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Heavy Metal Accumulation by *Telfairia occidentalis* Hook f. Grown on Waste Dumpsites in South-eastern Nigeria

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ABSTRACT

Leachates from waste dumpsites in Abakaliki metropolis, South eastern Nigeria has become a major source of heavy metal pollution to the soil. Cultivation of *Telfaria occidentalis* is practiced in these waste dumpsites due to its high organic matter in order to increase yields. *Telfaria occidentalis* grown on two selected waste dumpsites in the metropolis was collected. Heavy metals (Cu, Zn, Pb and As) in their plant parts as well as in the soil were determined using digestion and Atomic Absorption Spectrophotometric methods. Heavy metal values in leaf were highest for Pb followed by shoot. Pb ranged from 0.35-0.54 mg kg^{-1}, Copper ranged from 0.02-0.07 mg kg^{-1} and Zn ranged from 0.04-0.06. Transfer factors were high suggesting that consumption of vegetables grown on the waste dumpsites is dangerous to human health. The Translocation Factor (TLF) for As, Pb and Cu was higher than 1.0 but lower than 1.0. The enrichment coefficient of Pb and As was higher than 1.0. In view of plants role in food chain, cultivation of *Telferia occidentalis* in waste dumpsites should be eschewed.

Key words: Heavy metal, *Telfairia occidentalis*, accumulation, pollution, safety risk

INTRODUCTION

Vegetables constitute essential components of the diet, by contributing proteins, vitamins, calcium and other nutrients which are in short supply (Thompson and Kelly, 1990). Vegetables also feature as barriers for acidic substances gained during digestion process.

However, it may have essentials and toxic metals at very high concentration (Bahemuka and Mubofu, 1999). Metals such as lead, zinc arsenic and copper are cumulative poisons. These metals are toxic and can be hazardous to the environment (Ellen *et al.*, 1990). Vegetables possess beneficial antioxidative effects and a rich source of vitamins, minerals and fibres (Sharma *et al.*, 2009). The potential sources of essential nutrients are a functional food component constituting of protein, vitamin and calcium which marked with health effect. The application of modern technologies are likely to result in pollution, thus leading the contamination of food chain.

There is deposition of heavy metals on plants parts exposed to air pollution and contaminants in the soil which are subsequently absorbed into the tissues of the vegetable (Cui *et al.,* 2004). The biovailability and mobility of heavy metals is brought to bear by solubility which is associated with various chemical forms (Jarup, 2003). It has been reported that plant species have the ability to sequester specific heavy metals thus causing a threat to human when eaten (Farooq *et al.*, 2008;

Wenzel and Jackwer, 1999). The uptake and bioaccumulation of heavy metals in vegetables is influenced by many factors such as climate, atmospheric depositions, the concentration of heavy metal in soils, the nature of soil and the degree of maturity of the plants at the time of the harvest (Voutsa *et al.*, 1996). Solid waste management constitute a big challenge to Nigeria, Ebonyi State inclusive because waste sorting and separation is not practiced. Thus a material that has lost its value is sent to the waste dump sites. Some farmers have resorted to cultivating their vegetables on such lands due to its high organic content in order to increase their yields and gains. Human health is being endangered due to heavy metal uptake by vegetables grown in soils contaminated with heavy metals (Carlson, 1976; Alloway, 1996). Therefore, there is need to analyze soils and vegetables from these dumpsites to determine the levels of contaminants by these harmful metals. Bioconcentration Factor (BCF) which is the ratio of the metal concentration in the soil environment is a convenient and reliable way of quantifying the relative differences in bio-availability of metals to plants (Haynes and Toohney, 1998).

Telfairia occidentalis was chosen for heavy metal contamination as well as for phytoremediation study because it plays an important role in human and livestock nutrition and is an extremely important vegetable predominantly grown by small scale farmers and commonly consumed by majority of the people in Southern Nigeria. This study was undertaken to evaluate heavy metal concentration of the soil and *Telfairia occidentalis* grown on the dumpsites and draw conclusions from the results obtained on the suitability or otherwise of the plant cultivated on its phytoremediation ability and for human consumption as well. The specific objectives are to:

- Determine the status of heavy metal (Pb, Cu, Zn and Cd) contamination in the selected waste dump soil in Abakaliki Urban
- Determine heavy metal concentrations in *Telfairia occidentalis* from these waste dumpsites
- Determine the extent of heavy metal uptake from these sites using transfer factor

MATERIALS AND METHODS

Telfairia occidentalis plants as well as soil samples used in this study were obtained from waste dump sites located at Abakaliki, South-eastern Nigeria. Sampling of the plant biota was done manually. At least three plants of the same species were collected at each site. The samples were later packed in polyethylene bags and transported to the laboratory in an ice box at 4°C. Samples were separated into portions of roots, stems and leaves samples. Plant were then cut into smaller portions and washed with distilled water and then double rinsed with deionised water. The samples were air dried and then homogenized into fine grained fractions in a grinding mill.

Dried samples of 1.2 g were transferred into 250 mL Pyrex beakers, 20 mL of 65% HNO_3 added and left overnight before heating them on a hot plate. An open-beaker digestion was performed at 250°C hot plate attained gradually until the mixture was heated to near dryness. Then 5.0 mL of 30% hydrogen peroxide was added to complete the digestion and the resulting mixture heated again to near dryness. The residues were not completely dissolved. The beaker walls were washed with 2.5 mL of deionised water and the digest heated till boiling. The digest liquor was allowed to cool and later transferred into 25 mL standard flasks which were filled with deionised water to the mark. Soil samples were analysed as described by Sekabira *et al.* (2010). Heavy metals were then analyzed by direct aspiration of the sample solution into a Perkin-Elmer model 2380 Flame Atomic Absorption Spectrophotometer.

Data analysis: The mobility of the heavy metals from the polluted substrate into the roots of the plants and the ability to translocate the metals from roots to the harvestable aerial part were evaluated respectively by means of the Bioconcentration Factor (BCF) and the Translocation Factor (TF).

BCF is defined as the ratio of metal concentration in the roots to that in soil ([Metal] Root/[Metal] Soil), TF is the ratio of metal concentration in the shoots to the roots ([Metal] Shoot/[Metal]Root).

The ability of plants to tolerate and accumulate heavy metals is useful for phytoextraction and phytostabilization purpose (Yoon *et al*., 2006). Plants with both bioconcentration factors and translocation factors greater than one (TF and BCF>1) have the potential to be used in phytoextraction. Besides, plants with bioconcentration factor greater than one and translocation factor less than one (BCF>1 and TF<1) have the potential for phytostabilization (Yoon *et al*., 2006).

The definition of metal hyper accumulation has to take in consideration not only the metal concentration in the above ground biomass, but also the metal concentration in the soil.

Both Enrichment Factor (EF) and Translocation Factor (TF) have to be considered while evaluating whether a particular plant is a metal hyperaccumulator (Ma *et al*., 2001).

The enrichment factor is calculated as the ratio plant shoot concentration to soil concentration ([Metal] shoot/[Metal] Soil) (Branquinho *et al*., 2007). Therefore, a hyperaccumulator plant should have EF>1 or TF>1, as well as total accumulation >1000 mg kg^{-1} of Cu, Co, Cr, Ni or Pb, or >10000 mg kg^{-1} of Fe, Mn or Zn.

Accumulation and translocation of metals in plants: A plant's ability to accumulate metals from soils can be estimated using the BCF and a plant's ability to translocate metals from the roots to the shoots is measured using the TF. The process of phytoextraction generally requires the translocation of heavy metals to the easily harvestable plant parts, i.e., shoots (Yoon *et al*., 2006) while phytostabilization process requires the strong ability to reduce metal translocation from roots to shoots (Deng *et al*., 2004). By comparing BCF and TF, the ability of different plants in taking up metals from soils and translocating them to the shoots can be determined (Yoon *et al*., 2006).

RESULTS

The mean heavy metal concentration present in the two sites is shown in Table 1. The soil concentration of Pb (0.25±0.01) in site 2 was higher than site 1 (0.23±0.02). Cu concentrations was found to be significant higher ($p<0.05$) at site 2 (0.66±0.01) while site 1 has least accumulation (0.15±0.03). Zinc (0.66±0.33) was significantly higher in site 2 when compared to site 1. Arsenic concentration in site 2 (0.60±0.05) was significantly higher than that of site 1 (0.17±0.03). Table 1. The mean heavy metal concentrations in the soils in site 1 shown that Pb >Zn>As>Cu while in site 2 Zn>Cu> As> Pb (Table 1).

Table 1: Heavy metal variations (mg kg^{-1}) in soil sample from some waste dump sites

Sample location	Pb (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})	As (mg kg^{-1})
Site 1	0.23±0.02^{a}	0.15±0.03^{a}	0.24±0.01^{a}	0.17±0.03^{a}
Site 2	0.25±0.01^{a}	0.66±0.01^{b}	0.66±0.03^{b}	0.60±0.05^{b}

Means followed by different letters in the same column are not statistically different at 5% level

The comparison of various heavy metals in the soil from the studied sites to revealed that Pb ranged between 0.23-0.25 mg kg^{-1}, As: 0.17-0.60 mg kg^{-1}, Zn:0.17-0.60 mg kg^{-1} and Cu: 0.15-0.66 mg kg^{-1}. There were significant differences ($p<0.005$) between the sites in Cu, Zn and As.

The accumulation of metals in the plant parts of *Telfairia occidentalis* from site 1 varied with Pb ranging from 0.37 mg kg^{-1} -root, 0.35 mg kg^{-1}-stem and 0.57 mg kg^{-1}-leaf. Cu ranged from 0.06 mg kg^{-1},0.06 mg kg^{-1}-Stem and leaf 0.01 mg kg^{-1}. Zn ranging from 0.07 mg kg^{-1}-Root,0.06 mg kg^{-1} for stem and 0.02 mg kg^{-1} for leaf. Arsenic concentration were 0.03 mg kg^{-1}-root, Stem-0.05 mg kg^{-1} and 0.42 mg kg^{-1}-for leaf (Table 2).

Telfairia occidentalis from site 2 ranged as follows: 0.87 mg kg^{-1}-root, 0.35 mg kg^{-1}-Stem and 0.51 mg kg^{-1}-leaf. Cu concentration were 0.06 mg kg^{-1} for root, 0.07 mg kg^{-1}-Stem and for leaf 0.02 mg kg^{-1}.Zn ranged as follows 0.65 mg kg^{-1}-root, 0.06 mg kg^{-1}-Stem and leaf 0.06 mg kg^{-1}. Arsenic concentration were 0.07 mg kg^{-1} for root, 0.07 mg kg^{-1} for Stem and 0.05 mg kg^{-1} for leaf. (Table 2).

The Bioconcentration Factor (BCF) Table 3 below denotes the capability of *Telfairia occidentalis* to extract heavy metals from the soil.BCF values of zero indicated limited movements from the soil to the plant. The BCF values of metals in site 1 were in the sequence Pb >Cu>Zn>As. The BCF values of the metals in site 2 was highest for Pb followed Zn, As and Cu.

Metals that are accumulated by plants are largely stored in the roots of plants are indicated by Translocation Factor (TF) values <1. TF values >1 indicate translocation to the aerial parts of the plant (Table 4). TF values >1 were found for Pb (2.49), Cu (1.17), Zn (1.14) and As (15.67) in site

Table 2: Heavy metal contamination of *Telfairia occidentalis* (Plant parts) (mg kg^{-1}) at waste dump sites

	Plant part					
	Site 1			Site 2		
Metal	Root	Stem	Leaf	Root	Stem	Leaf
Pb	0.37 ±0.01	0.35±0.01	0.57±0.01	0.87±0.01	0.35±0.01	0.51±0.02
Cu	0.06±0.04	0.06±0.04	0.01±0.03	0.06±0.01	0.07±0.02	0.02±0.01
Zn	0.07±0.01	0.06±0.02	0.02±0.01	0.65±0.03	0.06±0.01	0.06±0.01
As	0.03±0.01	0.05±0.04	0.42±0.05	0.07±0.01	0.07±0.01	0.05±0.01

Results represent Mean±SE of three replicates

Table 3: Bioconcentration factor (BCF) movement from soil to plant of each metal at the studied sites

	Pb	Cu	Zn	As
Site 1	1.61	0.40	0.29	0.18
Site 2	3.48	0.09	0.99	0.12

*: High BCF value (values>2)

Table 4: Translocation factor (TF) of each metal at the study sites for the determination of indirect movement of each metal from the roots to the aerial parts of the plant

	Pb	Cu	Zn	As
Site 1	2.49	1.17	1.14	15.67
Site 2	0.99	1.5	0.18	1.17
Average	1.74	1.34	0.66	8.42

*Values>1 are regarded as high

Table 5: Enrichment factor values of each metal at the study sites

	Pb	Cu	Zn	As
Site 1	4.00	0.47	0.33	2.76
Site 2	3.44	0.14	0.18	0.20

1. TF values >1 were found for Cu (1.50) and As (1.17) in site 2. Other TF values were less than 1. Enrichment Factor (EF) indicates phytoremediation potential of a given species. In this study, *Telfaria occidentalis* showed EF values >1 for Pb (4.00) and As (2.76) in site 1 while site 2 showed a high EF value for Pb (3.44) (Table 5).

DISCUSSION

The difference of soil heavy metal content for Cu, Zn and As were significantly different between the sites. According to Ebong *et al.* (2004), the high levels of heavy metals in the dumpsite could be attributed to huge amount of waste products disposed of at the dumpsite. The high levels of these metals present the sites as a potentially hazardous and highly inimical to the food chain and biological life and a clean environment. The BCF signifies the amount of heavy metals in the soil that ended up in the vegetable crop. The mean BCF value was >2 for Pb. These results enable us to conclude that *Telfairia occidentalis* can tolerate and sequester Pb from the soil and translocate it to the shoots, thus making *T. occidentalis* cultivated on these waste dump sites unfit for human consumption.

Transfer factors can be used to estimate a plants potential for phytoremediation purpose. The transfer factors of metals in *Telfairia occidentalis* are shown in Table 3-5. The mean translocation factor (TLF) for As, Pb and Cu was higher than 1.0 but the mean TLF for zinc was lower than 1. This implies that *T. occidentalis* effectively transferred heavy metals from root to body. The excluder ability was in the order As> Pb>Cu>Zn. The differences in TLF values indicated that each metal has different phytotoxic effect on *T. occidentalis*. Baker (1981) and Yanqun *et al.* (2005) reported that TLF higher than 1.0 were determined in metal accumulator species. TLF higher than 1 indicates efficient ability to transport metal from to leaf most likely due to efficient metal transport systems (Zhao *et al.*, 2003, 2002) and sequestration of metals in leaf vacuoles and apoplast (Lasat *et al.*, 2000). Enrichment coefficients are very important factor which indicate phytoremediation of a given species (Zhao *et al.*, 2003). In this study, the mean enrichment coefficient of Pb and As was higher than 1.0. This indicates a special ability of the plant to absorb and transport metals from soil and then stored them in their above ground part (Wei *et al.*, 2002).

CONCLUSION

Findings from this study revealed that *Telferia occidentalis* tend to absorb and accumulate heavy metal in its stem and leaves. In view of their important role in the food chain, it is recommended that *Telferia occidentalis* should not be cultivated in waste dumpsites.

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