

## Evaluation of Selected Heavy Metals Distribution on Bitter Leaf (*Vernonia amygdalina*) Grown around e-Waste Dumpsite in Abraka Delta State, Nigeria

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### ABSTRACT

The level of heavy metals in soil and *V-amygdalina* plant planted around e-waste dump site were investigated in this work, due to their associated pollution that is not biodegradable but accumulate in plants and animals. The soil around the e-waste dump site and two sample of *V-amygdalina*, i.e. both polluted and control soil were collected and analyzed via digestion and Atomic Absorption Spectrophotometer (AAS). The heavy metals mean concentrations ranged from 2.60 mg/kg (20 – 30 cm) – 1759.54 mg/kg (0 – 10 cm) across depths the trends where Fe > Co > Mn > Pb > Zn > Cr > Cu > Ba > Ni > Cd across depths. The polluted *V-amygdalina* (bitter leaf) plant mean concentrations follows the trend of unwashed leaf > washed leaf > stem > root across each metals. The statistical analysis displayed minimal significant difference that spanned from  $t = 0.06 - 0.22$  and  $p = 7.27 - 88.34$  for all the metals. The comparison of the heavy metals concentrations on the polluted plant with control and WHO/FAO permissible limit, it shows that pollution of some of the metals were observed on the plant while the reverses is the case for other metals since their values were above and below the control and WHO/FAO value. Contamination factors were low for all the metals in the categories of  $CF < 1$ , except Cd which displayed negative and high CF of  $CF > 6$  on both polluted and control plant. The leaf (washed and unwashed) and stem displayed very high concentrations that fell in the categories of  $C_{deg} \geq 32$ , while only the unwashed and stem displayed very high  $C_{deg}$ . The root displayed considerable  $C_{deg}$  of  $16 \leq C_{deg} < 32$  respectively. The transfer factor follows the trend of  $Cu > Fe > Ba > Co > Ni > Zn > Cd > Cr > Pb > Mn$  respectively. Pollution were observed when heavy concentration were compared with control and WHO/FAO concentration limit, hence effort should be made to control the rate of dumping e-waste indiscriminately.

**Keywords:** Heavy metals, soil, bitter leaf plant, e-waste, dumpsite, pollution.

### Introduction

The environmental concentration of heavy metals has risen up greatly, due to the anthropogenic activities globally, either from individual homes or other sources like industries all over the world.

These activities pollute soil, water and air, due the hazardous substances like cobalt (Co), cadmium (Cd), mercury (Hg), lead (Pb), polycyclic aromatic hydrocarbon (PAHs) among others, present in

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them. These substances are found in e-waste and have much chronic effect on plants and animals, due to their level of accumulation in plants and animals to an extent that is beyond acceptable limit (Benedicta *et al.*, 2017 Eyenubo *et al.*, 2020c).

Page | 4207 Much quantity of e-waste is generated globally and they lead to serious environmental issues. These e-waste consist of different components such as metals, plastic, ceramics and glasses that contains hazardous compound like polychlorinated biphenyls (PCBs) and brominated flame retardant (BFRs) (Jinhul *et al.*, 2011 Eyenubo *et al.*, 2020b.). Pollution occurs when the level of heavy metals in soil are beyond acceptable limit values for unpolluted soil (Salman *et al.*, 2019). From the polluted soil, plant absorb heavy metals depending on their solubility in the soil, soil pH, plant growth stages, fertilizers and soil types (Doherty *et al.*, 2012). It is wise for the public to know whether vegetable like *Vernonia amygdalina*, fruits and other food crops planted around e-waste polluted area are safe or not for human consumption, since the quality of food production is of greater interest (Emmanuel *et al.*, 2020). Within the food chain, plant may absorb a high quantity of heavy metals that will result into health problems to consumers. This absorption occurs via the root of plant and is based on the types of metal absorb, the physiochemical characteristics of the soil and variety of plant (Emmanuel *et al.*, 2020). Food items pollution with heavy metals is an important issue needed to be considered for human consumption. Hence, food contamination by heavy metals will not be undermined because of the nutritive values of the food that help in maintaining the human body (Emmanuel *et al.*, 2020). As a result of the risk generated by toxic metals in food varieties, the global regulatory bodies of food quality have brought down the optimum permissible limit of such metals in food (Emmanuel *et al.*, 2020).

Bitter leaf is majorly planted in Africa countries, majorly in Sub – Saharan Africa. It is a small plant

of 23 feet in height, the stem having a rough texture with brownish colour. It is medicinal with its leaf have a significant role in human food since it contains some nutrients like vitamins and mineral salt (Echem and Kabari, 2012, Sobukola and Dairo, 2007). *Vernonia amygdalina* plant (leaf, stem and root), as an important plant, since it has a maintenance features to human and find its use as preventive agent and cure for various types of diseases, because of the compound called steroid glycosides, found in Vernonioside B1, which serves as an anti-parasitic, ant – tumour and bactericida effect (Echem and Kabari, 2012). It also used for the cure of Schistosomiasis, which emanated from parasitic worm and diaorrhoea treatment. It plays the role of cleansing agent for some important organs in human body like liver and kidney and in the cure of skin diseases like eczema, rashes and ringworm. Notwithstanding, *Vernonia amygdalina* can accumulate some toxic and non-toxic heavy metals in a large amount, hence it is selected for the study alongside with the soil.

Anthropogenic activities like e-waste dumping may deposits heavy metals through photolytic degradation into the environment where plant dwell and will in turn absorb these contaminants through its root, though some of them are important in plant growth and nourishment to animal and human. When their levels exceed the standard limit, i.e. at elevated state, they become toxic to human body when those contaminated food are consume by man. The absorption of metals and its bioaccumulation in plant is subject to some factors like background geology and soil composition, climate, roads and areas where industries are located, deposits from atmosphere and the extent of plant maturity at the time of harvest (Emmanuel *et al.*, 2020). This study tends to investigate the extent to which soil around e-waste dumpsite and *Vernonia amygdalina* close to the dumpsite absorb heavy metals.

## Materials and Methods

### Study Area

Abraka is a University community, and is among the top most developing town known in Ethiopia East Local Government Area of Delta State, Nigeria. The sampling site has a geographical location of Latitude 06.23°01' 45"N and Longitude 007.73° 09' 80"E. It has a plain surface topography with a porous drainage system and high quantity of rainfall during wet season (Eyenubo *et al.*, 2020b).

### Soil Sample Collection

The soil samples were obtained from the surroundings of the e-waste dumpsite at depths 0 – 10 cm, 10 – 20 cm and 20 – 30 cm. They were properly placed in a clean polythene bags, labeled and conveyed to the laboratory for further analysis. The plant samples grown very close the dumpsite were also collected. The plant that serves as the control was collected from a far distance (4.83 km or 3 mile) that has no history of dumpsite and use of fertilizers, herbicides or vehicular or industrial emission.

### Soil Sample Preparation and Digestion

The soil samples were dried via spreading on clean polythene paper in the laboratory at room temperature for 5 days. Thereafter, crushing with mortar and pestle was done and made to pass through 2 mm mesh sieve to obtain the finest particles and remove the coarse particles. The plant sample, leaf, stem, root, both washed and unwashed were chopped into pieces and placed in the oven at 80° C for drying until a stable weight was achieved. Then they were pulverized into small particles and also sieve with 2 mm mesh sieve. The sieved samples of soils and plants were stored in polythene bags awaiting digestion. 1 g was weighed from each of the sieved sample and placed in Teflon beakers and 3 ml of nitric acid and 9 ml of hydrochloric acid were added and heated using hot plate at 70° C until brownish fumes were observed almost at the drying stage of the solutions. They were then mixed with

50 ml of deionised water and filtered with No. 42 Watchman filter paper and then discharged into a sterile universal bottle for further analysis using Atomic Absorption Spectrophotometric (AAS) (Perkin Elmer 1100).

### Contamination Factor (Cf) and Degree of Contamination

The equation (1) was used for the determination of CF

$$C_f^i = \frac{C_o^i - 1}{C_n^i} \text{-----} (1)$$

Where  $C_f^i$  stands for contamination factor of the metal,  $C_o^i$  stands for elemental concentration in the sample and  $C_n^i$  is the continental crustal average generated by Taylor and Mclennan (1985) or background values. By categories, the variable definitions of the variables are as follows;  $CF < 1$  = low contamination,  $1 < CF \leq 3$  = moderate contamination,  $3 < CF \leq 6$  = considerable contamination, and  $CF > 6$  = very high contamination. The determination of the degree of contamination can be done by equation (2).

$$C_{deg} = \sum C_f^i \text{-----} (2)$$

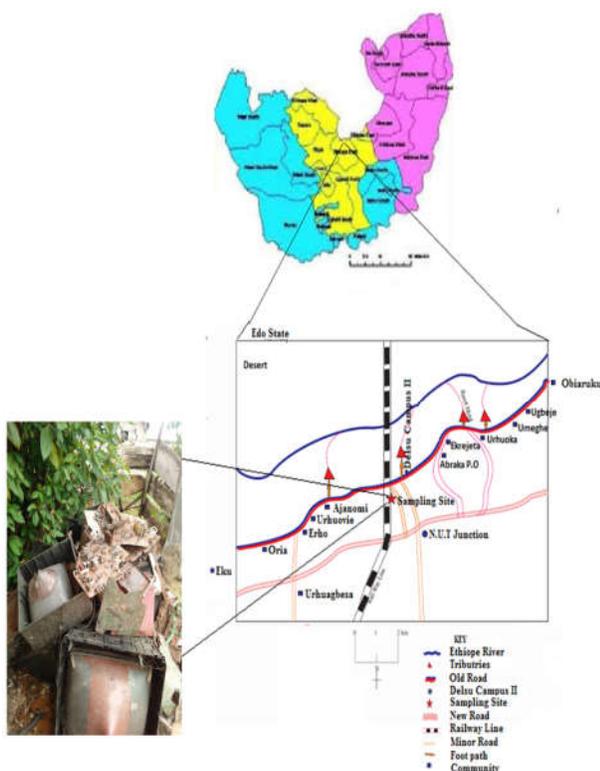
Which is the sum of all element for contamination factors under study. Variables definitions by categories are  $C_{deg} < 8$  = low degree of contamination,  $8 \leq C_{deg} < 16$  = moderate degree of contamination,  $16 \leq C_{deg} < 32$  = high degree of contamination and  $C_{deg} \geq 32$  = very high degree of contamination.

### Transfer Factors

This is the ratio of heavy metals in plant to heavy metals in soil concentration.

### Data Analysis

Window 10 was used to analyze the data and tested with one tailed t-test at 95% confidence level. This analysis was done in triplicate.



**Figure 1:** Map of sample site showing sampling points.



**Figure 2:** Sample site showing dumped electronic wastes and bitter leaf plant around it.

## Results and Discussion

The mean and the median concentration of heavy metals in the soil around e-waste dumpsite across various depths were presented in table 1.

Figures 2, 3, 4 and 5 shows the contamination factors and degree of contamination profile for polluted and control plant across its parts.

The concentration trends of the heavy metals (Table 1) were iron (Fe) > cobalt (Co) > manganese (Mn) > lead (Pb) > zinc (Zn) > chromium (Cr) > copper (Cu) > barium (Ba) > nickel (Ni) > cadmium (Cd) across depths.

Ba concentrations at depths 0 – 10 cm and 20 – 30 cm ranged from 24.27 – 2.12 mg/kg. The values Ba reported in this work are far lower than the report of Khadijah, (2016) (627.66 mg/kg) in a related study. The mean and median data at depth 0 -10 cm and 20 – 30 cm were close to each other, this indicates that at these depths, the data sets were properly circulated. At depth 10 – 20 cm, there is considerable variation which indicates that the data sets were not properly circulated (Kahdijah, 2016). The values of Ba were about 8 – 25 times lower than the maximum and action values of Dutch (200.00 and 625.00 mg/kg) (Kadijah, 2016).

Cd concentration decreases down the depths, spanning from 0.47 mg/kg (20 – 30 cm) to 8.77 mg/kg (0 – 10 cm). There were significant differences in the data obtained from the dump site (40.92 mg/kg) at depth 20 – 30 cm. Similar observation had been reported (Eyenubo *et al.*, 2020c). This implies that Cd leaching down the soil profile is poor due to poor pattern of drainage system at the dump site. Comparing the concentration of Cd with the maximum and action values of Dutch (1.00 and 12.00 mg/kg)

indicates the adequacy of the soil for agricultural purpose. The mean and median values were close to each other at depths 0 -10 cm and 20 – 30cm, which implies that the data sets were properly circulated there at those depths. The reverse is the case at depth 10 – 20 cm. The concentration trends across depths are 0 -10 cm > 10 – 20 cm > 20 – 30cm.

Co showed high mean concentration in the soil, which spanned from 86.06 mg/kg (20 – 30 cm) to 108.59 mg/kg (0 – 10 cm) i.e. it decreases with increase in depths. The values are higher than the maximum and action values of Dutch (20.00 and 240.00 mg/kg). This implies that considerable concentration has been by the e-waste to the surrounding soil, rendering the soil unfit for agriculture. In comparing mean and median values, there is much level of variation across the depths, which led to irregular circulation of the data sets. These values corroborates with the report of Jadhav *et al.*, (2017) (68.18 – 93.99 mg/kg) in a similar study.

Cr displayed low mean concentrations that spanned from 14.29 mg/kg (20 – 30 cm) to 29.31 mg/kg (0 – 10 cm). In relating these values with the maximum and action values of Dutch (100.00 and 380.00 mg/kg) shows that Cr has a minimal contaminant in the electrical electronics waste that leached out contaminant to the soil closer to the e-waste and as such, there is no cause for alarm. The values of Cr at depths 0 – 10 cm and 10 – 20 cm are close to the median values, while at 20 – 30cm, it varied significantly. This reveals that the data sets displayed usual circulation at 20 – 30 cm. This decrease in the mean concentration of Cr across the depths corroborate with the findings of Eyenubo *et al.* (2020b) and those of Oladunni

*et al.*, (2013). It has been reported that chronic exposure to Cr compounds lead to permanent injury to eye and damaging effects of DNA (Oladunni *et al.*, 2013).

The mean level of Cu spanned from 9.31 mg/kg (20 – 30 cm) to 28.96 mg/kg (0 – 10 cm), Cu displayed low values when compared to the maximum and action values of Dutch (36.00 and 190.00 mg/kg). This indicates that the level is not alarming and there is no significant leaching of Cu content from the e-waste to the surrounding soil. Depth wise Cu distribution decreases with increase in depths and at depths 0 – 10 cm and 10 – 20cm, the median values are close to the mean values. This indicates that the circulation of the data sets were normal. At depth 20 – 30 cm, there is significant variation which shows an irregularity in the data sets circulation at that depth. Our previous study values Eyenubo *et al.*, (2020c) are higher than the values reported in this study.

Fe levels show high values that spanned from 706.83 mg/kg (20 – 30 cm) to 1759.50 mg/kg (0 – 10 cm) across depths. These data are consistent with the values Eyenubo *et al.*, (2020b) reported in similar study and higher than the value Adaramodu *et al.*, (2012) reported. The high values of Fe might be anchored on the leaching of Fe from the e-waste dump site and geogenic effects. In comparing the mean and the median values, there is a significant variation all through the depths. This indicates that the data sets were not properly circulated. Long term exposure to Fe via inhaling of iron oxide results in pneumoconiosis (Adaramodu *et al.*, 2012).

Mn concentrations showed low values that spanned from 18.68 mg/kg (20 – 30 cm) to 66.74 mg/kg (0 – 10 cm). As the depths

increases, there is decrease in the values of Mn and the mean values varied significantly from the median. This shows that there is an irregular arrangement of the data sets. The values reported in these study are similar to the report of Emmanuel *et al.*, (2020) (41.33, 77.19 and 36.60 mg/kg) across different sites and Eyenubo *et al.*, (2020b) in related studies.

Ni displayed low mean concentrations across depths, it spanned from 2.60 mg/kg (20 – 30 cm) to 10.44 mg/kg (0 – 10 cm). As the depth increases, the concentration decreases. The mean and the median values shows some level of closeness across depths. This indicates that the circulation of the data sets were normal. Ni concentrations in this study are far lower when they are compared to the report of Oladunni *et al.*, (2013) (62.68, 69.55, 56.68 mg/kg etc.) in a related study. In comparing Ni values with the maximum and action values of Dutch (35.00 and 210.00 mg/kg), they are found to be 13 – 20 times lower, hence is not alarming.

Pb concentrations were low across depths, varying from 9.31 mg/kg (20 – 30 cm) to 58.89 mg/kg (0 – 10 cm). The maximum and action values of Dutch (85.00 and 530.00 mg/kg) are higher than these values, but these values are higher than WHO/FAO standard limit value of 50.00 mg/kg (Ahiakwo and Kingsley, 2019). This might be anchored to weak drainage system due to the level topography of the soil at the dump site and also high binding capacity of the top soil to e-waste contaminant. The Pb values in these study are quite similarity to the report of Oladunni *et al.* (2013) (288.35 and 232.55 mg/kg) in a related study. The values also decrease with depths.

Zn concentrations revealed low levels that spanned from 9.24 mg/kg (20 -30 cm) to 34.54

mg/kg (0 – 10 cm). As the depths increases, the value decreases. The maximum and action values of Dutch (140.00 and 720.00 mg/kg) are higher than these values. As such, it is not alarming. There is relative closeness of these values to some values (0 – 10 cm) reported by Oladunni *et al.*, (2013) (36.54, 35.59, 32.08 mg/kg) and are far lower than the report of Emmanuel *et al.*, (2020) in a related study.

The concentration of the mean and median in relation to all the parts of plants around e-waste dumpsite and control site are showed in table 2 and 3.

Ba displayed low concentrations in all the parts of *V. amygdalina* plant, ranging from 1.39 mg/kg (root) to 7.37 mg/kg (unwashed leaf) (Table 1). When compared with the control (Table 3), no trace of pollution was observed and this might be anchored on the leaching from the electrical electronic dump site. Ba concentrations displayed a tangible variation between the unwashed (7.37 mg/kg) and the washed leaf (3.37 mg/kg) and the pattern of the heavy metal concentrations in all the segments of plants were unwashed leaf > washed leaf > stem > root. The mean and median values of washed leaf were closer to each other which shows that the data sets were properly arranged, while in the unwashed leaf, sets of stem and root, the data sets displayed irregularity in terms of arrangement since the values are not close to each other. Statistically, minimal significant difference were observed in all the plant segments ( $t = 0.14$ ,  $p = 8.00$ ). This implies that the tendency of Ba to be leached out from the e-waste to the surrounding soil is minimal.

Cd displayed high concentrations in all the parts of plant under investigation (Table 1),

spanning from 0.06 mg/kg (root) to 8.24 mg/kg (unwashed leaf). The concentration trends is unwashed > washed > stem > root which when compared to WHO/FAO standard limit value of 1.00 mg/kg (Ahiakwo and Kingsley, 2019), trace of pollution was not detected. As such Cd level is alarming due to some threat it poses to human when consume. Statistically, minimal significant variation was detected in all the plant parts ( $t = 0.14$ ,  $p = 8.62$ ). This reveals that the tendency of leaching out Cd by the e-waste to the surrounding soil is minimal. Since we observed a p value is higher than 0.1, the mean and median values are not relatively close to each other which shows that the circulation of the data sets were irregular. The values reported by Doherty *et al.* (2012) (0.001 mg/kg) are lower than the values observed in these study.

Co mean concentrations (Table 2) in all the parts of plant revealed higher concentrations which span from 1.31 mg/kg (root) to 20.35 mg/kg (unwashed leaf) when compared to WHO/FAO allowable limit of 0.10 mg/kg (Zahraddin *et al.*, 2017). Also in comparison with the values of control which varied from 5.74 – 6.97 mg/kg (Table 3), the leaf shows evidence of pollution which call for alarm. Statistically, much differences were noticed across the segments of the plant ( $t = 0.14$ ,  $p = 19.70$ ). This indicates that there is low capability of the e-waste to leach the contaminant of Co to the surrounding soil. This may be geared to the poor drainage pattern of the soil. These values are lower in comparison with the value reported by Zahradden *et al.* (2017). There is a tangible different on the mean and median of all the parts of the plant except on the root. This implies that the data set

does not undergo proper circulation except on those data obtained from the root.

Cr displayed high concentrations (Table 1) which ranged from 1.79 mg/kg (root) to 13.08 mg/kg (unwashed), as the data were compared with WHO/FAO safe limit of 1.30 mg/kg (Zahradden *et al.*, 2017) and with the control values, pollution was not noticed from the leaching of the e-waste contaminant. Hence its concentration might be anchored on anthropogenic activities like spraying of herbicides and geogenic origin. Since the concentrations are higher than the allowable value of WHO/FAO, it calls for alarm. Statistically, much differences are observed in all the parts of plant ( $t = 0.14$ ,  $p = 13.38$ ), which is built on the fact that the e-waste has low capability of leaching out Cr contaminant to the nearby soil harboring the plants. The data sets are perfectly circulated in the control plant (Table 3) than the plant near the e-waste dumpsite (Table 2), since the mean versus median values close, while on the plant close to the e-waste dumpsite, the reverse is the case. The concentrations are higher than those reported by Zahradden *et al.* (2017) (0.07 mg/kg). Cr displayed the concentration trend of unwashed leaf > washed leaf > stem > root.

The concentrations of Cu were in the order of unwashed > washed > stem > root (Table 2), which ranged from 4.41 mg/kg (root) to 51.71 mg/kg (unwashed). This order shows that much of the heavy metals concentrations were observed on the leaf than the other parts of the plant in this study. Comparing the Cu values in all the segments of the plant with WHO/FAO allowable limit of 40.00 mg/kg (Fatai *et al.*, 2019) and the control values (Table 3), there is evidence of pollution. The leaf concentrations

call for alarm, since it is above safe limit. Statistically, high variations were observed in all parts of the plant ( $t = 0.14$ ,  $p = 47.32$ ). This shows that the e-waste displayed high probability to leach out Cu into the surrounding soil. When the mean versus the median values for the plant near the e-waste dumpsite (Table 2) were compared with those of the control site, it shows a considerable variation, which is anchored on the fact that there is improper pattern in the arrangement of the data sets. Those control site values (Table 3), show that there is a regular circulation of the data sets since the mean and median are almost of the same values.

The mean concentrations of Fe were higher (Table 2) in the trend of unwashed > washed > stem > root and it varied from 317.04 mg/kg (root) to 1447.65 mg/kg (unwashed). This indicates that the leaf displayed high binding capacity to the heavy metal concentrations than the other parts of the plant. When compared with WHO/FAO safe standard of 425.00 mg/kg (Fatai *et al.*, 2019) and the control data (Table 3), pollution was observed. This might be anchored to the leaching of Fe from the dump site to the soil harboring the plant due to the weak pattern of drainage on the site. Statistically, considerable difference were observed in all the parts of plant ( $t = 0.15$ ,  $p = 88.34$ ), which indicates that there is high probability of the e-waste to leach Fe to the surrounding, leading to high level of pollution in the plant, the trend were unwashed leaf > washed leaf > stem > root. This results corroborate with the findings of Emmanuel *et al.*, (2020) (318.97, 450.48 mg/kg etc.) for root and (1650.36, 552.64 mg/kg etc.) for leaf of *V. amygdalina* at different sites. The minimal difference observed between the mean and

median values for the plant near the e-waste dumpsite (Table 2) and the control site (Table 3), it shows that there is an irregular arrangement of the data sets within the parts of the plant, since there is significant variation.

High values of Mn mean concentrations displayed in all the parts of the plant samples (Table 2) in the order of unwashed leaf > washed leaf > stem > root and it ranged from 14.95 mg/kg (root) to 145.69 mg/kg (unwashed leaf). When compared with WHO/FAO acceptable limit of 40.00 mg/kg (Fatai *et al.*, 2019), and the control plant values (Table 3), pollution was noticed. This might be anchored on the leaching of Mn from the e-waste dump site to the surrounding soil. Statistically, there were little differences observed in all the segments of the plant ( $t = 0.11$ ,  $p = 11.25$ ). This reveals that the tendency of the e-waste leaching out Mn to the nearby soil harboring the plant is small. These data also corroborated with the value reported by Emmanuel *et al.*, (2020) (94.14 mg/kg) for leaf and lower value for root. The mean versus the median values for plants near the e-waste dumpsite (Table 2) and control site (Table 3), showed no closeness. This indicates that there is abnormality in the circulation of the data sets.

Ni mean concentrations within the parts of the plant (Table 2), show minimal concentration with the trend of unwashed leaf > washed leaf > stem > root are which spanned from 3.90 mg/kg (root) to 24.83 mg/kg (unwashed leaf). Comparing the data observed from the plant near the e-waste dumpsite (Table 2) with the control site values (Table 3), there is no evidence of pollution. This implies that e-waste has not leach Ni to the nearby soil. The Ni concentrations observed on the root agree with

the findings of Emmanuel *et al.* (2020) (7.93, 7.10, 15.75 and 3.90 mg /kg) at different sites, while the data for the leaf sample are higher. Statistically, there were some variations in the various segments of the plant under study ( $t = 0.06$ ,  $p = 23.62$ ). This implies that the probability of the e-waste to leach out Ni to the soil where plant grows is a bit high. Comparing the mean and median values for plants around the e-waste dumpsite (Table 2) and the control site (Table 3), there is abnormality in the arrangement of the data sets, since there is considerable variation between them.

Pb displayed low mean concentration in all the segments of plant, though on the leaf samples (Table 2) and across all parts (Table 3) were higher than the WHO/FAO allowable limit of 2.00 mg/kg (Ahiakwa and Kingsley, 2019), in comparing with the control values (Table 3), pollution was leached out from the e-waste to the surrounding. Statistically, there is minimal variation in all segments the plant samples ( $t = 0.23$ ,  $p = 7.26$ ), indicating that the e-waste has minimal probability to leach out Pb to the surrounding. The mean versus median values for plants around the e-waste dumpsite and control plant samples are close, which indicates that there is normality in the spreading of the data sets.

Zn displayed low mean concentration in all the segments of plant, and they are higher than the WHO/FAO standard limit of 8.00 mg/kg. Pollution was not observed when compared with the control values (Table 3). The analysis indicates some degree of significant variation ( $t = 0.22$ ,  $p = 27.6$ ), this may be tied to the fact that the electronic-waste has some capacity to leach out Zn to the surrounding. There is improper arrangement of the data sets since the

values of the mean and the median displayed high variation from each other.

From figure 2, all metals determined displayed low factors of contamination since their values are within categories of  $CF < 1$  in all the parts of plant, except Cd which displayed negative root contamination factor (fig.2) and positive contamination factor (fig.3). This implies that pollution were not observed at the root while for the other parts of the plant, it was noticed that  $CF > 6$ , indicating high contamination factor on the plant samples.

Figure 4 and 5 show evaluated contamination degree for the *V-amygdalina* plant. Low contamination degree was observed only on root (fig.4), since it fell into the category of  $C_{deg} < 8$  and only washed leaf samples (fig. 5) that displayed degree of contamination of  $C_{deg} < 8$ . The washed leaf, unwashed leaf and stem samples displayed high contamination degree of the categories of  $C_{deg} \geq 32$  (fig. 4). The unwashed leaf and stem samples (fig.5), displayed very high contamination degree, the root showed considerable level of contamination, since it fell on the categories of  $16 \leq C_{deg} < 32$  (fig. 5).

Figure 6 reveal the profile of the transfer factors obtained via calculation for the metals contamination from soil to plant and the trends were  $Cu > Fe > Ba > Co > Ni > Zn > Cd > Cr > Pb > Mn$  and is obtained by the ratio of the contamination level of metals in plant to the contamination level of metals in soil. Cu having the highest transfer factor may be attributed to the fact that the physicochemical properties of soil displayed minimal influence on Cu, since the migration of metals from soil to parts of plant is influenced greatly by the physicochemical properties possessed by the

soil (Emmanuel *et al.*, 2020). Hence, there is high transfer in Cu, Fe, Ba and Co. However, physicochemical influence was minimal on the other metals, hence they yield minimal transfer factors of 8.42, 4.68, 2.75, 1.99 and -53.26 respectively. These values were higher than those reported by Emmanuel *et al.*, (2020),

except for Mn which is far lower since it displayed negative transfer factor.

**Table 1:** Mean  $\pm$  SD Concentration of soil heavy metals around e-waste dumpsite across the various depths.

Metals	Mean $\pm$ SD			Median			Dutch (mg/kg)	
	0-10 cm	10-20cm	20-30cm	0-10 cm	10-20cm	20-30cm	Optimal	Action
Ba	24.27 $\pm$ 25.14	13.64 $\pm$ 22.59	2.12 $\pm$ 0.95	24.00	2.75	1.79	200.00	625.00
Cd	8.77 $\pm$ 9.81	4.84 $\pm$ 8.78	0.47 $\pm$ 0.33	8.54	0.67	0.56	1.00	12.00
Co	108.59 $\pm$ 155.13	95.90 $\pm$ 163.12	86.06 $\pm$ 168.62	46.75	21.43	1.79	20.00	240.00
Cr	29.31 $\pm$ 23.40	24.50 $\pm$ 27.33	14.29 $\pm$ 26.48	31.25	21.62	1.25	100.00	380.00
Cu	28.96 $\pm$ 20.65	16.27 $\pm$ 17.05	9.31 $\pm$ 15.46	31.00	15.67	1.75	36.00	190.00
Fe	1759.54 $\pm$ 1139.35	1200.99 $\pm$ 1307.85	706.83 $\pm$ 1252.12	2185.50	1068.00	84.24	-	-
Mn	66.74 $\pm$ 46.22	39.79 $\pm$ 42.71	18.68 $\pm$ 29.88	75.75	33.72	3.83	-	-
Ni	10.44 $\pm$ 8.38	5.31 $\pm$ 5.56	2.60 $\pm$ 3.94	10.00	4.62	0.71	35.00	210.00
Pb	56.89 $\pm$ 68.50	17.94 $\pm$ 17.63	9.31 $\pm$ 10.60	32.25	15.29	5.29	85.00	350.00
Zn	34.54 $\pm$ 24.84	19.75 $\pm$ 21.17	9.24 $\pm$ 14.51	37.50	16.58	2.05	140.00	720.00

Ba= Barium, Cd= Cadmium, Co= Cobalt, Cr= Chromium, Cu= Copper, Fe= Iron, Mn= Manganese, Ni= Nickel, Pb= Lead, Zn= Zinc & SD= Standard Deviation

**Table 2:** The mean  $\pm$  SD and median concentration for leaf, stem and root samples of plant around e-waste dumpsite.

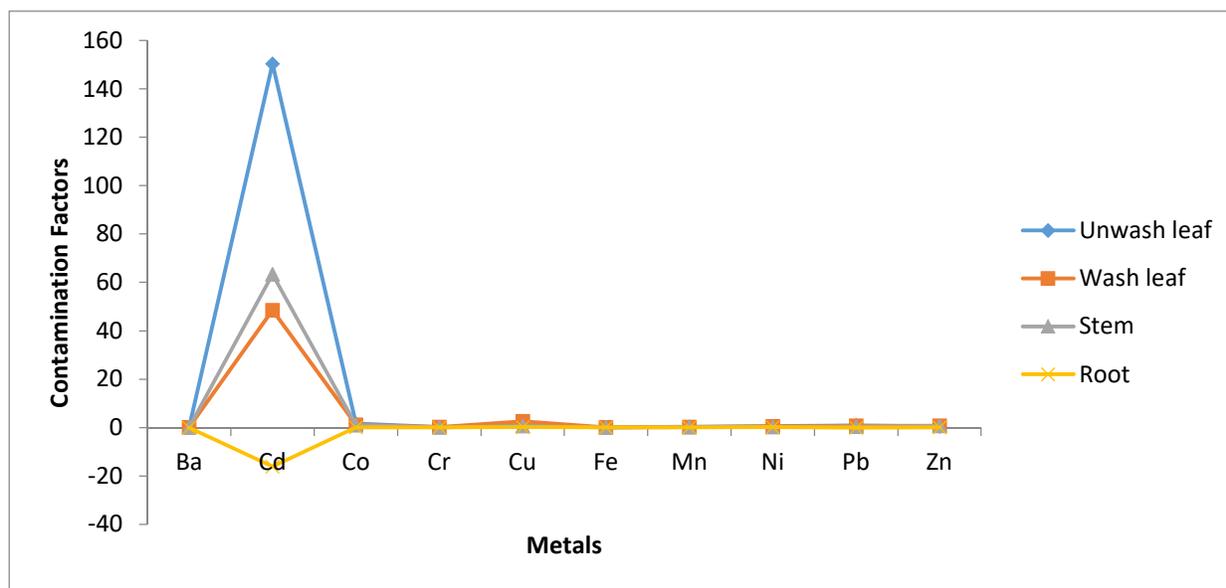
Metals	Mean $\pm$ SD				Median				WHO/FAO (mg/kg)
	Unwashed leaf	Washed leaf	Stem	Root	Unwashed leaf	Washed leaf	Stem	Root	Bitter leaf
Ba	7.37 $\pm$ 4.60	5.09 $\pm$ 4.71	3.37 $\pm$ 4.38	1.39 $\pm$ 2.13	9.23	5.20	0.64	0.39	-
Cd	8.24 $\pm$ 9.97	6.76 $\pm$ 10.49	2.18 $\pm$ 4.74	0.06 $\pm$ 0.91	8.28	0.77	0.65	0.31	1.00
Co	20.35 $\pm$ 18.10	11.99 $\pm$ 14.33	6.28 $\pm$ 10.49	1.31 $\pm$ 0.77	25.03	2.30	1.55	1.40	0.10
Cr	13.08 $\pm$ 9.84	8.30 $\pm$ 8.52	4.39 $\pm$ 5.57	1.79 $\pm$ 2.40	13.48	6.08	0.84	0.81	2.00
Cu	51.71 $\pm$ 60.62	41.15 $\pm$ 63.65	11.00 $\pm$ 13.33	4.41 $\pm$ 4.34	33.83	11.43	4.99	2.20	40.00
Fe	1447.65 $\pm$ 944.07	958.44 $\pm$ 876.93	548.57 $\pm$ 641.60	317.04 $\pm$ 522.40	1251.48	1251.33	82.48	82.48	425.00
Mn	145.69 $\pm$ 116.82	88.99 $\pm$ 95.77	52.29 $\pm$ 80.48	14.95 $\pm$ 15.91	190.58	42.80	12.09	9.49	40.00
Ni	24.83 $\pm$ 19.56	14.88 $\pm$ 14.91	7.64 $\pm$ 8.72	3.90 $\pm$ 5.73	19.73	14.15	1.67	1.41	-
Pb	6.08 $\pm$ 5.78	3.68 $\pm$ 4.91	1.41 $\pm$ 2.12	0.38 $\pm$ 0.23	5.20	0.70	0.44	0.41	2.00
Zn	29.24 $\pm$ 25.65	22.42 $\pm$ 27.78	11.65 $\pm$ 20.59	2.01 $\pm$ 1.31	36.20	3.48	3.00	1.86	8.00

Ba= Barium, Cd= Cadmium, Co= Cobalt, Cr= Chromium, Cu= Copper, Fe= Iron, Mn= Manganese, Ni= Nickel, Pb= Lead, Zn= Zinc & SD= Standard Deviation

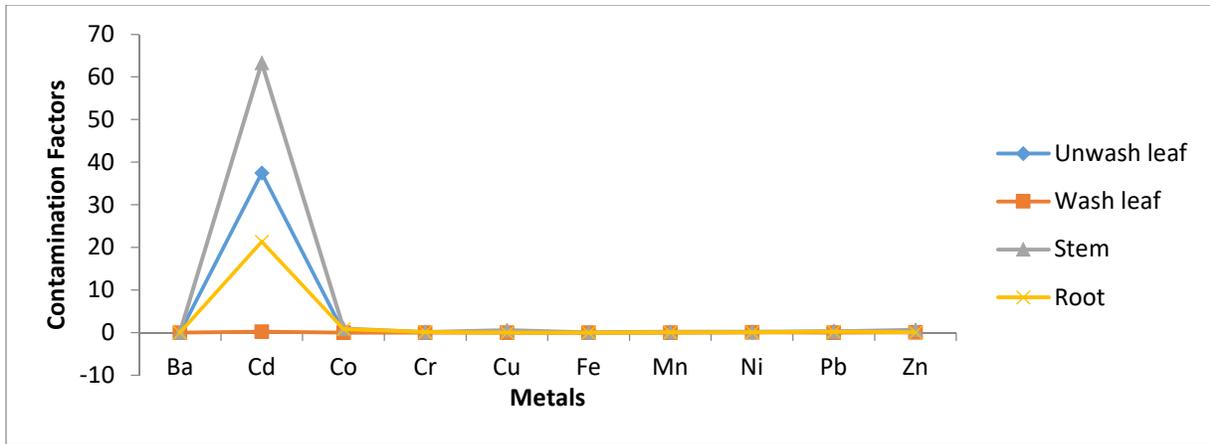
**Table 3:** Mean ± SD and median Concentration of heavy metals in the leaf, stem and root samples of the plant collected from control site.

Metals	Mean ± SD		Stem	Root	Median		Stem	Root	WHO/FAO (mg/kg) Bitter leaf
	Unwashed leaf	Washed leaf			Unwashed leaf	Washed leaf			
Ba	0.41 ± 0.37	0.41 ± 0.39	0.41 ± 0.40	0.41 ± 0.40	0.33	0.33	0.33	0.33	-
Cd	4.25 ± 2.28	5.79 ± 5.10	6.06 ± 4.81	5.16 ± 5.19	4.20	4.20	4.20	3.24	1.00
Co	5.74 ± 8.36	5.86 ± 8.31	6.10 ± 8.12	6.97 ± 8.03	2.88	3.48	3.48	3.48	0.10
Cr	10.63 ± 6.99	9.92 ± 6.55	11.22 ± 4.67	8.28 ± 3.03	10.55	10.55	10.55	7.54	2.00
Cu	1.50 ± 0.91	1.80 ± 1.39	1.94 ± 1.22	1.54 ± 1.31	1.28	1.28	1.28	1.13	40.00
Fe	73.25 ± 12.29	101.58 ± 72.46	113.79 ± 55.57	92.93 ± 46.86	134.18	88.15	88.15	68.31	425.00
Mn	15.08	22.78 ± 76.54	19.25 ± 77.60	20.21 ± 77.08	16.25	8.91	8.91	8.91	40.00
Ni	4.48 ± 1.73	21.11 ± 36.93	20.33 ± 37.37	19.48 ± 37.82	4.35	5.93	4.35	2.31	-
Pb	5.34 ± 6.01	5.58 ± 5.59	6.73 ± 5.25	3.91 ± 2.02	4.10	4.10	5.58	4.10	2.00
Zn	9.41 ± 5.34	14.67 ± 15.72	15.20 ± 15.27	12.83 ± 16.31	7.57	7.57	7.57	6.58	8.00

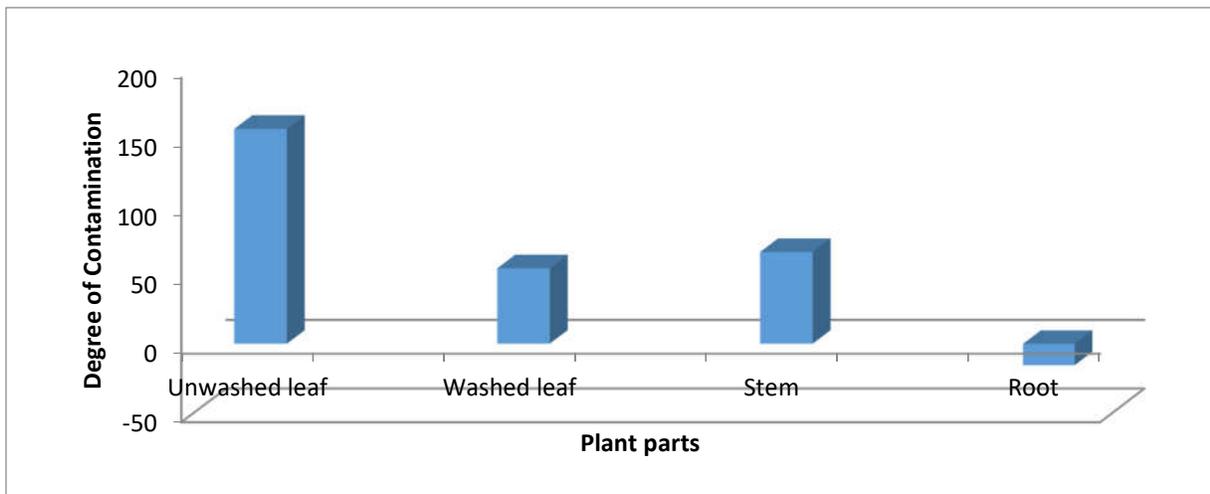
Ba= Barium, Cd= Cadmium, Co= Cobalt, Cr= Chromium, Cu= Copper, Fe= Iron, Mn= Manganese, Ni= Nickel, Pb= Lead, Zn= Zinc & SD= Standard Deviation



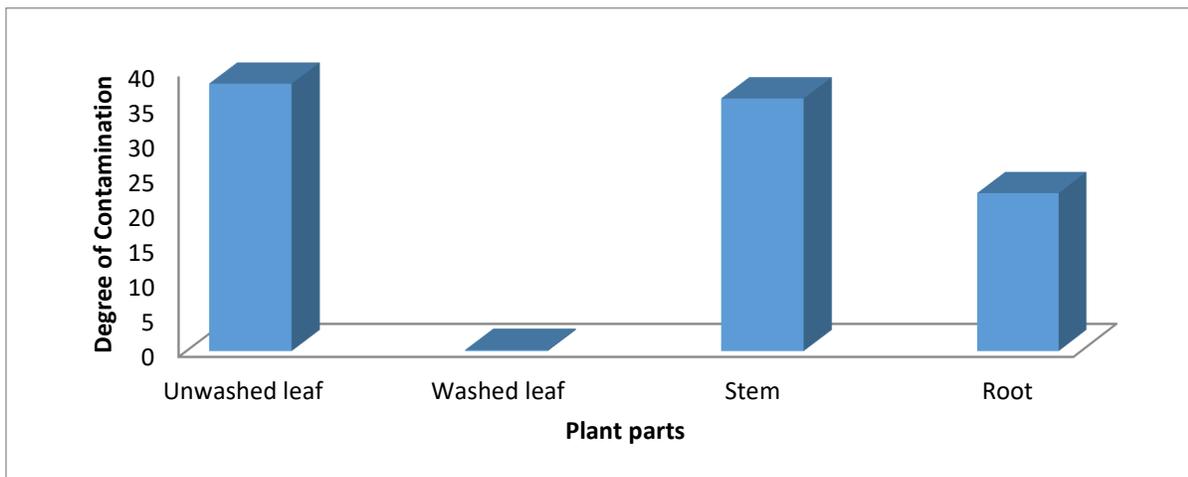
**Figure 3:** Contamination factors profile of the metals across plant part samples (around e-waste dumpsite).



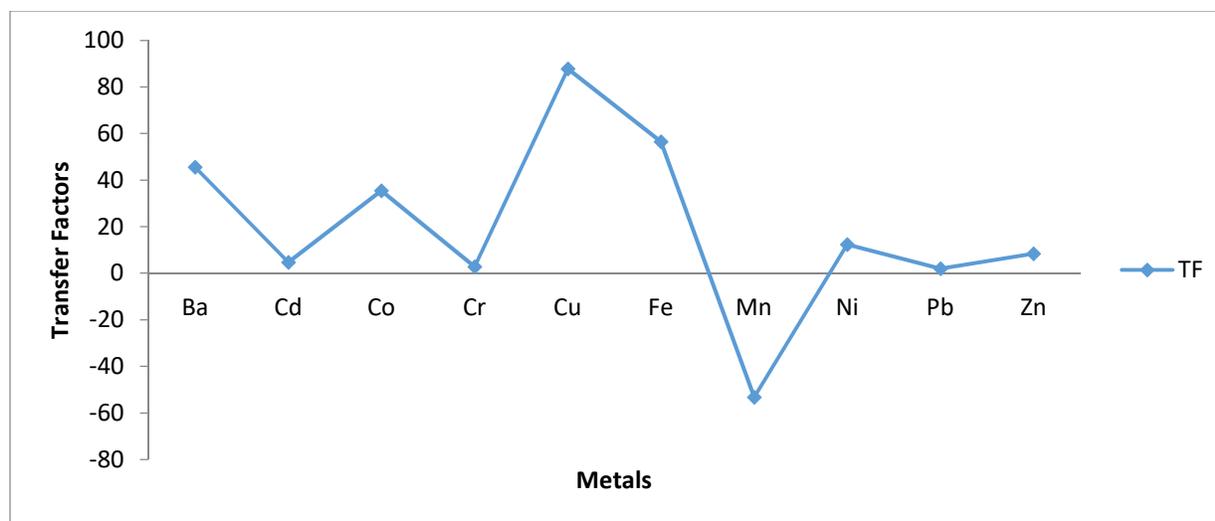
**Figure 4:** Contamination factors profile of the metals across all part of plant samples under study (control site).



**Figure 5:** The plot of contamination degree of heavy metals in all part of plant samples under study (around e-waste dump site).



**Figure 6:** Contamination degree of heavy metals in all part of plant samples under study (control site).



**Figure 7:** Profile of soil to plant transfer factors.

## Conclusions

Based on the results obtained in this research work, conclusion can be drawn that the leaf (washed and unwashed), stem and root samples of *V-amygdalina* obtained from the vicinity of e-waste in Abraka are polluted to a high level with the heavy metals under study (Ba, Ca, Co, Cr, Cu, Fe, Mn, Pb and Zn). Also the soil around the e-waste shows some pollution level across depths for each metals in relation to the control plant and WHO/FAO permissible limit, the high pollution level observed might be as a result of the e-waste leaching each metals to the nearby soil and the mobility strength of these contaminants into the plant. The trend of pollution by metals on soil and plant were  $Cu > Fe > Ba > Co > Ni > Zn > Cd > Cr > Pb > Mn$  and unwashed leaf > washed > stem > root. Variable contamination level were investigated across the parts of plant, there were significant different between the unwashed and washed leaf. This implies that the washing had much influence on the leaf by reducing the level of heavy metals present. Pollution from indiscriminate dumping of e-waste should be strictly controlled, in order to keep our environment safe.

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