



Heavy Metals in Cassava (*Manihot esculenta* Crantz) Harvested from Farmlands along Highways in Owerri, Nigeria

Josephat Nwabueze Okereke^{1,a*}, Judith Nkeiru Nduka^{1,b}, Ukaoma Augustina Adamma^{2,c}, Odangowei Inetiminebi Ogidi^{3,d}

¹Department of Biotechnology, School of Biological Sciences, Federal University of Technology, Owerri, Nigeria

²Department of Biology, School of Biological Sciences, Federal University of Technology, Owerri, Nigeria

³Department of Science Laboratory Technology, Federal Polytechnic, Ekowe, Bayelsa, Nigeria

*Corresponding author

| ARTICLE INFO | ABSTRACT |
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| <p><i>Research Article</i></p> <p>Received : 31/05/2019 Accepted : 01/12/2019</p> <p>Keywords: Heavy Metals <i>Manihot esculenta</i> Farmlands Highways Owerri</p> | <p>Concentrations of heavy metals (Cu, Pb, Zn, Ni, Cd) in cassava grown on farmlands along highways in Owerri, was investigated. Cassava leaves and root samples were harvested from cassava farms along three major roads with high traffic density and another rural road that served as control location. Standard laboratory procedures to determine the concentration of these metals were adopted using Atomic Absorption Spectrophotometer. The metal concentrations in mg/kg in cassava root showed high levels of Cu (6.29±0.0346), Zn (8.49±2.243), Pb (0.5267±0.3156) and Cd (0.1167±0.0833). The concentrations of the heavy metals in the cassava leaves were of the order: Zn > Cu > Pb > Ni > Cd. Soil plant transfer factor values for all the metals in all the sites indicated medium accumulation. Heavy metal concentrations in soil showed significant correlation with concentrations in cassava root with no significant statistical differences in bioaccumulation of heavy metals in different parts of cassava. The overall results showed evidence of some heavy metal pollution on the soils and cassava plant.</p> |

^a chinwendubueze1@yahoo.com

^b <https://orcid.org/0000-0002-8544-2216>

^c ndukankeiru@gmail.com

^d <https://orcid.org/0000-0002-1871-7427>

^e ukaoma.adamma@yahoo.com

^f <https://orcid.org/0000-0003-2432-2576>

^g ogidiodangowei@gmail.com

^h <https://orcid.org/0000-0002-9961-893X>



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Introduction

Cassava is important part of a human diet because it is a source of nutrient. Cassava plant constitute important functional food components by contributing carbohydrate, vitamins, iron, calcium and other nutrients which have marked health effects (Thompson and Kelly, 1990; Arai, 2002). There is an inherent tendency of plants to take up toxic substances including heavy metals that are subsequently transferred along the food chain (Singh et al., 2010). As such, heavy metal contamination in plants cannot be underestimated as food stuffs are important components of human diet. Heavy metal contamination of the food items is one of the most important aspects of food quality assurance (Wang et al., 2005; Radwan and Salama, 2006; Khan et al., 2011).

Contamination of foods by heavy metals has become a challenge for producers and consumers. The main sources of heavy metals to vegetable crops are their growth media (soil, air, nutrient solutions) from which these heavy metals are taken up by the roots or foliage (Lokeshwari and Chandrappa, 2006). Research on the mechanism of heavy metal uptake by crops or plants from contaminated soils has

become of ever-increasing importance as heavy metal accumulation in crops may lead to the lowering, damage and alteration of animal or human physiological functions through the food chain (Gupta, 1995). Plants show certain reactions to the increasing of toxic elements concentration in soil, depending upon the sensitivity of plants, exposure intensity and chemical species. On lands containing metals, some plant species (metalophytes) have developed tolerance towards them, and others (hyper-accumulators), are characterized by the capacity to accumulate high quantities of metals in their tissues. Heavy metal uptake by plants grown in polluted soils has been studied at a considerable extent. All findings have shown that elevated levels of metals in soil may lead to increased uptakes by plants.

Plants grown on soils possessing enhanced metal concentration have increased metal ion content. Amusan et al. (2003) studied heavy metal uptake by plants and found that Pb uptake by water leaf (*Talinum traingulare*) and Okra (*Abelmoschus esculentus*) increased by 200% and 733% in leaves and by 126% on the fruit of Okra relative to the control. Jassir et al. (2005) reported elevated levels

of heavy metals in vegetables sold in the markets at Riyadh city in Saudi Arabia due to atmospheric deposition, and recently, Sharma et al. (2008) and Zurayk et al. (2001) reported that atmospheric depositions could significantly elevate the levels of heavy metals contamination in plants. This also is synonymous with the report of Abegunde et al. (2015). However, hyper-accumulating plants have been found to accumulate heavy metals above critical levels (Brady and Weil, 1999). Lettuce is a very good bio-accumulator of heavy metals and nutrients. The differences depend on plants sensitivity, and time exposure intensity (concentration of heavy metals, cultivation length, etc.), presence or absence of nutrients and other chemical species in soil (Smical et al., 2008). The uptake of these heavy metals by plants results in bioaccumulation of these elements which according to Alloway (1996) and Kabata-Pendias and Pendias (2011) cause a serious risk to human health when plant-based food stuff are consumed. Studies on heavy metal bioaccumulation of selected tuber crops from Ishiagu, Ebonyi State, South East, Nigeria showed different levels of lead (Pb), Cadmium, Chromium Ni, Mn and Zn (Osuocho et al., 2014).

Centella asiatica has the potential of being used as a bio-monitoring plant for heavy metal pollution in the polluted soils (Yap et al., 2010). Heavy metals uptake in different parts of plants follows the order: roots > stems > leaves. A close positive relationship has been established between the concentrations of metal accumulated in different parts of the plant and the metal levels in the most contaminated soil. A report by Ololade and Ologundudu (2007) showed that cadmium in plants comes to a large extent from atmospheric cadmium as a result of foliar absorption or root uptake of cadmium deposited on soils. The transfer of cadmium from soil to the food chain depends on a number of additional factors, such as the type of plant, the type and pH of the soil, and the zinc and organic matter content of the soil. It is however imperative to note that heavy metal absorption is governed by other soil characteristics like inorganic matter (Gideon-ogero, and Josephine, 2008)

Heavy metals contamination and bioaccumulation can lead to a reduction in cassava root length (Mbong et al., 2013). Metals such as Cd, Ni, Pb, have been reported to inhibit root growth in *Brassica juncea*, alfalfa, and wheat (John et al., 2009). The reduction in the growth of the cassava roots was caused by the suppression of the elongation growth rate of cells, because of an irreversible inhibition exerted by the heavy metals on the proton pump responsible for the root elongation process (Aidid and Okamoto, 1993). Heavy metals can as well lead to reduction in root weight of cassava and other crop plants. Also, constant application of Cd, Ni or Pb can result to reduction in stem girth of cassava as stated by Padmaja et al. (1990) who further reported that the reduction of stem girth of cassava could partly be the direct consequence of the inhibition of chlorophyll synthesis, and photosynthesis by these metals. The effect of the heavy metals on cassava stem girth is dependent on the cassava variety. Furthermore, cassava leaves are also heavy metal target because it causes reduction in number of leaves as reported by Mbong et al. (2013). This has also been observed by Sandalio et al. (2001) in pea plant and John et al. (2009) in *Brassica juncea* L.

Material and Methods

Study Area: The sampling locations were chosen to span a wide range of traffic density and to give a good geographical coverage in Owerri, Imo State. Owerri consists of three Local Government Areas including Owerri Municipal, Owerri North and Owerri West. It has an estimated population of more than 401,873 as at 2006 and approximately 100 square kilometres in area. Geographic coordinates of Owerri, lies within Latitude: 5°29.0178' North, Longitude: 7°1.995' East. Owerri has a tropical wet climate with average temperature is 26.4°C; sits in the rain forest, and produces many agricultural products, such as yams, cassava, corn, rubber and palm products. Some major roads that go through the city are: PortHarcourt road, Aba road, Onitsha road, and Okigwe road with other roads within the city.

Sample Collection

Samples of soil, cassava leaves and roots were randomly collected from three farmlands situated along busy roads in Owerri: Owerri-Onitsha road, Owerri-PortHarcourt road and Owerri-Aba road. Control samples were collected from another cassava farmland in a rural settlement in Owerri (Oforola). Samples were collected at 0 – 10 cm depth at distance intervals of 10, 15, and 20 meters from the roadway with sterilized auger in a polythene bag. Three soil samples were taken from three points from each distance and mixed together to form composite samples.

Preparation, Digestion of Soil samples, and Pre-Treatment of cassava plant

Samples were air-dried and sieved through a 2 mm sieve to remove coarse particles before chemical analysis. Measured 0.5 g of air-dried ground soil was transferred into 250 ml conical flask; 5 ml of concentrated H₂SO₄ was added followed by 25 ml of concentrated HNO₃ acid and 5 ml of concentrated HCl. The flask was heated at 200°C for 1hr in a fuming hood and then cooled to room temperature. After cooling, 20 ml of distilled water was added and the mixture was filtered to complete the digestion. Finally, the mixture was transferred to a 50 ml volumetric flask, filled to the mark and left to settle for at least 15 hours. The filtrate was analysed for total Cu, Fe, Mn, Pb, Zn, Ni, and Cd using Atomic Absorption Spectrometer (AA500F).

The cassava samples (roots and leaves) were washed under running water to remove dust particles. The root samples were cut to small sizes using a knife. Both the roots and leaves were air-dried and then placed in a dehydrator at 80°C for 2-3 days and then dried in an oven at 100 °C. Dried samples of different parts of cassava plant were ground into fine powder (80 mesh) using a commercial blender (TSK- WestPoint, France) and stored in polyethylene bags, until used for acid digestion.

Digestion of Plant Samples

Weighed 5 g of the powder was put into a 250 ml conical flask: 5 ml of concentrated H₂SO₄ was added followed by 25 ml of concentrated HNO₃ and 5 ml of concentrated HCl. The contents of the tube were heated at 200°C for 1 hour in a fuming hood and then cooled to room temperature. About 20 ml of distilled was added and the

mixture was filtered using filter paper to complete the digestion of organic matter. Lastly, the mixture was transferred to a 50 ml volumetric flask, filled to mark, and allowed to settle for at least 15hours. The resultant supernatant was analysed for Cu, Fe, Mn, Pb, Zn, Ni, and Cd using Atomic Absorption Spectrometer (AA500F).

Transfer Factor of Metal from Soil to Plant

Metal concentrations in the extracts of soils and plants were calculated on the basis of dry weight. The plant Transfer factor was calculated as follows:

$$Tf = \frac{C_{plant}}{C_{soil}}$$

Where; Tf is Transfer factor, C plant and C soil represent the heavy metal concentration in extracts of plants and soils on dry weight basis, respectively (Cui et al., 2005).

Results

Concentrations of Heavy metals in cassava plants in farmlands along Highways

The mean concentrations of heavy metals (Cu, Pb, Zn, Ni, Cd,) obtained for the cassava root samples planted at 5 m, 10 m, and 15 m distances from the highways, and rural farms are summarized in Table 1. The levels of heavy metals in the roots ranged between 8.49 mg/kg and 0.113 mg/kg along Owerri-Onitsha, Owerri-PortHarcourt, and Owerri-Aba roads with Zn recording highest value (8.49 mg/kg) in samples from Owerri-Onitsha road and Cd, the least (0.07 mg/kg) in samples from Owerri-Aba road. The heavy metal levels tended to be lower in control samples.

Figures 1a – 1e present values of different metal concentration (Cu, Pb, Zn, Ni, Cd) in cassava samples harvested at 10 m, 15 m, and 20 m distance away from the highway. The level of copper in cassava root grown along Owerri-Aba road ranged from 6.18 mg/kg - 6.23 mg/kg while Owerri-Onitsha road recorded highest copper content (6.33 mg/kg) at 15 m distance. The level of Pb at 10 m, 15 m, 20 m were 0.62 mg/kg, 0.41 mg/kg, and 0.20 mg/kg respectively, along Owerri-Aba road while values along Owerri-Portharcourt road differed. Zn levels in samples from Owerri-Onitsha road were 9.82 mg/kg, 9.755 mg/kg, and 5.90 mg/kg, at 10 m, 15 m, and 20 m respectively.

The total mean concentrations of Copper, Lead, Zinc, Nickel and Cadmium obtained from the cassava leaves samples at the four sites are presented in Table 2. The mean values of Cu along all the highways and control ranged between 6.31±0.02 and 3.33±0.11 mg/kg; Pb, 0.95±0.39 – 0.17±0.001 mg/kg; Zn, 6.26±0.58 – 4.03±0.13 mg/kg; Ni, 0.14±0.02 – 0.12±0.02 mg/kg; Cd, 0.16±0.03 – 0.07±0.01. The total metal concentration deposition on cassava leaves from 10 m, 15 m, and 20 m distance at different sampling locations are presented in Figures 2a- 2e.

Transfer factor (Tf): Table 3 shows the transfer factor (Tf) of heavy metals from the soil to plants, which is the ratio of the concentration of metals in plants to the total concentration in the soil. Cu and Zn recorded high transfer factors along different sites sampled.

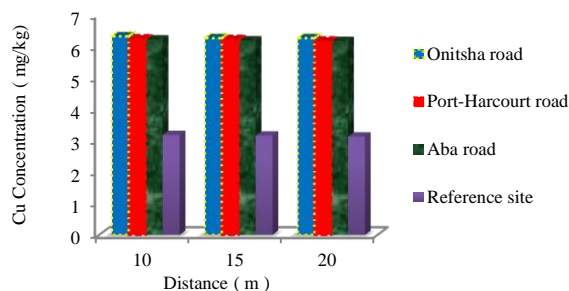


Figure 1a. Total Cu level in cassava root

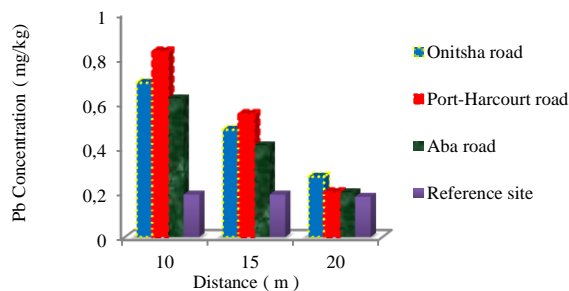


Figure 1b. Total Pb level in cassava root

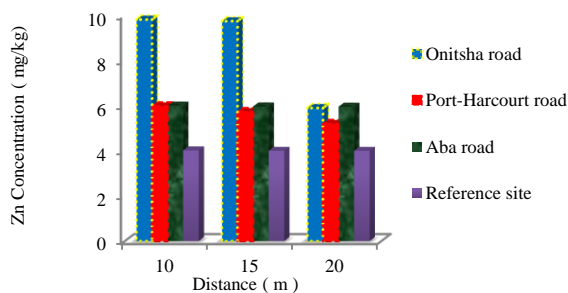


Figure 1c. Total Zn level in cassava root

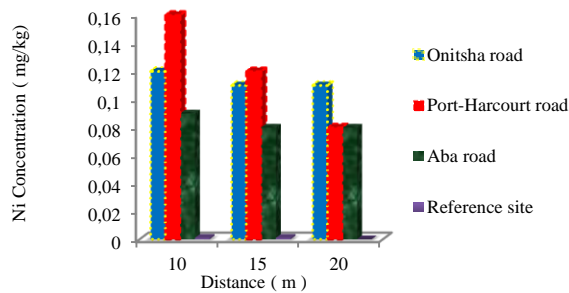


Figure 1d. Total Ni level in cassava root

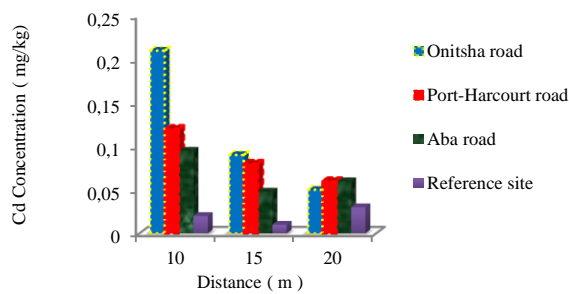


Figure 1e. Total Cd level in cassava root

Table 1. Mean concentrations of heavy metals in cassava roots

| Metal | OW-NS | OW-PH Concentrations | OW-AB (mg/kg) | Control |
|-------|---------------|----------------------|---------------|---------------|
| Cu | 6.29±0.0346 | 6.2±0.0361 | 6.2033±0.0252 | 3.1667±0.0251 |
| Pb | 0.48±0.2100 | 0.5267±0.3156 | 0.41±0.2100 | 0.1867±0.0058 |
| Zn | 8.49±2.2430 | 5.6267±0.3980 | 5.98±0.0265 | 4.0067±0.0115 |
| Ni | 0.113±0.0058 | 0.12±0.0400 | 0.0833±0.0058 | 0.0007±0.0006 |
| Cd | 0.1167±0.0833 | 0.0867±0.0306 | 0.0677±0.0244 | 0.02±0.0100 |

Legends: OW-NS = Owerri-Onitsha road, OW-PH = Owerri-PortHarcourt road, OW-AB = Owerri-Aba road

Table 2. Mean concentrations of heavy metals in cassava leaves

| Metal | OW-NS | OW-PH Concentrations | OW-AB (mg/kg) | Control |
|-------|----------------|----------------------|---------------|----------------|
| Cu | 5.90667±0.6813 | 6.31±0.0200 | 6.2267±0.0252 | 3.333±0.1069 |
| Pb | 0.7833±0.2250 | 0.95±0.3904 | 0.713±0.2829 | 0.1667±0.00578 |
| Zn | 6.2633±0.5781 | 5.953±0.0252 | 5.99±0.0265 | 4.03±0.1308 |
| Ni | 0.1367±0.0058 | 0.1333±0.0379 | 0.1233±0.0208 | 0.1433±0.0153 |
| Cd | 0.1033±0.0153 | 0.158±0.0327 | 0.0763±0.0068 | 0.0667±0.0115 |

Legends: OW-NS = Owerri-Onitsha road, OW-PH = Owerri-PortHarcourt road, OW-AB = Owerri-Aba road

Table 3. Plant Transfer factor (Tf) of mean of metals

| Metal | Onitsha Road | Ph Road | Aba Road | Referencee |
|-------|--------------|---------|----------|------------|
| Cu | 0.99 | 1.03 | 0.99 | 1.06 |
| Pb | 0.24 | 0.52 | 0.20 | 0.11 |
| Zn | 1.07 | 0.97 | 1.00 | 0.99 |
| Ni | 0.17 | 0.23 | 0.18 | 0.06 |
| Cd | 0.20 | 0.21 | 0.09 | 0.13 |

Table 4. Mean difference in concentrations between distance and Cassava root.

| Metal | 10 – 15 m | Sig. diff | 15 – 20 m | Sig. Diff | 10 – 20 m | Sig. diff |
|-------|------------------|-----------|-----------------|-----------|-----------------|-----------|
| Cu | 0.03000±0.020680 | 0.197 | 0.0300±0.020683 | 0.197 | 0.000±0.020683 | 1.000 |
| Pb | 0.05250±0.15777 | 0.751 | 0.1900±0.157770 | 0.274 | 0.1375±0.15777 | 0.417 |
| Zn | 0.77000±0.83730 | 0.393 | 0.92750±83730 | 0.310 | 0.15750±0.83730 | 0.857 |
| Ni | 0.01500±0.01438 | 0.337 | 0.01975±0.01438 | 0.219 | 0.00475±0.01438 | 0.753 |
| Cd | 0.04425±0.03193 | 0.215 | 0.00300±0.03193 | 0.928 | 0.04125±0.03193 | 0.244 |

Mean ± SEM

Table 5. Correlation between concentration of heavy metals in soil and root of Cassava crop.

| Metal | Spearman's corr. Coefficient | Sig diff |
|-------|------------------------------|----------|
| Cu | 0.632 | 0.368 |
| Pb | -1.000 | 0.000 |
| Zn | -1.000 | 0.000 |
| Ni | -0.500 | 0.667 |
| Cd | 0.200 | 0.800 |

$\alpha = 0.05$

Statistical correlation of heavy metals in soil at different distance and cassava plants

The result for the mean difference in concentration of the heavy metals between distance and Cassava root showed no significant increase or decrease (Table 4), but the values showed an increasing trend from the 20 m region to the 10 m region. In determining the correlation between heavy metals in the soil and root of cassava crops, Cu, Ni and Cd showed no correlation at $\alpha = 0.05$ (Table 5). Zn showed a positive correlation while Pb showed a negative correlation even at $\alpha = 0.001$ for both Zn and Pb. This implies that increase in the concentration of Zn in soil causes a highly significant increase in Zn in the root of Cassava crop while an increase in concentration of Pb in soil causes significant decrease in the in the root concentration of Cassava crop.

Discussion

The levels of heavy metals bioaccumulation in cassava root and leaves reported in this study are generally lower than the WHO/FAO (2001) safe limit. There were also evidences of decrease in concentration with increase in distance at each site. Possibly due to low pH, Cd was found to bio-accumulate in cassava roots and leaves. Several studies have reported that cadmium is a highly mobile metal, easily absorbed by plants through root surface and moves to wood tissue and transfers to upper parts (Adu et al., 2012), which is synonymous with the findings as recorded in this study. Itanna (2002) and Muhammad et al. (2008) reported that there is a direct relation between the levels of cadmium in the root zone and its absorption by plant. Thus in this study, soil Cd concentration is higher than plant Cd concentration.

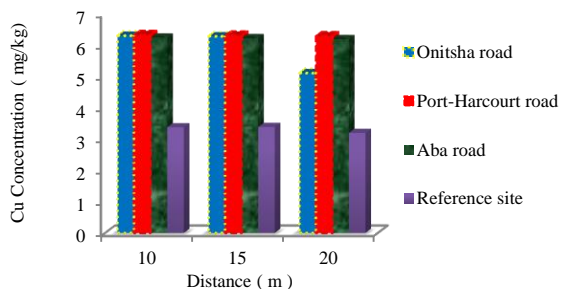


Figure 2a. Total Cu content in cassava leaves

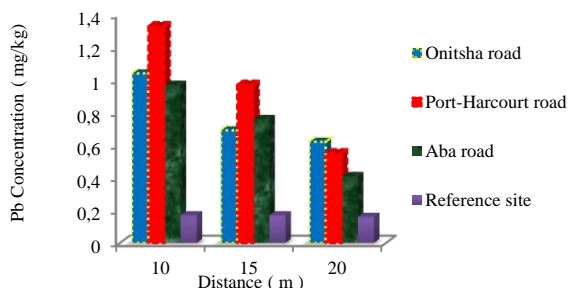


Figure 2b: Total Pb content in cassava leaves

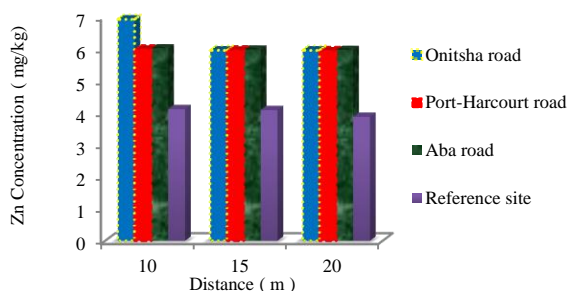


Figure 2c. Total Zn content in cassava leaves

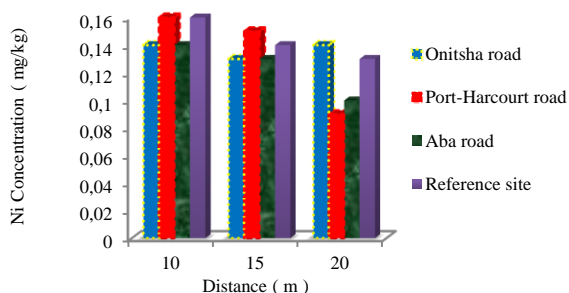


Figure 2d. Total Ni content in cassava leaves

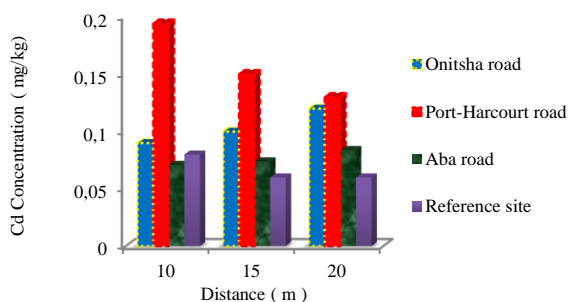


Figure 2e. Total Cd content in cassava leaves

Zinc accumulated more in cassava root (9.82 mg/kg) than the leaves which is an evidence of root mineral absorption. Chiroma et al. (2003) in their study on heavy metal contamination of vegetables and soils irrigated with sewage water in Yola, Nigeria, reported that heavy metal concentrations vary in different parts of the plant with Fe accumulating in roots and leaves while Zn accumulated in roots and possibly translocated gradually to the leaves. Amusan et al. (2003) studied heavy metal uptake by plants and found that Pb uptake by water leaf (*Talinum traingulare*) and Okra (*Abelmoschus esculentus*) increased by 200% and 733% respectively in leaves and by 126% on the fruit of Okra relative to the control. There are reports of direct relationship between levels of lead in plants and traffic density (Turan et al., 2011; Shafiq et al., 2012; Verma et al., 2013). One possible explanation for this situation is that the Pb uptake can be promoted by the pH of soil and the levels of organic matter. According to Sharma and Prasad (2010), only 3% of Pb in soil is translocated through the root to the shoot of plants while the rest is through foliage. The Cu plant concentration was highest in the root (6.29±0.0346 mg/kg) and lowest in the leaf (3.333±0.1069 mg/kg). The copper levels found in cassava plant were within safe limits in all samples. A report by Adelasoye and Ojo (2014) showed that cassava leaf contained higher concentration of the heavy metals at high traffic than low traffic density roads. In the same vein, regions closer to the roads had plant leaves higher in the metal concentrations than 20 - 30 m away from the roads. Muhammad et al. (2008) studied the response of three vegetables to Cu toxicity and found that Cu levels in both root and shoot increased, but root Cu concentration increased more sharply than shoot with increasing Cu levels in growth media. Cu mainly accumulated in roots while a small fraction (10%) of absorbed Cu was transported to shoot. Moshen and Moshen (2008) found that Cu concentration in the shoots was significantly influenced by Cu concentration in soil. The statistical analysis result showed that there was no significant difference in the bioaccumulation of heavy metals in the different parts of cassava crop which implies that cassava crop is not a hyper-accumulator plant. Reports show that leafy vegetables have greater potential for accumulating heavy metals in their edible parts than grains and fruit crops, due to their higher transpiration rate (Jacob, 2010).

The values of heavy metal transfer recorded are considered high because values close to or above 1 (one) are considered high Tf values (Uwah et al., 2009). The high Tf value may be due to its weak adsorption onto the organic matter which renders it more bio-available to plants (Alloway and Ayres, 1998). Pb showed low Tf values with the highest being 0.52, indicating that cassava plants from the study area did not have a high Pb contamination. From the results obtained, the highest transfer factor recorded was in Zn, with all values above 0.5, indicating that cassava plants were contaminated with Zn probably from anthropogenic sources, and this is based on the suggestion that the greater the transfer coefficient value above 0.50, the greater the chances of plant-metal contamination (Kloke et al., 1984). Chiroma et al. (2003) showed that Zn accumulates in roots and translocates gradually to the leaves. This implies that the bioaccumulation of heavy metals in plant was very high and food processed from such

could lead to hypertension, arthritis, diabetes, anaemia, cancer, cardiovascular disease, cirrhosis, reduced fertility; hypoglycemia, headaches, osteoporosis, kidney disease, and stroke (Lokeshappa et al., 2012) due to Zn poisoning. Cd had very low Tf in all the samples which is in contrast with work carried out by Mohammed and Folorunsho (2015) who recorded a mean Cd value of 3.214 mg/kg. The difference may be due to location of study, considering the fact that soil from different locations differ in properties. The bioaccumulation of heavy metal in cassava root and leaves showed a mean value with no significant difference for the three locations and control. Plants are known to take up and accumulate trace metals from contaminated soil (Abdul Kasheem and Singh, 1999), hence detection in plant leaves and crop samples was not surprising. Although the levels of these metals were within normal range for plants, continual consumption could lead to accumulation and adverse health implications particularly for Pb, As, and Cd (Opaluwa, 2012). Furthermore, values obtained in soil and crop plant samples could be attributed to vehicular emission deposit on farmlands and crops.

Conclusion

The overall results showed evidence of some heavy metal pollution on the soils and bio-accumulation in cassava plants, from farmlands along highways in Owerri. The heavy metal levels tended to be lower in control samples. Cu and Zn recorded high transfer factors along different sites sampled. While Zn showed a positive correlation, Pb showed a negative correlation. This implies that increase in the concentration of Zn in soil causes a highly significant increase in Zn in the root of Cassava plant while an increase in concentration of Pb in soil causes significant decrease in the in the root concentration.

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