56 ± 25.42	22.65 ± 24.25	10.82 ± 17.28	20.21 ± 40.31	20.21 ± 40.31	24.16 ± 38.41	20.00	240.00
Cr	10.19 ± 9.74	8.65 ± 10.83	6.55 ± 11.33	5.66 ± 11.21	5.66 ± 11.21	6.75 ± 10.69	100.00	380.00
Sb	0.04 ± 0.02	0.03 ± 0.03	0.02 ± 0.02	0.05 ± 0.01	0.05 ± 0.01	0.04 ± 0.02	3.00	15.00
Mn	78.15 ± 64.44	51.16 ± 68.01	41.98 ± 71.35	53.70 ± 55.01	68.74 ±47.76	50.51 ± 45.84	1500.00	2,500.00
Fe	1095.60 ± 52.92	652.02 ± 666.31	420.44 ± 659.77	128.44 ± 114.26	118.32 ± 122.14	120.75 ± 120.38	-	-
As	0.04 ± 0.02	0.03 ± 0.03	0.02± 0.02	0.05 ± 0.01	0.05 ± 0.01	0.04 ± 0.02	29.00	55.00

S D = Standard Deviation

Table 2 : The median concentration of both polluted and control soil across depths.

Metals	Polluted soil – Median			Control soil – Median		
	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm
Co	18.325	20.516	3.346	0.056	0.056	7.957
Cr	8.440	5.365	1.167	0.056	0.056	2.239
Sb	0.050	0.027	0.004	0.050	0.050	0.042
Mn	79.005	25.789	7.424	50.567	79.952	43.501
Fe	1211.765	553.719	92.282	83.648	70.764	75.615
As	0.050	0.027	0.004	0.050	0.050	0.042

3.1 Cobalt

From Table 1, Co displayed high concentration at depth 10 – 20 cm and 20 – 30 cm on both soils. The values are almost of the same range at 0 – 10 and 10 – 20cm, and about 2 times higher in control than the polluted soil, the concentration of Co on the control is of geogenic origin. Statistically, there was not much significant difference between the concentration across the depths on the polluted and control sites (t = 0.595, p = 3.020). This shows that the e-waste has contributed little contamination of Co to the soil across the depths. These values were lower than the values reported by Jadhav et al. (2017) (68.18 – 93.99 mg/kg) in a similar study. Since the mean values of Co in depth 0 – 10 and 10 – 20 cm are close to the median values (Tables 1 and 2), there is an indication that the dataset undergoes normality after transformation. For depth 20 – 30 cm, there is significant variation in the concentration of Co. This indicates that the dataset was log transformed (Tables 1 and 2). The mean values of Co in both polluted and control soil were above the optimal value of Dutch (20.00 mg/kg) at depth 0 – 10 cm and 10 – 20 cm for polluted soil and across the three depths for control soils but were lower in depth 20 – 30 cm for polluted soil. All the values were below Dutch action value of 240 mg/kg. Co and its compounds are known to be in group 2B and is possibly carcinogenic to human, they are also responsible for skin irritation (IARC, 2015).

3.1.1 Chromium

Chromium showed a good distribution of concentration as it decreased across the depths. The mean concentration of Cr in polluted soil is about 1 - 2 times higher than that of the control in depths 0 – 10 cm and 10 – 20 cm and there is no significant difference in depth 20 – 30 cm. The mean and median values of Cr across the depths (Tables 1 and 2) of both soils varied significantly from each other. This implies that the datasets were not normally distributed. The decrease with increase in depths corroborate with the findings of Oladunni et al. (2013). The value on both sites were 10 – 30 times lower than the optimal and action values of Dutch (100.00 and 380.00 mg/kg). This implies that the content of Cr in the e-waste is minimal to generate much of its concentrations in the soil. Therefore, there is no cause for alarm since the levels of Cr are low. Statistically, there was no significant difference between the concentration of both site across the depths (t = 0.222, p = 1.440). Concentrations of Cr in this study were low when compared to those of Jadhav et al. (2017). The concentration of Cr at both sites varied from 6.55 – 10.19 mg/kg and 5.66 – 6.75 mg/kg respectively. This is an indication that the e-waste has contributed some levels of contaminants to the soil. These values were low when compared to those reported by Sampson et al. (2012) (21.60 mg/kg)and higher than those reported by Benedicta et al, (2017) (3.03, 2.28, and2,36 mg/kg) in similar studies. Cr is a component of floppy disc and magnetic tape (Jinhui et al., 2011). Cr has been reported to cause skin rashes, kidney and liver damages and carcinogenic effects in human (Adaramodu et al., 2012). Cr (VI) compounds irritate the eyes, skin and mucous membrane (Oladunni et al., 2013).

3.1.2 Antimony

Antimony showed not much difference in concentrations on both soils across depths indicating that the e-waste has not contributed contaminants to the soil. The non much difference observed in mean and median (Tables 1 and 2) for Sb across depths, shows that the datasets were normally distributed. The mean concentration of Sb on both soil across depths were lower than optimal and action values of Dutch (3.00 and 15.00 mg/kg) respectively (Khadijal, 2016). Statistically, there was no significant difference on both sites across depths (t = 0.038, p = 0.020). This implies that the probability of e-waste contributing contaminants of Sb(0.02 - 0.04 mg/kg) to the soil is minimal. Sb concentration on both soils were far lower when compared to those reported by Jinhui and Pixing (2011) (9.90, 7.20, 9.10, 1,100 mg/kg) at different site. Sb is known to be toxic to blood, kidney, lungs, nervous system, liver and the mucous membranes through ingestion or inhalation (IARC, 2015).

3.1.3 Manganese

Manganese displayed high concentration at depths 0 - 10 cm and 10 – 20 cm (78.15 and 68.74 mg/kg) (Table 1) on both sites. The data showed significant difference across depths and sites (78.15, 51.16, 41.98 mg/kg and 53.70, 68.74,50.51 mg/kg) respectively. These concentrations are low when compared to the value reported by Jinhui and Pixing (2011) (300.00 mg/kg) and higher than those reported by Brigden et al. (2005) (< 2.00 mg/kg). Also, the mean concentration is relatively close to the findings of Wu et al. (2008) (85.5 mg/kg). Contaminant of Mn on the polluted soil only occurred at depth 0 – 10 cm. The mean and median values (Tables 1 and 2) for polluted soil were not close to each other across depths. This signifies that the datasets are not normally distributed, which also proves that the datasets were log transferred. While in the control soil, the mean and median values (Tables 1 and 2) were close. This implies that the datasets were normally distributed. The concentration of Mn on both sites were below the recommended standard of level that demand attention and intervention (1,500.00 and 2,500.00 mg/kg) (Sampson et al, 2012). Statistically, there is much difference on both site and across depths (t = 0.969, p = 25.42). This signifies that the probability of Mn contaminating the soil via the e-waste dump is high. Mn is found in batteries (Jinhui et al., 2011).

Corresponding author's e-mail address: eyenokero2013@gmail.com

3.1.4 Iron

Iron displayed high concentrations across depths on both sites ranging from 420.43 – 1095.60 mg/kg for polluted soil and 118.32 – 128.44 mg/kg for control soil. These values are high when compared to those reported by Adaramodu et al. (2012) (108.00 and103.30 mg/kg). The high concentration of Fe on both soils might be ascribed to the presence of the e-waste and other anthropogenic activities. The highest concentration was observed at depth 0 – 10 cm for both soils. There is much difference between the mean and median values across depths. This proves that the datasets were not normally distributed on both sites. As such, the datasets were log transferred. Statistically, there is much difference between the datasets across depths and site ($t = 0.092$, $p = 71, 15$). This implies that the probability of contamination of Fe by the e-waste is very high. This might also be due to high percentage of iron present in them, such as 20.47% of Fe in desktop computer (Adaramodu et al., 2012).Long term exposure by inhaling iron oxide fumes or dust can lead to a problem of benign pneumoconiosis, called siderosis that can be detected as an x-ray change (Adaramodu et al. (2012).

3.1.5 Arsenic

There is not much difference between the concentrations of As across depths and sites. This implies that the e-waste has not contributed contaminant to the soil. The closeness of the mean and median values on both sites shows that the datasets are normally distributed. Statistically, there were not much different across depths and sites ($t = 0.037$, $p = 0.020$). This signifies that the probability of As contamination by the e-waste on the soil is minimal. All the values of As (0.02 - 0.05 mg/kg) for both soils are lower than the optimal and action values of Dutch (29.00 and 55.00 mg/kg). Arsenic concentrations are lower than the value reported by Jinhui and Pixing (2011) (26.03 mg/kg) and those of Brigden et al. (2005) (< 200 mg/kg), but corroborated with the findings of Benedicta et al (2017) (0.04-3.67 mg/kg). Arsenic is found in light emitting diodes (Furlani et al., 2009, Jinhui et al., 2011). Long term exposure of As can lead to acute poison and injurious to human health (Jadhav et al., 2017). Arsenic also exhibit toxicity symptoms in plant, such as inhibition of seed germination, decrease in plant height, reduction in root growth, lower fruit and grain yields and even death can occur (Salman et al., 2019). Arsenic associated with the human solid food chain at the contamination of the products and fodder (Salman et al., 2019).

Figures 2, 3, 4 and 5 present the contamination factors profile and the degree of contamination for both polluted and unpolluted soils across the depths.

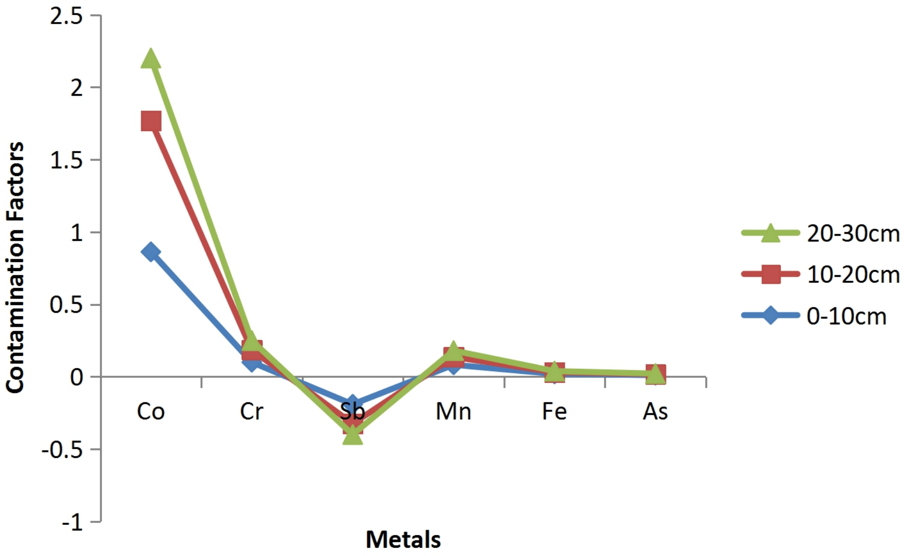

Figure 2 : Contamination factors profile of the metals under study on the polluted soil.

Corresponding author's e-mail address: eyenokero2013@gmail.com

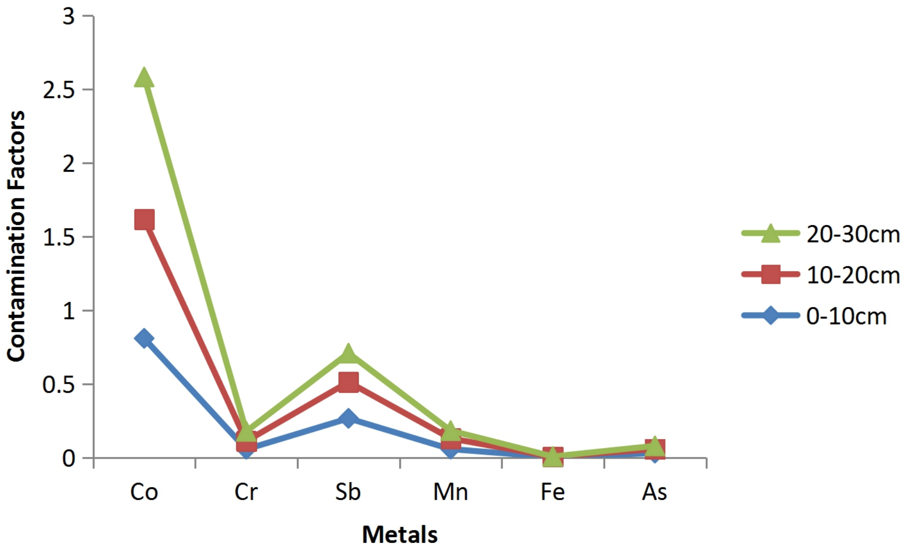

Figure 3 : Contamination factors profile of the metals under study on the unpolluted soil.

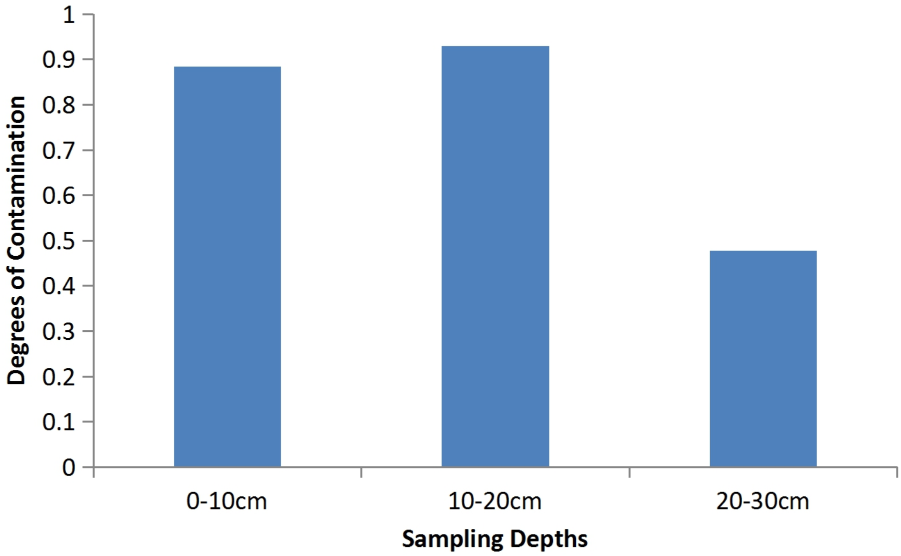

Figure 4 : Degrees of contamination of different depths on polluted soil.

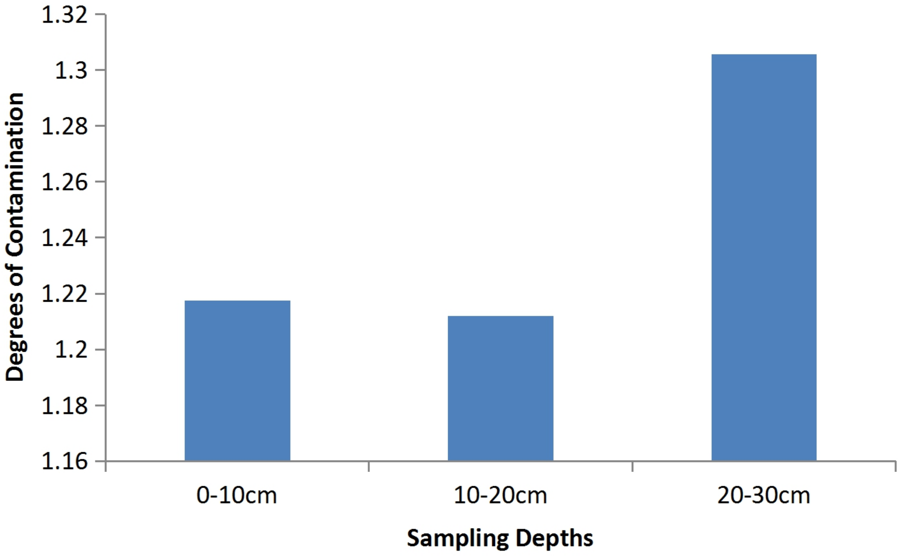

Figure 5 : Degrees of contamination of different depths on unpolluted soil.

Corresponding author's e-mail address: eyenokero2013@gmail.com

The calculated contamination factors profile in figure 2 (polluted soil), display that at depths 10 – 20 cm and 20 – 30 cm, Co shows moderate contamination since its values fell into the categories of $1 < CF \leq 3$ and at depth 0 – 10 cm, it displayed low contamination since its values fell into the categories of $CF < 1$. Cr, Sb, Mn, Fe and As shows low contamination, Figure 3 (unpolluted soil) also followed the same trend.

The calculated degree of contamination plot in Figures 4 and 5 displayed low degree of contamination since all the values fell into the categories of $C_{deg} < 8$. The highest calculated degree of contamination was observed in depth 10 – 20 cm (1.00) and 20 – 30 cm (1.31) for polluted and unpolluted soil respectively. This might be due to the penetrating ability of the metals in the soils.

4.0 Conclusion

E-waste is generally known to cause environmental pollution with serious health problems as a result of the chemical constituents associated with them. The results of this study showed that the e-waste contributed Co, Cr, Mn, and Fe to the soil across depths, except in depth 20 – 30 cm for Co, which indicates that e-waste dumping can generate toxicity risk to human with long term exposure, and there was no evidence of contamination of Sb and As on the soil. However, the concentration of Co, Cr, Mn and Fe are still below the optimal and action level of Dutch. It was also observed that the datasets of some of the metals across depths were normally distributed, since there is a relative closeness between the mean and the median values, while some other were not, as there is no relative closeness between the mean and median values. The results from the calculated contamination factors and degree of contamination showed low contamination for some metals and moderate contamination for others. In fact, environmental pollution by heavy metals through e-waste dumping generates hazards to human, animals and even plants development, via bioaccumulation and biomagnifications as animals occasionally graze on grasses around the area. The dumping of e-waste, especially by the electrical and electronics work men around their premises has the capability to pollute the environment. Therefore, it should be monitored and prevented to save the immediate environment from pollution.

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Corresponding author's e-mail address: eyenokero2013@gmail.com