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Heavy metal accumulation by *Amaranthus hybridus* L. grown on waste dumpsites in South-Eastern Nigeria.

Authors:
Uka UN[1], Chukwuka KS[2, 3] and Okorie N[1].

Institution:
1.Department of Applied Biology, Ebonyi State University, Abakaliki-Nigeria.

2. Department of Botany, University of Ibadan, Ibadan-Nigeria.

3. Department of Plant Science and Biotechnology, Abia State University, Uturu-Nigeria.

Corresponding author:
Chukwuka KS.

ABSTRACT:

The accumulation of some heavy metals by *Amaranthus hybridus* grown on two waste dump sites within Abakaliki metropolis, South-Eastern Nigeria was studied using atomic absorption spectrophotometer. The results indicate that Cd, Cu and Pb in the two dump sites were above the stipulated standard, while Zn was within the stipulated standard in the soil. The two dumpsites had high level of Pb in the plant leaves; in Site 2, Cu and Zn showed the highest value while Zn in site 2 has the lowest value. Although all the values obtained in the leaves of *Amaranthus hybridus* were within recommended limits, but it may be dangerous to consume *Amaranthus hybridus* grown on dump sites since it can accumulate most of these toxic metals. The BCF value was >2 for Pb and Cd in site 1 while in site 2 the BCF value was >2 for Pb, Cu, Zn and Cd, showing that *Amaranthus hybridus* can tolerate and sequester these metals from soil and translocate them to the shoots. The TLF in *Amaranthus hybridus* indicate the following: in Iyiudele stream (Site 1) the rate of Cd and Zn in *Amaranthus hybridus* up take is >1 and in site 2 the rate of Pb, Cd, Cu, and Zn up take in *Amaranthus hybridus* were >1. The results obtained from this study showed that heavy metals in soils at the waste dump sites ended up in the studied plant, *Amaranthus hybridus*, cultivated on such land. Therefore farmers should be discouraged from cultivating their crops on these waste dump sites.

Keywords:
Heavy metal, *Amaranthus hybridus*, accumulation, pollution, Safety risk.

Email:
kanayodrchukwuka97@gmail.com

Web Address:
http://jresearchbiology.com/documents/RA0298.pdf.

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INTRODUCTION

Vegetables constitute important functional food components by contributing protein, vitamins, iron and calcium which have marked health effects in all organisms (Arai, 2002). Vegetables, especially leafy vegetables, grown in heavy metal contaminated soils, accumulate higher amounts of metals than those grown in uncontaminated soils (Al Jassir *et al.,* 2005). Heavy metals are important contaminants and are found in the surface and tissues of vegetables in environments with such contaminants. The quest for urbanisation and industrialization has resulted to the contamination of soil and metal accumulation in soils and crops, resulting to metal contamination exceeding the maximum permissible level. Plant species have a variety of capacities in removing and accumulating heavy metals, so there are reports indicating that some species may accumulate specific heavy metals, causing serious health risk to human health when plant based food stuff are consumed (Wenzel and Jackwer, 1999).

Odai *et al.,* (2008) studied the concentration levels of heavy metals in vegetables grown on urban waste dump sites. This study was carried out on three waste dump sites in Kumasi where vegetables cultivation (cabbage, lettuce and spring onions) are practiced. Crops and soil samples were collected and analyzed for the presence of four heavy metals: Cadmium, lead, copper and zinc. The levels of the two most toxic heavy metals were far higher in the vegetables than the WHO/FAO recommended values and the transfer factors of these two metals were also the highest suggesting that consumption of vegetables grown on such sites could be dangerous to human health. Chove *et al.,* (2006) carried out a study to determine the levels of two heavy metals, Lead (Pb) and Copper (Cu), in two popular leafy vegetables grown around Morogoro Municipality in Tanzania. Vegetable samples of Pumpkin leaves (*Cucurbita moschata*) and Chinese cabbage (*Brassica chinensis*) were collected from three sites and analyzed for the concentrations of the two metals using an Atomic Absorption Spectrophotometer. The results showed that levels of Lead and Copper in the two vegetables were found to be below the maximum permissible levels recommended by FAO/WHO for the two metals in the vegetables.

In Abakaliki, South-eastern Nigeria, there is an indiscriminate and inappropriate waste disposal. This implies that the concentration of heavy metals in both plant and soil is expected to be high. In this study, *Amaranthus hybridus* was chosen for phytoremediation study as well as heavy metal contamination because it is a vegetable crop, rich in proteins, vitamins and minerals. Its yield, ability to grow in hot weather conditions, high nutritive value and their pleasant taste and the fact that they grow all year round, makes it a popular vegetable. (Grubben, 1976). This study was undertaken to determine:

- the status of heavy metal (Pb, Cu, Zn and Cd) contamination in the selected waste dump soil in Abakaliki Urban.
- heavy metal concentrations in *Amaranthus hybridus* from these waste dump sites and compare the levels with WHO/FAO permissible levels.
- the extent of heavy metal uptake from these sites using transfer factor

MATERIALS AND METHODS

The study was carried out during the month of October, 2011 which is part of the rainy season in the area under investigation. Samples of *Amaranthus hybridus* and soils were collected from 2 dump sites located at Iyiudele street and Abakaliki-Enugu Expressway located within Abakaliki Urban, Ebonyi State. Ebonyi State lies within the Cross River plain, approximately between 7°30’ N and 8°30’ N latitude and 5°40’E and 6°45’E longitude (Nnamani *et al,* 2009). A total of 12 plants and soil samples were collected from the two dump sites (six per

Table 1 Heavy metal variations (Mg/g) in soil sample from some waste dumpsites in Abakaliki Urban.

Sample Location	Pb	Cu	Zn	Cd
Site 1	0.12±0.01	0.24±0.01	0.01±0.00	0.05±0.01
Site 2	0.07±0.01	0.06±0.01	0.01±0.00	0.08±0.01

dump site). The plants were washed with tap water to remove sand from the leaves, stem and roots. The plants were put into separate polythene bags, labelled and taken to the laboratory. In the laboratory the plants were further washed with distilled water.

Identification of plants

The selected plant was collected in triplicate. The identification and taxonomic characterization was performed at the herbarium facility of the Ebonyi State University, Abakaliki through botanical keys where the vouchers were deposited.

Sample preparation and analysis

The plants were separated into leaves, stem and root and air dried for 21 days to remove moisture. Soil samples were air dried for 21 days, then sieved through 2 mm mesh. 0.5 g dried, grinded and sieved plant and soil samples were analysed according to methods of Umoren and Onianwa (2005). Concentrations of Pb, Cu, Zn and Cd were determined using atomic absorption spectrophotometer model sp-9 (Pye Unicam). The mean values of three determinations per composite sample were recorded.

The Bioconcentration Factor (BCF) of metals was used to determine the quantity of heavy metals that were absorbed by the plant from the soil (Ghosh and Singh, 2005a) and is calculated using the formula:

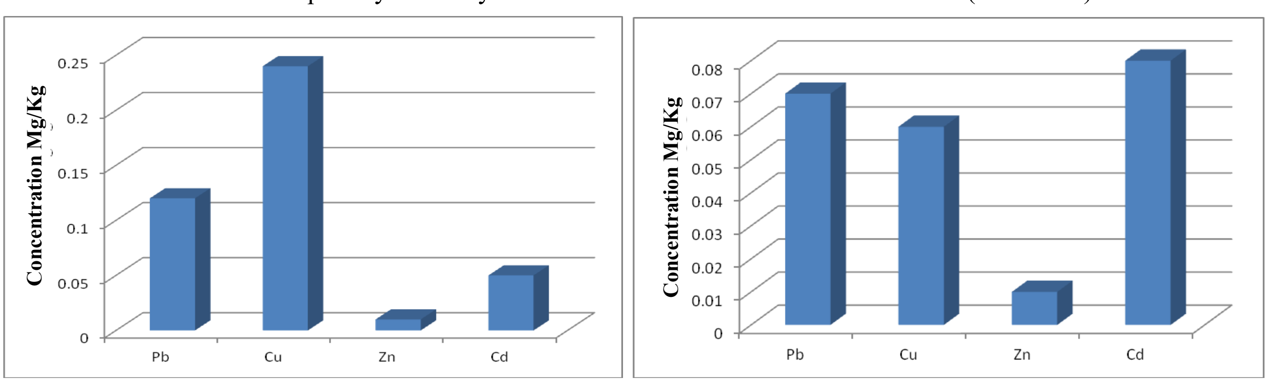
$$BCF = \frac{\text{Metal Concentration in whole plant}}{\text{Concentration of metal in soil}}$$

To evaluate the potential of plants for phytoextraction the translocation factor (TF) was used, according to Marchiol *et al.,* (2000) and is calculated as follows:

$$TF = \frac{\text{Metal Concentration (Stem + leaves)}}{\text{Metal concentration (roots)}}$$

RESULTS

The mean concentration of the four heavy metals (Pb, Cu, Zn and Cd) in soil samples from the waste dump sites in Abakaliki Urban are presented in Table 1. The mean concentration of Pb ranged from 0.07±0.01 in site 2 to 0.12±0.01 Mg/g in site 1 (Table 1and Fig 1). Mean concentration of Cu ranged from 0.06± 0.01 Mg/g in site 2 to 0.24±0.01 Mg/g in site 1. These differences were significant ($P<0.05$). The mean concentration of Zn (0.01±0.00) in both sites were similar, while the highest mean concentration of Cd (0.08±0.01) was found in



Site 1 **Site 2**

Figure 1 Concentration of metals in soil samples from the waste dump soil samples

Table 2 Heavy metal contamination of *Amaranthus hybridus* (Plant parts) (Mg/kg) at waste dumpsites in Abakaliki Urban.

	Site 1			Site 2			
Metal/Plant Part	Root	Stem	Leaf	Root	Stem	Leaf	*WHO/FAO
Pb	0.01±0.00	0.33±0.08	0.5±0.11	0.2±0.06	0.04±0.01	0.6± 0.12	0.30
Cu	0.12±0.01	0.07±0.01	ND	0.08±0.01	0.05±0.01	0.08±0.02	73.30
Zn	ND	ND	0.01±0.00	0.03±0.01	0.04±0.01	0.09±0.01	99.40
Cd	0.02±0.01	0.43±0.01	ND	0.05±0.01	0.38±0.01	0.15±0.01	0.20

WHO/FAO = Guideline for heavy metal concentration in leafy vegetables

site 2 compared to 'site 1' (0.05± 0.01). However, the differences were not significant (P >0.05).

The comparison of the maximum levels of the various heavy metals in the dump site soil from site 1 and site 2 to acceptable standards is as shown in Table 2. Cd, Cu and Pb were above the stipulated standard. Zn was within the acceptable standard.

The accumulation of metals in the *Amaranthus hybridus* parts from Iyiudele stream were varied with Pb ranging from 0.01 mg/g- root, 0.33 mg/g-stem and 0.5 mg/g leaf, Cu ranged from 0.12 mg/g-root,0.07 mg/g stem and leaf (not detected); Zn ranging from 0.01 mg/g for leaf, while it was detected in root and stem. Cd ranged from 0.02 mg/g for root, 0.43 mg/g for stem, while in leaf it was not detected (Figure 1, Table 2). The concentration of Pb in leaf and stem in site 1 were above the WHO/FAO limit for vegetables, while Cu and Zn were within the acceptable standard. Cd concentration in stem was also above WHO/FAO Limit.

Amaranthus hybridus from old Kpirikpiri ranged as follows: Pb-0.2 mg/g for root,0.04 for stem and 0.6 mg/g for leaf. Cu ranged from 0.08 mg/g-root, 0.05 mg/g-stem, 0.08 mg/g for leaf. Zn ranging from 0.03 mg/g-root, 0.04 mg/g-stem and 0.09mg/g leaf and Cd ranging from 0.05 mg/g- root, 0.38 mg/g- stem and 0.15 mg/g - leaf (Figure 1, Table 2). Pb concentration in leaf at site 2 was above the recommended dietary allowance. The concentration of Cd in stem was above the WHO/FAO allowance.

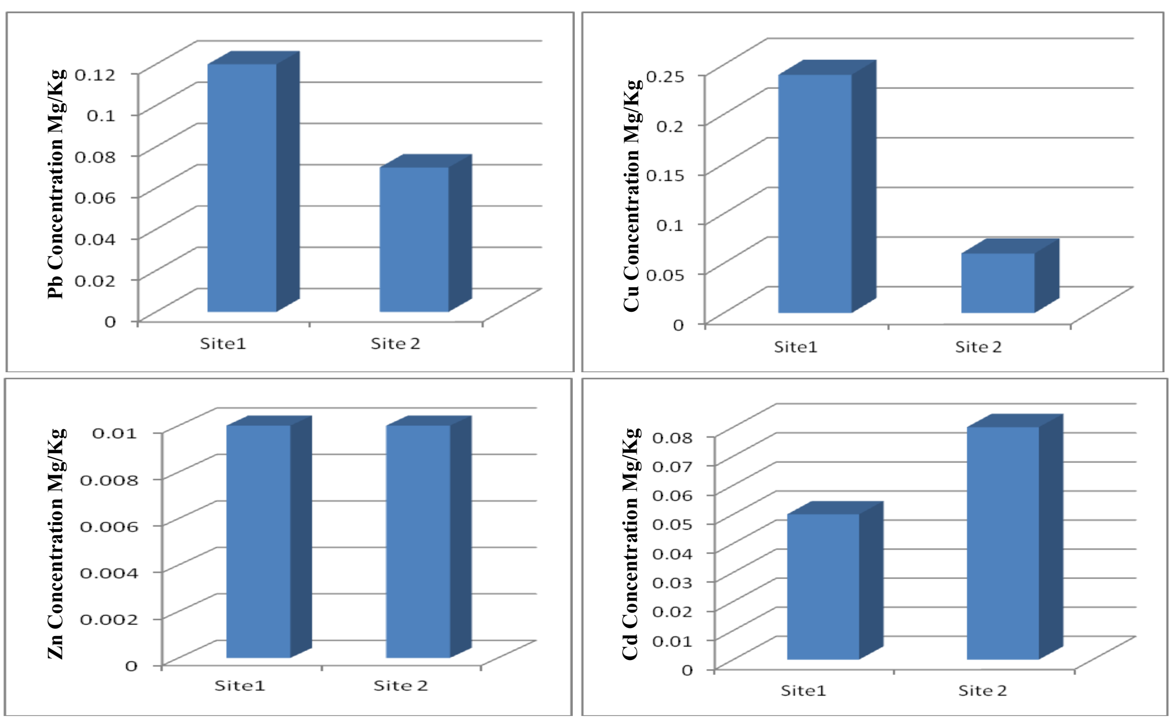


Figure 2 Comparison of metal content in soil from the study sites

Table 2 Mean concentration (Mg/g) found in the dumpsite soil and maximum permissible metal content in soil

	This Study	Maximum Standards
Pb	0.13	0.0066
Cu	0.26	0.0066
Zn	0.02	0.05
Cd	0.08	0.07

Source: Kabata-Pendias and Pendias 1992;

Determination of the movement of metals from soil to plant

The Bioconcentration factor (BCF) represented in Table 4 showed the ability of *Amarathus hybridus* to extract heavy metals from the soil. BCF Value at the site 1 was highest for Cd followed by Pb, Zn and Cu. At site 2, the BCF index was highest for Zn followed by Pb, Cd and Cu.

Translocation Factor

Metals that are accumulated by plants and mostly stored in the roots of plants are indicated by TF values <1. Values >1 indicate translocation to the aerial parts of plant. These are represented in Table 5. Values <1 were found for Cu and Zn in site 1, while values >1 were found for Pb and Cd in site 1. TF values were >1 in site 2.

DISCUSSIONS

A study of Pb, Cu, Zn and Cd in soils and naturally growing *Amaranthus hybridus* from selected waste dump sites in Abakaliki urban was carried out. The results show that Cd, Cu and Pb concentration in the soil from the studied sites were above the stipulated standard, while zinc was within the acceptable standard (Table 2). The high levels of heavy metals in the dump site could be attributed to huge amount of waste products disposed of at the dump site (Ebong *et al.,* 2007). The high levels of these metals present the sites as potentially hazardous and highly inimical to the food chain and biological life and a clean environment. Al Jassir *et al., (*2005) reported that leafy vegetables grown in heavy metals contaminated soils, accumulate higher amount of metals than those grown in uncontaminated soils because of the fact that they absorb these metals through their leaves.

Pb is a chemical pollutant in the environment and an element that is toxic to plants. (Sasmaz *et al.,* 2008). Kabata-Pendias and Pendias (2001) reported that Pb contents of plants grown in uncontaminated areas varied between 0.05 and 3.0 mg/kg. Carranza- Alvarez *et al.,* (2008) also reported that Pb concentration ranged from 10 to 25 Mg/kg. In this study, Pb accumulation was higher in the leaves of *Amaranthus hybridus* in the two sites. According to Zurera-Cosano *et al.,* (1989), vegetables take up metals by absorbing them from contaminated as well as from deposits on different parts of vegetables exposed to the air from polluted environment.

The ranges of Cu obtained in all the plant parts in both dump sites are lower than 11.50±2.16, 2.50, 0.923 mg kg^{-1} as reported in different types of vegetables by Farooq *et al.,* (2008). In site 1 there was no trace of

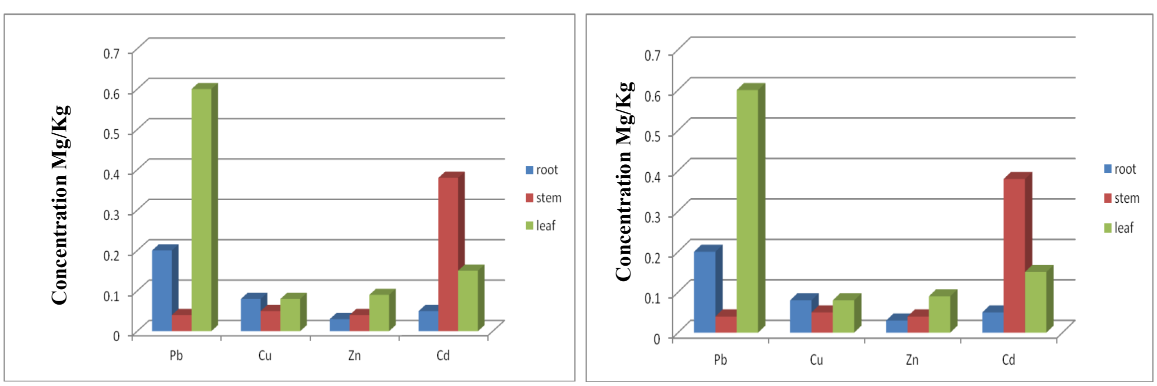


Figure 3 Heavy metal content (Pb,Cu, Zn and Cd) of *Amaranthus hybridus* at the study sites

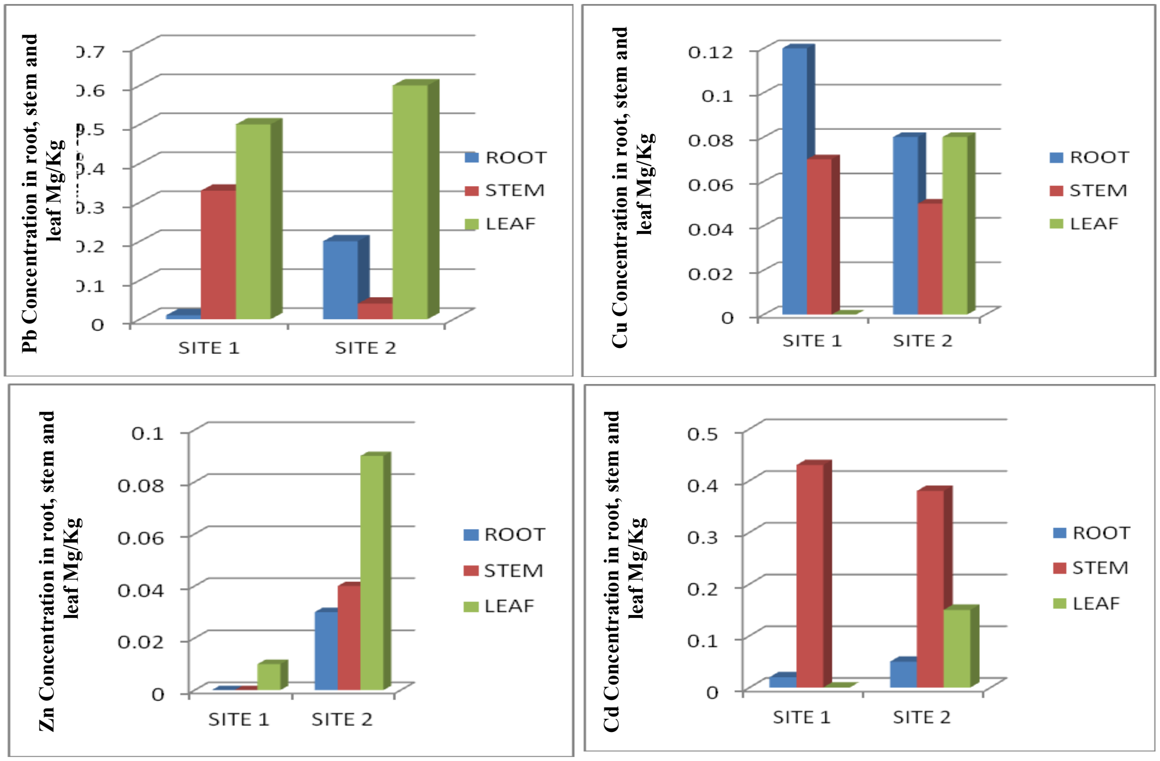


Figure 4 Mean concentration of Pb,Cu,Zn and Cd in roots, stem and leaf of *Amaranthus hybridus* from the two respective sites

Cu in the leaf of *Amaranthus hybridus*, it could be that the metal is within the root and stem, thus it has not been translocated to the leaf. Despites the presence of Cu in the other parts of *Amaranthus hybridus,* it was within the recommended limit.

In site 1 there were no trace of Zn in the root and stem but present in the leaf with low value, the absence of Zn in the root and stem of *Amaranthus hybridus* in site 1 may be that it has been volatilized or that it is not essential for plant growth, the presence of Zn in the leaf may be due to emissions from the environment. In site 2, there were presence of Zn in the root, stem and leaf of *Amaranthus hybridus* although the leaf had higher heavy metal but they were all within recommended standard. However, since the leaf of this vegetable is the edible part, continuous intake of this vegetable from the dump sites may be toxic and lethal to the health of the consumers.

The ranges of Cd obtained from *Amaranthus hybridus* in Site 1 are, root 0.02±0.01, stem, 0.43±0.01 and leaf was below detection limit. Cd in the stem of *Amaranthus hybridus* in site 1 was higher when compared to the ranges of Cd obtained from other vegetables as reported by Maleki and Zarasvard (2008) but lower than 0.667-0.933 as reported in other vegetables (Abdullahi *et al.,* 2009). However, the level of Cd in the stem is within the recommended limit.

Comparing the two dump sites, stem had a higher heavy metal, it could be that *Amaranthus hybridus* had taken these metals up and stored mostly in the stem. The BCF signifies the amount of heavy metals in the soil that ended up in the vegetable crop. The BCF values were >2 for Pb and Cd at site 1 whereas in site 2 BCF values was >2 for Pb, Cu, Zn and Cd. This implies that the degree of transportability of these metals is site dependent and could be due to different forms in which these metal ions are available at these sites. These results enable us to conclude that *Amaranthus hybridus* can tolerate and sequester these metals from the soil and translocate it to the shoots, thus making *Amaranthus hybridus* cultivated

Table 5 Translocation factor of the studied heavy metals at the dumpsite soil in Abakaliki Urban

	Translocation Factor	
	Site 1	**Site 2**
Pb	83*	3.20*
Cu	0.53	1.63*
Zn	0.01	4.33*
Cd	21.50	10.60*

Values > 1 are regarded as high values

Table 4 Bioconcentration factor (BCF) of each metal at the dumpsite soil in Abakaliki Urban

	Bioconcentration Factor	
	Site 1	**Site 2**
Pb	7	12
Cu	0.8	3.5
Zn	1	16
Cd	9	7.3

BCF values > 2 will be regarded as high values

on these waste dump sites unfit for human consumption.

The translocation factor can be used to estimate plants potential for phytoremediation purposes. Metals that are accumulated by plants and mostly stored in the roots of plants are indicated by TLF values greater than 1. The translocation ability of *Amaranthus hybridus* for these heavy metals were in these order Pb (83) >Cd (21.50), while in site 2, Cd (10.60) >Zn (4.33) >Pb (3.20) >Cu (1.63). This is an indication of efficient way of transportation of these metals from root and its accumulation in shoot. Baker (1981) and Zu *et al.,* (2005) reported that TLFs higher than 1.0 were determined in metal accumulator species, whereas TLFs was typically lower than 1.0 in metal excluder species. The TLFs higher than 1.0 indicated an efficient ability to transport metal from root to leaf, most likely due to efficient metal transporter system of plants (Zhao *et al.,* 2002), and probably sequestration of metals in leaf vacuoles and apoplast (Lasat *et al.,* 2002). The vacuole is generally considered to be the main storage site for metals in yeast and plant cells, and there is evidence that phytochelatin-metal complexes are pumped into the vacuole (Gratão *et al.,* 2005). It was reported that plants also have the ability to hyperaccumulate various heavy metals by the action of phytochelatins and metallothioneins, forming complexes with heavy metals and translocate them into vacuoles (Suresh and Ravishankar, 2004).

The results obtained from this study have shown that heavy metals in soils at the waste dump sites ended up in the studied plant, *Amaranthus hybridus*, cultivated on such land. The Four heavy metals Lead, Cadmium, Copper and Zinc were present in the studied sites. The concentration of lead and Cadmium that ended up in this vegetable far exceeded the WHO/FAO dietary allowance. Therefore farmers should be discouraged from cultivating their crops on these waste dump sites.

REFERENCES

Abdullahi MSA, Uzairu and Okunota OJ. 2009. Quantitative determination of Heavy metal concentrations in onion leaves. Int. J. Environ. Res., 3:271-274.

Al-Jassir MSA Shaker and Khaliq MA. 2005. Depositin of heavy metals on green leafy vegetables sold on roadsides of Riyadh city, Saudi Arabia. Bull. Environ. Contam. Toxicol., 75:1020-1027.

Arai S. 2002. Global view on functional foods: Asian Perspectives. Brit J.Nutr.88: S139 - S143.

Baker AJM. 1981. Accumulators and Excluders strategies in the response of plants to heavy metals. Journal of Plant Nutrition 3:643-654.

Carranza-Alvarez C, Alonso-Castro AJ, Alfaro-De La Torre, MC, Gareia-De La Cruz RF. 2008. Accumulation and distribution of heavy metals in *Scirpus americanus* and *Typha latifolia* from an artificial lagoon in San Luis Potos, Mexico.*Water* Air Soil Pollution 188:279-309.

Chove BE, Ballegu WR and Chove LM. 2006. Copper and lead levels in two popular leafy vegetables grown around Morogoro municipality, Tanzania. Tanzania Health Res. Bull., 8:37-40.

Ebong GA, Udoessien EI and Ita BN. 2004. Seasonal Variations of Heavy metal concentration in Qua Iboe River, Estuary, Nigeria. Global J. Pure Applied sic., 1: 247-256.

Farooq M, Anwar F and Rashid U. 2008. Appraisal of Heavy metals grown in the vicinity of an industrial area. Pak. J. Bot., 40:2099-2106.

Ghosh M and Singh SP. 2005a. A comparative study of cadmium phytoextraction by accumulator and weed species. Environmental Pollution*,* 133**:**365-371.

Gratao PL, Prasad MNV, Cardoso PF, Lea PJ and Azevedo RA. 2005. Phytoremediaion: green technology for the clean up of toxic metals in the environment. Braz. J. Plant Physiol., 17:53-64.

Grubben GJH. 1976. The cultivation of amaranth as a tropical leaf vegetable with special reference to South Dahomey. IN RESEARCH, C. D. O. A. (Ed.). Amsterdam, Royal Tropical Institute.

Kabata-Pendias A and Pendias A. 2001. Trace Elements in plants and Soils. CRC Press Inc Boca Raton Florida, 337.

Kabata-Pendias A, Pendias H. 2001. Trace Elements in Soils and Plants. CRC Press, Washington, D.C.

Lasat MM. 2002. Phytoextraction of toxic metals: a review of biological mechanism. Journal of Environmental Quality 31:109-120.

Maleki A and Zarasvand MA. 2008. Heavy metals in selected edible vegetables and estimation of their daily intak in Sanandaj, Iran. South East Asian. J. Trop Med. Public Health. 39:335-340.

Marchiol L, Assolari S, Sacco P and Zerbi G. 2004. Phytoextraction of heavy metals by canola (*Brassica napus*) and radish (*Raphanus sativus*) grown on multicontaminated soil. Environmental Pollution, 132:21-27.

Nnamani CV, Oselebe HO and Agbatutu A. 2009. Assessment of nutritional values of three underutilized indigenous leafy vegetables of Ebonyi State,Nigeria. African Journal of Biotechnology 8(9):2321-2324.

Odai SNE, Mensah D. Sipitey, Ryo S and Awuah E. 2008. Heavy metals uptake by vegetables cultivated on urban waste dumpsites. Case study of Kumasi, Ghana. Res. J. Environ. Toxicol., 2:92-99.

Sasmaza A, Obekb E and Hasarb H. 2008. The accumulation of heavymetals in *Typha latifolia* L. grown in a stream carrying secondary effluent. Ecological engineering 33: 278-284.

Suresh B and Ravishankar GA. 2004. Phytoremediation-A novel and promising approach for environmental clean up. Crit Rev Biotechnol., 24:97-124.

Umoren IU and Onianwa PC. 2005. Concentration and distribution of some heavy in urban soils of Ibadan, Nigeria. Pak. J. Ind. Res., 48: 397-401.

Wenzel W and Jackwer F. 1999. Accumulation of heavy metals in plants grown on mineralized solids of the Austrian Alps. Environ. Poll., 104:145-155.

WHO. 1996. trace Elements in Human Nutrition and Health. World Health Organization, Geneva.

Zhao FJ, Hamon RE, Lombi E, McLaughlin MJ and McGrath SP. 2002. Characteristics of cadmium uptake in two contrasting ecotypes of the hyperaccumulator *Thlaspi caerulescens*. Journal of Experimental Botany 53:535-543.

Zu YQ, Li Y, Chen JJ, Chen HY, Qin L and Schvartz C. 2005. Hyperaccumulation of Pb,Zn and Cd in Herbaceous grown on Lead and Zinc Mining area in Yuman, China. Environmental International 31:755-762

Zurera-Cosano G, Moreno-Rojas R, Samlmeron-Egea J and lora RP. 1989. Heavy metal uptake from greenhouse border soils for edible vegetables. J. Sci. Food Agric., 49:307-314.