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Full Length Research Paper

Assessment of heavy metals bioaccumulation by *Eleusine indica* from refuse dumpsites in Kaduna Metropolis, Nigeria

Abdallah S.A[1]., Uzairu A[2]., Kagbu J. A[2]. and Okunola, O. J[3]

[1]Hussaini Adamu Federal Polytechnic, Kazaure, Jigawa State, Nigeria.
[2]Department of Chemistry, Ahmadu Bello University, Zaria, Nigeria.
[3]National Research Institute for Chemical Technology, Basawa, Zaria, Nigeria.

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The levels of bioaccumulation of heavy metals (Pb, Cr, Zn, Cd, Mn and Cu) in *Eleusine indica* and waste soil samples from ten refuse dumpsites located in Kaduna Metropolis was assessed using atomic absorption spectrophotometer (AAS).The soil pH, electrical conductivity (EC), organic matter (OM) and available phosphorus (AP) were also determined. The results of analysis of the waste soils from the refuse dumpsites indicated that levels of the metals were in the range of; 131.93 to 205.18 mgkg^{-1} (Pb), 27.13 to 94.198 mgkg^{-1} (Cr), 259.30 to 354.708 mgkg^{-1} (Zn), 27.23 to 45.498 mgkg^{-1} (Cd), 151.68 to 227.568 mgkg^{-1} (Mn) and 42.09 to 132.11 mg kg^{-1} (Cu). The concentration recorded for *E. indica* ranged widely from 116.40 to 239.74, 6.97 to 24.84, 86.94 to 261.40, 5.10 to13.24, 90.22 to 318.51 and 41.11 to 103.84 mgkg^{-1} for Pb, Cr, Zn, Cd, Mn and Cu respectively. The results of soils pH, EC, OM and AP were found to be 7.85 to 8.60 and 0.54 to 3.22 S cm^{-1}, 2.77 to 6.32% and 42.11 to 175.55 mgkg^{-1} respectively. The bioaccumulation factors (BCF) of these metals were less than unity for all the metals except for Pb. The trend in bioaccumulation for metals in *E. indica* followed the sequence: Zn>Cu>Pb>Mn>Cd>Cr. Though the results indicated low bioaccumulation of metals by *E. indica*, however, further dumping of toxic waste could lead to toxicity to man through the food chain.

Key words: Waste soils, Refuse dump, Metals, Kaduna.

INTRODUCTION

Rapid population growth and urbanization in developing countries have led to the generation of enormous quantities of solid wastes and consequential environmental degradation (Nagendran et al., 2006). In many Nigerian cities, due to inadequate planning in the face of this rapid population growth, expectedly this put immense pressures on available public infrastructure, leading to deterioration in environmental quality and decline in the quality of life for most urban dwellers. Because of poor planning of waste collection, coupled with widespread poverty and limited awareness of the likely implications of poor waste management in the environment by the urban populace, refuse is thrown unto roadways, and pedestrian walkways and sometimes dumped in open gutters (Okpoechi, 2007).

Furthermore, an estimated 7.6 million tons of municipal solid waste is dumped per day in developing countries (Nagendran et al., 2006). Recent studies have revealed that wastes dumpsites can transfer significant levels of toxic and persistent metals into the soil environment and eventually these metals are taken up by plants parts and transfer same into the food chain (Benson and Ebong, 2005). Consequently, higher soil heavy metal concentration can result in higher levels of uptake by plants, even though the rate of metal uptake by crop plants could be influenced by factors such as metal species, plants species, plant age and plant part (Ebong et al., 2008). Several literatures have indicated that most

*Corresponding author. E-mail: okunolaoj@gmail.com.

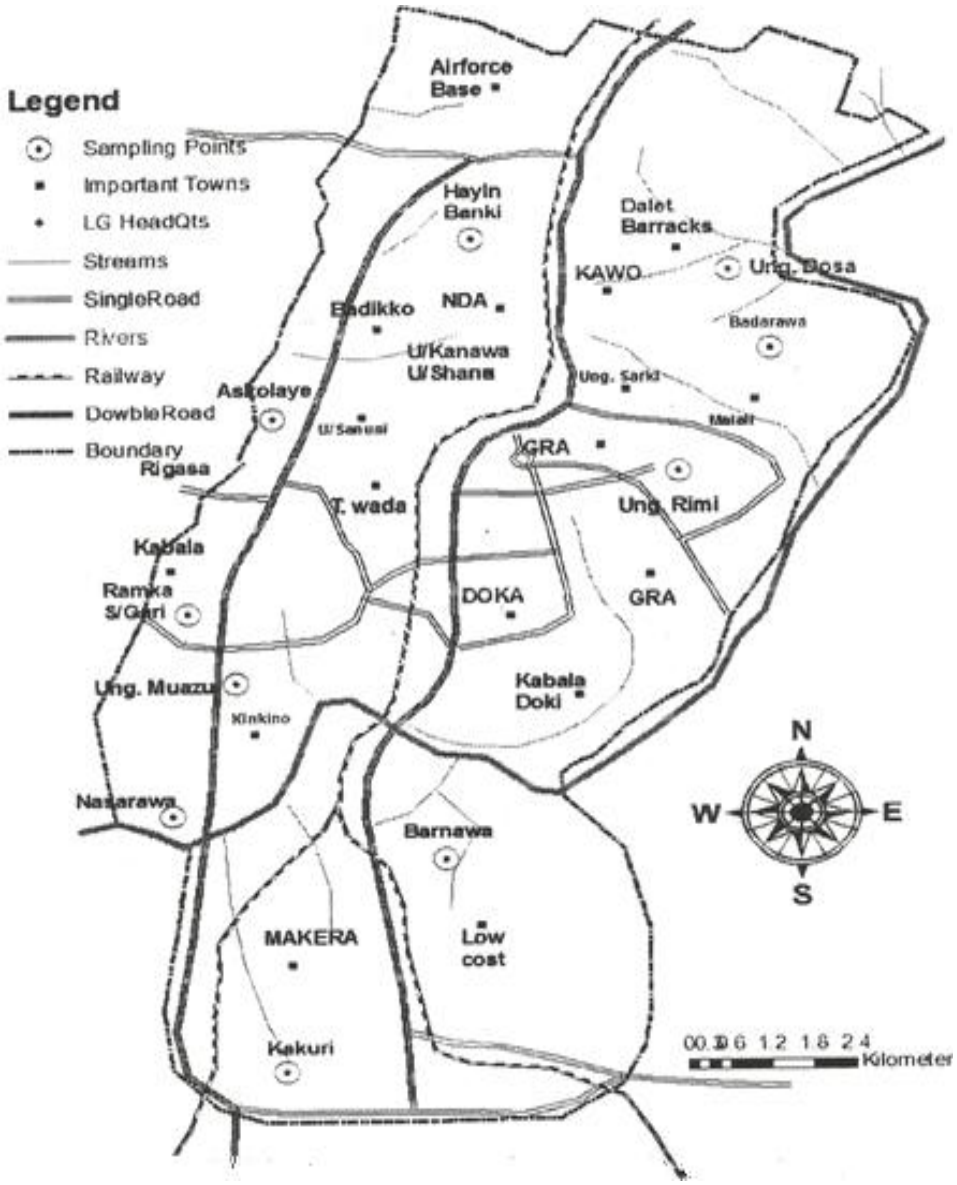

Figure 1. Map of Kaduna Metropolis showing the sampling.

of the dumpsites in the urban areas are used as fertile soils for the cultivation of some fruits and vegetables (Amusan et al., 2005; Okorokwo et al., 2005; Ebong et al., 2008). Some farmers, due to lean economic resources, resort to the use of decomposed parts of the dumpsites as manure to improve their farm yields. The cultivated plants take up these metals either as mobile ions in the soil solution through their roots or through their leaves thereby making them unfit for human consumption (Amusan et al., 2005). Based on this analogy, the present study is aimed with the objectives to determine the levels of Pb, Cr, Zn, Cd, Mn and Cu in soils and plant samples (*Eleusine indica*) from refuse dumpsites in Kaduna metropolis and evaluate the bioaccumulation of the metals in *E. indica*.

MATERIALS AND METHODS

Sampling sites

Kaduna metropolis is the capital of Kaduna State occupying the central portion of Northern Nigeria with location matrix of Latitude 10.52°N and Longitude 7.44°E. Annual temperature varies between 29 to 38.6°C. It is an administrative, industrial, a veritable commercial center and a functional urban area. It ranks second only to Kano in Northern Nigeria in terms of population (about 4,000,000 residents) (Achi et al., 2011). The study areas comprised of ten refuse dumpsites selected from four Local government areas within the metropolis which include: Kaduna South, Kaduna North, Chikun and Doka Local Government areas respectively as shown in Figure 1. The refuse dumpsites selected and their codes were: Badarawa (BD), Askolaye (AK), Ramka Sabon Gari (RSG), Unguwar Dosa (UD), Kakuri (KKR), Unguwar Rimi (UR), Nasarawa

Table 1. Mean (mgkg^{-1}±SD) % recoveries of heavy metals from spiked samples.

Metal	Soil Sample	*Eleusine indica*
Pb	90.11±0.23	86.57±0.47
Cr	89.10±0.15	95.25±0.09
Zn	91.51±0.42	97.94±0.13
Cd	106.22±0.29	101.61±0.68
Mn	96.07±0.34	104.92±0.24
Cu	101.07±1.32	103.85±0.15
Range	89.10 – 106.22	86.57 – 104.92

(NS), Hayin Banki (HB), Barnawa (BN) and Unguwar Mu'azu (UM). Control samples were equally taken 20 m away from the refuse dumpsites and the results were presented side by side with those of the impacted refuse dumpsites.

Sample Collection

The areas to be sampled in each sampling station were divided into four quadrants, each 5m^2 and five plant samples (*E. indica*) were collected by uprooting the whole plant from each quadrant in a diagonal basis following the method described by Nuonamo et al. (2002). The leafy *E. indica* in prime condition were bagged in paper bags and transported to the laboratory for pretreatment and subsequent analysis. Soil samples were collected in the same quadrants as the *E. Indica* from the dumpsites. Soil and plant samples from the background (20 m away from dumpsites) were equally collected. The background sites were located on the up-slope of each dumpsite. Three composite samples of the top soil (0 to 15 cm) were also taken from each of the quadrants. Each composite soil sample comprised 9 core soil samples (taken also in diagonal basis) bulked and homogenized before sub-sampling for laboratory analysis.

Sample preparation and pre-treatment

In the laboratory, the plant samples were thoroughly washed under running tap water to remove any attached soil particles and rinsed with double distilled water. Stainless steel scissors was used to cut the plant samples into very small portions and placed in large clean crucibles where they were oven dried at 105°C for 48 h. The dried crisp plant samples were then pulverized to powder using clean acid washed mortar and pestle and passed through 2 mm sieve. The ground plant samples were collected in labeled polythene bags and placed in desiccators to attain constant weight. The digestion of the plant sample was carried out according to the procedure described by Awofolu (2005). 0.5 g of the sieved plant sample was accurately weighed into 100 ml beaker. A mixture of 5 ml concentrated trioxonitrate (V) acid and 2 ml perchloric acid was added and this was digested on low heat using hot plate until the content was about 2 ml. The digest was allowed to cool and filtered into 50ml standard flask using Whatman Filter Paper No. 42. The beaker was rinsed with small portions of double distilled water and filtered into the flask. Triplicate digestions of each sample together with blank were carried out. The metal content was assessed using spectrophotometer (Model VGB210, Buck Scientific).

The soil samples from each site were air dried, crushed and passed through a 2 mm sieve. The fine earth fraction was retained for analysis. 5 g of the soil samples was placed in 100 ml beaker. 3 ml of 30% hydrogen peroxide was added following the procedure described by Shriadah (1999). This was left to stand for 60 min until the vigorous reaction ceased. 75 ml of 0.5 M HCl solution was added and the content heated gently at low heat on hot plate for about 2 h. The digest was then filtered into 50 ml standard flask. Triplicate digestions of each sample together with blank were carried out. Calibration and measurement of metals were done on atomic absorption spectrophotometer, Model VGB210 Buck Scientific.

Physico-chemical parameters of soils

The pH and electrical conductivity (EC) of the soils were determined using Hanna Model No 111991000 using soil sample to distilled water 1:2 on a volume basis in accordance with the method described by Hendershot et al. (1993). Organic matter was determined based on the procedure described by Walkley and Black (1934). Available phosphorus was determined by methods described by Udo and Ogunwale (1978).

Quality assurance

Spiking experiment was conducted on the predigested soil samples and plants samples in order to ensure the reliability of the methods. This was achieved by spiking 0.5 g of the predigested *E. indica* samples with multi element standard solutions. 0.5 g each of the samples were weighed into a 100 ml beaker and spiked with 30 ml portions of multi element standards solution (0.5 mgkg^{-1}, Cd, Pb and Cr and, 5 mgkg^{-1} Zn, Cu and Mn) (Awofolu, 2005). This was then digested in triplicates. The triplicate digestion was done together with blank. Measurement of metals was done on atomic absorption spectrophotometer, VGB210 Buck Scientific model. The soil samples were similarly treated as the plant samples. Concentrations of metals in spiked and unspiked sample were used to calculate percentage recovery in order to validate the analytical procedure.

Statistical data analyses were done using SPSS version 17 (SPSS Inc. Chicago, IL, USA). All means recorded were determined considering a level of significance of less than 5% ($p < 0.05$) at 95%.

RESULTS AND DISCUSSION

Quality assurance

Table 1 indicated the percent recoveries of the heavy metals in the soil and the *E. indica* for each metal investigated. Cd showed the highest recovery in the soil (106.22 ± 0.29 mgkg^{-1}) while Cr the least (89.10 ± 0.15 mgkg^{-1}). The trend in the percent recovery in the soil was: Cd>Cu>Mn>Zn>Pb>Cr. Percent recovery was higher in *E. indica* with Mn having the highest percent recovery (104.92 ± 0.24mgkg^{-1}) and Pb having the least (86.57 ± 0.47mgkg^{-1}). The trend of metal recovery in *E. indica* was Mn>Cu>Cd>Zn>Cr>Pb. The observed good percentage recoveries indicated the validity and reliability of the digestion method and the AAS analysis adopted for this research.

Soil chemical characteristics

The results of some selected soil chemical characteristics

Table 2. Chemical parameters in waste soils of refuse dumpsites.

Sampling stations	pH	OM (%)	AP (mg/kg)	Heavy metal (mg/kg)					
				Pb	Cr	Zn	Cd	Mn	Cu
BD	8.60±0.14	3.68±0.04	91.24±2.14	143.31±0.02	29.20±0.02	354.70±0.50	30.77±0.21	179.04±0.10	70.12±0.10
AK	8.15±0.07	5.27±0.08	141.02±1.44	131.93±0.17	28.85±0.13	294.09±0.06	27.55±0.09	157.01±0.11	68.62±0.21
RSG	8.45±0.21	4.72±0.20	50.88±0.18	205.18±0.05	27.13±0.11	295.65±0.04	37.25±0.03	151.68±0.05	61.42±0.00
UD	8.10±0.14	5.04±0.25	150.00±0.47	154.25±0.05	29.61±0.04	282.50±0.23	27.23±0.01	158.02±0.02	49.37±0.02
KKR	8.1±0.15	2.87±0.11	85.86±.17	154.95±0.16	36.15±0.02	259.30v0.00	28.41±0.12	227.56±0.17	46.40±0.01
UR	7.95±0.07	4.04±0.05	77.56±0.79	148.02±0.02	28.29±0.02	283.28±0.14	38.41±0.13	168.28±0.21	42.09±0.09
NS	8.1±0.14	6.07±0.03	42.11±0.15	158.76±0.45	35.35±0.28	299.09±0.10	28.36±0.08	166.66±0.06	53.94±0.12
HB	7.85±0.07	6.32±0.08	82.06±0.08	176.00±0.12	48.19±0.02	287.39±0.13	45.49±0.28	193.37±0.14	132.11±.08
BN	8.05±0.07	4.89±0.28	175.55±0.78	161.41±0.14	48.19±0.07	289.55±0.18	31.26±0.05	170.10±0.00	88.50±0.10
UM	8.45±0.79	2.77±0.01	104.05±1.35	140.02±0.26	94.19±0.03	304.23±0.06	33.41±0.07	165.66±0.00	72.27±0.14
Mean ± sdv	8.18±0.24	4.57±1.22	100.03±43.17	157.38±20.82	40.52±20.43	294.98±24.32	32.81±5.93	173.74±22.32	68.48±26.41
Range	7.85-8.60	2.77-6.32	42.11-175.55	131.93-205.18	27.13-94.19	282.50-354.70	27.23-45.49	151.68-227.56	42.09-132.11
CONTROL	7.19±0.62	2.60±1.16	41.74±22.88	7.95±5.47	6.95±5.13	64.07±18.35	5.19±2.17	86.12±29.74	53.18±18.94
USEPA (1986) $mgkg^{-1}$	-	-	-	30 - 300	100	300	3.0	100-300	250

were summarized in Table 2. The pH values in the study areas ranged from 7.85 to 8.60 suggesting that all the soils were basically alkaline in nature. The control areas depicted mean pH value of 7.19. Soil pH, nature of soil and climatic changes affect the rate of uptake of metals by plants (Alloway and Ayres, 1997). Metal mobility has been shown to decrease with increasing soil pH due to precipitation of hydroxides, carbonates or formation of insoluble organic complexes (Smith et al., 1996). Hence, high pH values observed in the present study could lead to decreased mobility of metals in the soil.

The electrical conductivity of the soils ranged from 0.54 to 3.22 Scm^{-1} The control areas have EC mean value of 1.10 Scm^{-1}.The organic matter content of waste soils from the dumpsites ranged from 2.77 to 6.32% while the mean organic matter for the control areas was 2.60%. The waste soils from the refuse dumpsite have higher organic matter content than the control areas. This observation agrees with the work of Bamgbose et al. (2000). The organic matter content of the waste soils from the refuse dumpsites ranged from 2.77 to 6.32% while the mean organic matter for the control areas was 2.60%. Researches have shown that among other factors such as presence of dolomite and phosphates, organic matter in soils reduce the concentration of metals by precipitation, adsorption and complexation (Mench et al., 1994, Chen and Lee, 1997) and thus making them unavailable to the plants. In the present study, the refuse dump soils were observed to have higher levels of organic matter (2.77 to 6.32%) and available phosphorus (phosphates) (42.11 to 175.55 $mgkg^{-1}$) which reduced the concentrations of the metals absorbed by plant refuse dump soils than the control areas.

The levels of concentration of the six metals investigated in waste soils from the refuse dumpsites as shown in Table 2 revealed the level of Pb in the study area ranged from 131.93 – 205.18$mgkg^{-1}$ while Cr and Zn ranged from 27.13 to 94.19 and 259.30 to 354.70 $mgkg^{-1}$ respectively. Cd has the least concentrations compared to the other metals with a range of 27.23 to 45.49 $mgkg^{-1}$. Other ranges of metal concentrations were 151.68 to 227.56 $mgkg^{-1}$ for Mn and 42.09 to 132.11 $mgkg^{-1}$ for Cu. The mean concentrations of the metals from the study and control areas (side by side) respectively were: Pb: 157.38, 40.52, Cr: 7.95, 6.95, Zn: 294.98, 64.07, Cd: 32.81, 5.19, Mn: 173.74, 86.12 and Cu: 68.48,

Table 3. Correlation matrix between metals in waste soils of refuse dumpsites.

Metal	Pb	Cr	Zn	Cd	Mn	Cu
Pb	1					
Cr	-0.210	1				
Zn	-0.190	0.030	1			
Cd	0.507*	0.162	-0.040	1		
Mn	-0.060	0.039	-0.320	0.068	1	
Cu	0.238	0.334	0.140	0.612*	0.126	1

*indicate significant at $p < 0.05$

Table 4. Concentrations of heavy metals ($mgkg^{-1}$ dw) in *E. indica* in refuse dumpsites.

Sampling stations	Metals					
	Pb	Cr	Zn	Cd	Mn	Cu
BD	181.64±0.19	18.03±0.03	138.39±0.06	13.24±0.04	90.22±0.01	66.93±0.09
AK	173.18±0.06	16.32±0.04	216.35±0.01	8.02±0.02	108.01±0.02	61.05±0.05
RSG	148.03±0.03	17.42±0.14	261.40±0.01	13.08±0.03	212.06±0.17	51.63±0.13
UD	239.74±0.20	24.84±0.17	136.43±.02	5.10±0.01	160.16±0.05	41.11±0.12
KKR	128.34±0.11	15.67±0.11	103.33±0.04	12.94±0.06	318.51±0.05	60.00±0.11
UR	116.4±0.09	16.38±0.05	143.84±0.17	10.32±0.09	129.26±0.19	64.99±0.10
NS	163.48±0.02	9.67±0.06	86.94 ±0.16	8.02±0.01	213.28±0.05	103.84±0.17
HB	184.92±0.08	12.95±0.05	150.67±0.34	6.89±0.11	102.5±0.13	65.34±0.05
BN	192.42±0.03	6.97±0.03	229.85±0.22	8.10±0.01	194.64±0.02	60.39±0.05
UM	131.34±0.11	15.94±0.06	177.09±0.02	8.72±0.05	122.23±0.05	46.84±0.17
Mean±SD	165.95±36.82	15.42±4.86	164.43±56.13	9.44±2.84	165.09±70.60	62.21±16.92
Range	116.4-239.74	6.97-18.03	86.94-261.40	5.10-13.24	90.22-318.51	41.11-103.48
Ctrl	34.91±10.98	4.83±3.25	73.79±31.15	3.72±0.86	64.64±41.11	34.33±15.33
USEPA $mgkg^{-1}$ (1986)	0.2–20*	0.03–14*	1-400*	0.1–2.4*	-	5 -20*

*Radojevic and Bashkin (2006).

53.18 $mgkg^{-1}$. This indicated that the dumpsites had significantly higher heavy metals burden than the control areas. This agrees well with the findings of past researchers (Bamgbose and Odukoya, 2000; Eddy et al., 2006; Ebong et al., 2008 and Uba et al., 2008). The profile of metal abundance in the study areas was: Zn>Mn>Pb>Cu>Cr>Cd. Among the six metals investigated, only Cd exceeded the EC (1986) permissible limit (2.0 - 3.0mg/kg).

Nickel-cadmium batteries, cadmium-pigments, ceramics, glasses, paints and enamels, cadmium coated ferrous and non-ferrous products, cadmium stabilized polyvinyl chloride (pvc) products, cadmium alloys, cadmium electronics or electronic compounds are among anthropogenic sources of Cd in the environment (Baldini et al., 2000). Values of 950 mg/kg Mn, 100 mg/kg Cr, and 75 mg/kg Zn were reported for uncontaminated soils (Sparks, 2003). However, the values of concentrations of metals from waste soils reported by Uba et al. (2008) were higher than those reported in this study. Statistical analysis performed using Pearson correlation as shown in Table 3 indicated positive correlations among the metals except Pb vs Cr, Zn and Mn and Zn vs Cr and Mn which were negatively correlated. Significant correlations ($p < 0.05$) were observed between Pb vs Cd and Cd vs Cu. Positive correlation among the metals in soils samples could indicate common sources of the metals which could be related to known geochemical associations among them while negative or insignificant positive correlation between the metals indicate that the appearance of local high concentration for one metal by possible contamination does not necessarily indicate high values for other metals. It may also indicate different sources or biogeochemical behaviours (Okunola et al., 2008).

Heavy metal levels in plants

The mean levels of metals in *E. indica* are shown in Table 4. Pb ranged from 116.40 to 239.74 $mgkg^{-1}$ while Cr and Zn ranged from 6.97 to 24.84 $mgkg^{-1}$ and 86.94 to

Table 5. Correlation between metals in plant and waste soil from refuse dumpsites.

Parameter	Pb-soil	Cr-soil	Zn-soil	Cd-soil	Mn-soil	Cu-soil
Pb-plant	0.017	-0.229	0.161	-0.246	-0.268	0.288
Cr-plant	-0.110	-0.234	0.061	-0.161	-0.171	-0.400
Zn-plant	0.360	0.067	0.064	0.199	-0.527*	0.249
Cd-plant	0.209	-0.221	0.264	0.035	0.327	-0.309
Mn-plant	0.340	-0.162	-0.600*	-0.336	0.474	-0.421
Cu-plant	-0.038	-0.232	0.162	-0.066	0.110	-0.010

*Indicate significant at $p < 0.05$.

Table 6. Correlation between metals in plant from refuse dumpsites.

Parameter	Pb-plant	Cr-plant	Zn-plant	Cd-plant	Mn-plant	Cu-plant
Pb-plant	1					
Cr-plant	0.233	1				
Zn-plant	0.038	-0.079	1			
Cd-plant	-0.603*	0.018	0.082	1		
Mn-plant	-0.249	-0.191	-0.181	0.320	1	
Cu-plant	-0.163	-0.604	-0.482	0.032	0.121	1

*Indicate significant at $p < 0.05$.

261.40 $mgkg^{-1}$ respectively. Cd had the least concentrations among the metals investigated in the plant. It had values that fluctuated between 5.10 to 13.24 $mgkg^{-1}$. Mn had range of values from 90.22 to 318.51 $mgkg^{-1}$g and Cu 41.11 to 103.84 $mgkg^{-1}$.

The relative abundances of the heavy metals as detected in the *E. indica* samples from the refuse dump sites followed the sequence: Pb>Mn>Zn>Cu>Cr>Cd. The levels of the metals in the plant were generally lower than those of the waste soils from the refuse dumpsites. It has been reported that high soil pH can stabilize soil toxic elements resulting in decreased leaching effects of the soils toxic elements (Li et al., 2005). This may explain the low absorbability of the elements from the soil solution and translocation into plant tissues.

The higher level of heavy metals in the dumpsite plants may also be attributed to the large amount of wastes disposed at the dumpsite. Studies have shown that crops harvested from soils of the refuse dump sites presented higher levels of the metals when compared to the those crops from the control sites. This may be interpreted that if the level of these metals in soils is significantly increased, the plants have the potential of showing increased uptake of the metals. This is also supported by studies that plants grown in soils possessing enhanced metal concentrations have increased heavy metal ion content (Alloway and Ayres, 1997; Amusan et al., 2005). High levels of heavy metals as revealed in this study; Pb (15.28 to 76.92 $mgkg^{-1}$), Cd (1.96 to 9.80 $mgkg^{-1}$), Zn (45.37 to 237.96 $mgkg^{-1}$) Mn (84.00 to 132.00 $mgkg^{-1}$) and Cu (2.14 to 48.00 $mgkg^{-1}$) had already been reported in soils in roadside soils in Kaduna metropolis (Okunola *et al*., 2008). Correlation calculations between metals in plants and waste soil as shown in Table 5 revealed mild positive correlation between Pb-plant vs Pb, Zn, Cu in soil, Cr-plant vs Zn-soil, Zn-plant vs Pb, Cr, Zn, Cd and Cu in soil, Cd-plant vs Pb, Zn, Cd and Mn in soil, Mn-plant vs Pb and Mn in soil, and Cu-plant in Zn and Mn in soil. It can therefore be inferred that with an increase in the amount of metals in soil due to percolation, the uptake of metals by plants also increases (Aksoy et al., 2000). Also, the positive relationships among both plants and soil content of metals might be a cause of metal toxicities to both plants and animals through their entry into food chain (Awofolu, 2005).

Also, correlation coefficients between the metals in plants are presented in Table 6. A perusal of the table revealed mild positive correlation between the different metals in plant. The positive correlation could indicate common sources of metals in plants.

Bioaccumulation factor (BCF)

The Bioaccumulation factor (BCF) is a competent technique developed to assess the level of the metal in the plant as a fraction of the soils total. Previous studies have indicated that the uptake of metals by plants differs from one metal to another, from one plant species to

Table 7. Bioaccumulation factor of heavy metals in *E. indica* from refuse dumpsites.

Sampling Sites	Metal					
	Pb	**Cr**	**Zn**	**Cd**	**Mn**	**Cu**
BD	0.86	0.19	0.75	0.30	0.78	1.24
AK	0.29	0.20	0.93	0.18	0.42	0.47
RSG	0.22	0.12	1.06	0.19	0.68	0.45
UD	1.27	0.41	0.48	0.08	0.18	0.41
KKR	0.54	0.10	0.48	0.37	1.06	0.63
UR	0.60	0.12	0.82	0.34	0.43	0.73
NS	0.37	0.19	0.48	0.26	0.13	1.11
HB	0.51	0.20	0.83	0.13	0.29	0.83
BN	0.96	0.10	1.12	0.12	0.25	0.26
UM	0.53	0.08	0.51	0.18	0.36	0.41
Control	0.60	0.50	1.00	0.62	0.70	0.34

another and from one dumpsite to the other (Amusan et al., 2005; Agyarko et al., 2010). The results from this study as shown in Table 7 indicated that the uptake of each metal differs from one dump site to another. This variation might be explained in terms of the available salts present in the soil which differ from one dumpsite to the other. The ranges of BCF for *E. indica* – soil were as follows: Pb: 0.22 to 1.27, Cr: 0.08 to 0.41, Zn: 0.48 to 1.12, Cd: 0.08 to 0.37, Mn: 0.13 to 1.06 and Cu: 0.26 to 1.24 respectively.

The general sequence of bioaccumulation of the metal in *E. indica* was: Zn>Cu>Pb>Mn>Cd>Cr. The mean BCF values for the soil - *E. indica* in the control areas were: 0.60, 0.50, 1.00, 0.62, 0.70 and 0.34 for Pb, Cr, Zn, Cd, Mn and Cu respectively. The mean BCF value for Zn in the control area was unity, which indicated that the concentration of the metal in the *E. indica* was equal to that of the soil. Generally, the BCF of the heavy metals in the control area were higher than those of the refuse dumpsites. This depicted higher bioavailability of the metals in the control areas than the refuse dumpsite. Amusan *e*t al. (2005) reported that other factors apart from total soil metal concentration could influence the bioaccumulation factor (soil plant transfer ratios). Chambers and Sidle (1991) found that metal levels in plants highly vary when related to soil metal levels and according to Fleming and Parle (1977), the uptake of heavy metals varies widely depending on the plant species being studied. They also found out that metal uptake was controlled by such variables like pH, organic matter content and soil type. Generally most of the heavy metals were less available to plants under alkaline conditions than under acid conditions (Hess and Schmid, 2002). The results showed that the BCF value for Cu at BD and NS were greater than unity. This indicated that plant uptake of this metal at the sites were not restricted by pH or other parameters. Zinc also depicted BCF greater than unity at RSG and BN, Pb at UD and Mn at KKR. The high level of these metals in the plant at these sites might be due to direct deposition and foliar absorption more than the translocation from roots to the upper part of the plant.

Conclusion

The results of this study have revealed high levels of heavy metals in the waste soils and *E. indica* from the metropolitan refuse dumpsites. The metals were however within the concentration limits set by USEPA (1986) except Cd which exceeded the set limit (3.0 mg/kg) in all the dumpsites. The result also depicted the concentrations of the metals in the waste soil samples to be higher than the plant samples. The soil-plant transfer ratios (BCF) were less than unity except for Pb (1.27) in UD, Zn (1.06 and 1.12) in RSG and BN, Mn (1.06) in KKR and Cu (1.24 and 1.11) in BD and NS respectively. The BCF for the investigated metals followed the sequence: Zn>Cu>Pb>Mn>Cd>Cr. Soil factors such as pH, electrical conductivity, organic matter and available phosphorus might have contributed to the low absorbability of the metals. The practice of using dumpsites for cultivation of crops should be avoided since plants can bioaccumulate heavy metals into food chain.

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