Environment and Pollution; Vol. 2, No. 2; 2013
ISSN 1927-0909 E-ISSN 1927-0917
Published by Canadian Center of Science and Education

# Uptake of Heavy Metals by *Dioscorea rotundata* (White Yam) and *Ipomoea batatas* (Sweet Potato) from Enyigba Lead-Zinc Derelict

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Received: July 27, 2012 Accepted: January 11, 2013 Online Published: March 27, 2013
doi:10.5539/ep.v2n2p79 URL: http://dx.doi.org/10.5539/ep.v2n2p79

**Abstract**

The levels of heavy metals in *Dioscorea rotundata* (white yam) and *Ipomoea batatas* (sweet potato), in addition to the soil, were examined using X-ray Fluorescence (XRF) technique. The results revealed that heavy metal in soil decreased in the order Pb > Zn > Cu > Mn > Cd > Ni > As > Cr. The mean concentration (mg $kg^{-1}$) of metals was found in the range of Pb (0.04-0.14); As (0.02-0.04): Cd (0.02-0.04); Cu (40.12-62.12); Cr (0.01-0.21); Zn (24.18-74.60); (Mn 18.46-84.90); and Ni (8.24-14.86). As and Cd were not detected in leaves of *Dioscorea rotundata.* Generally accumulation of metals was observed to be higher in the root than in the leaves and the Translocation Factor (TF) was highest (2.0) in *Ipomoea batatas* and lowest (0.22) in *Dioscorea rolundala*. High Pollution Indices (PI > 1) of As and Pb was observed in the two investigated tubers. The variation in the parameters determined were found to be statistically significant ($p < 0.05$) as determined by one way analysis of variance.

**Keywords:** heavy metals, tuber crops, X-ray fluorescence, Enyigba lead-zinc derelict

## 1. Introduction

Increasing industrialization has been accompanied throughout the world by the extraction and distribution of mineral substances from their natural deposits (Sing, 2001). Unlike many other pollutants associated with the environments, metals are non-biodegradable and can undergo biomagnifications in living tissues (Clark, 1992). Uptake and accumulation of heavy metals by plants is either via the roots and foliar surfaces (Sawidis et al., 2001). Some factors which affect metal uptake include soil pH, metal solubility, conductivity, stages of plant growth, plant species, soil type and fertilizers (Sharma et al., 2006; Ismail et al., 2005). Previous work by Kaplan et al. (2005) showed that individual plants have different capacity to absorb and accumulate heavy metals which leads to contamination of the food chain. This situation causes varying degrees of illness based on acute and chronic exposures (Demirezen & Ahmet, 2006). The present study was carried out within the vicinity of a lead - zinc derelict mine, Enyigba in South East Nigeria where farmers cultivate their crops around the mine waste. The contamination status of many edible plants from Enyigba is yet to be established. Previous works in Enyigba by Nweke et al. (2008) and Chukwuma (1993) focused on soils and wild plants respectively. Tuber crops such as *Dioscorea rotundata* and *Ipomoea batata* are very common in Enyigba and its environs. Mothers often fry these tubers and serve as breakfast to young children. The aims of this study are in two fold; first, establish the Pollution Index or contamination status of the investigated tubers by comparing the concentration of As, Cd, Pb, Zn, Cu, Cr, Mn, and Ni in the tubers with the World Health Organization (WHO) Maximum Allowable Limit. Second, establish Translocation Factor (TF) of the tubers by comparing the concentrations of metals in roots with those in the leaves of the tubers. Translocation Factor reveals the plant's ability to translocate heavy metals from the root to aerial part is used to evaluate the plants potential for phytoremediation purposes (Mattina et al., 2003).

## 2. Materials and Methods

### *2.1 Study Area*

Enyigba is located approximately 14 km South of Abakaliki, the capital of Ebonyi State, Nigeria and has a sparse rural population of farmers. The prevailing climate conditions are high temperatures, high atmospheric humidity and precipitation usually exceeding evapotranspiration. The vegetation types are mangrove and freshwater swamp communities, rainforest, forest/savanna mosaic and derived savanna zone. The farming systems prevailing in the region are dominated by yam/root crops/plantain, oil palm bush and indigenous trees of nutritional economic, medicinal and cultural importance. Mining of lead began around 1925 but was interrupted by the Nigerian civil war and as a result many villagers have resorted to cultivating their economic plants around the derelict properties (Oti et al., 2012).

### *2.2 Sampling*

*Dioscorea rotundata* and *Ipomoea batatas* were selected for the analysis because they form staple food consumed by the masses on a daily basis (Taiwo, 1985). Composite samples of the plants and soil were collected within a 200 meter radius of the mine.

Soil sample pre-treatment: Soil samples were air-dried, mechanically ground and sieved to obtain < 2 mm fraction. A 30 g subsample was drawn from the bulk soil (< 2 mm fraction) and reground to obtain < 200 µm fraction using a mortar and pestle.

Plant sample pre-treatment: The roots and leaves of the *Dioscorea rotundata* and *ipomoea batatas* were separated in each case and the components were cut into pieces. Samples were then put through a three step washing sequence, air dried, weighed and placed in a dehydrator at 80 °C for 48 hours. The moisture and water droplets were removed with the help of blotting papers. The sample was pulverized into fine powdery form by the use of an agate mortar.

Sample analysis: Standard Operating Procedure for XRF was followed in accordance with Shefsky (1995) and Galadima and Garba (2012). A 13 mm pellet of the sample was formed using CAVER model manual palletizing machine at a pressure of 6–8 torr. A voltage of 25 KV and current of 50 µA produced from X-ray tube was used to bombard the sample in XRF system for 18 minutes at 1000 counts. Si-Li detector was used to detect the characteristic X-ray of the metals and their corresponding concentrations were computed in the read out device.

## 3. Results

Table 1 shows the mean concentration of heavy metals in soil with their corresponding pollution indices while Table 2 shows the properties of the soil respectively. Values shown in Tables 1 and 2 are mean ± Standard Deviation. Tables 3, 4 and 5 illustrate the levels, the Translocation Factor and the Pollution Indices of heavy metals in the investigated tubers, respectively. Figures 1, 2 and 3 show the Translocation Factors of heavy metals and the Pollution Indices of the roots and leaves of the investigated plants, respectively.

Table 1. Mean concentrations (mg/kg) of heavy metals in soil and their pollution indices (n=3)

| Metals | Pb | As | Cd | Cu | Cr | Zn | Mn | Ni |
|---|---|---|---|---|---|---|---|---|
| Conc (mg/kg) | 1116.8±43.2 | 4.8±1.8 | 126.0±42.1 | 812.2±141.2 | 2.12±0.2 | 995.2±82.4 | 424.0±50.4 | 82.6±22.0 |
| PI | 2.7 | 0.06 | 1.5 | 0.19 | - | 0.13 | - | 1.1 |
| USEPA | 420 | 75 | 85 | 4300 | - | 75000 | 1-1830* | 75 |

*Values refer to metal concentration in typical soils (Miroslav & Vladimir, 1999), PI = Pollution index.

Table 2. Properties of Enyigba soil

| Properties | Enyigba soil (n=3) |
|---|---|
| Sand (%) | 61.28±5.2 |
| Silt (%) | 7.12±0.8 |
| Clay (%) | 31.60±2.6 |
| Organic matter (%) | 1.34±0.5 |
| Mean pH | 6.80±0.38 |

Table 3. Levels of heavy metals in the leaves and root of *Dioscorea rotundata* and *Ipomoea batatas* and their translocation factor

| Heavy metals concentration (mg/kg) (n =3) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Botanical name | Common Name | Plant parts | Pb | As | Cd | Cu | Cr | Zn | Mn | Ni |
| *Dioscorea rotundata* | White yam | Leaves | 0.21 | ND | ND | 42.12 | 0.01 | 24.18 | 18.46 | 12.42 |
| | | Root | 0.41 | 0.12 | 0.02 | 40.12 | 0.01 | 62.43 | 82.62 | 14.86 |
| Translocation Factor | | | 0.51 | - | - | 1.05 | 1.0 | 0.39 | 0.22 | 0.84 |
| *Ipomoea batatas* | Sweet | Leaves | 0.04 | 0.02 | 0.04 | 62.12 | 0.21 | 46.12 | 28.12 | 8.24 |
| | Potato | Root | 0.12 | 0.14 | 0.02 | 42.24 | 0.18 | 74.60 | 84.90 | 10.24 |
| Translocation Factor | | | 0.33 | 0.14 | 2.0 | 1.47 | 1.17 | 0.62 | 0.33 | 0.81 |

ND = Not Detected

Table 4. Pollution indices of heavy metals in *Dioscorea rotundata* and *Ipomoea batatas*

| Pollution Indices | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Botanical Name | Common Name | Plant parts | Pb | As | Cd | Cu | Cr | Zn | Mn | Ni |
| *Dioscorea rolundala* | White yam | Leaves | 0.7 | - | - | 0.56 | 0.2 | 0.24 | 0.04 | 0.19 |
| | | Root | 1.37 | 1.2 | 0.2 | 0.55 | 0.2 | 0.62 | 0.17 | 0.22 |
| *Ipomoea batatas* | Sweet | Leaves | 0.13 | 0.2 | 0.4 | 0.85 | 4.2 | 0.46 | 0.06 | 0.12 |
| | Potato | Root | 0.4 | 1.4 | 0.2 | 0.58 | 3.6 | 0.75 | 0.17 | 0.15 |
| WHO/FAO | Maximum | Limit | 0.3 | 0.1 | 0.1 | 73 | 0.05 | 100 | 500 | 67 |

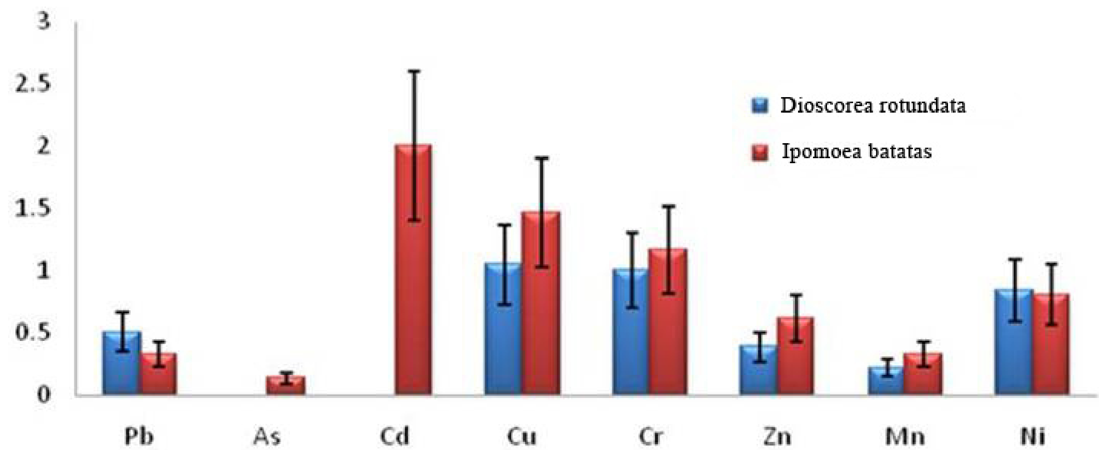


Figure 1. Translocation factors of heavy metals in *Dioscorea rotundata* and *Ipomoea batatas*

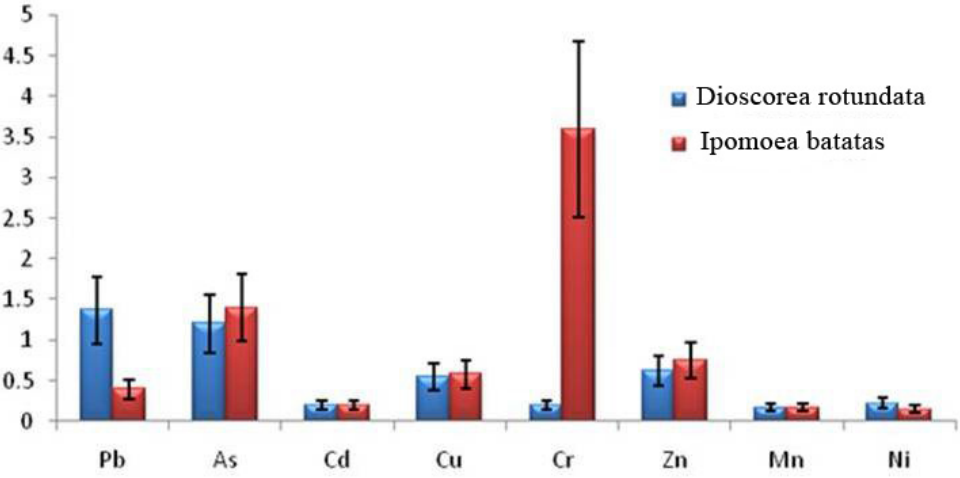


Figure 2. Pollution indices of roots of *Dioscorea rotundata* and *Ipomoea batatas*

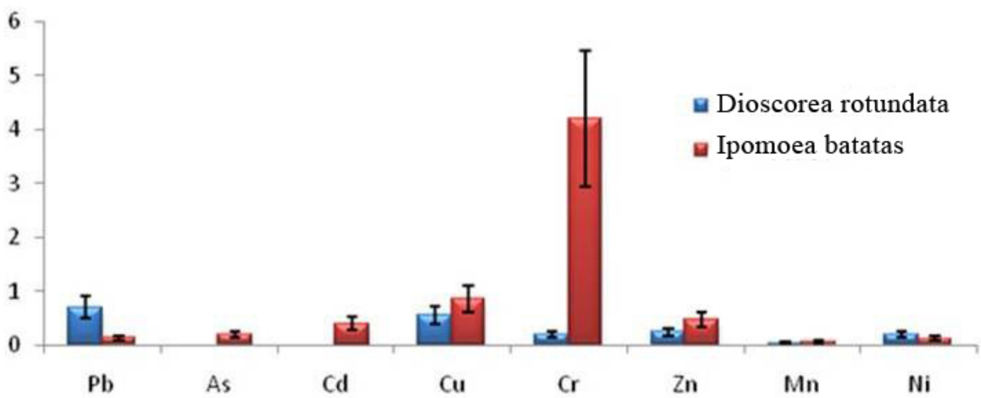


Figure 3. Pollution indices of leaves of *Dioscorea rotundata* and *Ipomoea batatas*

Trace metal levels in soil decreased in the order Pb > Zn > Cu > Mn > Cd > Ni > As > Cr (Table 1). Table 2 illustrates that mean pH of soils was 6.8 indicating that the soil environment is neutral. The availability of nutrients for plants is directly influenced by soil pH. Since tuber crops have been established to do best in slightly acidic soils of 5.8-6.4 pH (CU-DA Bulletin, 1994), suggesting that these categories of crop will not grow well in the study area unless something is done to reduce the pH value. Data obtained from this analysis suggests that Enyigba soils were polluted with Pb, Cd and Ni having their pollution indices as 2.7, 1.5 and 1.1 respectively (Table 1, Figures 2 and 3). Lower concentrations of the studied metals were observed in unpolluted soil samples of Abakaliki, and their corresponding pollution indices were low (Oti et al., 2012). Accumulation of metals in roots was found to be higher than in the leaves (Table 3). High PI value of Pb in white yam suggests that the tuber were already contaminated with Pb (Table 4). A recent study in Zamfara State, Nigeria of environmental Pb poisoning of youths and children of a community engaged in artisanal mining resulted in deaths of 163 people between March and June 2010 (The Punch, 25th December, 2012). Demirezen and Ahmet (2006) observed a high concentration of Pb ranging between 3.0 mg/kg–10.7 mg/kg in a similar study done in Turkey. At 95% confidence level ($p < 0.05$), it was discovered Translocation Factor of the studied metals in *Dioscorea rotundata* was significantly higher than in *Ipomoea batatas*. Their results contradict Muhammad et al. (2008) where concentration of Pb was observed to be higher in leaves than in roots of the plants. Lead uptake is promoted by the pH of soils and organic matter. Toxicological effects of Pb on humans include inhibition of hemoglobin formation, sterility, hypertension and mental retardation in children (Amdur, 1991). Pollution Index of As in roots of *Dioscorea rotundata* and *Ipomoea batatas* were >1 (Table 4, Figure 2 and 3) suggesting As contamination of affected tubers. Arsenic toxicity like Pb, affects not only the central nervous system, but the gastrointestinal dysfunctions (ASTDR, 2010). According to Alam et al. (2003), high values of As were recorded in plants grown in polluted sites in Bangladesh. Highest values of Translocation Factor was observed in *Ipomoea batatas* for Cd (2.0) suggesting that tubers have a greater ability to transfer Cd from the root to the leaves. Cadmium is known to accumulate in kidneys where it damages filtering mechanisms. It takes a very long time before cadmium that has accumulated in kidneys is excreted from a human body (Jennings, 2005).

The PI of Cu in the two tubers from Enyigba was < 1 (Table 4, Figures 2 and 3). Copper is an essential trace element in plants and animals. The human body contains copper at a level of about 1.4 to 2.1 mg $kg^{-1}$ of body mass. However, chronic (long-term exposure) affects of Cu exposure can damage the liver and kidneys (USEPA, 2010). The PI of Cr in *Ipomoea batatas* was > 1 while that of *Dioscorea rotundata* was < 1 (Table 4, Figures 2 and 3). TF of Cr in *Ipomoea batatas* was found to be higher than in *Dioscorea rotundata*. Morishima and Oka (1980) reported high uptake of Cr in plant grown in polluted soils. The PI of Mn, Zn and Ni in the investigated tubers were found to be < 1 implying that their levels in the tubers have not reached a critical point. Critical point is reached when PI = 1 (Miroslav & Vladimir, 1999).

## 4. Conclusion

This study provides a baseline data for further research in this part of the country ravaged by mining activities. The concentrations of metals were observed to be high in the tubers with levels of As and Pb exceeding WHO maximum limit in *Dioscorea rotundata*. Similarly As exceeded WHO maximum limit in *Ipomoea batatas.* Consumption of these tubers over a period of time may result to bioaccumulation of these toxic metals which can lead to adverse health effect or even death. On the other hand, hyperaccumulation of these metals indicates the potential of these plants as bioindicators and phytoremediation agents for environmental monitoring and cleaning up of polluted sites respectively. Further studies on the socio-economic and health status of the neighboring communities will provide more insight on the overall impact of mining activities.

**Acknowledgements**

The authors are grateful for the support and input of Dr. Mrs. C. D. Nnamani of Applied Biology Department of Ebonyi State University, Abakaliki, Nigeria for authenticating our plant samples and Mr Godwin Eze of Center for Energy Research and Development, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria for his priceless contribution in the XRF facilities at the Center.

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