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Phytoaccumulaion effects of *Amaranthus hybridus* L grown on buwaya refuse dumpsites in Chikun, Nigeria on heavy metals

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Abstract

Phytoaccumulation of heavy metals by *Amaranthus hybridus* L. grown on Buwaya dumpsites in Chikun were evaluated. The results showed higher level of heavy metals in Fe followed by Pb while Cr and Cd recorded the least heavy metals content in the dumpsites. Heavy metals accumulated in the shoots and roots of A. *hybridus* were highest in Fe followed by Zn. Values of Cd, Pb, Cu, Ni and Cr were less than 4, with there corresponding values of control less than 1. Bioaccumulation potentials of A. *hybridus* L. result indicated the following trends Fe>Cd>Cu>Zn>Ni>Cr>Pb for shoot to root (S/R) ratio and Fe>Zn>Cd>Cr>Cu>Ni>Pb for bioaccumulation factor. Percentage metal uptake indicated that the rate of metal uptake was highest in Fe and least in Pb. Results revealed that S/R ratio for all the metals were greater than 1.0 and these suggest that A. *hybridus* L. can serve as phytoaccumulator of heavy metals and can be used for phytoremediation purposes.

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Introduction

Large amount of heavy metals are released into 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 the soils. (Ebong *et al*., 2007a; Ololade *et al*., 2007; Eja *et al*., 2003).

Odukoya *et al*. (2000) and Udosen *et al*. (1990) reported that soil at refuse dumpsites contain different concentration of heavy metals, depending on the age, contents and locations of the dumpsite. Recently, it has been reported that metals from refuse dumpsites can accumulate and persist in soil at an environmentally hazardous levels (Udosen *et al*., 2006; Amusan *et al*., 2005). However in Nigeria, most refuse dumpsites have been extensively used for cultivating varieties of edible vegetables and plant-based food stuffs despite existing data on their heavy metals phytoaccumulation potentials from contaminated and polluted soils (Benson and Ebong, 2005; Cobb *et al*., 2000). This constitutes serious health and environmental concern due to the phytotoxicity effect of these metals to the plants and animals feeding on such plants (Ellis and Salt, 2003; Jarup, 2003; Pillay *et al*., 2003). The assessment of the heavy metal contents of plants grown on dumpsites do not only provide data on the safety and wholesomeness of such edible plants but also provides an invaluable data on the heavy metals phytoaccumulation potentials of such plants (Mclntire and Lewis, 1997; Raskin *et al*., 1997).

This research work is aimed at evaluating the quality of soil and *Amaranthus hybridus* L. plants grown on Buwaya Refuse dumpsites in order to determine the soil quality and the suitability or otherwise of the plant for human consumption and for heavy metal phytoremediation purposes.

Materials and methods

Sampling sites

Buwaya dumpsites are located in the southern part of Chikun local government area of Kaduna State, Nigeria. The main source of the solid waste dumped in these sites comes from Chikun and Kaduna south local government area which share common boundary with the local government location of the study sites. Heterogeneous industrial and municipal wastes from these two local governments are dumped in these sites where the settlers of Buwaya and their neighborhood use as arable land for cultivating vegetables and plant- based food stuffs. Five main dumpsites within the mapped out area were covered. Soil and plants (*Amaranthus hybridus* L.) from a farm land located at about 2km away from the dumpsites in the community served as control.

Sample collection

This study was carried out between the month of May and July, 2008. Five soil and *Amaranthus hybridus* L. samples were randomly collected from each of the dumpsites.

Sample preparation and analysis

Soil and plant samples preparation and analysis were carried out according to the method of Radiojevic and Baskin (1999).The homogenous soil and plant samples were air-dried for 14 days to remove moisture, crushed by hand in a porcelain mortar and sieved through a 0.5mm screen. 0.5g of the dried, disaggregated and sieved soil and plant samples were placed separately in 50ml Teflon beakers and then digested with 10ml of HNO_3-$HCLO_4$-HF and the mixture heated on a hot plate to near dryness at 80-90^oC. The digests were then allowed to cool and filtered into a 50ml volumetric flask using whatman No.42 filter paper. The cadmium (Cd), lead (Pb), copper (Cu), Iron (Fe), Zinc (Zn), Nickel (Ni) and Chromium (Cr) contents of the soil and plants (shoots and roots) in the dumpsites and control site samples were determined using atomic absorption spectrophotometer (Model SP-9 Pye Unicam).

Data analysis

All the experimental results are expressed as mean ± Standard Deviation (SD) of triplicate determinations in mg/kg^{-1}. Transfer ratios, bioaccumulation factors

(BCF) and the percentage (%) metal uptake in the soil plant system were calculated according to the methods of Oyedele *et al.,* (1995).

Results

Heavy metals levels in the Buwaya dumpsite soil and *Amaranthus hybridus* L (shoots and roots) samples grown on the dumpsites is given in tables 1, 2 and 3 respectively. The concentrations of these metals in the dumpsite soil and plant (shoots and roots) were significantly higher than their corresponding concentrations in the control samples (Tables 1, 2 and 3).

Cadmium levels recorded in the dumpsite-soil ranged between 1.71-6.11mgkg^{-1} which is higher than 0.01-2.00 ppm reported for agricultural soil. The lead concentration in the dumpsite soil ranged between 49.17-118.64mgkg^{-1} and Copper levels (19.41-46.64mgkg^{-1}) while Iron, nickel and chromium are 102.92-226.39mgkg^{-1}, 3.84-18.30mgkg^{-1} and 2.13-5.89mgkg^{-1} respectively.

Table 1. Levels of heavy metals (mgkg-1dm) in soil samples from some buwaya refuse dumpsite sites in chikun – Nigeria.

Sample location	Cadmium (Cd)	Lead (Pb)	Copper (Cu)	Iron (Fe)	Zinc (Zn)	Nickel (Ni)	Chromium (Cr)
Refuse Dumpsite I	3.03± 0.03	74.34 ± 0.05	24.06±0.02	188.57±0.11	10.35±0.01	5.46±0.03	3.17±0.03
Refuse Dumpsite II	2.44±0.05	118.64±0.04	46.64±0.02	102.92±0.02	38.70±0.00	12.10±0.00	2.13±0.01
Refuse Dumpsite III	6.11± 0.02	53.47± 0.11	19.41± 0.01	226.39± 0.07	57.74± 0.04	18.30 ±0.06	5.89 ±0.01
Refuse Dumpsite IV	1.71± 0.07	49.17 ± 0.07	28.99± 0.01	151.11± 0.05	21.94± 0.02	6.62 ± 0.02	2.81 ± 0.01
Refuse Dumpsite V	2.81± 0.01	66.05 ±0.02	34.96± 0.09	201.36 ±0.03	43.20 ±0.02	3.84 ±0.02	3.63 ±0.02
Control site	0.14± 0.02	0.03 ±0.01	2.68 ±0.03	73.62 ±0.11	8.55 ±0.03	0.18 ± 0.05	0.08 ±0.01

Table 2. Levels of heavy metals (mg kg-1dm) in *Amaranthus hybridus* shoots from some buwaya refuse dumpsite in Chikun – Nigeria.

Sample location	Cadmium (Cd)	Lead (Pb)	Copper (Cu)	Iron (Fe)	Zinc (Zn)	Nickel (Ni)	Chromium (Cr)
Refuse Dumpsite I	0.31 ±0.01	0.42 ±0.02	1.98 ±0.02	128.21±0.03	1.74 ±0.02	0.11±0.03	0.37 ±0.01
Refuse Dumpsite II	0.81± 0.01	0.73 ± 0.01	3.42± 0.02	57.83 ± 0.01	4.59 ± 0.03	0.31±0.05	0.13 ± 0.01
Refuse Dumpsite III	1.19 ± 0.03	0.21±0.03	1.51± 0.01	147.41±0.01	11.83±0.01	0.59±0.03	0.88 ± 0.07
Refuse Dumpsite IV	0.22 ± 0.02	0.13 ± 0.01	1.20± 0.00	112.46±0.02	2.82 ± 0.01	0.23±0.01	0.24 ± 0.02
Refuse Dumpsite V	0.86 ± 0.02	0.35 ± 0.03	3.00± 0.05	86.91 ± 0.03	9.50 ± 0.00	0.13±0.01	0.43 ± 0.01
Control site	0.04 ± 0.01	0.00 ± 0.00	0.98± 0.02	32.19 ±0.01	1.06 ± 0.02	0.03±0.01	0.04 ± 0.01

Heavy metals contents in Plant from the dumpsites were relatively higher than the levels in the control sample. The study revealed that the level of cadmium in *A. hybridus* L grown in the dumpsites were enough to cause phytotoxicity. Lead levels recorded in *A. hybridus* L. ranged from 0.13-0.73mgkg^{-1} in shoots and 0.11-0.68mgkg^{-1} in roots.

The copper levels of *A. hybridus* L. ranged from 1.20-3.42mgkg^{-1} in shoots and 0.82-2.32mgkg^{-1} in roots which were higher than their corresponding values obtained in the control sites. Zinc levels ranged from 1.74-11.83mgkg^{-1} in shoots and 1.41-10.80mgkg^{-1} roots. Nickel levels ranged from 0.11-0.59mgkg^{-1} in shoots and 0.09-0.49mgkg^{-1} in roots while Chromium levels recorded ranged from 0.13-

0.88mgkg^{-1} in shoots and 0.12-0.68mgkg^{-1} in roots.

Relative Standard Deviation (RSD) of Heavy Metal Levels in soil and *Amaranthus hybridus* L: The computed statistical data on the variability of levels of heavy metals in dumpsite soil and *A. hybridus* L. shoots and roots are shown in tables I, 2, and 3 respectively. In the dumpsite soils, Ni had the highest RSD values of 57% followed by Zn and Cd with values of 48% and 47% respectively. Cr, Pb and Cu recorded RSD values of 36%, 34% and 31% respectively with Fe recording the least RSD values of 25%. Thus, the trends in variability in dumpsite soil were Ni> Zn> Cd > Cr > Pb > Cu > Fe.

Table 3. levels of heavy metals (mg kg-1dm) in *Amaranthus hybridus* Roots from some buwaya refuse dumpsite in chikun – Nigeria.

Sample location	Cadmium (Cd)	Lead (Pb)	Copper (Cu)	Iron (Fe)	Zinc (Zn)	Nickel (Ni)	Chromium (Cr)
Refuse Dumpsite I	0.12 ± 0.01	0.35 ± 0.03	1.29 ± 0.01	42.76 ±0.13	1.41 ±0.01	0.09±0.01	0.27 ±0.03
Refuse Dumpsite II	0.31 ± 0.01	0.68 ± 0.02	2.32 ± 0.07	22.31± 0.07	3.25 ± 0.03	0.24±0.02	0.12 ± 0.05
Refuse Dumpsite III	0.47 ± 0.05	0.19 ± 0.01	1.02 ± 0.02	52.66 ± 0.02	10.80 ± 0.00	0.47±0.03	0.68 ± 0.02
Refuse Dumpsite IV	0.10 ± 0.00	0.11 ± 0.01	0.82 ± 0.02	37.49 ± 0.03	2.02 ± 0.02	0.18±0.02	0.19 ± 0.01
Refuse Dumpsite V	0.33 ± 0.03	0.31 ± 0.03	2.01 ± 0.01	30.08 ± 0.02	7.65 ± 0.03	0.10±0.00	0.32 ± 0.02
Control site	0.02± 0.01	0.00 ± 0.00	0.67± 0.03	11.50 ± 0.00	0.75 ± 0.02	0.02±0.01	0.03 ± 0.01

In the *A. hybridus* L. plants samples collected from the dumpsites, the trends in variability of heavy metals were: Cr > Zn > Ni > Pb > Cd> Cu > Fe with values 66%, 64%, 63%, 57%, 53%, 38% and 30% for Cr, Zn, Ni, Pb, Cd, Cu and Fe respectively in the shoots and Zn > Ni > Pb > Cr > Cd > Cu > Fe with values 72%, 64%, 61%, 59%, 52%, 39% and 28% for Zn, Ni, Pb, Cr, Cd, Cu and Fe, respectively in the roots.

Heavy metals Bioaccumulation Potentials of *Amaranthus hybridus* L. from the various refuse dumpsites: The shoots/roots (S/R) ratio of the heavy metals concentrations of *A. hybridus* L. from the various dumpsites is shown in table 4. The order recorded for S/R ratio in *A. hybridus* L. were as follows; Fe > Cd > Cu > Zn > Ni >Cr > Pb. The S/R ratio for all the metals was > 1.0

Table 4 also shows the bioaccumulation factor (BCF) or transfer ratio of the metals from the dumpsite soils to *A. hybridus* L. The trends recorded for bioaccumulation factor (BCF) in *A. hybridus* L. were: Fe > Zn > Cd > Cr > Cu > Ni > Pb. These results indicate that *A. hybridus* L. has the potential of accumulating more Fe followed by Zn while it can accumulate less Pb and Ni. The percentage (%) metals uptake of *A. hybridus* L. from the dumpsites were in this trends Fe > Zn > Cd > Cr > Cu > Ni > Pb. This results indicated that *A. hybridus* L. can be used for the efficient remediation of soils pollutant.

Discussion

The high levels of heavy metals in the dumpsite soil and plants could be attributed to the huge amount of heterogeneous industrial and municipal waste products dumped at the dumpsites. However, reports by Ebong *et al.*, (2007b); Onianwa, (2001) have shown that aerial deposition of these metals could be from another source to these soils and plants from dumpsites. The lead concentration in the dumpsite soil was higher than 0.46-44.50mgkg^{-1} reported in cultivated soil by Sharma *et al.*, (2005). Cadmium levels recorded in the dumpsite-soil was also higher than 0.01-2.00ppm for agricultural purposes while Copper, Iron and Zinc levels which falls within the standard (2-100mgkg-1) and (10-300mgkg-1) respectively for agricultural soils as reported by Vecera *et al.,* (1999). Chromium levels in the dumpsite soils were lower than 13.40-679.89mgkg-1 reported by Sharma *et al.*, (2005) for agricultural farms.

Table 4. Heavy metals phytoacumalation potentials of *Amaranthus hybridus* L. from buwaya refuse dumpsite in Chikun– Nigeria.

Parameters	Sample location	Cadmium (Cd)	Lead (Pb)	Copper (Cu)	Iron (Fe)	Zinc (Zn)	Nickel (Ni)	Chromium (Cr)
SHOOT /ROOT (S/R) RATIO *	Refuse Dumpsite I	2.58	1.20	1.53	3.00	1.23	1.22	1.37
	Refuse Dumpsite II	2.61	1.07	1.47	2.59	1.41	1.29	1.08
	Refuse Dumpsite III	2.53	1.11	1.48	2.80	1.10	1.25	1.29
	Refuse Dumpsite IV	2.20	1.18	1.46	3.00	1.40	1.28	1.26
	Refuse Dumpsite V	2.61	1.13	1.49	2.89	1.24	1.30	1.34
BIOACCUMULATION FACTOR (BCF) **	Refuse Dumpsite I	0.142	0.010	0.136	0.907	0.304	0.037	0.202
	Refuse Dumpsite II	0.459	0.012	0.123	0.779	0.203	0.045	0.117
	Refuse Dumpsite III	0.272	0.007	0.130	0.884	0.392	0.058	0.265
	Refuse Dumpsite IV	0.187	0.005	0.070	0.992	0.221	0.062	0.153
	Refuse Dumpsite V	0.423	0.010	0.143	0.581	0.397	0.060	0.207
% METAL UPTAKE ***	Refuse Dumpsite I	12.43	0.99	11.96	47.55	23.33	3.53	16.80
	Refuse Dumpsite II	31.46	1.17	10.96	43.78	16.85	4.35	10.50
	Refuse Dumpsite III	21.36	0.74	11.53	46.91	28.16	5.48	20.94
	Refuse Dumpsite IV	15.76	0.49	6.51	49.81	18.07	5.83	13.27
	Refuse Dumpsite V	29.75	0.99	12.53	36.75	28.42	5.65	17.12

* Shoot/Root (S/R) Ratio = $[M_{shoot}]/[M_{root}]$

** Bioaccumulation factor (BCF) = $[M_{plant}] / [M_{soil}]$

*** % Metal uptake = $\frac{[M_{plant}]}{[M_{plant}] + [M_{soil}]} \times \frac{100}{1}$

Where (M plant) = $[M_{shoot}] + [M_{Root}]$, [M]= concentration of metals.

The Cd levels in plants from the dumpsites were relatively higher than the levels in the control sample and this could be attributed to the presence of Cd accumulated waste in the dumpsites. The study revealed that the level of cadmium in *A. hybridus* L grown in the dumpsites were enough to cause phytotoxicity. The copper levels of *A. hybridus* L. shoots and roots were higher than their corresponding values obtained in the control sites and lower than 223.43-260.00μgg^{-1} and 630.10-742.00 μgg^{-1} reported for *Talinum triangulare* and *Manihot utilissima* grown on dumpsites in Nigeria (Ebong *et al*., (2007a) and Udosen *et al*., (2006) but were higher than 44.09-88.18 μgg^{-1} reported for *Talinum triangulare* from dumpsite as reported by Amusan *et al*., (2005). Zinc levels in the shoots and roots were higher than 19.23-24.73 μgg^{-1} reported in *Talinum triangulare* from Uyo and Ife dumpsites (Ebong *et al*., 2007b; Amusan *et al*., (2005) respectively. Nickel levels were also higher than 1.38-99.1 μgg^{-1} and 1.90-197.4 μgg^{-1} obtained for leaves and roots of plants from Ojota dumpsites (Ololade *et al*., 2007) while Chromium levels were comparatively higher than 0.24-19.60μgg^{-1} and 1.12-24.60μgg^{-1} obtained for leaves and roots of plants from Ojota dumpsite (Ololade *et al*., 2007).

Relative Standard Deviation (RSD) of Heavy Metal Levels in soil and *Amaranthus hybridus* L.. The trend in variability of RSD in dumpsite soil were as follows; Ni> Zn> Cd > Cr > Pb > Cu > Fe. These difference in the degree of variability in heavy metals in the dumpsite soils may be attributed to the differences in the natural and anthropogenic conditions of the substrates from the dumpsites (Udosen *et al*., 2006) as well as the level of inconsistency in the distribution of each of the metals in the study area due to its availability (Ebong *et al*., 2007b).

In the *A. hybridus* L. plants samples collected from the dumpsites, the trends in variability of heavy metals were: Cr > Zn > Ni > Pb > Cd> Cu > Fe in the shoots and Zn > Ni > Pb > Cr > Cd > Cu > Fe in the roots. The differences in the degree of variability of heavy metals in the shoots and roots of the plants from the dumpsites may be attributed to the differences in the distribution pattern of the metals in the study area due to its availability as well as the physiological state of the plant combined with the environmental conditions in each study area (Zhang *et al*., 1995).

Heavy metals Bioaccumulation Potentials of *Amaranthus hybridus* L. from the various refuse dumpsites: The shoots/roots (S/R) ratio of the heavy metals concentrations of *A. hybridus* L. from the various dumpsites is shown in table 4. The order recorded for S/R ratio in *A. hybridus* L. was: Fe > Cd > Cu > Zn > Ni >Cr > Pb. The S/R ratio for all the metals was > 1.0 which indicates that *A. hybridus* L. is a phytoaccumulator of metals. This is supported by the fact that plants with S/R ratio of > 1.0 are phytoaccumulators of heavy metals (Baker, 1981). Thus, the results reveal that *A. hybridus* L. can accumulate these metals and as such feeding on the plants grown on highly heavy metals polluted area should be avoided to avert heavy metals poisoning.

Table 4 also shows the bioaccumulation factor (BCF) or transfer ratio of the metals from the dumpsite soils to *A. hybridus* L. The trends recorded for bioaccumulation factor (BCF) in *A. hybridus* L. was: Fe > Zn > Cd > Cr > Cu > Ni > Pb. These results indicate that *A. hybridus* L. has the potential of accumulating more Fe followed by Zn while it can accumulate less Pb and Ni. This is supported by reports documented by Ebong *et al*., (2007a). However, the genetic characteristics of plants species and the environmental conditions such as soil pH, exchange and binding capacities of the metals in the soil-plants system determine the transfer ratios and as such the transfer rates (Lee *et al*., 2002).

The percentage (%) metals uptake of *A. hybridus* L. from the dumpsites were were in this trends Fe > Zn > Cd > Cr > Cu > Ni > Pb. This results indicated that

A. hybridus L. can be used for the efficient remediation of soils pollutant.

Conclusion

The results obtained from this study have shown higher levels of heavy metals in soil and *Amaranthus hybridus* L. samples obtained from the various dumpsites relative to those of the control site. These results clearly implicated anthropogenic inputs as the sources of the elevated heavy metals in dumpsite soils and plants. The results also showed that *A. hybridus* L. has high potentials of accumulating heavy metals and as such could be utilized to remediate heavy metals contaminated soils. Although the levels obtained for most of the metals were within the World Health Organization (WHO) acceptable standards, indiscriminate dumping of refuse and cultivating edible vegetables and plants-based foodstuffs on dumpsite soils should be discouraged to avoid the multiple toxicity effects of heavy metals poisoning.

The results also indicated that *A. hybridus* L. has high tolerance to high heavy metals levels and the ability to translocation such metals from roots to shoots at high rate. This suggests that plants that grow well in dumpsite soils can be utilized for the purposes of phytoremediation of heavy metals in heavy metals polluted soils.

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