*Chemical Science International Journal*

***20(1): 1-8, 2017; Article no.CSIJ.33724***
***ISSN: 2456-706X***
*(Past name: American Chemical Science Journal, Past ISSN: 2249-0205)*

# Heavy Metals Presence in Some Vegetables and Crops Harvested From Farms in Ebocha, Egbeda and Igbo-Etche in Rivers State, Nigeria

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Author IAK designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author OGE performed the statistical analysis and managed the analyses of the study. Authors MLO, HCO, FO and CO carried out sample collections from the four farms sites and managed the literature searches. All authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/CSJI/2017/33724
*Editor(s):*
(1) Francisco Marquez-Linares, Full Professor of Chemistry, Nanomaterials Research Group School of Science and Technology, University of Turabo, USA.
*Reviewers:*
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(2) Aysun Turkmen, Giresun University, Turkey.
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(6) Gideon Ramtahal, The University of the West Indies, West Indies.
Complete Peer review History: http://www.sciencedomain.org/review-history/20028

***Original Research Article***

***Received 26th April 2017***
***Accepted 25th June 2017***
***Published 13th July 2017***

## ABSTRACT

Studies of the presence of heavy metals were carried out on some vegetables and crops harvested from farms in Ebocha, Egbeda and Igbo-Etche in Rivers State, Nigeria. These farms are located in communities where oil exploration activities are ongoing. The samples were prepared by wet digestion using a mixture of Perchloric acid ($HClO_4$): Nitric acid ($HNO_3$) in the ratio 1:4 and analyzed using Atomic Absorption Spectroscopy (AAS). The heavy metals concentration in almost all the vegetables and crops studied were high compared to the maximum permissible limits prescribed by World Health Organisation (WHO), Food Agriculture Organization (FAO) and

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European Union (EU) except Zn. The concentrations of these metals in the vegetables and crops studied are Co (0.10 – 3.88 $mgkg^{-1}$), Pb (3.34 – 11.27 $mgkg^{-1}$), Zn (4.21 – 94.34 $mgkg^{-1}$), Cd (0.03 – 6.97 $mgkg^{-1}$), Ni (0.10 – 5.70 $mgkg^{-1}$), Mn (1.65 – 109.86 $mgkg^{-1}$), Cu (2.15 – 16.11 $mgkg^{-1}$) and Fe (22.20 – 334.97 $mgkg^{-1}$). Concentrations of Co are within acceptable limits except in bitter leaf, scent leaf and water leaf from Ebocha (Site 1) farm which were 2.44 $mgkg^{-1}$, 2.27 $mgkg^{-1}$ and 3.78 $mgkg^{-1}$ respectively. Waterleaf from Igbo-Etche farm recorded a concentration of 3.88 $mgkg^{-1}$. From the results obtained in this study, the tuberous crop (cassava) has higher concentrations of the metals in comparison to the plantain. The order of the levels of heavy metal concentration in the vegetables and crops is presented in the decreasing order of Scent Leaf > Water Leaf > Fluted Pumpkin >Bitter Leaf > Cassava > Plantain. From the four farms, the levels of concentration is Igbo-Etche>Ebocha 1 = Ebocha 2 > Egbeda. Analysis of variance [ANOVA] confirmed significant differences (P<0.05) among the heavy metals present in the vegetables and the crops from these four farms.

*Keywords: Concentrations; Ebocha; Cassava; crops; farms; Egbeda; Igbo-Etche.*

## 1. INTRODUCTION

Heavy metals uptake by plants grown in polluted soils has been studied to a considerable extent. In many developing countries, it is a common practice to grow vegetables along banks of rivers passing through urban and rural centers, along road sides near power plant and even near oil companies, which have often been reported to be polluted by heavy metals [1,2]. The extent of absorption of the elements by the plant depends on among other things, the nature of the plant, and chemical constitution of the pollutants, concentrations of the element in the soil, pH and the interaction with other metals. The uptake and bioaccumulation of heavy metals in vegetables is influenced by many factors such as climate, atmospheric depositions, the concentrations of heavy metals in soil, the nature of soil and the degree of maturity of the plants at the time of the harvest [3,4]. Other anthropogenic sources of heavy metals include the addition of manures, sewage sludge, fertilizers and pesticides which may affect the uptake of heavy metals by modifying the physico-chemical properties of the soil such as pH, organic matter, bio availability of heavy metals in the soil [5]. Heavy metals are very harmful because of their non-biodegradable nature, long biological half lives and their potential to accumulate in different body parts. Vegetables take up metals by absorbing them from contaminated soils, as well as from deposits on parts of the vegetables exposed to the air from polluted environment. In recent years, the associations between elevated steady-state transcript levels of heavy metal-transporter genes and metal accumulation in plants have been revealed and many heavy metal-transport proteins have been cloned and identified [6]. Heavy metal ions such as $Cu^{2+}$, $Zn^{2+}$, $Mn^{2+}$, $Fe^{2+}$ and $Ni^{2+}$ are essential micronutrients for plant metabolism but when in excess, these and non-essential metals such as $Cd^{2+}$, $Hg^{2+}$ and $Pb^{2+}$ can become extremely toxic [7]. Prolonged consumption of unsafe concentration of heavy metals through foodstuffs may lead to the chronic accumulation of heavy metals in the kidney and live of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases [8]. The intake of heavy metals can lead to altering of humans and animals healthiness state. Thus, the carcinogenic effects generated by continuous consumption of crops and vegetables loaded with heavy metals such as cadmium (Cd), lead (Pb), or even copper (Cu) and Zinc (Zn) are known. This may be related to the incidence of gastro-intestinal cancer [9,10] and cancer of the pancreas, urinary bladder or prostate [11]. Several vegetables and crops species abound in Nigeria and most West African countries where they are used partly as condiments or spices in human diets or as supplementary feeds to live stock such as rabbits, poultry, swine and cattle [12]. These vegetables are harvested at all stages of growth and fed either as processed, semi-processed or fresh to man while they are usually offered fresh to livestock. Leafy vegetables are known to add taste and flavor, as well as substantial amount of proteins, fiber, minerals and vitamins to our diet. The aim of this study is to determine the level of concentration of metals in selected crops and vegetables grown in crude oil exploration communities.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

An existing image of Rivers State was geo-referenced using Arc GIS 10.3 and the coordinates collected using a handheld GPS in the UTM (Universal Transverse Mecartor) Zone 32 N. Ebocha is located at 247670 mE and 605854 mN (UTM Zone 32 N) in Ogba - Egbema Ndoni local government area of Rivers State, Nigeria. It is in a community called Mgbedein Onelgaanditis naturally endowed with crude oil. The occupation of the people in Ebocha is predominantly farming, fishing and hunting. The second study site, referred to as site 3, is a farm in Egbeda situated in Emohua local government area of Rivers State. Egbeda is located at the Southern part of the state at 251121 mE and 579298 mN (UTM Zone 32 N). The village records heavy rain and sunshine in the midday, sun is always overhead. The vegetation is mangrove swamp which is along the coastal region of Rivers State. The soil is wet and the water is shallow. The main vegetation is the mangrove. The third study area, referred to as site 4 in Igbo-Etche, Etche local government area is located at 287366 mE and 547039 mN. It is an oil exploration site. It is also close to Port Harcourt with a large number of multinational companies and other industrial concerns relating to petroleum industry.

## 2.2 Procedure

### 2.2.1 Sampling

A total of six (6) samples consisting of four (4) different leafy vegetables and two (2) crops were collected from Ebocha, Egbeda and Igbo-Etche in Rivers State, Nigeria. The vegetable samples include water leaf (*Talinum triangulare*), scent leaf (*Ocimum grattissimum*), Bitter leaf (*Vernonia amygdalina)* and fluted pumpkin leaf (*Telfaria occidentalis*). The selected crop samples include cassava (*Manihot esculentum*) and plantain (*Musa accuminata*). These plants were cultivated using their stems and suckers (for plantain). The samples were submitted for proper identification by a plant taxonomist, they were air dried and stored in a plastic containers until analysis.

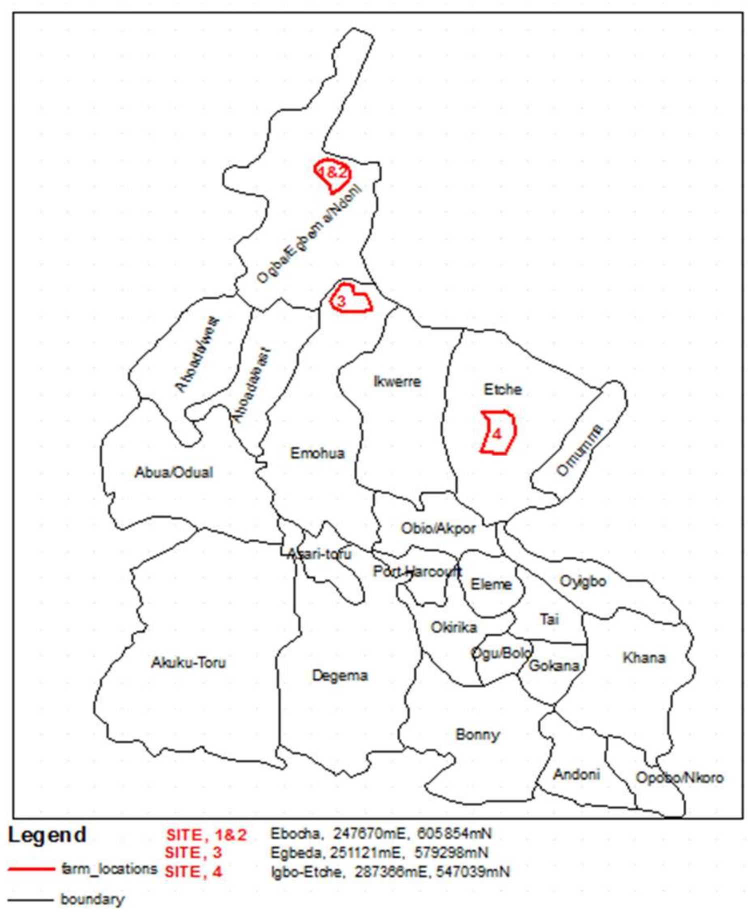


**Fig. 1. Map of Rivers State showing Ebocha, Egbeda, and Igbo-Etche**

#### 2.2.2 Wet digestion

Wet digestion is the conversion of an organic compound into ash (decomposition) by treating the compound with nitric or sulfuric acid. Wetdigestion is primarily used in the preparation of samples for subsequent analysis of specific minerals. This method breaks down and removes the organic matrix surrounding the minerals so that they are left in an aqueous solution. A dried ground food sample is usually weighed into a flask containing strong acid and oxidizing agents (e.g. nitric acid, perchloric or sulphuric acid) and then heated [13]. Heating is continued until the organic matter is completely digested, leaving only the mineral oxides in solution. The temperature and time depends on the type of acids and oxidizing agents used [14]. Typically, a 1:1:2 acid mixture of HCl: $HNO_3$: $H_2O$ is used to dissolve the ash. The advantage of wet digestion over dry ashing is that little loss of volatile minerals occurs because of the lower temperatures used, more rapidly than dry ashing. $HNO_3$ and $HClO_4$ mixture is used because it gives better digestion of the heavy metals than when HCl and $HNO_3$ is used.

A modified method [15] was used for the preparation of the samples supported by other analytical methods [16,17]. Quality control materials were used to validate accuracy of results. Analytical grades of perchloric acid ($HClO_4$) and nitric acid ($HNO_3$) from Aldrich Chemical Company were used. 2 g of the ground sample was quantitatively weighed on a weighing balance and put in a beaker. A mixture of these acids in the ratio of 1:4 was prepared and added to each sample and heated on a hot plate in a fume chamber until all the fumes were given off. Then the beaker was allowed to cool. This was transferred to a 50 ml volumetric flask and made up to mark with deionized water.

#### 2.2.3 Sample analysis

The plant and soil samples were prepared in triplicates and the digested samples were taken for analysis of the following metals, lead (Pb), cadmium (Cd), nickel (Ni), cobalt (Co), copper (Cu), iron (Fe), manganese (Mn) and Zinc (Zn) using AAS model AA500F (PG Instrument).

#### 2.2.4 Statistical analysis

Mean values and standard deviation were calculated and analysis of variance (ANOVA) was performed.

## 3. RESULTS AND DISCUSSION

From the results presented in Tables 1-4, concentration of Co in the crops were from 0.10 - 1.17 $mgkg^{-1}$. In the vegetables, the observed concentrations ranged from 0.10 - 3.88 $mgkg^{-1}$. For the crops, these values were within the acceptable limits of FAO, WHO and EU [18] as presented in Table 5. However, the vegetables had values above the limit (2.00 $mgkg^{-1}$) with the results in Table 1 from Ebocha Farm (site 1) being the highest. This metal was not detected in any of the farms. It was also noted that in all the four farms studied, Co concentration were highest for waterleaf samples. This can be attributed to the morphology and nature of this plant [19]. It is also possible that atmospheric deposition can be responsible as reported [20,21,22]. Pb concentrations in all the crops and vegetables were found to be very high (3.34 - 11.20 $mgkg^{-1}$) compared to the acceptable limits of 0.10 $mgkg^{-1}$ and 0.30 $mgkg^{-1}$ for crops and vegetables respectively. Pb was detected in the soil samples from the four farms and the average concentrations were 33.75 $mgkg^{-1}$, 29.75 $mgkg^{-1}$ and 24.75 $mgkg^{-1}$ for Ebocha (site 1 and 2), Egbeda and Igbo- Etche respectively. These values are higher than those recorded in the crops. The maximum acceptable limit for Zn in both crops and vegetables is 99.40 $mgkg^{-1}$. From all the sites studied, the crops and vegetables were within this limit. For the crops the range was 4.21 - 16.85 $mgkg^{-1}$ while in the vegetables the range was 6.36 - 94.3 $mgkg^{-1}$. Zn concentrations in the soils was highest (112.5 $mgkg^{-1}$) in the Ebocha farms followed by Igbo-Etche (27.75 $mgkg^{-1}$) while the soil from the Egbeda farm recorded the least (5.55 $mgkg^{-1}$). Cd concentrations have been the lowest in comparison to the other seven metals. The range is from 0.06 $mgkg^{-1}$ to 6.97 $mgkg^{-1}$. The highest value of 6.97 $mgkg^{-1}$ was recorded for plantain from Igbo-Etche farm. There are no specific trend in the results obtained as both crops and vegetables showed varied concentrations from one farm to the other. This could be as a result in the difference in pH, organic matter content and chemical speciation of the metal ions. The mobilityand interference of other metal ions present inthe soil is another factor as recorded by [23,24]. Cd was not detected in the soil from three farms except Igbo-Etche which recorded concentrations of 1.90 $mgkg^{-1}$ while the crops from this farm had higher concentrations of 0.94 $mgkg^{-1}$ and 6.97 $mgkg^{-1}$ for cassava and plantain respectively. These crops recorded values of 0.06-0.51 $mgkg^{-1}$ from the other farms studied.

Cu concentrations were also high (2.15-16.10 $mgkg^{-1}$) with bitter leaf from Ebocha farm (site 1) recording the highest value followed by scent leaf (15.80 $mgkg^{-1}$) from the same farm. The crops showed lower concentrations (2.15-6.82 $mgkg^{-1}$) than the vegetables. The only vegetable that recorded a lower value was scent leaf from Igbo-Etche farm (3.12 $mgkg^{-1}$). These values for Cu are above the acceptable limit of 0.50 $mgkg^{-1}$. The concentrations of Cu for the soil samples from these farms are 15.65 $mgkg^{-1}$, 0.85 $mgkg^{-1}$ and 0.80 $mgkg^{-1}$ for Ebocha, Egbeda and Igbo-Etche respectively. The levels of Ni concentration in this study was from 0.10 $mgkg^{-1}$ to 5.70 $mgkg^{-1}$. These values are above the acceptable limit set by FAO, WHO and EU. For this metal, no specific trend was observed in the results obtained. Ni was detected in all the farms in low concentrations of 2.25 $mgkg^{-1}$, 4.20 $mgkg^{-1}$ and 1.85 $mgkg^{-1}$ for Ebocha, Egbeda and Igbo-Etche respectively. However, more of the vegetable samples had higher concentration of Ni. Plants differ in their morphology, preference for different speciation of metals and root system. These among others may be the likely reason for the observed different levels of metal concentrations in the vegetables and crops [25]. They also differ in crop species as reported [26]. Mn concentration for the crops from the four farms ranged from 1.65 $mgkg^{-1}$ to 31.10 $mgkg^{-1}$ with cassava having the higher concentrations in each farm except from Egbeda farm. The vegetables had concentrations of 9.73 $mgkg^{-1}$ to 109.86 $mgkg^{-1}$. The highest concentration was recorded for water leaf from Igbo-Etche farm. These values exceed the maximum acceptable limits as shown in Table 5. The soils from Ebocha, Egbeda and Igbo-Etche farms had Mn concentrations of 38.35 $mgkg^{-1}$, 14.75 $mgkg^{-1}$ and 63.00 $mgkg^{-1}$ respectively. The levels of Fe in this study are very high and above the acceptable limit of 0.80 $mgkg^{-1}$ for both crops and vegetables. The vegetables recorded concentration of 43.50 – 334.97 $mgkg^{-1}$ while the value for the crops is between 22.30 $mgkg^{-1}$ - 51.80 $mgkg^{-1}$ across the four farms except cassava from Igbo-Etche farm which recorded a concentration of 137.94 $mgkg^{-1}$. Fe concentrations from the three farms were found to be high. The soil from Egbeda farm had the highest concentration (432.90 $mgkg^{-1}$) followed by Igbo-Etche (349.00 $mgkg^{-1}$) and Ebocha with a concentration of 86.00 $mgkg^{-1}$. The high levels of Fe, Pb, and the other metals recorded in this study is in agreement with the findings of [22-30]. Some of these values are higher the values obtained for the soils from the respective farms indicating hyper accumulation in these plants. It has been reported [30-32] that some common vegetables are capable of accumulating high levels of heavy metals from contaminated and polluted soils and this confirms our findings. The Analysis of Variance (ANOVA) test is significant at 5% level of significance since the probability value of <0.00001 is less than 0.05 (P<0.05). We therefore conclude that there are significant differences among the heavy metals present in the vegetables and crops studied.

**Table 1. Concentration of heavy metals from Ebocha farm (Site 1) $mgkg^{-1}$**

| Plant | Co | Pb | Zn | Cd | Cu | Ni | Mn | Fe |
|---|---|---|---|---|---|---|---|---|
| Cassava | 0.92±0.01 | 3.79±0.03 | 16.85±0.04 | 0.37±0.01 | 6.82±0.11 | 3.35±0.01 | 6.00±0.02 | 42.31±0.01 |
| Plantain | 0.54±0.03 | 4.59±0.01 | 15.96±0.06 | 0.44±0.04 | 5.77±0.07 | 1.70±0.01 | 4.06±0.02 | 51.80±0.21 |
| BL | 2.44±0.02 | 4.78±0.02 | 42.51±0.02 | 0.77±0.02 | 16.11±0.01 | 4.26±0.05 | 29.71±0.06 | 76.28±0.03 |
| FP | 1.17±0.01 | 8.08±0.02 | 47.01±0.02 | 0.49±0.02 | 12.50±0.02 | 3.14±0.02 | 48.10±0.02 | 119.00±0.82 |
| SL | 2.27±0.02 | 8.69±0.02 | 33.20±0.03 | 3.37±0.06 | 15.80±0.06 | 3.06±0.02 | 16.29±0.01 | 78.10±0.02 |
| WL | 3.78±0.03 | 9.01±0.01 | 94.34±0.01 | 1.13±0.03 | 12.60±0.02 | 4.48±0.03 | 70.18±0.02 | 83.48±0.02. |
| Soil | - | 33.75±0.03 | 112.50±0.05 | - | 15.65±0.02 | 2.25±0.02 | 38.35±0.02 | 86.00±0.01 |

*The above values in this table are means of replicate values of (n=3)*
*Key: Bitter leaf = BL, Fluted Pumpkin = FP, Scent Leaf = SL, Water Leaf = WL*

**Table 2. Concentration of heavy metals from Ebocha farm (Site 2) $mgkg^{-1}$**

| Plant | Co | Pb | Zn | Cd | Cu | Ni | Mn | Fe |
|---|---|---|---|---|---|---|---|---|
| Cassava | 0.11±0.01 | 5.26±0.01 | 5.48±0.02 | 0.51±0.02 | 3.59±0.02 | 0.11±0.02 | 5.68±0.01 | 22.20±0.19 |
| Plantain | 0.10±0.01 | 7.74±0.02 | 7.73±0.05 | 0.28±0.02 | 4.10±0.02 | 1.26±0.02 | 1.65±0.02 | 32.27±0.12 |
| BL | 0.10±0.02 | 10.11±0.02 | 36.33±0.05 | 0.64±0.02 | 9.75±0 .02 | 2.23±0.01 | 24.59±0.02 | 114.13±0.52 |
| FP | 0.12±0.02 | 8.72±0.05 | 29.78±0.04 | 0.03±0.01 | 10.59±0 .05 | 1.04±0.01 | 21.10±0.03 | 276.43±4.75 |
| SL | 0.58±0.03 | 10.49±0.14 | 48.32±0.08 | 0.17±0.01 | 13.72± 0.06 | 2.26±0.02 | 15.40±0.08 | 281.38±2.70 |
| WL | 0.10±0.03 | 8.89±0.05 | 17.40±0.08 | 0.94±0.01 | 9.26±0. 03 | 0.82±0.03 | 54.30±0.08 | 150.35±1.43 |
| Soil | - | 33.75±0.03 | 112.50±0.05 | - | 15.65±0.02 | 2.25±0.02 | 38.35±0.02 | 86.00±0.0 1 |

**Table 3. Concentration of heavy metals from Egbeda farm (Site 3) mgkg$^{-1}$**

| Plant | Co | Pb | Zn | Cd | Cu | Ni | Mn | Fe |
|---|---|---|---|---|---|---|---|---|
| Cassava | 0.15±0.02 | 3.79±0.02 | 5.65±0.02 | 0.16±0.02 | 2.4 2±0.02 | 1.65±0.02 | 4.76±0.02 | 33.27±0.51 |
| Plantain | 0.11±0.01 | 6.14±0.02 | 7.29±0.02 | 0.06±0.02 | 5. 84±0.01 | 0.36±0.02 | 9.03±0.02 | 28.37±0.17 |
| BL | 0.67±0.02 | 4.57±0.01 | 17.74±0.02 | 0.28±0.02 | 6.00±0.01 | 1.16±0.01 | 60.51±0.01 | 103.30±.59 |
| FP | 0.98±0.01 | 4.14±0.02 | 40.89±0.01 | 0.27±0.01 | 14.40±0.02 | 2.36±0.01 | 97.20±0.01 | 252.67±0. 50 |
| SL | 0.79±0.01 | 11.27±0.12 | 15.87±0.02 | 0.29±0.01 | 7.89±0.02 | 3.69±0.02 | 10.80±0.02 | 334.97±0.8 7 |
| WL | 1.93±0.02 | 7.46±0.01 | 58.60±0.02 | 0.13±0.02 | 7.94±0.02 | 4.49±0.02 | 49.82±0.05 | 159.00±0.1 6 |
| Soil | - | 29.75±0.01 | 5.55±0.02 | - | 0.850±0.01 | 4.20±0.02 | 14.75±0.05 | 432.90±0.18 |

*The above values in this table are means of replicate values of samples (n=3)*

**Table 4. Concentration of heavy metals from Igbo-Etche farm (Site 4) mgkg$^{-1}$**

| Plant | Co | Pb | Zn | Cd | Cu | Ni | Mn | Fe |
|---|---|---|---|---|---|---|---|---|
| Cassava | 0.58±0.02 | 6.67±0.02 | 15.68±0.02 | 0.94±0.02 | 5.13±0.02 | 3.09±0.02 | 31.10±0.03 | 137.94±1.79 |
| Plantain | 1.17±0.02 | 4.13±0.02 | 4.21±0.02 | 6.97±0.02 | 2.15±0.02 | 3.67±0.02 | 5.12±0.01 | 47.73±0.17 |
| BL | 1.09±0.02 | 8.21±0.02 | 13.50±0.02 | 1.54±0.02 | 8.64±0.02 | 4.21±0.02 | 73.10±0.03 | 95.23±0.17 |
| FP | 0.92±0.01 | 6.91±0.02 | 33.60±0.06 | 1.34±0.02 | 12.40±0.02 | 5.70±0.03 | 93.60±0.05 | 289.46±0.72 |
| SL | 0.73±0.02 | 3.34±0.02 | 6.36±0.02 | 0.53±0.01 | 3.12±0.01 | 2.42±0.01 | 9.72±0.02 | 43.50±0.08 |
| WL | 3.88±0.02 | 10.92±0.02 | 39.20±0.02 | 0.14±0.02 | 7.89±0.01 | 2.29±0.02 | 109.86±0.29 | 115.63±0.46 |
| Soil | - | 24.75±0.00 | 27.75±0.02 | 1.90±0.00 | 0.80±0.02 | 1.85±0.02 | 63.00±0.01 | 349.00±0.01 |

*The above values in this table are means of replicate values of (n=3)*

**Table 5. Acceptable limits**

| | Metals | Crops | Organization | Vegetables | Organization |
|---|---|---|---|---|---|
| 1. | Co | 2.00 mgkg$^{-1}$ | WHO, 2006 | 2.00 mgkg$^{-1}$ | WHO, 2006 |
| 2. | Pb | 0.1 mgkg$^{-1}$ | FAO/WHO, 2010 | 0.30 mgkg$^{-1}$ | FAO/WHO, 2010 |
| 3. | Zn | 99.4 mgkg$^{-1}$ | FAO/WHO, 2010 | 99.4 mgkg$^{-1}$ | FAO/WHO, 2010 |
| 4. | Cd | 0.1 mgkg$^{-1}$ | FAO/WHO, 2010 | 0.2 mgkg$^{-1}$ | FAO/WHO, 2010 |
| 5. | Cu | 0.05 – 0.5 mgkg$^{-1}$ | FAO/WHO, 2010 | 0.05 – 0.5 mgkg$^{-1}$ | FAO/WHO, 2010 |
| 6. | Ni | 0.05 mgkg$^{-1}$ | EU, 2006 | 0.14 mgkg$^{-1}$ | WHO, 2006 |
| 7. | Mn | 2.0 – 5.0 mgkg$^{-1}$ | EU, 2006 | 0.30 mgkg$^{-1}$ | WHO, 2006 |
| 8. | Fe | 0.8 mgkg$^{-1}$ | FAO/WHO, 2010 | 0.80 mgkg$^{-1}$ | FAO/WHO, 2010 |

*Source: FAO/WHO,(2010). WHO. Summary and Conclusions. Joint FAO/WHO Expert Committee on food Additives (JECFA/73/Sc)*

According to [8], the prolonged consumption of unsafe concentration of heavy metals through foodstuffs may lead to the chronic accumulation of heavy metals in the kidney and liver leading to cardiovascular, nervous, kidney and bone diseases.

## 4. CONCLUSION

All the vegetables had the higher concentrations of the heavy metals studied in comparison to the crops. The results obtained showed that the tuberous crop (cassava) had higher concentrations of the metals studied than plantain. The trend of the concentration of these metals is: WL>SL>FP>BL>Cassava>Plantain for samples from Ebocha farm Site 1 while for the other three farms, the order is SL>WL>FP>BL>Cassava>Plantain. The plantain samples from Ebocha site 2 had the highest concentrations for all the metals except Cd and Mn compared to the cassava from this farm. The plants showed higher bio-accumulation for the metals studied in the order of Fe>Mn>Zn>Cu=Pb>Ni>Cd=Co. Lowering the levels of these heavy metals in the soils can be achieved through phytoremediation as this process is cost effective, has easy application and wider coverage of expanse of land. The results from the various farms indicate that the levels of these metals vary from one farm to another. The plantain from Igbo-Etche has the highest concentration of Cd and the cassava from the farm in Igbo Etche has the highest concentration of all the metals. This is worrisome as processed cassava (garri) is the staple food of the people and they export same to neighboring towns and states. The study has shown that there are high levels of these metals in the vegetables and crops from these farms. It is therefore recommended that since there are no available substitutes in this region, the people should minimize the rate of consumption and quantity consumed of these plants. This way the rate of bio-accumulation of these heavy metals in their body tissues and organs will be reduced. Presently, based on the culture of the people, there are no acceptable foods that can replace these contaminated foods which are the staple food of the people in the area of study. The levels of concentration for the farms can be summarized as follows:

Igbo-Etche > Ebocha 1 = Ebocha 2 > Egbeda.

## ACKNOWLEDGEMENT

The authors wish to express their gratitude to Wisdom N. Barade (Ph.D), Botanist and Taxonomist of the Department of Science Laboratory Technology and Florence N. Fred-Nwagwu of the Department Surveying and Geoinformatics of Ken Saro-Wiwa Polytechnic for their invaluable contributions in identification of samples and geo-referencing of the farm sites respectively.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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