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Heavy Metals Bioavailability and Phyto-accumulation Potentials of Selected Plants on Burrow-pit Dumpsites in Aba and Ntigha Dumpsite in Isiala Ngwa of Abia State, Nigeria

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ABSTRACT: In this study, dumpsite soil physicochemical parameters, eight heavy metals speciation and soil-plant transfer of five plants species were investigated. The soil and plants parts (roots, stem and leaves) obtained from burrow-pit dumpsite in Aba and Ntigha dumpsite in Isiala Ngwa as well as a nearby farm land (control site) were subjected to standard methods of chemical analysis. Results obtained showed that mean pH, electrical conductivity, moisture, cation exchange capacity, total organic carbon, total organic matter, phosphate, sulphate, carbon:nitrogen ratio and total extractable metal for Cd, Cu, Mn, Pb, Zn, Fe, Ni, and Cr were significantly higher ($P < 0.05$) in the dumpsites compared to control site. Sequential extraction showed higher percentages of the non-residual fraction for all the metals studied except Cu. The order of mobility and bioavailability of these metals were: Cd > Fe > Pb > Mn > Zn > Cr > Ni > Cu. Total mean concentration of metals in different parts of *Amaranthus hybridus*, *Talinum triangulare*, *Carica papaya*, *Ipomea batatas* and *Luffa aegyptica* were significantly higher ($P < 0.05$) in the dumpsites compared to control site. The translocation factor, biological concentration factor and biological accumulation coefficient values of the plant species varied for all the metals. These results imply that pollution of an environment by dumpsites has health and ecological risks and that the plants studied could be used for environmental friendly phytoremediation technologies.

KEYWORDS: Bioavailability, Phytoaccumulation, Dumpsites, Burrow-pit, Ntigha, Aba

1. Introduction

Soil is a reservoir of metals whose concentrations are associated with several factors such as biological and biogeochemical cycling, parent materials and mineralogy, soil age, organic matter, pH, redox concentrations and microbial activities (Lee *et al*., 1997; Ma *et al*., 1997; Greenly and Hayes, 2000; Kabata-Pendias, 2004). However, large amounts, exceeding the threshold limit of these heavy metals are released into the soil as a result of increased anthropogenic activities such as agricultural practices, industrial activities, energy consumption and waste disposal methods, thus leading to the contamination of soils (Ebong *et al*., 2008; Ikhouria *et al*., 2010). Solid wastes are sources of environmental pollution and reports have shown that they introduce additional heavy metals into the surrounding soil and ground water (Elaigwu *et al*., 2007; Uba *et al.*, 2008; Nubi *et al.*, 2009).

Heavy metals are associated with organic matter, adsorbed onto Fe/Mn oxides or complexed with hydroxides, sulphides and carbonates (Tessier *et al*., 1979; Kabata-Pendias, 2004). High contents in the exchangeable, soluble and easily reducible fraction may indicate pollution from anthropogenic origin (Kabata-Pendias, 2004). Furthermore, high contents in the more resistant fractions, the residual, may be significant in the long term. Bioavailability and toxicity of heavy metals depend on metal speciation in sediments (Ewa-Szarek *et al*., 2006). The mechanisms of mobility and bioavailability of heavy metals relative to the various fractions of heavy metals in sediments have been documented (Tsai *et al*., 1998; Yu *et al*., 2001; Hlavay *et al*., 2004).

In Nigeria, areas with high refuse disposal rate are associated with high population density, increased commercial and industrial activities

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(Ogwueleka, 2009; Abul, 2010). The pollution of the environment with heavy metals has become a world-wide problem during recent years because they are non-biodegradable and are toxic to flora and fauna in the ecosystem (Benjamin and Mwashote, 2003; Ikem *et al*., 2003; Krissanakriangkrai *et al*., 2009; Ozturk *et al*., 2009).

In South-East Nigeria, most refuse dumpsites have been extensively used for cultivating varieties of edible vegetables and plant based foodstuff despite existing data on the heavy metals phyto-accumulation potentials of plants in contaminated and polluted soils (Cobb *et al*., 2000; Benson and Ebong, 2005). This practice constitutes serious health and environmental concern arising from the phytotoxic effects of these metals to the plants and the animals feeding on such vegetables and plant-based foodstuff (Ellis and Salt, 2003; Jarup, 2003). While heavy metal content is a critical measure in assessing risk of a refuse dumpsite, total heavy metal content alone does not provide predictive insights on the bioavailability, mobility and fate of the heavy metal contaminants (Cataldo and Wildung, 1978; Kabata-Pendias, 2004). It is the chemical form or species of these heavy metals that is important in assessing their impacts on the environment because their chemical forms control their bioavailability or mobility which ultimately influence heavy metal soil-plant transfer (Kabata-Pendias, 2004; Gupta and Sinha, 2006; Iwegbue *et al*., 2007; Uba *et al*., 2008; Ikhouria *et al*., 2010).

Data on soil biochemical quality of most refuse dumpsites in Eastern Nigeria is lacking and the extensive use of most of these dumpsites as arable lands for cultivating varieties of edible vegetables and plant-based foodstuff without proper routine assessment of the associated health risks is misleading. Thus, there is need for assessment of dumpsite waste soils to ensure environmental sustainability. This research therefore, was aimed at providing baseline data to fill these gaps.

2. Materials and methods

2.1 Refuse waste soil collection

Refuse waste soils were collected from three dumpsites, Burrow-pit dumpsite in Aba (Latitude 05° 07′ 16.45″, Longitude 006° 57′ 25.30″) and Ntigha dumpsite in Isiala-Ngwa (Latitude 05° 27′ 29.41″, Longitude 007° 05′ 07.78″) and from the control site (Latitude 05° 16′ 23.18″, Longitude 006° 59′ 36.15″), which is a farm land situated within the region. Triplicate sample from each dumpsite and control site were collected seven meters within the vicinity of the sites and composite samples were made in the laboratory. The samples were air dried, ground using manual soil grinder (DGSI Geotechnical instrumentation Model S-178), sieved (using 2mm sieve), put in polythene bags and kept in glass desiccators (Baroda Scientific Glass Works) until analysis. During soil sample collection, care was taken to ensure that top soil at 0-20 cm depth from the rhizosphere of the studied plants were obtained from each site from where plant samples were rooted.

2.2 Dumpsite/control site plant sample collection

Five common/dominant plant species *Amaranthus hybridus*, *Talinum triangulare*, *Carica papaya*, *Ipomea batatas* and *Luffa aegyptia* within each study location were obtained and used for the study. A total of 6-10 samples of each plant species were randomly uprooted, collected from each of the dumpsite and control site and separately mixed to form a composite sample, placed in labeled pre-cleaned polythene bags and transported within 14 hours to the Chemistry Laboratory of National Research Institute for Chemical Technology, Zaria, Nigeria for further analysis. Before analysis, plant roots and a mixture of the stems and leaves (shoots) were carefully removed and washed (for 2-3 minutes approximately) in tap water and de-ionized water to remove any soil and surface dust. Plant samples were dried at room temperature for a day, oven dried at 80^{o}C to constant weight and pulverized to fine powder using milling grinder (Thomas Wiley Model 4). Ground plant samples collected in labeled pre-cleaned polythene bags were placed in glass desiccators (Baroda Scientific Glass Works).

2.3 Physicochemical Analysis of Samples

Soil pH was determined using digital pH meter (Jenway 3015) at a ratio of 1:2.5 soil/water according to the procedure described by Bates (1954). Soil electrical conductivity was determined using digital electrical conductivity meter (Jenway 615D) according to the procedure outlined by Whitney (1998) with some modifications. The soil moisture content was determined according to the procedure outlined by APHA (1998) while the cation exchange capacity of the soil samples were determined by ammonium saturation method described by Dewis and Freitas (1970). Organic carbon and organic matter were determined according to the procedure outlined by Osuji and Adesiyan (2005) while total nitrogen was determined as described by Yeomans and Bremmer (1991). SO_4^{2-} was quantified by the procedure described by Butters and Chenery (1959) and PO_4^{3-} was determined by procedure described by Olsen and Sommers (1982) respectively.

2.4 Sequential extraction of heavy metals

The conventional method developed by Tessier *et al* (1979) as outlined with modifications by Uba *et al* (2008) was employed for the sequential extraction of heavy metals.

2.5 Determination of heavy metals in plant species

The mineral elements comprising cadmium (Cd), copper (Cu), manganese (Mn), lead (Pb), zinc (Zn), iron (Fe), nickel (Ni) and chromium (Cr) were determined according to the procedure described by Shahidi *et al* (1999) with some modifications using atomic absorption spectrophotometer (Bulk Scientific Model 210 VGP).

2.6 Determination of phytoremediation quotient

The translocation factor (TF) defined as the ratio of heavy metals in plant shoot to that in plant root was calculated using the procedure described by Cui *et al* (2007). It is expressed as:

$$\text{Translocation factor (TF)} = \frac{[\text{Metals}]_{shoot}}{[\text{Metals}]_{root}}$$

The biological concentration factor (BCF) was calculated as metal concentration ratio of plant roots to soil as described by Yoon *et al* (2006). It is expressed as:

Biological concentration factor (BCF) = $[\text{Metals}]_{root} / [\text{Metals}]_{soil}$

Biological accumulation coefficient (BAC) was calculated as a ratio of heavy metal in shoots to that in soil as described in the procedure by Li *et al* (2007).

i.e. Biological accumulation coefficient (BAC) = $[\text{Metals}]_{shoot} / [\text{Metals}]_{soil}$

2.7 Statistical analysis

The data were expressed as mean ± standard deviation of triplicate determinations. Analysis of variance for all the measured variables was performed by SPSS version 9.2 (Inc., Chicago, USA) software and significant differences were shown at $P < 0.05$ (Kerr *et al.*, 2002).

3. Results

The results of physico-chemical properties are shown in Table 1. The mean pH, electrical conductivity, moisture, cation exchange capacity, total organic carbon, total organic matter, phosphate, sulphate, and carbon:nitrogen ratio were significantly higher ($P < 0.05$) in the dumpsites compared to control site. Mean percentage total nitrogen was significantly higher ($P < 0.05$) in the control site compared to Burrow-pit dumpsite in Aba but the difference was not signicant ($P > 0.05$) compared to Ntigha dumpsite in Isiala Ngwa. The results of the sequential extractions of the heavy metals are shown in Tables 2a and 2b. The total extractable metals were significantly ($P < 0.05$) higher in all the dumpsites compared to the control site. In almost all cases, the highest levels of heavy metals were present in Burrow-pit dumpsite in Aba except for Zn whose level was higher in Ntigha dumpsite than that in Burrow-pit dumpsite. The results also revealed higher percentages of the non-residual fraction for all the metals studied except Cu. The mean percentage order of mobility and bioavailability of these metals were: Cd > Fe > Pb > Mn > Zn > Cr > Ni > Cu (Tables 2a and 2b).

The results of total heavy metals concentration in the roots and shoots of the plant

Table 1: Physico-chemical parameters of waste soils in the dumpsites

SITES/ PARAMETER	A	B	AB
pH (H_2O)	8.60 ± 0.02^{b}	7.30 ± 0.02^{b}	7.05 ± 0.01^{a}
Electrical Conductivity (mScm-1)	3.12 ± 0.02^{b}	3.08 ± 0.01^{b}	1.25 ± 0.01^{a}
Moisture (%)	44.70 ± 0.02^{c}	38.50 ± 0.05^{a}	40.90 ± 0.08^{ab}
Cation Exchange Capacity (Cmol/kg)	8.80 ± 0.10^{ab}	18.00 ± 0.02^{c}	8.20 ± 0.00^{a}
Total Organic Carbon (%)	4.25 ± 0.03^{c}	2.76 ± 0.02^{b}	0.85 ± 0.05^{a}
Total Organic Matter (%)	7.33 ± 0.05^{c}	4.76 ± 0.02^{b}	1.47 ± 0.03^{a}
Total Nitrogen (%)	0.11 ± 0.03^{a}	0.16 ± 0.02^{ab}	0.20 ± 0.00^{bc}
PO_4^{3-}(%)	167.98 ± 0.06^{c}	146.40 ± 0.02^{b}	132.70 ± 0.05^{a}
SO_4^{2-}(%)	6.36 ± 0.02^{c}	5.50 ± 0.00^{a}	6.15 ± 0.03^{bc}
C:N Ratio	20.45^{c}	17.25^{b}	9.25^{a}

Values are mean of three (n=3) replicates ± standard deviation ; A = Burrow pit-Aba, B = Ntigha-Isiala Ngwa, AB = Control site
Values with same alphabets along the row are not significantly different at $P < 0.05$ using Ducan Multiple Range Test (DMRT)

Table 2a: Heavy metal concentrations in each fraction of waste soils in studied dumpsites

SITES/FRACTIONS	Cd			Cu			Mn			Pb		
	A	B	AB	A	B	AB	A	B	AB	A	B	AB
Exchangeable	24.89 ±0.11	11.29 ±0.07	1.02 ±0.03	13.56 ±0.02	ND	ND	35.11 ±0.03	3.08 ±0.02	0.24 ±0.02	171.50 ±0.02	13.12 ±0.02	3.85 ±0.03
Oxidizable	18.86 ±0.04	13.06 ±0.03	2.45 ±0.02	ND	9.57 ±0.11	0.97 ±0.03	187.94 ±0.02	14.11 ±0.03	3.72 ±0.02	50.73 ±0.11	ND	6.07 ±0.01
Acid soluble	19.86 ±0.12	13.15 ±0.03	1.10 ±0.02	3.50 ±0.02	ND	ND	30.66 ±0.11	32.25 ±0.05	1.86 ±0.02	ND	12.98 ±0.04	2.30 ±0.02
Reducible	19.43 ±0.09	10.98 ±0.02	1.39 ±0.03	ND	ND	0.92 ±0.03	160.14 ±0.02	118.03 ±0.09	7.55 ±0.03	144.36 ±0.02	ND	5.75 ±0.03
Residual	23.14 ±0.02	14.66 ±0.05	4.58 ±0.04	221.44 ±0.06	18.42 ±0.02	2.04 ±0.05	28.18 ±0.06	1.46 ±0.02	3.85 ±0.03	268.72 ±0.24	13.04 ±0.07	6.73 ±0.05
Total extractable metals	107.18 ± 0.07^{c}	63.14 ± 0.02^{b}	10.54 ± 0.02^{a}	238.50 ± 0.05^{c}	27.99 ± 0.15^{b}	3.93 ± 0.03^{a}	442.03 ± 0.13^{c}	168.93 ± 0.05^{b}	17.22 ± 0.02^{a}	635.31 ± 0.19^{c}	39.14 ± 0.06^{b}	23.70 ± 0.02^{a}
Non-residual (%)	78.41	76.78	58.44	7.15	34.19	48.09	93.62	99.14	77.64	57.70	66.68	71.61
Residual (%)	21.59	23.32	41.56	92.85	65.81	51.91	6.38	0.86	22.35	42.30	33.32	28.39
Mobile phase (%)	41.75	38.71	20.11	7.15	0.00	0.00	14.88	20.03	12.19	26.99	66.68	25.95

Values are mean of three (n=3) replicates ± standard deviation; A = Burrow pit-Aba, B = Ntiga-Isiala Ngwa, AB = Control site
Values with same alphabets for each metal along the row are not significantly different at $P < 0.05$ using Ducan Multiple Range Test (DMRT)

Table 2b: Heavy metal concentrations in each fraction of waste soils in the studied dumpsites

SITES/FRACTIONS	Zn			Fe			Ni			Cr		
	A	B	AB	A	B	AB	A	B	AB	A	B	AB
Exchangeable	65.71 ±0.03	20.14 ±0.02	1.86 ±0.02	78.50 ±0.02	82.26 ±0.05	13.14 ±0.02	ND	ND	ND	ND	1.83 ±0.05	0.21 ±0.03
Oxidizable	59.56 ±0.02	131.27 ±0.09	4.40 ±0.02	65.12 ±0.04	73.53 ±0.05	24.62 ±0.012	8.98 ±0.05	8.11 ±0.03	1.64 ±0.02	3.15 ±0.03	ND	0.55 ±0.01
Acid soluble	17.96 ±0.02	63.77 ±0.05	2.02 ±0.02	57.60 ±0.02	22.24 ±0.02	14.40 ±0.02	2.80 ±0.02	ND	0.58 ±0.01	2.04 ±0.01	2.66 ±0.03	0.25 ±0.01
Reducible	46.38 ±0.02	44.80 ±0.02	4.98 ±0.06	78.35 ±0.02	40.50 ±0.02	25.80 ±0.10	ND	ND	1.90 ±0.02	3.45 ±0.03	ND	0.71 ±0.01
Residual	96.48 ±0.05	190.28 ±0.02	3.38 ±0.02	92.16 ±0.14	63.45 ±0.03	25.74 ±0.08	11.19 ±0.03	13.04 ±0.05	2.43 ±0.07	18.13 ±0.11	15.70 ±0.02	1.14 ±0.01
Total extractable metals	286.09 ±0.13 ^{b}	450.26 ±0.05^{c}	16.14 ±0.02^{a}	371.73 ±0.23^{c}	281.98 ±0.06^{b}	103.70 ±0.12^{a}	22.97 ±0.13^{b}	21.15 ±0.05^{b}	6.55 ±0.03^{a}	26.77 ±0.09^{c}	20.19 ±0.05^{b}	2.76 ±0.02^{a}
Non-residual (%)	66.28	57.74	79.06	75.21	77.50	75.18	51.28	38.35	62.90	32.27	22.24	58.70
Residual (%)	33.72	42.26	20.94	24.79	22.50	24.82	48.72	61.65	37.10	67.73	77.76	41.30
Mobile phase (%)	29.25	18.64	24.04	36.61	37.06	26.56	12.20	0.00	8.85	7.62	22.24	16.67

Values are mean of three (n=3) replicates ± standard deviation
A = Burrow pit-Aba, B = Ntiga-Isiala Ngwa, AB = Control site
Values with the same alphabets for each metal along the row are not significantly different at P < 0.05 using Ducan Multiple Range Test (DMRT)

species are shown in Tables 3a and 3b. Total mean concentration of metals in different parts of *A. hybridus*, *T. triangulare*, *C. papaya*, *I. batatas* and *L. aegyptica* were significantly higher ($P < 0.05$) in the dumpsites compared to control site. The highest levels for all the metals (Tables 3a and 3b) were found in *C. papaya* followed by *A. hybridus*, *T. triangulare*, *L. aegyptiaca* and then *I. batatas* in all the sites. The different plant species absorbed metals at varying concentrations in their various parts (Tables 3a and 3b).

Translocation Factor (TF) values vary from one plant species to another and from one heavy metal to another (Figure 1). *A. hybridus* had TF > 1 for Mn, Zn, Cr and Fe, *T. triangulare* had TF > 1 for Cr, Zn and Fe, *C. papaya* had TF > 1 for all the studied metals except Ni and Pb while *I. batatas* and *L. aegyptiaca* had TF > 1 for Cd, Cu, Mn, Pb, Zn, Fe, Ni and Cr (Figure 1). All the plant species studied had BCF > 1 for Fe (Figure 2). In addition, *A. hybridus* had BCF >1 for Cr and Cu while *C. papaya* had BCF > 1 for Cr, Cu, and Cd. The BCF value for Cu was greater than 1 for all the plant species in the control site. The Biological Accumulation Coefficient (BAC) shows that all the plant species studied had BAC> 1 for Fe. BAC > 1 for Cu was observed for *A. hybridus* at the control site and BAC > 1 for Fe was also observed for *L. aegyptica* at Burrow-pit dumpsite in Aba respectively (Figure 3).

4. Discussion

The observed mean pH shows that the dumpsites soils are alkaline and the entire physicochemical parameters suggested that the soils are highly fertile and could support plants growth relative to the control site. Similar findings were reported for dumpsites by other researchers (Gupta and Sinha, 2006; Elaigwu *et al*., 2007; Uba *et al*., 2008). pH plays a role in soil microbial reactions. Therefore, the pH values in the present study may have implications on the soil alkalinity and availability and uptake of metals by plants and microorganisms. The high conductivity value of the waste soil may be attributed to the presence of metal scraps which is one of the constituents of the refuse dumpsite and this impies that there are more soluble salts in the soil (Karaca, 2004; Arias *et al*., 2005). Moisture content which is directly proportional to the water holding capacity of the soil were generally high and this is expected considering the overall climatic predisposition of the studied site. Cation exchange capacity gives the soil a buffering capacity which may slow down the leaching of nutrient cations and positively charged pollutants because they affect both soluble and exchangeable metal levels (Yoo and James, 2002). The mean percentages of total organic carbon and total organic matter values were high based on the classification of organic matter given by Enwezor *et al*. (1988). While soil organic carbon is not a requirement for plant growth, the levels of organic matter in soils influence a number of chemical and physical processes in the soil and it is an important indicator of the soil as a rooting environment (Okalebo *et al*., 1993). The high concentration of the total nitrogen, PO_4^{3-} and SO_4^{2-} in the refuse waste soils may enhance the growth of plants in these sites. Also, the high ratio of carbon to Nitrogen (C:N) suggest that the soils would support the growth of diverse plant species (Okalebo *et al*., 1993; Obute *et al*., 2010).

The high values of total extractable metals in this study may be attributed to dumping of numerous metal containing wastes such as cadmium and lead acid batteries, metal scraps among others on the dumpsites. Total extractable cadmium levels in the dumpsites were above the critical permissible concentration of 3.0 mg kg^{-1} for agricultural soils (USEPA, 1986; MAFF, 1992). The high percentage of the total extractable fraction in the mobile phase suggests that Cd in these soils was potentially more bioavailable for plants uptake (Xian, 1989). This result was similar to the findings of Kuo *et al*. (1993); Gupta and Sinha (2006) and Uba *et al* (2008). Copper concentrations in the dumpsites were below the toxic limit of 250 mg kg^{-1} set by USEPA (1986) for agricultural lands. The results indicated that Cu was mostly found in the residual phase (i.e. bound to silicates and detrital materials) which is similar to the reports of Gupta and Chen (1975), Hickey and Kittrick (1984) and Uba *et al* (2008). The findings also indicated Cu to be mostly associated with the

Table 3a: Total heavy metals concentration in roots and shoots of plant species in the studied sites

Plants species/ Sites		*Amarathus hybridus*		*Talinum triangulare*		*Carica papaya*		*Ipomea batatas*		*Luffa aegyptiaca*	
		Roots	Shoots	Roots	Shoots	Roots	Shoots	Roots	Shoots	Roots	Shoots
Cd	A	85.63±0.16	34.95±0.03	56.05±0.01	18.98±0.17	66.75±0.04	80.25±0.10	8.92±0.10	13.38±0.05	9.51±0.03	26.75±0.11
	B	55.16±0.02	19.70±0.02	40.93±0.05	11.76±0.07	44.62±0.13	66.93±0.01	4.25±0.02	8.77±0.06	5.81±0.17	13.93±0.26
	AB	7.24±0.18	3.46±0.02	4.70±0.05	1.48±0.02	6.58±0.02	7.85±0.04	0.78±0.01	1.35±0.01	0.96±0.11	2.77±0.03
Cu	A	35.72±0.02	19.83±0.05	24.30±0.01	11.33±0.04	22.10±0.12	43.19±0.17	7.22±0.03	11.14±0.18	7.19±0.01	16.24±0.05
	B	17.44±0.06	9.17±0.02	9.75±0.01	7.05±0.15	16.32±0.02	24.70±0.02	3.80±0.10	5.60±0.02	5.83±0.15	9.76±0.02
	AB	6.14±0.05	3.99±0.01	4.13±0.10	2.18±0.02	3.94±0.02	7.17±0.23	1.06±0.02	2.95±0.04	2.04±0.01	3.45±0.02
Mn	A	8.84±0.02	15.92±0.14	11.65±0.04	7.72±0.02	9.35±0.01	17.18±0.06	3.45±0.04	8.74±0.02	5.17±0.03	14.06±0.02
	B	3.36±0.04	6.38±0.01	7.11±0.01	4.39±0.08	6.16±0.02	14.20±0.02	2.30±0.02	5.50±0.01	3.56±0.04	10.19±0.02
	AB	1.03±0.01	1.26±0.01	1.43±0.03	0.98±0.02	2.25±0.04	7.86±0.02	0.48±0.02	2.09±0.01	1.33±0.01	4.38±0.02
Pb	A	8.74±0.25	5.06±0.02	6.15±0.04	3.76±0.02	11.78±0.03	7.80±0.10	3.03±0.01	5.74±0.05	3.66±0.02	6.82±0.02
	B	18.13±0.05	11.43±0.01	12.97±0.05	8.13±0.05	23.11±0.03	18.95±0.02	4.61±0.03	5.13±0.01	4.85±0.04	6.06±0.02
	AB	1.14±0.01	0.76±0.02	0.66±0.02	0.27±0.03	1.85±0.04	1.06±0.02	0.23±0.01	0.84±0.02	0.42±0.02	1.18±0.02

Values are mean of three (n=3) replicates ± standard deviation;
Heavy metal concentration was expressed as mg/kg
A = Burrow pit-Aba, B = Ntigha-Isiala Ngwa, AB = Control site

Table 3b: Total heavy metals concentration in roots and shoots of plant species in the studied sites

Plant species/ Sites		*Amarathus hybridus*		*Talinum triangulare*		*Carica papaya*		*Ipomea batatas*		*Luffa aegyptiaca*	
		Roots	Shoots	Roots	Shoots	Roots	Shoots	Roots	Shoots	Roots	Shoots
Zn	A	28.50±0.02	33.8± 0.04	25.80±0.02	30.10±0.02	38.95±0.04	44.38±0.02	16.79±0.03	21.44±0.05	19.48±0.02	23.17±0.03
	B	12.61±0.03	15.36±0.02	11.34±0.05	14.93±0.01	16.24±0.02	19.50±0.02	8.36±0.04	11.40±0.00	10.53±0.05	14.90±0.01
	AB	1.05±0.02	2.20±0.00	0.98±0.01	1.90±0.02	1.55±0.03	2.30±0.01	0.95±0.02	1.62±0.04	1.02±0.01	1.70±0.02
Fe	A	98.34±0.25	131.43±0.08	114.67±0.29	128.11±0.37	156.11±0.17	179.35±0.08	104.86±0.25	117.34±0.38	119.18±0.16	123.57±0.33
	B	102.70±0.10	147.96±0.26	126.19±0.14	136.75±0.38	184.33±0.45	191.28±0.09	109.16±0.08	124.67±0.13	123.50±0.20	132.83±0.17
	AB	60.25±0.16	68.14±0.15	60.05±0.08	67.93±0.12	91.20±0.00	98.64±0.08	62.99±0.17	65.40±0.00	66.71±0.13	68.15±0.04
Ni	A	3.12±0.02	2.94±0.05	2.48±0.02	2.33±0.01	4.36±0.02	4.12±0.02	2.13±0.05	2.30±0.00	2.28±0.02	2.45±0.03
	B	2.86±0.02	2.53±0.01	2.40±0.00	2.18±0.04	3.79±0.03	3.64±0.08	2.05±0.09	2.17±0.03	2.24±0.02	2.32±0.02
	AB	1.26±0.02	0.97±0.03	1.06±0.02	0.94±0.02	1.28±0.02	1.11±0.01	0.86±0.02	0.95±0.04	0.87±0.02	2.32±0.02
Cr	A	6.82±0.14	8.67±0.08	7.01±0.03	8.31±0.17	8.66±0.02	11.43±0.15	4.88±0.04	7.12±0.06	6.83±0.05	9.25±0.04
	B	9.77±0.33	14.94±0.12	9.56±0.08	11.95±0.04	11.98±0.02	15.07±0.13	5.33±0.07	9.73±0.04	7.15±0.06	10.43±0.11
	AB	0.96±0.02	1.28±0.07	0.83±0.01	0.97±0.03	0.84±0.02	1.46±0.02	0.56±0.04	0.86±0.02	0.96±0.04	1.07±0.03

Values are mean of three (n=3) replicates ± standard deviation;
Heavy metal concentration was expressed as mg/kg
A = Burrow pit-Aba, B = Ntigha-Isiala Ngwa, AB = Control site

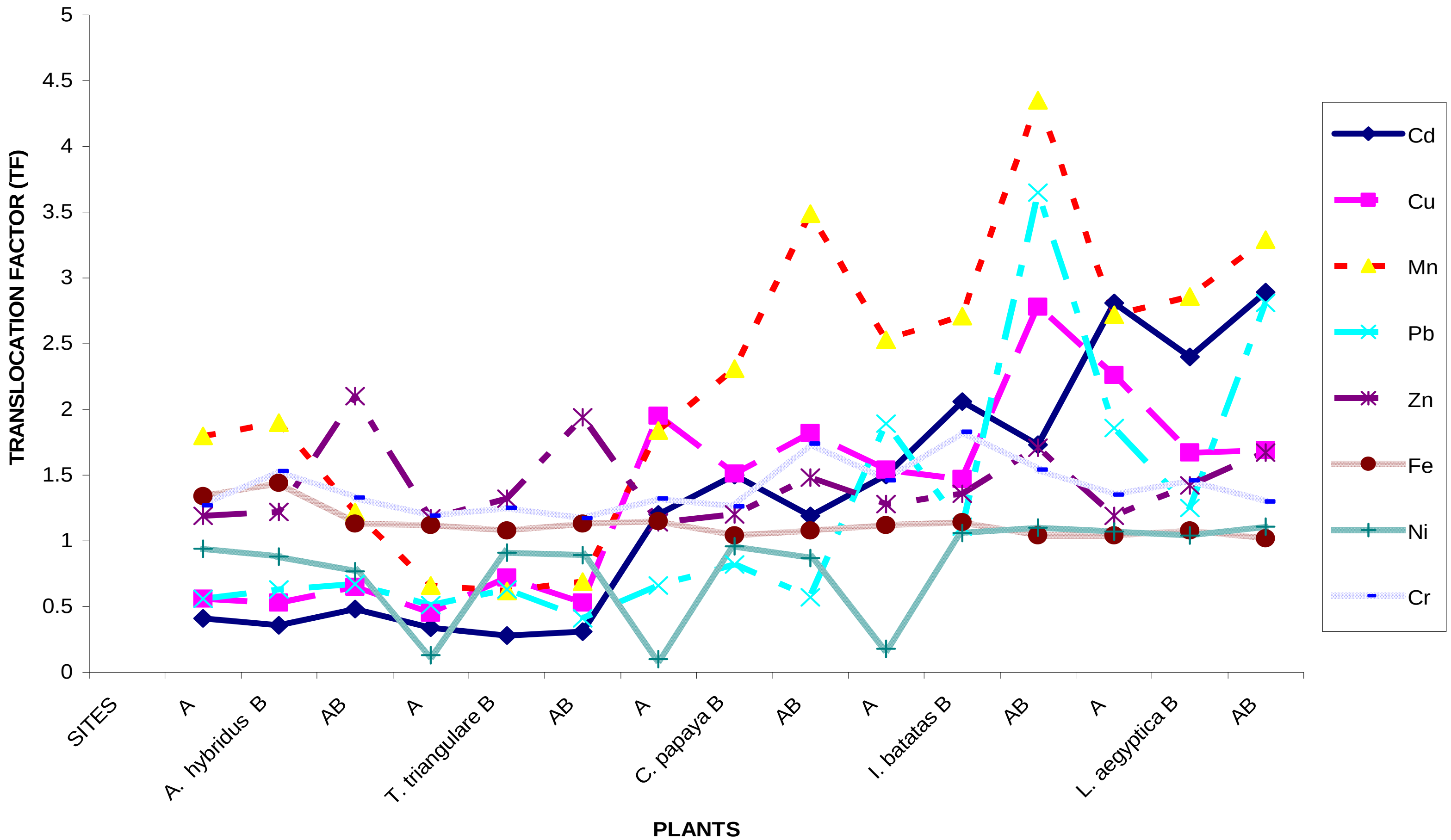

FIGURE 1: TRANSLOCATION FACTOR (TF) OF PLANTS FOR ALL THE METALS IN THE STUDIED SITES

A = Burrow pit-Aba, B = Ntigha-Isiala Ngwa, AB = Control site

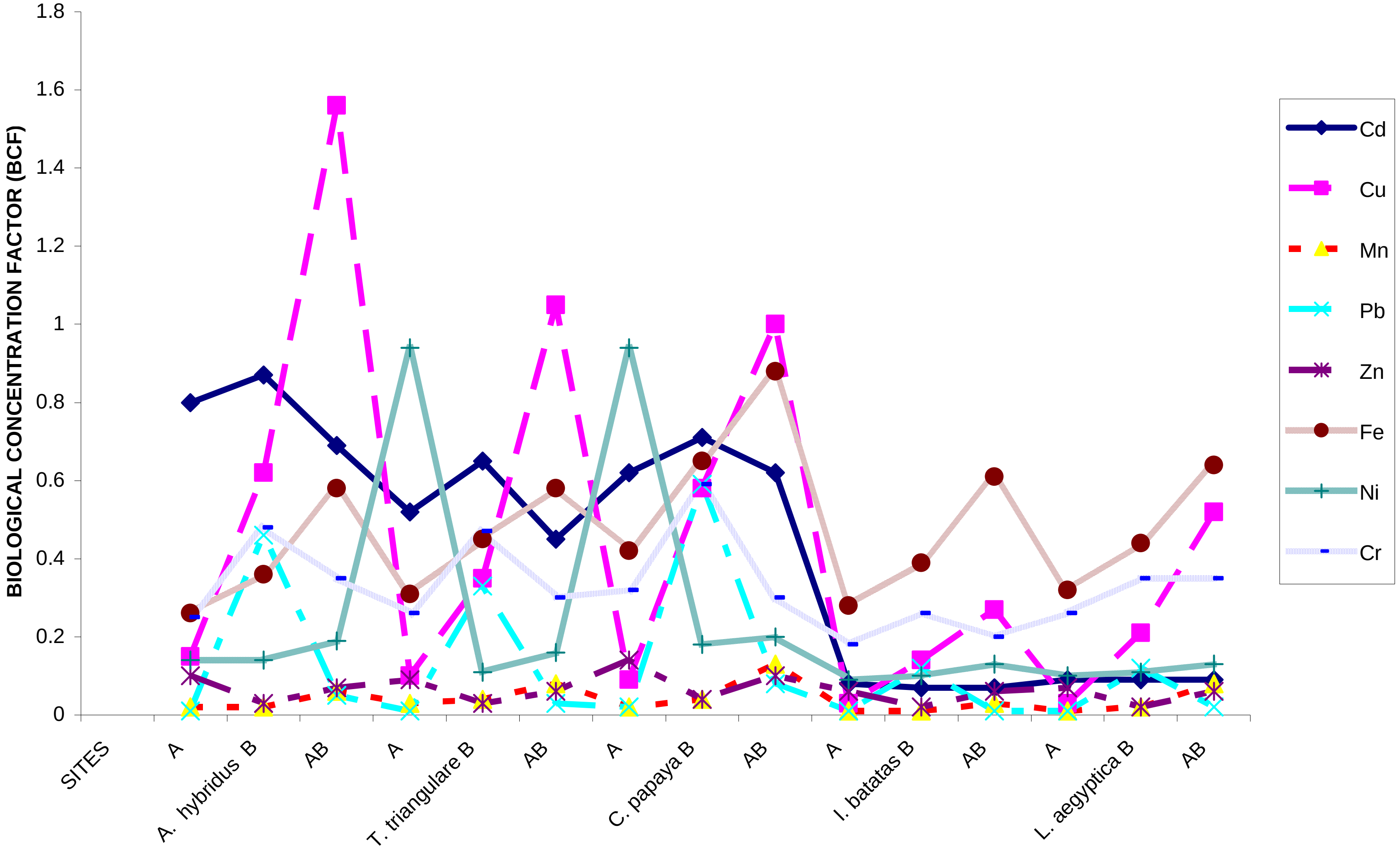

FIGURE 2: BIOLOGICAL CONCENTRATION FACTOR (BCF) OF PLANTS FOR ALL THE METALS IN THE STUDIED SITES

A = Burrow pit-Aba, B = Ntigha-Isiala Ngwa, AB = Control site

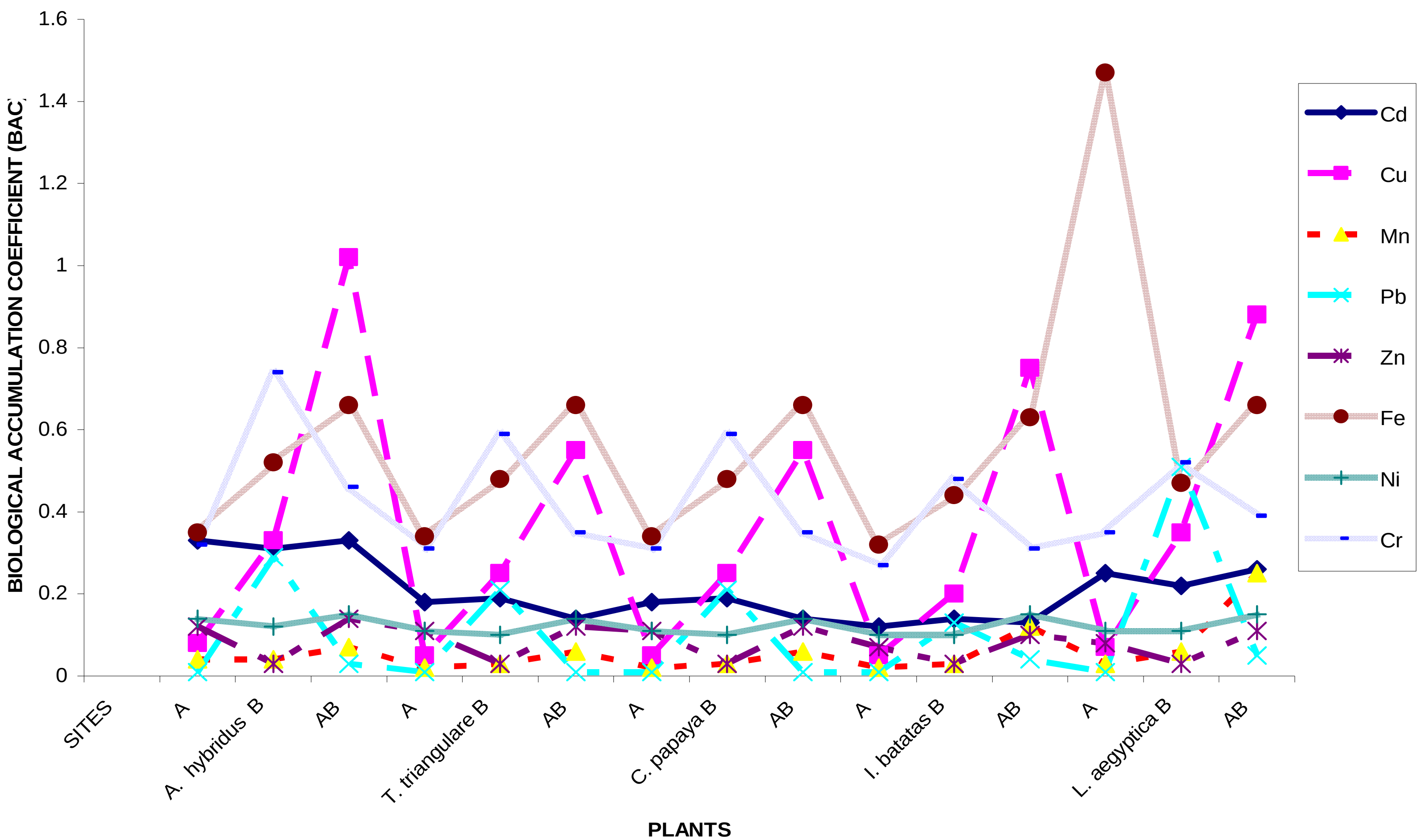

FIGURE 3: BIOLOGICAL ACCUMULATION COEFFICIENT (BAC) OF PLANTS FOR ALL THE METALS IN THE STUDIED SITES

A = Burrow pit-Aba, B = Ntigha-Isiala Ngwa, AB = Control site

with the oxidizable fraction (bound to organic matter) which may be attributed to the high formation constants of organic copper complexes (Stumm and Morgan, 1981).

Total extractable manganese concentration in Burrow-pit dumpsite exceeded the tolerable limits (100 – 300 mg kg^{-1}) set by USEPA (1986) for agricultural lands. However, the value obtained in Ntigha dumpsite in Isiala Ngwa was within this range. The high percentage of Mn in the reducible phase in all waste soils may be attributed to the precipitation of amorphous hydrous oxides of manganese during aging of dumpsites (Staelens *et al*., 2000).

Ntigha dumpsites had Pb concentrations within the USEPA (1986) allowed limits of 30-300 $mgkg^{-1}$ while Burrow-pit dumpsite had Pb content above USEPA (1986) limits for agricultural lands. Similar results were reported by Uba *et al* (2008). More than 50% of Pb was found in the non-residual fraction while high percentage of the total extractable fraction contributed to the mobile phase (exchangeable and acid soluble phases) and as such suggests higher risks for lead contamination. Zinc contents in Burrow-pit dumpsite was within the permissible limits of 300 mg kg^{-1} for agricultural lands set by USEPA (1986) while that in Ntigha dumpsite was above the USEPA (1986) set limit. The percentage mobile phase was high indicating that the Zn will be readily bio-available to the environment. The association of zinc with the reducible fraction has been reported earlier by several other workers (Kuo *et al*., 1983; Ramos *et al*., 1994).

The high level of Fe in the exchangeable and acid soluble phase of the fractions indicated that the metal may be potentially toxic if not regulated due to their high mobility. The level of Ni in Ntigha dumpsite was within the permissible limit of 150 $mgkg^{-1}$ set by CCME (1991) for residential and agricultural lands while its level in Burrow-pit dumpsite was higher. Most of the Ni was found in the residual and oxidizable fractions. The high content of Ni in the residual fraction of the waste soils may be attributed to the alkaline stabilization process of the soils (Su and Wong, 2003). Similar results have been reported by Gupta and Sinha (2006) using tannery sludge. The total extractable Cr in the dumpsites was below 750 $mgkg^{-1}$ limit permissible by Visser (1993) and CCME (1991) for domestic gardens, agricultural and residential areas. The Cr content was strongly associated with the residual and oxidizable fractions which is in agreement with those reported by other researchers (Tokalioglu *et al*., 2000; Alvarez *et al*., 2002) but differ from those reported by Gupta and Sinha (2006) for tannery sludge. The association of Cr with the oxidizable phase showed that it is strongly bound to organic matter which is an indication that the availability of the metals to the plant may be reduced due to organic complexation. Udom *et al* (2004) reported that metal organic complexation decrease metal mobility in soils at low pH. Thus, the relative high mobility of this metal in the dumpsites studied may be due to the alkaline nature of the soils.

The results indicated that accumulation of selected metals varied greatly among plants species. This is in line with the report of Chunilall *et al* (2005) that uptake of an element by a plant is primarily dependent on the plant species, its inherent controls and the soil quality. Furthermore, the levels of metals in plants in the present study are dependent upon their concentrations in their habitual soil environment. This observation is similar to the findings of Udosen (1994), Amusan *et al* (2005), Udosen *et al* (2006), Ebong *et al* (2007, 2008), Oyelola *et al* (2009), Ayari *et al* (2010) and Malik *et al* (2010).

The levels of the metals found in *C. papaya* followed by *A. hybridus*, *T. triangulare*, *L. aegyptiaca* and then *I. batatas* in all the sites were similar to the findings by Amusan *et al* (2005) and Ebong *et al* (2008) that plant species significantly influence their rate of metal uptake due genetic variability. This study has also revealed that different parts of plant species absorbed metals at varying concentrations. The reports by Kabata-Pendias and Pendias (2001), Shauibu and Ayodele (2002) and Ebong *et al* (2008) on the influence of plant species on the rate of uptake of various metal species are in line with the findings in the present study. Since the rate of metal uptake is greatly influenced by plant species, the transfer factors of the metals by each plant species are desirable for classification of the plants' phytoaccumulation, photostabilization and phytoextarction potentials (Chehregani and Malayeri, 2007; Ayari *et al*., 2010; Malik *et al*., 2010).

Cadmium levels at the dumpsites for the various plant species exceeded the values reported by Yusuf *et al* (2003), Udosen *et al* (2006) and Ebong *et al* (2008). The Cd range recorded in the studied plant species is high enough to cause phytotoxicity (Vecera *et al*., 1999). Cd phytotoxicity occurs when the level is above the range of 0.10-1.20 mgkg-^{1}. Although, Cd is not an essential element for plants, they generally exhibit measurable Cd concentrations, particularly in roots and shoots, most probably as a result of inadvertent uptake and translocation (Assuncao *et al*., 2003). A foliar concentration above 1000 mgkg-^{1} DW (0.01%) is considered exceptional and is used as a threshold value for hyperaccumulation (Baker *et al*., 2000). The study revealed that foliar contents of Cd was as high as 80.25 mgkg-^{1} in *C. papaya* and as such it presupposes that if recent transgenic approaches as reported by Zhu *et al* (1990a, b) are used, Cd accumulation may be further increased in the plant species. The presence of these plant species in the dumpsites with high level of Cd in shoots above the normal limits suggested their adaptation to contaminated soils and possibly development of mechanisms for the metal detoxification (Ghosh and Singh, 2005).

The high Cu concentrations in most of the plant species suggested that the botanicals accumulated higher concentration of Cu than the normal limits (10.0mgkg-^{1} DW) in shoots as given by Zu *et al* (2004). Values obtained in this study compared favourably with the values reported by Malik *et al* (2010) for some plant species except for *Parthenium hysterophoirus* L. and *Partulaca oleracea* L. whose values were exceedingly higher (Malik *et al*., 2010). However, the values were lower when compared to those reported by Cui *et al*., (2007) for some plants species at contaminated sites. The relative availability of Cu to the plant species in the studied dumpsites may be attributed to the higher pH values in these study areas. Cu is an essential metal for normal plant growth and development. It participates in numerous physiological processes and is an essential cofactor for many metalloproteins, although it is toxic when in excess (Prasad and Strzalka, 1999; Yruela, 2005). Cu concentration exceeding 40 mgkg-^{1} of dry matter could induce toxicity in plants and cause toxic effects in animals (sheep) feeding on them (Annenkov, 1982).

Manganese content was higher than that reported by Uwah *et al* (2009). Variations in the concentration of Mn in the study sites with previous works could be attributed to differences in the study area, age and composition of dumpsite, age of plant species, soil and other environmental conditions. Mn levels obtained were within the range of critical threshold limits of Mn in plants, 1.0-100.0 mgkg-^{1} (Vecera *et al*., 1999; Odukoya *et al*., 2000; Yusuf *et al*., 2003; Amusan *et al*., 2005; and Li *et al*., 2007).

The study revealed that most of the plant species accumulated higher concentration of Pb than their normal limits (5.0 mgkg-^{1} DW) in shoot as given by Zu *et al* (2004). This high concentration of Pb could have toxic effects on the plants. For example, Pb inhibits the activities of many enzymes, upsets mineral nutrition and water balance, changes in hormonal status and affects membrane structure and its permeability (Sharma and Dubey, 2005). Visual non-specific symptoms of Pb toxicity include stunted growth, chlorosis and blackening of the roots system (Sharma and Dubey, 2005).

The findings in the present study with respect to zinc suggest that most of the plants species accumulated higher concentration of Zn than those reported by Ebong *et al* (2008). However, the values were still below the permitted limit (100 mgkg-^{1}) in shoots as given by Zu *et al* (2004) and were lower when compared with the report on some species of plants by Malik *et al* (2010). In non-tolerant plants, Zn toxicity is apparent in soils with high Zn content which could effect inhibition of root elongation and chlorosis in young leaves. Soil pH, organic matter and hydrology primarily govern the availability of Zn (Kabata-Pendias, 2004; Iwegbue *et al*., 2007). Therefore, high pH values obtained in the studied sites may be responsible for the low level of Zn contents in the soil. Similar results were reported by Cui *et al* (2007).

The concentration of Fe in the present study compared favourably with the values reported by Ebong *et al* (2008). The values were however higher than those reported by Amusan *et al* (2005). The variations may be attributed to the differences in the study areas and plant species involved. Nevertheless, the findings were similar to those reported earlier that plants in dumpsites have higher metal concentrations than their corresponding plants at control sites (Ebong *et al*., 2008; Uwah *et al*., 2009). The elevated levels of Fe in the different parts of the plant species in this study could be attributed to the importance of the metal in plant growth, the high availability of Fe containing wastes at the dumpsites and the abundance of the metal in the earth's crust (Harrison and Chirgawi, 1989; Kabata-Pendias and Pendias, 2001). However, since most of the plant species studied are edible, the elevated Fe levels calls for concern as chronic consumption of iron can cause some health challenges such as vomiting, upper abdominal pain, diarrhoea, dizziness, shock, haemochromatosis, diabetes, diseases of the liver, lungs and kidney, haepatoma and cardinomyopathy (Dupler, 2001; Ferner, 2001; Khan *et al*., 2008, 2009). The nickel content of the plant species obtained in this study showed that they were high when compared to the values reported by Ebong *et al* (2008). However, these values were very low compared to the values reported by Ololade *et al* (2007). Ni accumulation by parts of the plants species in all the dumpsites did not exceed the critical limit (10-100 $mgkg^{-1}$) of the metal in plants (Vecera *et al*., 1999). The accumulation of Ni in some plant parts have been reported to exhibit some protective function against fungi and bacteria pathogens in some plants (Prasad, 2005).

The higher levels of chromium in the roots and shoots of the plants species at the dumpsites were similar to those reported by Ololade *et al* (2007) but lower than those of Ayari *et al* (2010). Toxic effect of Cr on plant growth and development includes alterations in the germination processes as well as in the growth of roots, stems, leaves, which may affect total dry matter production and yield. Cr also causes deleterious effects on plants physiological processes such as photosynthesis, water relations and mineral nutrition among others (Shanker *et al*., 2005). Since specific symptoms of Cr toxicity were not observed in the studied plant species at the various dumpsites, it can be inferred that the critical permissible limit in the plants were not exceeded or that the plants have developed a specific mechanism for Cr detoxification (Shanker *et al*., 2005). Cr relative abundance is very low in nature. This is evident from the results obtained in the control sites and this clearly showed anthropogenic influence as the source of Cr to plants. Similar results were reported by Ololade *et al* (2007). However, the values obtained from the study were within the normal range in plants (0.03-14 mg/kg) and the critical concentration limits in plants (2-18 mg/kg).

Translocation Factors (TF), Biological Concentration Factors (BCF) and Biological Accumulation Coefficient (BAC) values greater than one (>1) are used to evaluate the potential of plant species for phytoextraction, phytostabilization and phyto-remediation (Yoon *et al*., 2006; Cui *et al*., 2007; Li *et al*., 2007). High root to shoot translocation of these metals indicated that these plants have vital characteristics to be used in phytoextraction of these metals as reported by Ghosh and Singh (2005), La'zaro *et al* (2006) and Malik *et al* (2010). The TF > 1 for Zn, Fe and Cr in all the plant species is an indication that it is easy for these plant species to translocation these metals from roots to shoots. High metal accumulation may be attributed to well-developed detoxification mechanism based on sequestration of heavy metallic ions in vacuoles in the presence of enzymes that can function at high level of metallic ions and metal exclusion strategies of plants species (Hall, 2002; Ghosh and Singh, 2005; Cui *et al*., 2007). Plant species with high TF values are considered suitable for phytoextraction because they generally translocate heavy metals to easily harvestable parts (shoots) (Yoon *et al*., 2006). According to Ghosh and Singh (2005), phytoextraction is a process that removes heavy metal contaminants from soil without destroying soil structure and fertility. The results showed that the studied plant species especially *L. aegyptiaca* and *I. batatas* with high TF values could have enormous potential for phytoextraction of the metals studied. Several plant species have been reported suitable for phytoextraction of heavy metals (based on their TF values > 1) by researchers (Del-Rio-Celestino *et al*., 2006; Yoon *et al*., 2006; Chehregani and Malayeri, 2007; Cui *et al*., 2007; Li *et al*., 2007).

Phyto-stabilization is a process which depends on the ability of the roots to limit mobility and bioavailability of the heavy metal contaminants in the soils and these occurs through sorption, precipitation, complexation or metal valance reduction (Ghosh and Singh, 2005). Heavy metal tolerant species with high BCF and TF can be used for phytostabilization of contaminated soils. Results of the study indicated that all the plant species studied had BCF > 1 for Fe. In addition, *A. hybridus* had BCF >1 for Cr and Cu while *C. papaya* had BCF > 1 for Cr, Cu, and Cd. Similar results were reported by several others (Chunilall *et al*., 2005; Cui *et al*., 2007; Li *et al*., 2007; Malik *et al*., 2010). Elevated concentration of heavy metals in roots of plants species and low translocation into above ground parts indicate their suitability for phyto-stabilization (Ghosh and singh, 2005). The results show that some of the studied plant species with BCF>1 and TF<1 may be useful for phytostabilization of one, two or more of the metal contaminants of the study area. The results obtained showed that *A. hybridus* had BCF>1 and TF<1 for Cu and as such may be useful in the phyto-stabilization of Cu in the dumpsites. The results indicated that Mn followed by Zn generally had the least BCF values in all the plant species studied.

Biological accumulation coefficient (BAC) is used as an indicator of high heavy metal accumulation potentials for plant species which usually may be attributed to well-developed cellular mechanisms for heavy metal detoxification and tolerance (Hall, 2002; Ghosh and Singh, 2005). Tolerance of heavy metals to plants has been defined as the ability of the plants to survive in a soil toxic to other plants and this is manifested by an interaction between the plants genotype and its environment (Macnair *et al*., 2000). Plant species with BAC values > 1 for any metals are regarded as efficient in accumulating such metals and when the plant is able to accumulate up to 1000 mg/kg or more of the metal, the plant is classified as a hyper-accumulator (Baker and Brooks, 1989). The BAC values obtained in this study for the plant species were low compared to the values reported for some other plant species by other workers (Shu *et al*., 2000; Archer and Caldwell, 2004; Wei *et al*., 2006; Malik *et al*., 2010). It is evident from this study that some of the studied plant species are efficient in accumulating some of the heavy metals especially Fe. The results indicated that Mn followed by Zn had the least BAC values in all the plant species. Thus, the studied plant species are less tolerable to Mn and Zn. *C. papaya* showed higher efficiency in the accumulation of Fe, Cr, Cu and Cd among the other plants species and as such could be used to remediate soils with Fe, Cr, Cu and Cd toxicity. In general, the results demonstrated that none of the plant species could be identified as a hyper-accumulator of any of the studied metals because all the species accumulated Cd, Cu, Mn, Pb, Zn, Ni and Cr less than 1000 $mgkg^{-1}$ which according to Baker and Brooks (1989) is the critical baseline for such classification.

Conclusion

This study has provided baseline biochemical data on soil quality assessment of Burrow-pit in Aba and Ntigha dumpsite in Isiala Ngwa of Abia State, South-East, Nigeria. The soils of the dumpsites were rich in plants nutrients with the non-residual fraction having the most abundant pool for all the metals studied except Cu and Cr that were abundant in the residual fractions. Overall, the order of mobility and bioavailability of these metals are as: Cd > Fe > Pb > Mn > Zn > Cr > Ni > Cu. None of the plant species studied (*A. hybridus*, *T. triangulare*, *C. papaya*, *I. batatas* and *L. aegyptiaca*) were hyper-accumulator. The plant species also possess the potential for phytostabilization and phyto-extraction. These findings imply that pollution of an environment by dumpsites has human health and ecological risks and that these plants could be explored for environmental friendly phytoremediation technologies. Further research is needed to identify plants species with enhanced growth performance, biomass production, metal accumulation and heavy metal tolerance for management and conservation of contaminated soil.

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