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TOXICOLOGICAL ASSESSMENT OF VARIOUS METALS ON SELECTED EDIBLE LEAFY PLANTS OF UMUKA AND UBAHU DUMPSITES IN OKIGWE OF IMO STATE, NIGERIA

Obasi N A[1*], Akubugwo E I[2], Kalu K M[3], Ugbogu A E[2] and Okorie U C[4]

[1]Department of Biochemistry, Michael Okpara University of Agriculture Umudike-Nigeria
[2]Department of Biochemistry, Abia State University, Uturu-Nigeria
[3]Department of Animal and Environmental Biology, Abia State University, Uturu-Nigeria
[4]Department of Science Laboratory Technology, Akanu Ibiam Federal Polytechnic Unwana, Ebonyi State, Nigeria.

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ABSTRACT

This study investigated the effect of eight heavy metals speciation on soil physicochemical parameters and on five edible leafy plants species grown on dumpsites contaminated by these heavy metals. Results obtained from study showed that mean pH, electrical conductivity, moisture, cation exchange capacity, total organic carbon, total organic matter, phosphate, sulphate, carbon:nitrogen ratio and total extractable 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 dumpsites have associated human health and ecological risks.

* Corresponding author

E-mail: naobasi@yahoo.com (Obasi N A)

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1 Introduction

The effects of solid waste on the ecosystem have been an issue of global concern over the years (Barlaz et al., 2003; Kouznetsova et al., 2007; Goorah et al., 2009). Above threshold level these solid wastes cause alteration in the environment as well as in the soil and ground water quality (Elaigwu et al., 2007; Uba et al., 2008; Nubi et al., 2009). These heavy metals are non-biodegradable and as such, they accumulate in the ecosystem where they may cause toxic effects on the flora and fauna of the environment (Benjamin & Mwashote, 2003; Ikem et al., 2003; Krissanakriangkrai et al., 2009; Ozturk et al., 2009).

The level of toxicity of heavy metals in the environment is directly associated with the fractional chemical forms or species associated with organic matter, adsorbed onto Fe/Mn oxides or complex with hydroxides, sulphides and carbonates (Tessier et al., 1979; Kabata-Pendias, 2004). High contents in the exchangeable, acid soluble and easily reducible fraction may indicate pollution from man-made sources (Kabata-Pendias, 2004). Speciation of metals in the various chemical forms determines their bioavailability in the ecosystem. The mechanisms of mobility and bioavailability of heavy metals relative to the various fractions in sediments and waste soils have been documented (Tsai et al., 1998; Yu et al., 2001; Ewa-Szarek et al., 2006; Obasi et al., 2012).

Various studies have shown that dumpsite soils in south-eastern Nigeria and other parts of the country support plants growth and biodiversity and as such they have been extensively used for cultivating varieties of edible vegetables and plant based foodstuff (Cobb et al., 2000; Benson & Ebong, 2005). These practices pose serious health and environmental concern due to the anthropogenic contamination of these waste soils with intolerable level of chemical materials (Ellis & Salt, 2003; Jarup, 2003). Heavy metal content of soils is a critical measurement for assessing the risks of refuse dumpsites. However, only the chemical species/fractions of these heavy metals provide predictive insights on the bioavailability, mobility and fate of the heavy metal contaminants (Cataldo & Wildung, 1978; Kabata-Pendias, 2004). Thus, there is need to evaluate the chemical forms or species of these heavy metals since they control their bioavailability or mobility which ultimately control heavy metal soil-plant transfer (Kabata-Pendias, 2004; Gupta & Sinha, 2006; Iwegbue et al., 2007; Uba et al., 2008; Ikhouria et al., 2010).

Most dumpsite soils in Eastern Nigeria as in other parts of the country are extensively used for cultivating varieties of edible vegetables and plant-based foodstuff without proper routine assessment of the associated health and ecological risks (Obasi et al., 2012). This practice is scientifically unacceptable in this era and as such, there is need for proper assessment of dumpsite waste soils to ensure environmental sustainability. The aim of this research therefore is to provide biochemical data that will educate the general public on the possible ecological risks associated with the use of dumpsite soils for arable farming.

2 Material and Methods

2.1 Refuse Waste Soil Collection

Refuse waste soils were collected from two dumpsites viz Umuka (Latitude 05° 48′ 21.23″, Longitude 007° 57′ 50.85″) and Ubahu of Okigwe (Latitude 05° 50′ 10.18″, Longitude 007° 59′ 14.76″) and from a farm land situated within the region (Latitude 05° 47′ 58.45″, Longitude 007° 58′ 53.02″), which was used as control site. Samples from each dumpsite and control site were collected seven meters within the vicinity of the sites in triplicates and composite samples were made in the laboratory. The samples were air dried, ground by using manual soil grinder (DGSI Geotechnical instrumentation Model S-178) and sieved (using 2mm sieve). This prepared soil was put in polythene bags and kept in glass desiccators (Baroda Scientific Glass Works) until analysis. All the soil samples were collected from rhizosphere where plant samples were rooted.

2.2 Collection of Plant Sample from study site

Five commonly occurring leafy plant species i.e. *Amaranthus hybridus*, *Talinum triangulare*, *Carica papaya*, *Ipomea batatas* and *Luffa aegyptia* were collected from each study site. A total of 6-10 plants of each plant species were randomly uprooted and collected from each of the dumpsite and control site and mixed to form a composite sample. The entire collected plant sample were placed in labeled polythene bags and carried to the Chemistry Laboratory of National Research Institute for Chemical Technology, Zaria, Nigeria for further analysis. Under laboratory condition, plant roots, stems and leaves (shoots) were carefully separated and washed (for 2-3 minutes approximately) by tap water and distilled water to remove any soil and surface dust. Plant samples were dried at room temperature for a day, then oven dried at 80^{o}C and pulverized to fine powder using milling grinder (Thomas Wiley Model 4). Ground plant samples collected in labeled pre-cleaned polythene bags were stored in glass desiccators (Baroda Scientific Glass Works).

2.3 Physicochemical Analysis of Samples

Soil pH was determined by using digital pH meter at a ratio of 1:2.5 soil/water as par 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 & Freitas (1970). The total organic matter of the waste soils were determined gravimetrically as outlined by Osuji & Adesiyan

(2005), the method outlined by Yeomans & Bremmer (1991) was employed in the determination of total nitrogen availability while SO_4^{2-} was determined by the method outlined by Butters & Chenery (1959). Total phosphate (PO_4^{3-}) was determined by method outlined by Olsen & Sommers (1982).

2.4 Sequential Extraction of Heavy Metals

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

2.5 Determination of Heavy Metals in Plant Species

Available minerals from plant sample were determined by 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).

- −Translocation factor (TF) =$[Metals]_{shoot}$ / $[Metals]_{root}$
  The biological concentration factor (BCF) was calculated as metal concentration ratio of plant roots to soil as described by Yoon et al. (2006).
- −Biological concentration factor (BCF) = $[Metals]_{root}$ / $[Metals]_{soil}$
  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).
- −Biological accumulation coefficient (BAC) = $[Metals]_{shoot}$ / $[Metals]_{soil.}$

2.7 Statistical Analysis

The experimental results were expressed as mean ± standard deviation (SD) 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 and Discussion

The results of physico-chemical properties of soil are shown in Table 1. Results obtained showed that 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 as compared to control site. Mean percentage of total nitrogen was significantly higher ($P < 0.05$) in the control site compared to Umuka but this difference was not significant ($P > 0.05$) compared to Ubahu study site. 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 results were reported for dumpsites by other researchers (Gupta & Sinha, 2006; Elaigwu et al., 2007; Uba et al., 2008). The observed pH values in the waste soils may have some contribution to the observed differences in the various chemical forms of the various soil samples and as well as the differences in the level of metal uptake by the various plant species in line with the report of Kabata-Pendias (2004). The high conductivity value observed for the waste soils may be attributed to the presence of man-made metal scraps introduced in the refuse dumpsite and these implicate more soluble salts in the waste soils (Karaca, 2004; Arias et al., 2005). The high moisture content of the waste soils may be attributed to the overall climatic predisposition of the area under study. The observed high cation exchange capacity of the waste soils may have influenced the buffering capacity of the soils as could be inferred from the overall physicochemical parameters because cation exchange capacity affect both soluble and exchangeable metal levels (Yoo & James, 2002).

Table 1 Physico-chemical parameters of waste soils in studied dumpsites.

Sites/Parameter	A	B	AB
pH(H_2O)	7.51±0.01^{b}	7.90±0.02^{c}	7.18±0.02^{a}
Electrical Conductivity (mScm-1)	2.10±0.02^{c}	1.93±0.01^{bc}	1.05±0.01^{a}
Moisture (%)	71.65±0.03^{ab}	79.10±0.02^{c}	69.65±0.05^{a}
Cation Exchange Capacity (Cmol/kg)	15.80±0.02^{b}	17.05±0.07^{c}	10.70±0.02^{a}
Total Organic Carbon (%)	3.60±0.02^{c}	3.28±0.02^{b}	1.30±0.00^{c}
Total Organic Matter (%)	6.21±0.01^{c}	5.65±0.05^{b}	2.24±0.02^{a}
Total Nitrogen (%)	0.20±0.02^{a}	0.25±0.01^{bc}	0.29±0.03^{c}
PO_4^{3-}(%)	154.54±0.12^{a}	168.05±0.08^{c}	159.80±0.02^{b}
SO_4^{2-}(%)	9.17±0.03^{ab}	11.65±0.05^{c}	8.20±0.02^{a}
C:N Ratio	18.00^{c}	17.10^{b}	11.38^{a}

Values are mean of three (n=3) replicates ± standard deviation, A = Umuka dumpsite, B = Ubahu dumpsite, AB = Control site, Figures followed by the same alphabets along the row are not significantly different at $P < 0.05$ using Ducan Multiple Range Test (DMRT).

Table 2(a) 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	10.11 ±0.07	8.98 ±0.13	0.11 ±0.03	ND	1.85 ±0.05	ND	5.74 ±0.02	19.66 ±0.03	0.11 ±0.01	55.46 ±0.08	ND	1.60 ±0.02
Oxidizable	9.88 ±0.05	8.90 ±0.02	1.05 ±0.03	8.80 ±0.02	ND	0.83 ±0.01	9.35 ±0.03	35.05 ±0.07	5.21 ±0.03	98.50 ±0.02	35.00 ±0.00	4.00 ±0.02
Acid soluble	8.75 ±0.03	6.75 ±0.02	0.96 ±0.02	ND	ND	ND	38.44 ±0.02	17.11 ±0.03	0.87 ±0.05	79.85 ±0.02	39.11 ±0.03	1.95 ±0.03
Reducible	9.85 ±0.03	9.00 ±0.00	0.98 ±0.03	6.50 ±0.02	2.70 ±0.05	0.33 ±0.01	72.12 ±0.03	158.74 ±0.08	5.13 ±0.03	34.95 ±0.03	48.56 ±0.02	3.82 ±0.02
Residual	15.48 ±0.03	12.25 ±0.06	1.14 ±0.02	24.16 ±0.08	17.18 ±0.12	1.67 ±0.05	15.56 ±0.04	6.42 ±0.02	1.86 ±0.02	148.00 ±0.02	67.72 ±0.02	2.71 ±0.03
Total extractable metals	54.07^{c} ±0.06	45.88^{b} ±0.04	4.24^{a} ±0.02	39.46^{c} ±0.02	21.73^{b} ±0.07	2.83^{a} ±0.01	141.21^{b} ±0.09	236.98^{c} ±0.12	13.18^{a} ±0.02	416.76^{c} ±0.02	190.39^{b} ±0.05	14.08^{a} ±0.02
Non-residual (%)	71.37	73.30	73.11	38.77	20.94	40.99	88.98	97.29	85.89	64.49	64.43	80.75
Residual (%)	28.63	26.70	26.89	61.23	79.06	59.01	11.02	2.71	14.11	35.51	35.57	19.25
Mobile phase (%)	34.88	34.29	25.24	0.00	8.51	0.00	31.29	15.52	7.44	32.47	20.54	25.21

Values are mean of three (n=3) replicates ± standard deviation, A = Umuka dumpsite, B = Ubahu dumpsite, AB = Control site, Figures followed by the same alphabets along the row are not significantly different at $P < 0.05$ using Ducan Multiple Range Test (DMRT) for each metal.

Table 2(b) Heavy metal concentrations in each fraction of waste soils in studied dumpsites continued.

Sites/ Fractions	Zn			Fe			Ni			Cr		
	A	B	AB	A	B	AB	A	B	AB	A	B	AB
Exchangeable	3.14 ±0.02	9.85 ±0.05	1.19 ±0.03	45.74 ±0.02	18.14 ±0.06	19.86 ±0.02	1.18 ±0.01	ND	ND	ND	3.08 ±0.02	0.15 ±0.01
Oxidizable	138.70 ±0.02	76.00 ±0.00	2.64 ±0.05	11.74 ±0.02	12.48 ±0.02	25.60 ±0.02	ND	5.89 ±0.07	0.58 ±0.01	ND	1.41 ±0.03	0.16 ±0.02
Acid soluble	108.92 ±0.02	24.42 ±0.02	0.53 ±0.01	ND	13.17 ±0.03	18.35 ±0.05	4.68 ±0.06	ND	ND	3.66 ±0.03	ND	D
Reducible	96.50 ±0.02	56.76 ±0.04	2.66 ±0.02	37.48 ±0.07	19.00 ±0.00	23.95 ±0.05	ND	3.28 ±0.04	0.58 ±0.01	ND	2.13 ±0.03	0.15 ±0.01
Residual	106.86 ±0.02	244.54 ±0.05	2.20 ±0.02	70.22 ±0.13	39.34 ±0.05	30.69 ±0.11	14.35 ±0.03	11.28 ±0.07	0.68 ±0.01	11.18 ±0.03	14.99 ±0.07	0.51 ±0.03
Total extractable metals	454.12^{c} ±0.23	411.57^{b} ±0.11	9.22^{a} ±0.02	165.18^{c} ±0.04	102.13^{a} ±0.15	118.45^{b} ±0.05	20.21^{b} ±0.07	20.45^{b} ±0.04	1.84^{a} ±0.02	14.84^{b} ±0.05	21.61^{c} ±0.07	0.97^{a} ±0.03
Non-residual (%)	76.47	40.58	76.14	57.49	61.08	74.09	29.00	44.84	63.04	24.66	30.63	47.42
Residual (%)	23.53	59.42	23.86	42.51	38.52	25.91	71.00	55.16	36.96	75.34	69.37	52.58
Mobile phase (%)	24.68	8.33	18.66	27.69	30.65	32.26	29.00	0.00	0.00	24.66	14.25	15.46

Values are mean of three (n=3) replicates ± standard deviation, A = Umuka dumpsite, B = Ubahu dumpsite, AB = Control site, Figures followed by the same alphabets along the row are not significantly different at $P < 0.05$ using Ducan Multiple Range Test (DMRT) for each metal.

The observed mean percentages of total organic carbon (TOC) and total organic matter (TOM) values of the waste soils were high based on the classification of organic matter as reported by Enwezor et al. (1988) and this may have had an influence in a number of the soils chemical and physical processes since it is an important indicator of the soil as a rooting environment (Okalebo et al., 1993).

The observed high concentration of total nitrogen, PO_4^{3-} and SO_4^{2-} in the refuse waste soils may have contributed to the fertility of the waste soils which conferred the ability of the plants to grow and flourish as observed in these sites. Also, the observed high ratio of carbon to Nitrogen (C:N) implicated the waste soils as fertile as reflected in the plant species diversity and growth in the dumpsites. Similar results have been reported (Okalebo, 1993; Obute et al., 2010). The results of the sequential extractions of the heavy metals from the soil are shown in Tables 2a and 2b. The results indicated that total extractable metals were significantly ($P < 0.05$) higher in all the dumpsites samples compared to the control site. Among all samples, the highest levels of heavy metals were extracted from the sample collected from Umuka dumpsite except for Mn and Cr which were higher in Ubahu dumpsite than that in Umuka dumpsite.

Table 3(a) total heavy metals concentration (mg/kg) 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
Cd	A	46.12±0.01	19.55±0.03	37.44±0.01	11.70±0.04	37.24±0.06	61.82±0.12	4.15±0.03	7.18±0.01	4.72±0.02	14.21±0.03
	B	25.93±0.01	12.81±0.01	30.45±0.03	10.15±0.12	25.67±0.04	26.25±0.04	3.78±0.03	5.61±0.17	4.17±0.01	12.69±0.13
	AB	3.50±0.02	1.67±0.06	2.38±0.01	0.88±0.04	2.22±0.02	3.95±0.03	0.34±0.18	0.53±0.05	0.36±0.01	1.03±0.06
Cu	A	22.45±0.02	14.76±0.04	10.93±0.02	4.77±0.01	13.02±0.01	24.51±0.14	4.90±0.02	9.70±0.01	3.28±0.02	6.67±0.01
	B	18.06±0.05	11.70±0.02	9.78±0.01	3.49±0.01	8.97±0.10	21.33±0.01	3.72±0.23	8.94±0.02	3.76±0.02	7.43±0.02
	AB	4.11±0.01	3.68±0.01	3.18±0.02	2.85±0.04	2.81±0.01	5.04±0.01	2.26±0.02	3.05±0.02	1.08±0.05	2.15±0.02
Mn	A	2.89±0.13	5.22±0.01	6.31±0.06	2.25±0.04	3.97±0.02	8.44±0.02	1.32±0.02	3.86±0.05	3.65±0.04	10.05±0.01
	B	4.76±0.16	7.66±0.02	8.81±0.02	3.76±0.04	5.32±0.05	9.78±0.02	2.19±0.01	6.33±0.05	6.02±0.05	16.18±0.02
	AB	0.88±0.02	1.23±0.05	1.37±0.02	0.92±0.02	0.98±0.03	1.75±0.04	0.74±0.02	2.14±0.01	2.76±0.02	5.51±0.13
Pb	A	13.95±0.04	8.84±0.02	9.44±0.02	5.28±0.14	17.19±0.03	14.39±0.05	4.40±0.02	5.79±0.01	5.02±0.02	7.33±0.01
	B	6.98±0.02	4.25±0.04	5.12±0.02	2.97±0.03	9.05±0.04	6.14±0.02	3.95±0.02	5.30±0.00	4.27±0.03	5.98±0.02
	AB	0.64±0.02	0.24±0.02	0.80±0.01	0.34±0.01	1.16±0.01	0.97±0.03	0.65±0.02	1.12±0.02	0.82±0.02	1.24±0.02

Values are mean of three (n=3) replicates ± standard deviation, A = Umuka dumpsite, B = Ubahu dumpsite, AB = Control site.

Table 3(b) Total heavy metals concentration (mg/kg) in roots and shoots of plant species in the studied sites continued.

Plant Speci / Sites		*Amarathus hybridus*		*Talinum triangulare*		*Carica papaya*		*Ipomea batatas*		*Luffa aegyptiaca*	
		ROOTS	SHOOTS	ROOTS	SHOOTS	ROOTS	SHOOTS	ROOTS	SHOOTS	ROOTS	SHOOTS
Zn	A	9.88±0.04	29.70±0.02	23.75±0.14	26.33±0.11	28.96±0.04	32.27±0.03	17.73±0.17	20.68±0.02	18.31±0.03	21.05±0.04
	B	9.88±0.16	12.84±0.02	8.65±0.05	10.08±0.02	12.66±0.02	15.03±0.05	8.39±0.18	10.58±0.13	9.87±0.05	13.03±0.01
	AB	0.92±0.02	1.53±0.01	0.95±0.04	1.45±0.04	1.66±0.02	2.08±0.02	4.35±0.01	0.75±0.02	0.39±0.01	0.78±0.02
Fe	A	93.57±0.19	107.80±0.10	87.13±0.16	99.56±0.24	115.65±0.14	137.93±0.18	96.65±0.08	102.94±0.12	105.94±0.05	116.05±0.26
	B	103.06±0.05	127.14±0.15	103.84±0.28	119.64±0.05	138.76±0.14	151.36±0.16	103.98±0.33	118.77±0.86	114.36±0.13	126.93±0.96
	AB	61.44±0.05	64.35±0.04	61.22±0.14	63.18±0.08	86.67±0.16	91.45±0.24	59.67±0.13	62.15±0.04	64.11±0.18	66.67±0.29
Ni	A	3.88±0.02	3.51±0.50	3.20±0.02	2.98±0.02	4.72±0.02	4.55±0.04	2.84±0.02	3.09±0.03	2.93±0.05	3.17±0.01
	B	2.92±0.04	2.80±0.00	2.35±0.03	2.02±0.02	3.27±0.03	3.06±0.02	2.41±0.03	2.56±0.04	2.52±0.02	2.68±0.02
	AB	1.02±0.01	0.93±0.05	0.84±0.02	0.77±0.01	1.08±0.02	0.93±0.05	0.79±0.01	0.86±0.02	0.81±0.05	0.88±0.04
Cr	A	12.06±0.02	15.35±0.03	11.36±0.02	13.70±0.00	15.60±0.05	17.52±0.02	8.48±0.04	11.20±0.00	10.08±0.02	14.23±0.07
	B	8.50±0.15	10.98±0.02	6.92±0.04	9.28±0.02	9.87±0.07	13.45±0.03	5.13±0.01	8.99±0.09	7.65±0.04	10.85±0.03
	AB	0.97±0.03	1.34±0.02	0.91±0.03	1.14±0.05	0.95±0.04	1.60±0.01	0.66±0.02	0.85±0.04	0.87±0.03	0.94±0.02

Values are mean of three (n=3) replicates ± standard deviation, A = Umuka dumpsite, B = Ubahu dumpsite, AB = Control site.

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 (Tables 2a and 2b) were: Cd > Fe > Pb > Mn > Zn > Cr > Ni > Cu.

This observation may be attributed to the anthropogenic dumping of numerous metal containing wastes such as metal scraps and metal containing chemical substances among others in the dumpsites. Cadmium levels in the dumpsites were above 3.0 mg kg^{-1} recommended for agricultural soils (USEPA, 1986; MAFF, 1992). Higher fractions of the Cd were associated with the mobile phase which suggests that Cd in these soils was potentially more bioavailable for plants uptake (Xian, 1989). Similar findings have been reported for various forms of soils and sediments (Kuo et al., 1983; Gupta & Sinha, 2006; Uba et al., 2008). Copper concentrations in the dumpsites were all below 250 mg kg^{-1} recommended for agricultural lands (USEPA, 1986). Cu was mostly associated with the oxidizable fraction (bound to organic matter) and this may be attributed to the high formation constants of organic copper complexes (Stumm & Morgan, 1981).

Total extractable Mn concentration in the waste soils fell within 100-300 mg kg^{-1} recommended for agricultural lands (USEPA, 1986). Ubahu dumpsites had Pb concentrations within 30-300mgKg^{-1} while Umuka dumpsite had Pb content above 30-300mgKg^{-1} recommended for agricultural lands (USEPA, 1986). High percentage of Mn observed in the reducible phase in all the waste soils may be attributed to the precipitation of amorphous hydrous oxides of manganese during aging of dumpsites (Staelens et al., 2000). Similar results were reported by Uba et al. (2008).

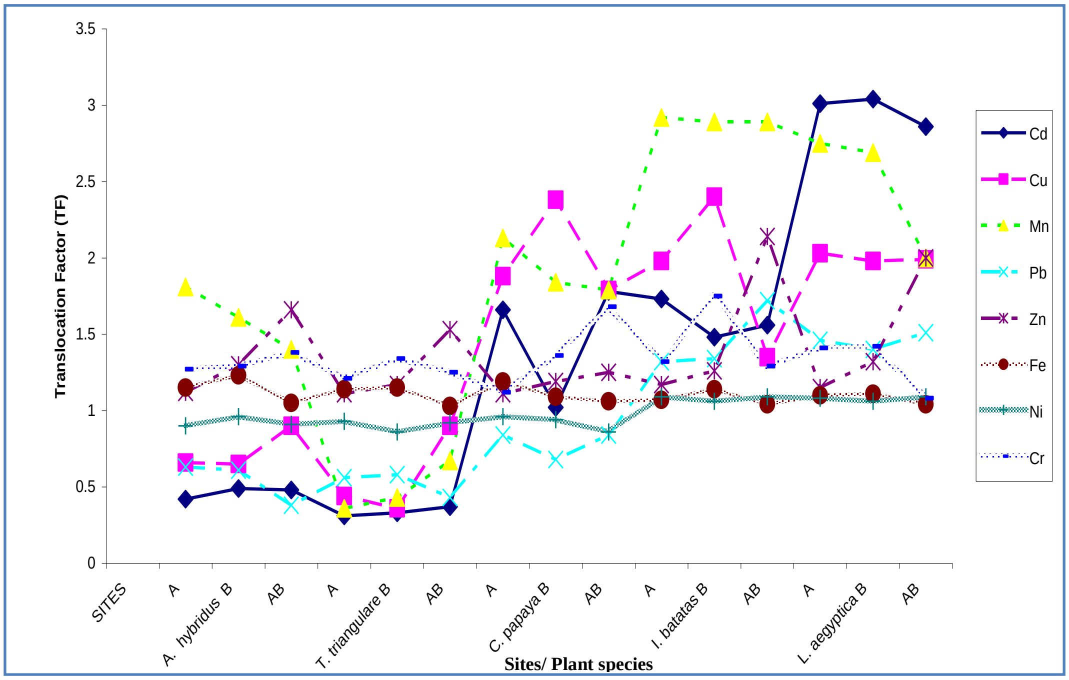

Figure 1 translocation factor (TF) of plants for all the metals in the studied sites.

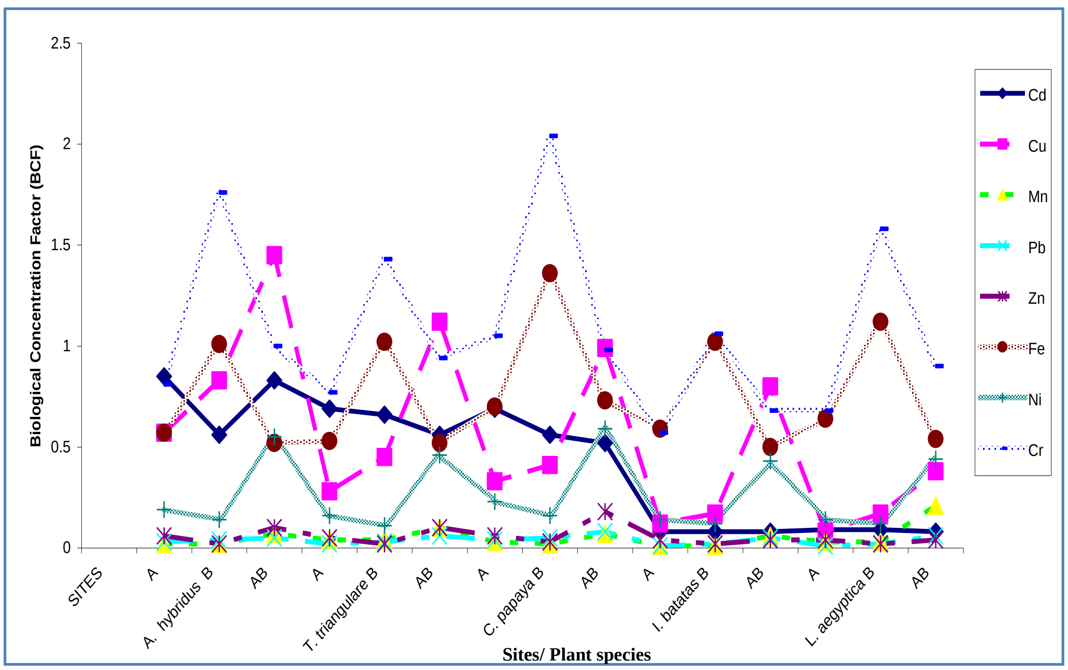

Figure 2 Biological concentration factor (BCF) of plants for all the metals in the studied sites.

More than 50% of Pb found in the non- residual fraction with high percentage in the mobile phase (exchangeable and acid soluble phases) may indicate higher risks for lead contamination. Zinc contents in the dumpsites were above recommended level (300mg Kg^{-1}) for agricultural lands (USEPA, 1986). The high percentage of Zn in the mobile phase (Table 2b) shows that Zn will be readily bio-available to the environment (Kuo et al., 1983; Ramos et al., 1994). High level of Fe (Table 2b) observed in the exchangeable and acid soluble phases of the fractions is an indication that Fe may be potentially toxic if not regulated because of their high mobility. The level of Ni in the dumpsites fell within 150mgKg^{-1} recommended for residential and agricultural lands (CCME, 1991). High Ni observed in the residual fraction of the waste soils (Table 2b) may be attributed to the alkaline stabilization process of the soils occasioned by the high pH values observed in the soils (Su & Wong, 2003; Gupta & Sinha, 2006). The total extractable Cr in the dumpsites was below 750mgKg^{-1} recommended for domestic gardens, agricultural and residential areas (CCME, 1991; Visser, 1993). The Cr was strongly associated with the residual and oxidizable fractions (Table 2b) which is an indication that availability of Cr to the plant may be reduced due to organic complexation (Tokalioglu et al., 2000; Alvarez et al., 2002; Udom et al., 2004). However slight differences were reported by Gupta & Sinha (2006) for tannery sludge. The relative high mobility of Cr in the dumpsites may be due to the alkaline nature (high pH) of the soils (Table 1).

The results of total heavy metals concentration (mg/kg) in roots and shoots of plant species are represented 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 both dumpsites compared to control site. The results showed that the highest levels for all heavy metals (Tables 3a and 3b) were reported from *C. Papaya* and it is followed by *A. hybridus*, *T. triangulare*, *L. aegyptiaca* and then *I. batatas* in all the samples collected from various sites. The results also showed that different plant species absorbed metals at varying concentrations in their various parts (Tables 3a and 3b). The variation in the level of metals taken up by the different plant species showed that uptake of an element by a plant depends primarily on the plant species, its inherent controls and the soil quality (Chunilall et al., 2005). The results also indicated that the levels of metals in plants are dependent upon their concentrations in their habitual soil environment (Tables 3a and b). Similar results have been reported by other researchers (Udosen, 1994; Amusan et al., 2005; Udosen et al., 2006; Ebong et al., 2007; Oyelola et al., 2009; Ayari et al., 2010; Malik et al., 2010). Shauibu & Ayodele (2002) and Ebong et al. (2008) revealed the influence of plant species on the rate of uptake of various metal species in line with earlier reports of Kabata-Pendias & Pendias (2001). 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 & Malayeri, 2007; Ayari et al., 2010; Malik et al., 2010).

A foliar concentration above 1000 mgkg-^{1} DW (0.01%) is considered exceptional and is used as a threshold value for hyper-accumulation (Baker et al., 2000). The Cd range recorded in the studied plant species (Table 3a) is high (Yusuf et al., 2003; Udosen et al., 2006; Ebong et al., 2008) and may cause phytotoxicity because according to Vecera et al. (1999), Cd phytotoxicity occurs when the level is above the range of 0.10-1.20mgkg-^{1}. Although, Cd is not an essential element for plants, plants accumulate it as a result of inadvertent uptake and translocation (Zhu et al., 1999; Assuncao et al., 2003). 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 Cd detoxification (Ghosh & Singh, 2005).

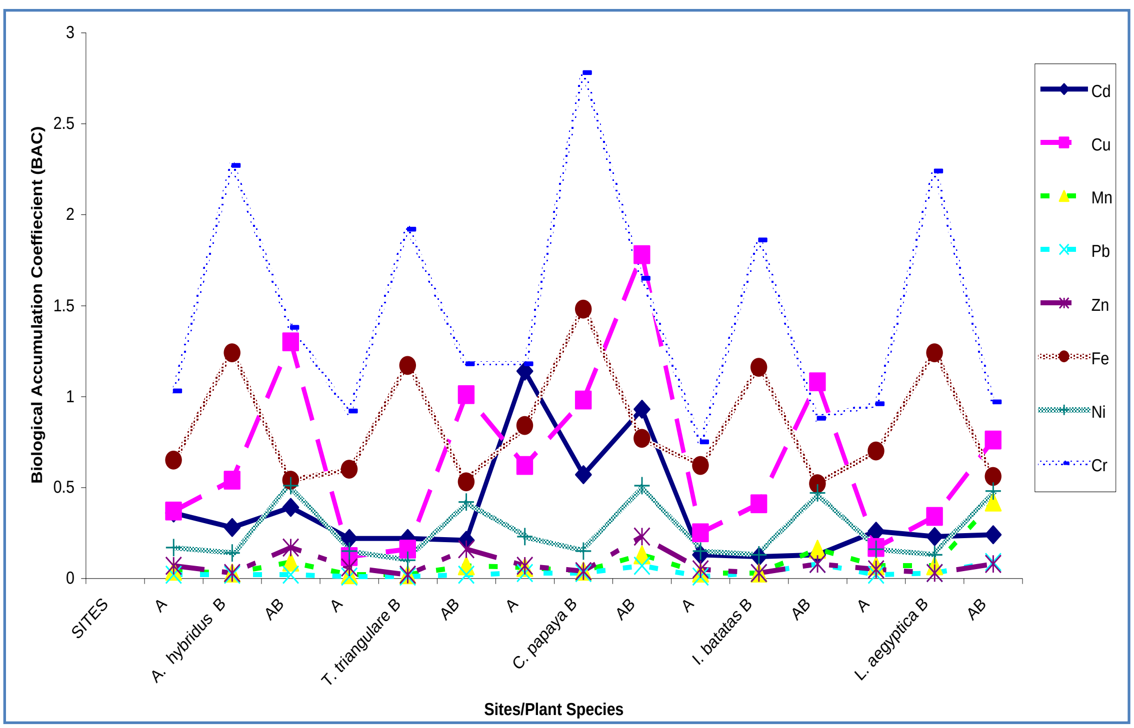

Figure 3 Biological Accumulation Coefficient (BAC) of plants for all the metals in the studied sites.

Cu concentrations (Table 3a) showed that most of the plant species in the dumpsites 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). However, the values were lower when compared to those reported by Cui et al., (2007) for some other plants species at contaminated sites. Cu is an essential metal for normal plant growth and development, although it is toxic when in excess (Yruela, 2005). Cu concentration exceeding 40mgkg-^{1} of dry matter could induce toxicity in plants and cause toxic effects in animals (sheep) feeding on such plants (Annenkov, 1982). Manganese (Mn) content (Table 3a) was higher than those reported by Uwah et al. (2009) but were within the range of critical threshold limits, 1.0-100.0mgkg-^{1} in plants (Vecera et al., 1999) and compared favourably with those reported by others (Odukoya et al., 2000; Yusuf et al., 2003; Amusan et al., 2005; Li et al., 2007) which all show that dumpsite plants have higher Mn levels than plants grown in unpolluted sites. The results (Table 3a) showed that most of the plants 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 (Sharma & Dubey, 2005). Most of the plants species (Table 3b) accumulated higher concentration of Zn than those reported by Ebong et al. (2008). However, the values were still below the permissible limit (100mgkg-^{1}) in shoots as given by Zu et al. (2004). The high pH values obtained in the studied sites (Table 1) may be responsible for the low level of Zn contents in the plants (Kabata-Pendias, 2004; Cui et al., 2007; Iwegbue et al., 2007). The elevated range of Fe in the various plant species parts (Table 3b) could be attributed to the importance of the metal in plant growth, the high availability of Fe containing wastes at the dumpsites and the general abundance of the metal in the earth's crust (Harrison & Chirgawi, 1989; Kabata-Pendias & Pendias, 2001). Since most of the plant species are edible, the elevated Fe levels calls for concern as it can cause some health hazards to the consumers at chronic levels (Dupler, 2001, Ferner, 2001; Khan et al., 2008; Khan et al., 2009). Ni accumulation by parts of the plants species in all the dumpsites did not exceed the critical limit (10-100mgkg-^{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 nickel content in the plant species (Table 3b) were high when compared to the values reported by Ebong et al. (2008) and very low compared to the values reported by Ololade et al. (2007).

Chromium levels (Table 3a) in the roots and shoots of the plants species fell within the normal range (0.03-14mg/kg) and the critical concentration limits (2-18mg/kg) in plants (Alloway, 1996; Shanker et al., 2005). Cr relative abundance is very low in nature. Thus, the results clearly showed anthropogenic influence as the source of Cr to plants (Ololade et al., 2007).

The results indicated that Translocation Factor (TF) values vary from one plant species to another and from one heavy metal to another (Figures 1). The results indicated that *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). Translocation Factors (TF) values greater than one (>1) are used to evaluate the potential of plant species for phytoextraction (Yoon et al., 2006; Cui et al., 2007; Li et al., 2007). High root to shoot translocation of metals indicate that the plants have vital characteristics to be used in phytoextraction of the metals (Ghosh & Singh, 2005; La'zaro et al., 2006; Malik et al., 2010).

It was observed that TF > 1 for Zn, Fe and Cr in all the plant species. This means that it is easy for these plant species to translocation Zn, Fe and Cr from roots to shoots. High metal translocation 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 & 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 & Singh (2005), phytoextraction is a process used to remove the contamination of heavy metals 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. Many plant species have been reported suitable for phytoextraction of heavy metals (based on their TF values > 1) by many researchers (Del-Rio-Celestino et al., 2006; Yoon et al., 2006; Chehregani & Malayeri, 2007; Cui et al., 2007; Li et al., 2007). Figure 2 shows the results of Biological Concentration Factor (BCF) of the five plant species for the different metals. The results (Figure 2) 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. Similar results were reported by several others (Chunilall et al., 2005; Cui et al., 2007; Li et al., 2007; Malik et al., 2010). The BCF value for Cu was greater than 1 for all the plant species in the control site. Biological Concentration Factors (BCF) values greater than one (>1) are used to evaluate the potential of plant species for phytostabilization (Yoon et al., 2006; Cui et al., 2007; Li et al., 2007). Phyto-stabilization process depends on roots' ability to limit the heavy metals' mobility and bioavailability in the soils and these occurs through sorption, precipitation, complexation or metal valance reduction (Ghosh & Singh, 2005).

Heavy metals tolerant species with high BCF and TF can be used for phytostabilization of contaminated soils. Elevated concentration of heavy metals in roots of plants species and low translocation into above ground parts indicate their suitability for phyto-stabilization (Ghosh & 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 phytostabilization of Cu in the dumpsites. It was also observed that Mn followed by Zn generally had the least BCF values in all the plant species studied. The results of Biological Accumulation Coefficient (BAC) are shown in Figure 3. The results (Figures 3) show that all the plant species studied had BAC> 1 for Fe. BAC > 1 for Cu was observed for all the plant species at the control site except for *L. aegyptica.* BAC > 1 for Cr was also observed for *L. aegyptica* at Ubahu dumpsite. Biological Accumulation Coefficient (BAC) values greater than one (>1) are used to evaluate the potential of plant species for phyto-remediation (Yoon et al., 2006; Cui et al., 2007; Li et al., 2007). Biological accumulation coefficient (BAC) is used as an indicator of high heavy metals accumulation potentials for plant species which usually may be attributed to well-developed cellular mechanisms for heavy metal detoxification and tolerance (Hall, 2002; Ghosh & Singh, 2005). Plant species with BAC values > 1 for any metal are regarded as efficient in accumulating such metal and when the plant is able to accumulate up to 1000mg/kg of metal and above, the plant is classified as a hyper-accumulator (Baker & Brooks, 1989; Macnair et al., 2000). All the plant species (Figures 3) had BAC> 1 for Fe. The BAC values for the plant species were low compared to the values reported for some other plant species by other workers (Shu et al., 2000; Archer & 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. Mn followed by Zn had the least BAC values in all the plant species (Figures 3). 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 polluted with Fe, Cr, Cu and Cd. 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 1000mgkg^{-1} which according to Baker & Brooks (1989) is the critical baseline for such classification.

Conclusion

This study provided baseline biochemical data on soil quality assessment of Umuka and Ubahu dumpsites in Okigwe of Imo State, South-East, Nigeria. The results of the physiochemical parameters of the dumpsites revealed that the dumpsite soils were rich in plants nutrients. Chemical fractionation of eight heavy metals from the dumpsite soils revealed that the non-residual fraction was the most abundant pool for all the metals studied except for Cu and Cr that had higher percentage (%) pool of residual fractions in all the dumpsites. Overall, the results indicated the order of mobility and bioavailability of these metals 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 species because all the species accumulated Cd, Cu, Mn, Pb, Zn, Fe, Ni and Cr less than the critical standard of 1000mgkg^{-1}. However, based on TF, BCF and BAC values, the plant species were identified to possess the potential for phytostabilization and phyto-extraction. These results imply that pollution of an environment by dumpsites has human health and ecological risks and that these plants studied could be used for commercial and environmental friendly phytoremediation technologies. Further research is needed to study the long term effects of dependence on dumpsite plants as sources of vegetables.

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