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ASSESSMENT OF HEAVY METALS IN *CHROMOLAENA ODORATA* (L.) AROUND A DUMPSITE IN IBADAN, SOUTH WESTERN NIGERIA

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ABSTRACT

Heavy metal contamination has become a critical environmental concern and poses a serious threat to the environment leading to hazardous health effect as they enter food chain. One of the main processes of human exposure to heavy metal through the food chain is transfer of nutrients from the soil to the plants. This study assessed heavy metal concentrations in Chromolaena odorata and the soils around Lapite dumpsite in Ibadan. Five *C. Odorata* samples (root, stem, leaf) each were taken from control, contaminated and waste dump sites considered in this study. Composite soil samples were collected from the topsoil (0-20m) around each of the site. Inductively Coupled Plasma- Atomic Emission Spectrometry (ICP-AES) instrumentation technique was used to determine the heavy metals (iron (Fe), zinc (Zn), lead (Pb), copper (Cu), nickel (Ni), cadmium (Cd), chromium (Cr), cobalt (Co) and Arsenic (AS) in soil samples and *C. odorata* tissues. These results showed that *C. odorata* and soil samples had significantly high levels of heavy metals in waste dump and contaminated sites than control site. Heavy metal concentrations in C. odorata and soil samples showed decreasing order of Fe> Zn> Cu> Pb> Ni> Co> Cr>Cd>As. The ability of *C. Odorata* to accumulate the metals was consistent with the high translocation ratio values of more than 1 and the low transfer factor values of less than 1.Heavy metals in soils showed positive correlation coefficient of 0.46-0.99 with the levels in *C. Odorata* plants. This study has shown the ability of *C. Odorata* plant to bio-accumulate translocate heavy metals.

Keywords: *Bio-accumulation, Dumpsite, Heavy metals, Soil contamination*

INTRODUCTION

The rapid development and urbanisation has led to severe waste management problems in the developing countries of the world (Uluturhan and Kucuksezgin, 2007; sut *et al,* 1995). Poor management of human, biological, agricultural or industrial wastes has led to severe soil and groundwater contamination as well as adverse effect on the ecosystem (Adewuyi, 2004; Roy *et al,* 2005).The term, 'heavy metals', refers to any metallic chemical element or elements that has a relatively high density but is toxic or poisonous at low concentrations. Heavy metals are natural components that cannot be degraded or destroyed (Arora *et al,* 2008). As trace elements, some heavy metals (e.g. selenium, iron, copper, manganese, and zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning (Hawkes, 1997).

Human activity affects the natural geological and biological redistribution of these heavy metals through pollution of the air, water, and soil thus, altering the chemical form of heavy metals released to the environment (Omar and Al-Khashman, 2004; Chen, 2005, Akinola and Adenuga,2008). Such alterations often affect heavy metals' toxicity by allowing it to bio-accumulate in plants and animals, bio-concentrate in the food chain, or attack specific organs of the body; hence, they are dangerous to the environment. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment (Goyer, 1996). Heavy metals can enter a water supply by industrial and consumer waste, or even from acidic rain breaking down soils and releasing heavy metals into streams, lakes, rivers, and groundwater (Perveen and Ihsanullah, 2011). Soils in and around waste dumpsites and the compost generated from it have been reported to contain a significant amount of heavy metals (Ukpebor and Unuigbe, 2003; Feng *et al.,* 2007; Hargreaves *et al,* 2008; Agyarko *et al,* 2010). These in turn contributes to elevated levels of heavy metals in plants grown in and around it (Ukpebor and Unuigbe, 2003; Chien, 2004; Hargreaves *et al.,* 2008; Hogarh *et al.,* 2008). Heavy metal contamination within waste dump sites and agricultural soils has been extensively studied (Ukpebor and Unuigbe, 2003; Feng *et al.,* 2007; Adeniyi *et al.,* 2008; Hargreaves *et al.,* 2008; Hogarh *et al.,* 2008; Agyarko *et al.,* 2010; Dasaram *et al.,* 2011 and Akintola, 2014).A geochemical implication of heavy metal contamination on soils and sediment has also been evaluated by various researchers using various geochemical indices (Loring and Rantala, 1992; Zwolsman *et al,* 1993; Adeniyi and Afolabi, 2002; Sharma and Reddy, 2004; Lim *et al,* 2008and Agyarko *et al.*, 2010). Heavy metals distribution in plant body depends upon their concentration in soil and water as well as plant species and its population (Seilsepour and Bigdeli, 2008).Heavy metals accumulation in agricultural soils may result in increased metal uptake by plants which in turn may affect food quality and safety (Lazat, 2000 and Zheng *et al,* 2007). Sewage, irrigation with contaminated water and infiltration of contaminants from wastes are responsible for increased concentration of metals in the soil and plants (Ramesh and Yogananda, 2012 and Jolly *et al,* 2013).Works have shown that some common plants have ability of accumulating high level of metals from the soil (Zheng *et al,* 2007; Zu *et al,* 2007; Yang *et al,* 2008 and Hu *et al,* 2012). It is therefore essential that a geochemical assessment of the effect of the solid waste on plants grown around Lapite dump site be done using the relevant evaluation indices. Evaluation index, a powerful tool for processing, analyzing and conveying raw environmental information to decision makers in geochemistry was used in this study (Caeiro *et al.,* 2005). This study assessed the heavy metal contents in Chromolaena Odorata and its ability to bioaccumulate and translocates heavy metals.

MATERIALS AND METHODS

Study Area

Ibadan city is located between longitude 7°2' and 7°40'E and latitude 3°35' and 4°10'N on the geographical map of Nigeria. The study area is located in Lapite village, within Akinyele Local Government area, Ibadan. It is between old Oyo road and newly constructed Ibadan- Oyo express road (Fig.1).The dumpsite covers an area of 200 by 400 meters, sitedon high elevation and situated on fractured rocks. Tones of wastes generated and collected from various locations inIbadan and its environs are deposited dumped on a daily basis giving rise to large heap of waste of varying composition, up to 3.0m high relative to the ground surface. Dumping at the site is unrestricted and industrial, agricultural, domestic and medical wastes (including used syringes) are strewn all over the dumping site.The long axis of the dumpsite or the length is oriented in the East – West direction. On the northern side of the dump site is a small stream which runs in the South West direction. Some of the waste from the dump ends up into the stream thus extending environmental and health risks to the communities living within the vicinity as well as those living downstream who could be using the water for domestic and agricultural purposes.The study area is one of the largest among the dumpsites established by Ibadan Waste Management Authority. The site came into use without proper environmental evaluation of its usage in terms of site selection, design and management but was established based on its remoteness from the habitable areas (IBWMA, 2008). Topography of the area can be described as undulating with height ranging from 246 to 265 m above sea level. Geologically, the area is underlain by Basement Complex rocks of southwestern Nigeria. They comprise igneous and metamorphic units such as gneisses, migmatites including older granite ridges and pegmatite.The major rock types in study area and it's environ

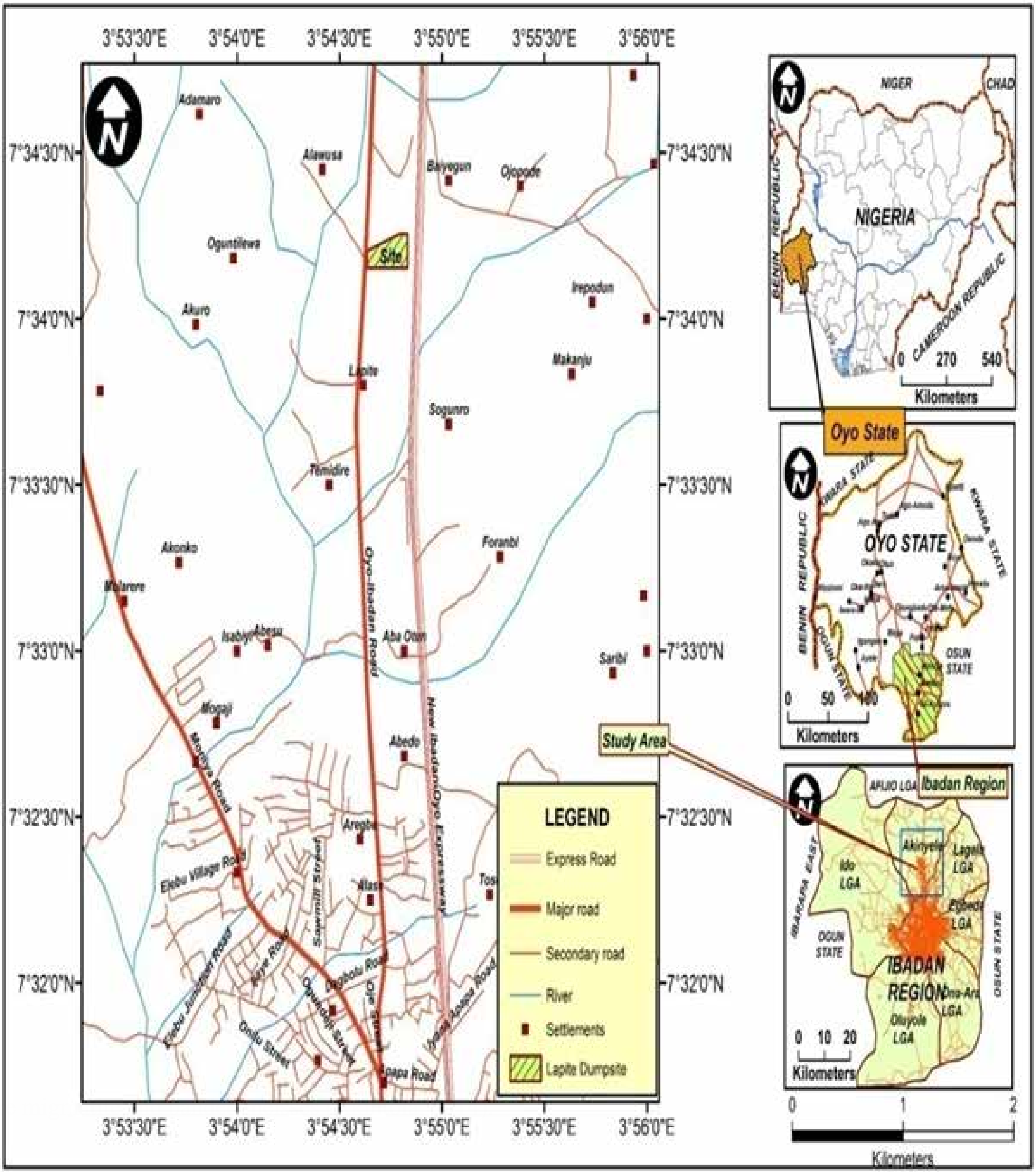

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Figure 1. Location Map of the study area

Description and collection of samples

Based on the previous study by Akintola (2014), three sites were selected for this study namely; control, contaminated and waste dump site. At each site, samples were taken from a grid. Control and contaminated sites are located at 500 m upslope and 100 m downslope side of the dumpsite respectively. A wider area of 20m x 20 m was used to take care of spatial variability in each of the sites.Three *C. odorata* stands were identified randomly from five location points in each of the sites. Three soil samples were collected from topsoil (0 -15cm) around the identified *C. Odorata* stand with a soil auger and mixed in a bowl. A composite soil sample collected from each location point was put in a labelled polythene bag. A total of 15 soil samples were collected from the control, contaminated and waste dump sites. From each *C.odorata* stand identified for soil sample collection, a total of three leaves, stems and roots were collected. The leaves, stems and roots collected from each stand were homogenized to make a composite sample for each of the five location points in the sites and labeled accordingly. Altogether, 15 *C.odorata* tissues of leaves stems and roots were collected from the three sites studied. Plant samples (roots, stems and leaves) were prepared for the laboratory analysis (Lark *et al,* 2002). All field procedures were in accordance with general and standard Quality Assurance and Quality Control requirements of the USEPA (1989). Clean and sterile sampling materials were used to avoid contamination of the samples. Samples were appropriately preserved. The raw samples were thoroughly washed to remove all adhered soil particles, initially with raw water and then distilled water. The samples were then cut into small pieces and then dried in the oven at 60- 70 ^{O}C for 72hours. The dried samples were ground in warm condition and passed through 1mm sieve. Also, soil samples were air-dried for a week and sieved using 2mm mesh gauge to remove debris and stones.

Laboratory analysis

Well- mixed samples of 2g each were taken and digested with 10 ml of 2% nitric acid, filtered and then diluted to 50 ml with distilled water. Well-mixed samples of 250 ml each were taken in 500 ml glass beakers and digested in 24 ml aqua regia on a sand bath for three days. After evaporation, the samples were filtered and diluted to 50 ml with distilled water. The digest samples of leaves, stems and roots were analysed in three replicates for heavy metals. Heavy metal {(iron (Fe), zinc (Zn), lead (Pb), copper (Cu), nickel (Ni), cadmium (Cd), chromium (Cr) and cobalt (Co) and arsenic (As)}concentrations in plant tissues and soil were determined by ARCOS, simultaneous Inductively Coupled Plasma- Atomic Emission Spectrometry (ICP-AES).

Data Analysis

Data were analyzed using one-way ANOVA (SPSS statisticalpackage) and evaluation indices. Evaluation indices such as contamination factor, contamination degree, transfer factor and translocation ratio were used in this study. Mean values of heavy metals in soil were compared with the permissible levels given by USEPA (1989) and other works (Brady, 1984; Kabata-Pendias, 2000 and Adriano, 2000) while those of *C.odorata* were compared with permissible levels of World Health Organization. Contamination Factor(CF) and contamination degree were evaluated for each studied site using equation 1 and 2 given by Hakanson, (1980). Plant / soil metal concentration and translocation factor were determined using indices given in equation 3 and 4. The transfer ratio (TR) was the value used in evaluation studies on the impact of routine or accidental releases of pollutant into the environment.

$$CF = \frac{C\ SAMPLE}{C\ Background} \quad \text{................................(1)}$$

$$CD = \text{Summation of all the CF} \quad \text{..................(2)}$$

Where,
C Sample is metal concentration in contaminated soil
C Background is mean natural background value of that metal

$$TF = \frac{\text{Concentration of metals in shoot}}{\text{Concentration of metals in soil}} \quad \text{.........(3)}$$

Transfer factor (TF) was calculated as the ratio of concentration of metal in the shoot (aerial parts) to the concentration of metal in the roots (Cui *et al.,* 2007).

$$TR = \frac{\text{Concentration of metals in aerial parts}}{\text{Concentration of metals in root}} \quad \text{.........(4)}$$

Translocation ratio (TR) is given as the ratio of the concentration of metal in the shoots to the concentration of metals in the soil (Chen *et al.,* 2004).

RESULTS AND DISCUSSION

Heavy metals content in soils

Heavy metal concentrations of iron, zinc, lead, copper, nickel, cadmium, chromium. Cobalt and arsenic in soil samples were presented in table 1. Mean concentrations of iron (Fe) showed highest values of 20399 mg/kg, 22102 mg/kg and 35720 mg/kg, followed by Zn with concentrations of 39.11mg/kg, 106.22mg/kg and 437.25mg/kg in soil samples from control, contaminated and waste dumpsites respectively while As (0.25mg/kg, 1,25mg/kg and 2.13mg/kg) recorded the lowest values. Generally, concentration of all the heavy metals in the soil samples studied recorded highest values in waste dumpsites when compared with contaminated and control sites. Higher concentration of Fe in soil samples from the sites could be attributed to its relative abundance in the earth crust (Adriano, 2001).

However, Zn and Cu concentrations in the studied soils are higher than those recorded from similar studies of Brady (1994); Vecera *et al* (1999); Kabata-Pendias (2000) and Amusan *et al* (2005). Heavy metals concentrations in soils are in order of Fe> Zn> Cu> Pb> Cr>Co> Ni>Cd> As. Mean concentrations of heavy metals were significant higher in soils from waste dumpsite than contaminated and control sites at $p< 0.05$ (table 1).

Heavy metals content in *Chromoleana odorata*

Higher concentrations of heavy metal were recorded in *C. Odorata* plants collected from waste dumpsite when compared with contaminated and control sites (Table 2). Higher concentrations of heavy metals recorded in C.odorata is in line with the findings of Kabata-Pendias (1984), Juste and Mench (1992), Micieta and Murin (1998), Amusan *et al* (2005) and Moreno *et al* (2006),that plant species can significantly influenced the rate of metal uptake from soils,Generally, heavy metal concentrations in the studied plants showed the order of Fe> Zn> Cu> Pb> Ni> Co> Cr> Cd>As. Higher concentration levels of Fe, Zn Cu,Pb and Ni in plants could be attributed to the importance of these metals in proper functioning of the biological system (Ward,1995), importance of Fe in plant growth and their abundance in the earth crust while low concentration levels of Co, Cr and Cd could be attributed to the metal being not essential for plant growth and metabolism(Harrison and Chirgawi,1989).

Table 1. Mean values of heavy metal concentrations in the studied soils with recommended values in soil.

Heavy metals (mg/kg)	Control site	Contaminated site	Waste dumpsite	Recommended Values
Fe	20399 b	22102 b	35720 a	10000 -50000*
Cu	38.94 c	91.31 b	356.71 a	10-40*
Zn	36.11 c	106.22b	437.25 a	20-200*
Pb	28.42 c	66.01b	205.29a	10-300*
Ni	18.51 c	28.96b	34.11 a	10-100*
Cd	0.45 c	2.46 b	5.69 a	0.05-1.00*
Cr	25.68 c	32.66b	38.99 a	54**
Co	16.50 c	34.21b	43.22 a	20**
As	0.25 c	1.25b	2.125 a	

* Kabata-Pendias (2000) and Adriano (2001)

** Brady (1984)

Table 2. Mean values of heavy metal concentrations in the *Chromolaena odorata* plants with recommended values in soil

Heavy metals (mg/kg)	Control site	Contaminated site	Waste dumpsite	Recommended Values
Fe	1750.10 b	2018.22 b	9963.10 a	425*/100**
Zn	28.22 c	66.88b	248.61 a	99.40**
Cu	25.01 c	74.28 b	264.35 a	73.30**
Pb	20.22 c	49.34b	146.19a	0.3*/18**
Ni	18.31 b	19.47b	22.61 a	1.0*
Cd	0.25 b	0.33 b	0.95 a	0.1*/0.20**
Cr	12.26 c	21.66b	26.99 a	
Co	10.40 c	18.45b	24.07 a	0.20*
As	0.05 c	0.20b	0.45 a	

*WHO/FAO ** Veceral *et al* (1999)

Translocation ratio and Transfer factor

Since the rate of metal uptake is greatly influenced by plant species (Chamberlain, 1983; Harrison and Chirgawi, 1989 and Smith, 1996), the ability of *Chromolaena Odorata* to accumulate and transport metals was characterized by determining their translocationratio (TR) and transfer factor (TF) in figure 1 and 2. It was observed that higher TR and TF were recorded in plants from waste dumpsite when compared to contaminated and control site. This could be attributed to the higher levels of contaminant in the waste dump. The results showed that *Chromolaena Odorata* plants have TF of <1 for all the heavy metals studied indicating its great ability to uptake and subsequently translocate these heavy metals in their parts. Furthermore, its efficiency of extracting of these heavy metals from soils is dependent on their levels of concentration in the soil (Abdul Kasheem, 1999 and Opaluwa, 2010). This study has clearly shown that heavy metals taken up by *Chromolaena Odorata* plants were largely retained in the shoot of the plants. Their ability to accumulate the metals was unswerving with the high TR values of more than 1 and the low TF values of less than 1. Heavy metal forbearance with high TR value have been recommended for phytoaccumulator of contaminated soils (Yoon *et al,*2006 and Waziri *et al,* 2016) and therefore *Chromolaena Odorata* plants can be used as phytoremediators of multi-metal contaminated soils. Also, the bioaccumulation of metals in the plant tissues indicates a great ability of this plant for phytoextraction and could be considered as accumulator plants (Serrag, 2005 and Opaluwa, 2010).A hyperaccumulator plant must have the following characteristics: a) high rate of contaminant build-up even at low concentrations; b) accumulate many contaminants concurrently; c) high growth rate and biomass production, d) resistance to pests and diseases and e) tolerance to contaminants (Accioly and Siqueira,2000). Also the variation in values of these heavy metals in the soil and plant samples is an indication of their mobility through leaching and runoffs from contaminants (Oluyemi *et al,* 2008).

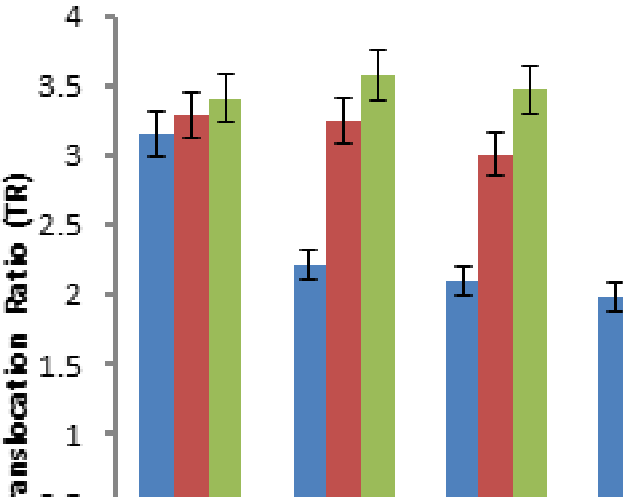

Figure 1. Translocation Ratio of Heavy Metals from Roots to Shoots of *C.odorata* plants

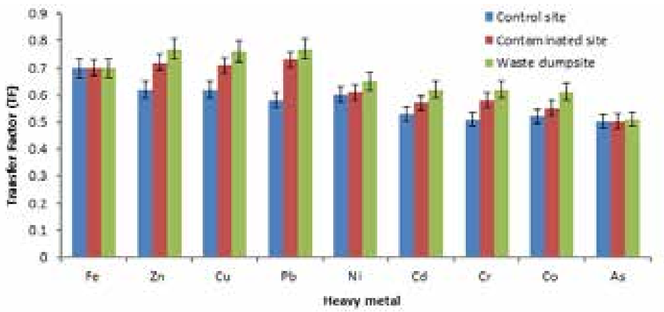

Figure 2. Transfer Factors of Heavy Metals from Soils to Shoots of *C.odorata* plants

Contamination Factor (CF) and Contamination Degree (CD) of Heavy Metals in soils and *C. odorata*

Contamination Factor (CF) and Contamination Degree (CD) given by Hakanson (1980) were used to assess the heavy metal concentrations in soils and *C.odorata* plants from contaminated (CS) and waste dumpsites (WDS). Heavy metal concentrations of soils from control site were used as background value for the determination of CF and CD. Values of contamination factors in soils (1-3) showed moderate contamination with Fe, Cu, Zn, Pb, Ni, Cr and Co from CS and Fe, Ni, Cr and Co from WDS; (3-6) considerable with Cd and As in CS and (>6) very high with Cu, Zn, Pb, Cd and As from WDS (Figure 3). CF values (1-3) in plants showed moderate with Fe, Zn, Cu, Pb, Ni, Cd, Cr and Co from CS and Fe, Ni, Cr, Co in WDS; (3-6) considerable with As from CS and (>6) very high contamination with Zn, Cu, Pb, Cd and As (figure 4). This is high when compared with similar works done by Abdullah *et al* (2012); Obasi *et al* (2013) and Okoro *et al* (2013). Soil samples from both contaminated and waste dumpsite showed very high degree of contamination while *C.odorata* plants showed high and very high degree of contamination from contaminated and waste dumpsites respectively (Figure 5)

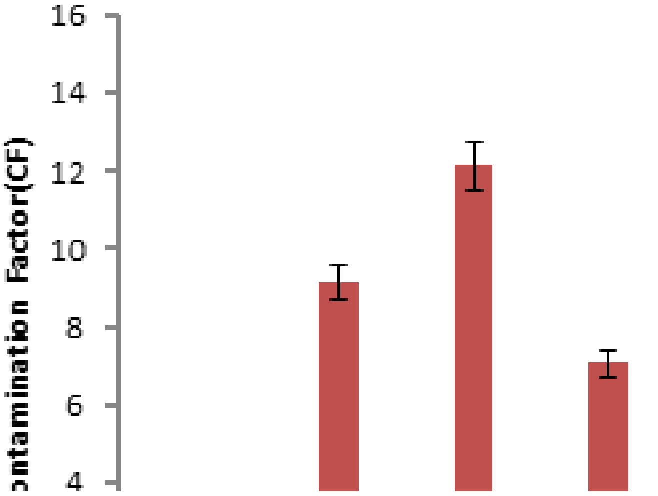

Figure 3. Contamination Factors of Heavy Metals in

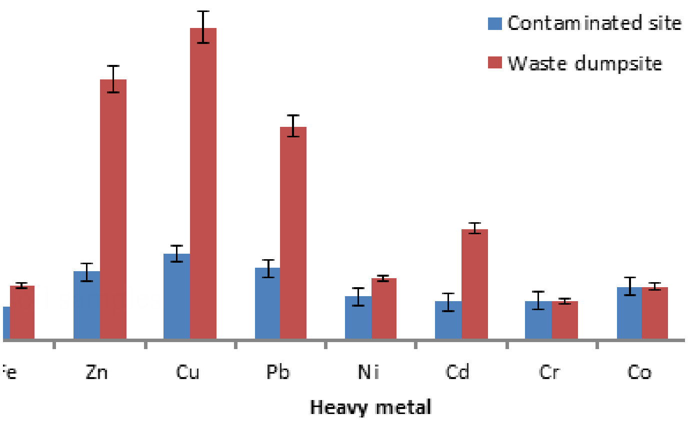

Figure 4. Contamination Factors of Heavy Metals in *C. odorata*plant samples

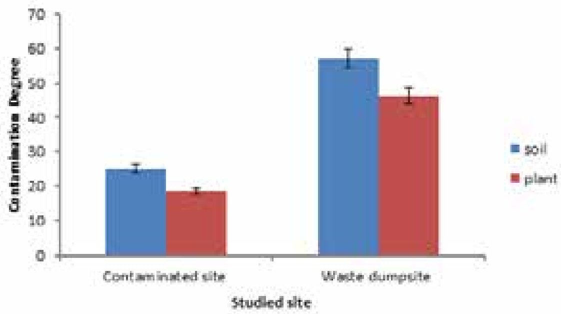

Figure 5. Contamination Degree of Heavy Metals in Soils and *C. odorata*plant samples

Correlation between the concentration of heavy metals in the soil and *C. odorata*

Table 3 showed positive correlation between soil and *C.odorata* plants for all the metals in the investigated sites. These relations were significant for all the metals with the exception of Ni and As from control site. The results of positive correlation between soiland plants have been recorded by Fatoki (2003) and Gune *et al* (2004). Results thus indicated that plants take nutritional elements from soil through their roots. However, the low correlation results indicated by Ni and As suggest that some elements might be accumulated through other plant parts other than their roots or some plants may have high ability to accumulate some elements directly from atmospheric deposition (Gune *et al*,2004; Schuhmacher *et al,* 2009).

Table 3. Correlation between the Concentration of Heavy Metals in the Soil and *Chromolaena odorata*

Heavy metal	Control site	Contaminated site	Waste dumpsite
Fe	0.86	0.88	0.90
Zn	0.52	0.85	0.91
Cu	0.55	0.84	0.99
Pb	0.51	0.78	0.99
Cr	0.50	0.77	0.84
Co	0.51	0.80	0.82
Ni	0.52	0.77	0.92
Cd	0.48	0.72	0.99
As	0.46	0.70	0.72

CONCLUSION

Soil and *C. Odorata* plant samples had significantly high concentrations of heavy metals in waste dump and contaminated sitesthan control site. Heavy metal concentrations in *C. Odorata* and soil samples showed decreasing order of Fe> Zn> Cu> Pb> Ni> Co> Cr>Cd>As. The ability of *C. Odorata* to accumulate the metals was consistent with the high translocation ratio values of more than 1 and the low transfer factor values of less than 1. Soils and *C. odorata* plant samples showed very high degree of contamination in contaminated and waste dumpsites. Heavy metals in soils showed positive correlation coefficient with the concentrations in *C. Odorata* plants. Anthropogenic inputs from the waste dump are responsible for the significant increase in the amount of metal deposited in the study area and has impacted the soil and *C. Odorata* plants. The potential of *C. Odorata* plants to biocummulate and translocate heavy metals has been indicated in this study. Thus, Soil amendments should be applied to reduce the mobility of heavy metals in the contaminated soils and to reduce further uptake of these heavy metals by plants in the area.

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