Research Journal of

Environmental Toxicology

ISSN 1819-3420

Academic Journals Inc.

www.academicjournals.com

OPEN ACCESS Research Journal of Environmental Toxicology

ISSN 1819-3420
DOI: 10.3923/rjet.2017.62.71

Research Article
Health Risk Assessment of Selected Dumpsites in Amata-Akpoha Community Using Cultivated Edible Plants

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Abstract

Background and Objective: In Nigeria, explosion in population growth and technological advancement has led to increase in the generation of high quantity of industrial and domestic solid wastes. These solid wastes are poorly managed in rural and urban communities and in most cases are indiscriminately dumped at arable farm lands where they constitute environmental pollution. The solid wastes undergo decompositions and are burnt in open air during dry seasons. The composts formed are often used by dwellers as manures for cultivation of edible plants. This study investigated the uptake of heavy metals by edible plants cultivated in the vicinity of selected dumpsites in Amata-Akpoha, Afikpo North, Ebonyi State, Nigeria to extrapolate the associated ecological and health risks. **Materials and Methods:** The soil and plant samples were obtained from farmlands in the vicinity of Ezi Mba, Amaozara and Evoekpiri dumpsites in Akpoha and a nearby farm land at Edaka where there was no dumping of waste in the vicinity (control site). The samples were processed and analyzed using standard protocols. Data obtained were analyzed using one way analysis of variance (ANOVA) by SPSS version 9.2 (Inc., Chicago, USA) and significant differences were established at $p<0.05$ using Duncan multiple range test. **Results:** The results obtained showed that the total extractable metals varied significantly ($p<0.05$) from one dumpsite to another and were generally higher in the dumpsites compared to control site. Results of speciation indicated that all the metals studied had more than 65% non-residual fractions except Cu. The mean order of mobility and bioavailability of the metals were: Fe>Zn>Mn>Cd>Pb>Cr>Ni>Cu in the sites. Total mean metal concentration in *Amaranthus hybridus*, *Telfairia occidentalis* and *Talinum triangulare* were significantly higher ($p<0.05$) in the dumpsites samples compared to control site. The different soil-plants transfer indices varied and indicated that the plants have varied potentials for phytoextraction and phytostabilization of the metals. **Conclusion:** The high level of metals in the waste soils indicated anthropogenic inputs and the soil-plants transfer coefficients for the edible plants indicated increased ecological and health risks implications. Hence, there is urgent need for enacting and enforcing policies on regulatory standards.

Key words: Dumpsites, pollution risks, edible plants, soil-plant transfer

Received: January 17, 2017 Accepted: March 10, 2017 Published: March 15, 2017

Citation: Nwogo Ajuka Obasi, Stella Eberechukwu Obasi, Getrude Obianuju Aloh and Emmanuel Okewe Nnachi, 2017. Health risk assessment of selected dumpsites in Amata-Akpoha community using cultivated edible plants. Res. J. Environ. Toxicol., 11: 62-71.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The management of solid wastes is a major environmental problem in most urban and rural centers in Nigeria. In most cases, these wastes comprising mainly paper, food wastes, glass wares, metal scrapes, ceramics and ashes are simply dumped and incinerated recklessly in open fields or farmlands[1,2]. Although, this form of waste when properly composited and processed can be used as fertilizers by farmers, their extensive use as fertilizers for cultivating varieties of edible vegetables and plant based food stuff in most rural and urban centers in Nigeria without proper sorting and processing is worrisome[3-5]. Reports have shown that heavy metals from these wastes can accumulate and persist in soils at level above permissible threshold limits and as such constitute environmental hazards impacting negatively on the ecosystem by being toxic to flora and fauna[4,6,7].

Although, abandoned dumpsites and/or the unprocessed waste soils may be fertile grounds for plants cultivation, these cultivated plants take up varying degrees of metals leading to bioaccumulation in their tissues and hence the ecosystem[5,8]. The toxic effects of these accumulated metals in food chain and food web within the ecosystem have been well documented[9,10]. Most rural and urban dwellers depend largely on the fertility of the waste soils for cultivation of edible vegetables and other plants food stuffs. Thus, there is urgent need for routine assessment of the heavy metal contents of these cultivated plants to ensure their safety and wholesomeness for animal and human consumption[11,12].

Amata-Akpoha community is suburb in Afikpo North L.G.A., Eboyi State, Nigeria. Ezi Mba, Amaozara and Evoekpiri aged dumpsites are the three major dumpsites in Amata-Akpoha community where the residents dump all sorts of their domestic refuse for over the years. The preoccupation of the residents in these areas is farming and they extensively use these dumpsites and their surrounding as arable lands for cultivating varieties of edible vegetables and plant-based foodstuff. Ukpong *et al.*[11] have shown that there may be danger along the food chain and food web for such practices due to the non-biodegradable nature and associated toxic effects of heavy metals, there is need for urgent assessment of these dumpsite soils and the cultivated plant. This study was therefore, aimed at providing baseline data on soil-plant transfer of heavy metals in this area in order to assess the futuristic health risks associated with such practice.

MATERIALS AND METHODS

Refuse waste soil collection: Refuse waste soils were collected within the months of August and September, 2015 from three dumpsites: Ezi Mba, Amaozara and Evoekpiri and from the control site at Edaka, which is a farm land situated within the region. Triplicate sample from each dumpsite and control site were collected 10 m 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 2 mm 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.

Dumpsite/control site plant sample collection: Three cultivated edible plant species within each study location: *Amaranthus hybridus*, *Telfairia occidentalis* and *Talinum triangulare* were obtained and used for the study. A total of 6-10 plant samples of each plant species were randomly uprooted and 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 h 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 min approximately) with tap water and deionized water to remove any soil and surface dust. Plant samples were dried at room temperature for a day, oven dried at 80°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 stored in glass desiccators (Baroda Scientific Glass Works).

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[13]. Soil electrical conductivity was determined using digital electrical conductivity meter (Jenway 615D) at a ratio of 1:2 soil-water suspension with continuous stirring for up to 30 min according to the procedure outlined by Whitney[14]. The soil moisture content was determined according to the procedure outlined in APHA[15] while the cation exchange capacity of the soil samples were determined by ammonium saturation method described by Dewis and Freitas[16]. Organic carbon and organic matter were determined according to the procedure outlined by Osuji and Adesiyan[17] while total nitrogen was determined as described by Yeomans and Bremmer[18]. The SO_4^{2-} was quantified by the procedure described by Butters and Chenery[19] and PO_4^{3-} was determined by procedure described by Olsen and Sommers[20], respectively.

Sequential extraction of heavy metals: The conventional method developed by Tessier *et al.*[21] as outlined with modifications by Obasi[22] was employed for the sequential extraction of heavy metals.

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 Obasi[22] using atomic absorption spectrophotometer (Bulk Scientific Model 210 VGP).

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.*[23]:

$$\text{Translocation Factor (TF)} = \frac{[\text{Metals}]_{\text{shoot}}}{[\text{Metals}]_{\text{root}}} \quad (1)$$

The Biological Concentration Factor (BCF) was calculated as metal concentration ratio of plant roots to soil as described by Yoon *et al.*[24]:

$$\text{Biological Concentration Factor (BCF)} = \frac{[\text{Metals}]_{\text{root}}}{[\text{Metals}]_{\text{soil}}} \quad (2)$$

Biological Accumulation Coefficient (BAC) was calculated as a ratio of heavy metal in shoots to that in soil as described by Li *et al.*[25]:

$$\text{Biological Accumulation Coefficient (BAC)} = \frac{[\text{Metals}]_{\text{shoot}}}{[\text{Metals}]_{\text{soil}}} \quad (3)$$

Statistical analysis: The experimental results were expressed as Mean±Standard Deviation (SD) of triplicate determinations. One way 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 $p<0.05$ using Duncan multiple range test according to Zamani *et al.*[26].

RESULTS

The results of soil physico-chemical properties are shown in Table 1. Results obtained showed that the mean values for the physicochemical parameters were significantly higher ($p<0.05$) in the dumpsites compared to the control site. The results also showed that the carbon:nitrogen ratio obtained in Ezi Mba and Amaozara dumpsites were significantly lower ($p<0.05$) compared to those obtained in Evoekpiri dumpsite and control site. The results of the sequential extractions of the heavy metals are shown in Table 2 and 3. The results indicated that total extractable metals were significantly ($p<0.05$) higher in all the dumpsites compared to the control site. The results indicated that the total extractable Cd, Cu and Mn were higher at Ezi Mba dumpsite compared to other dumpsites studied while that for Pb, Fe, Ni and Cr were higher at Evoekpiri dumpsite compared to other dumpsites studied. Higher percentages (%) of the non-residual fraction were observed for all the metals studied except Cu in all the sites as shown in Table 2 and 3. The mean percentage order of mobility and bioavailability of these metals (Table 2, 3) were: Fe>Zn>Mn>Cd>Pb>Cr>Ni>Cu.

The results of total heavy metals concentration (mg kg^{-1}) in roots and shoots of plant species are shown in Table 4 and 5. Total mean concentration of metals in different parts of *Amaranthus hybridus*, *Telfairia occidentalis* and *Talinum triangulare* were significantly higher ($p<0.05$) in the dumpsites compared to control site. The results also showed that different plant species absorbed metals at varying concentrations in their various parts (Table 4, 5).

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

Sites/parameter	EMD	AOD	EVD	CFA
pH	7.22±0.17^{d}	7.15±0.04^{c}	7.13±0.02^{b}	7.10±0.04^{a}
Electrical conductivity (mS cm^{-1})	2.12±0.05^{b}	2.31±0.07^{d}	2.24±0.13^{c}	1.02±0.05^{a}
Moisture (%)	81.08±0.05^{c}	79.48±0.15^{a}	80.55±0.05^{b}	79.64±0.17^{a}
Cation exchange capacity (cmol kg^{-1})	11.21±0.11^{c}	10.16±0.08^{b}	10.18±0.11^{b}	9.27±0.08^{a}
Total organic carbon (%)	2.51±0.06^{d}	2.37±0.07^{b}	2.43±0.07^{c}	1.32±0.09^{a}
Total organic matter (%)	4.33±0.09^{d}	4.09±0.13^{b}	4.19±0.05^{c}	2.28±0.05^{a}
Total nitrogen (%)	0.38±0.12^{c}	0.35±0.07^{bc}	0.32±0.12^{bc}	0.17±0.11^{a}
PO_4^{3-} (%)	191.67±0.10^{c}	190.50±0.09^{b}	191.03±0.11^{b}	185.24±0.07^{a}
SO_4^{2-} (%)	13.52±0.07^{c}	12.96±0.05^{b}	12.45±0.04^{b}	10.43±0.08^{a}
C:N ratio	6.61^{a}	6.77^{a}	7.59^{b}	7.76^{c}

Values are mean of three (n = 3) replicates±Standard deviation, EMD: Ezi Mba dumpsite, AOD: Amaozara dumpsite, EVD: Evoekpiri dumpsite, CFA: Control farmland Akpoha, Values followed by the same alphabets along the row are not significantly different at p<0.05 using Duncan Multiple Range Test (DMRT)

Table 2: Heavy metals (Cd, Cu, Mn and Pb) concentrations in each fraction of waste soils in studied dumpsites

	Cd				Cu				Mn				Pb			
Sites/fractions	EMD	AOD	EVD	CFA	EMD	AOD	EVD	CFA	EMD	AOD	EVD	CFA	EMD	AOD	EVD	CFA
Exchangeable	4.02±0.02	4.37±0.12	4.46±0.03	0.58±0.01	0.55±0.04	0.38±0.07	0.35±0.02	0.06±0.01	11.90±0.15	11.45±0.03	11.58±0.02	0.52±0.01	6.39±0.07	7.60±0.09	8.15±0.02	0.41±0.02
Acid soluble	3.39±0.03	1.76±0.02	1.83±0.01	0.12±0.01	0.32±0.02	0.25±0.02	0.23±0.03	0.13±0.04	3.24±0.03	2.59±0.11	2.41±0.03	0.38±0.07	3.53±0.02	2.46±0.03	2.99±0.03	0.28±0.03
Reducible	0.69±0.01	0.41±0.04	0.49±0.02	0.13±0.03	3.78±0.05	2.96±0.02	2.93±0.01	0.35±0.02	0.36±0.07	0.47±0.03	0.68±0.01	0.05±0.02	2.21±0.08	2.33±0.11	2.87±0.06	0.15±0.06
Oxidizable	0.62±0.07	0.25±0.05	0.32±0.02	0.11±0.02	2.42±0.13	1.40±0.03	1.37±0.03	0.46±0.05	0.56±0.04	0.65±0.07	0.95±0.02	0.08±0.01	1.10±0.03	0.51±0.02	0.14±0.02	0.11±0.02
Residual	2.97±0.11	2.76±0.11	2.85±0.01	0.17±0.03	6.12±0.03	5.58±0.06	5.18±0.02	1.12±0.03	4.80±0.04	4.95±0.03	4.58±0.03	0.27±0.02	5.61±0.03	5.52±0.13	5.78±0.05	0.38±0.05
Total extractable metals	11.69±0.13^{c}	9.55±0.03^{b}	9.95±0.12^{a}	1.11±0.05^{a}	13.19±0.09^{c}	10.57±0.15^{b}	10.06±0.11^{a}	2.12±0.07^{a}	20.86±0.12^{b}	20.11±0.05^{c}	20.20±0.04^{a}	1.30±0.04^{a}	18.84±0.17^{a}	18.42±0.15^{a}	19.93±0.08^{a}	1.33±0.08^{a}
Non-residual (%)	74.59	71.10	71.36	81.21	53.60	47.21	48.51	47.17	76.99	75.39	77.34	79.23	70.22	70.03	71.00	71.43
Residual (%)	25.41	28.90	28.64	18.79	46.40	52.79	51.49	52.83	23.01	24.61	22.67	20.77	29.78	29.97	29.00	28.57
Mobile phase (%)	63.39	64.19	63.22	63.06	6.60	5.96	5.77	8.96	72.58	69.82	69.23	69.23	52.65	54.61	55.90	51.88

Values are mean of three (n = 3) replicates ± standard deviation, EMD: Ezi mba dumpsite, AOD: Amaozara dumpsite, EVD: Evoekpiri dumpsite, CFA: Control farmland akpoha, Values 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 3: Heavy metals (Zn, Fe, Ni and Cr) concentrations in each fraction of waste soils in studied dumpsites

	Zn				Fe				Ni				Cr			
Sites/fractions	EMD	AOD	EVD	CFA	EMD	AOD	EVD	CFA	EMD	AOD	EVD	CFA	EMD	AOD	EVD	CFA
Exchangeable	42.47±0.05	39.25±0.04	44.72±0.04	4.21±0.04	45.35±0.07	43.18±0.03	46.12±0.05	21.15±0.05	1.25±0.02	1.13±0.11	1.45±0.03	0.41±0.03	3.33±0.02	3.12±0.03	3.86±0.03	0.30±0.03
Acid soluble	38.85±0.11	35.70±0.05	41.05±0.05	2.85±0.05	40.42±0.05	36.45±0.05	41.07±0.02	9.83±0.02	1.07±0.04	0.98±0.06	1.24±0.09	0.32±0.09	2.97±0.07	2.53±0.05	3.04±0.02	0.18±0.02
Reducible	5.32±0.06	4.03±0.03	4.56±0.05	0.43±0.05	3.85 ±0.03	3.45±0.11	4.02±0.03	1.06±0.03	0.53±0.08	0.58±0.03	0.61±0.05	0.22±0.05	1.40±0.04	1.21±0.07	1.33±0.05	0.05±0.05
Oxidizable	7.64±0.03	5.11±0.07	5.14±0.03	0.86±0.03	2.70±0.09	2.67±0.02	3.18±0.05	0.98±0.05	0.72±0.05	0.65±0.05	0.90±0.04	0.23±0.04	1.82±0.05	1.75±0.05	2.01±0.04	0.21±0.04
Residual	18.50±0.33	18.72±0.15	21.86±0.17	1.46±0.17	22.45±0.17	21.86±0.08	23.59±0.09	8.73±0.09	1.83±0.05	1.57±0.06	2.03±0.02	0.54±0.02	4.18±0.07	3.62±0.02	4.66±0.06	0.31±0.06
Total extractable metals	112.78±0.15^{c}	102.81±0.09^{b}	117.33±0.13^{a}	9.81±0.13^{a}	114.77±0.23^{c}	107.61±0.17^{a}	117.98±0.07^{b}	41.75±0.07^{b}	5.40±0.05^{b}	4.91±0.02^{b}	6.23±0.11^{a}	1.72±0.11^{a}	13.70±0.07^{b}	12.23±0.15^{c}	14.90±0.04^{a}	1.05±0.04^{a}
Non-residual (%)	83.60	81.79	81.37	85.12	80.44	79.68	80.00	79.09	66.11	68.02	68.39	68.39	69.49	70.40	68.72	70.48
RESIDUAL (%)	16.40	18.21	18.63	14.88	19.56	20.31	20.00	20.91	33.89	31.98	31.61	31.61	30.51	29.60	31.28	29.52
Mobile phase (%)	72.10	72.90	73.10	71.96	74.73	74.00	73.90	73.20	42.96	42.97	43.18	42.58	45.99	46.20	46.31	45.71

Values are mean of three (n = 3) replicates ± standard deviation, EMD: Ezi Mba dumpsite, AOD: Amaozara dumpsite, EVD: Evoekpiri dumpsite, CFA: Control farmland akpoha, Values 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 4: Total heavy metals (Cd, Cu and Mn) concentration (mg kg^{-1}) in roots and shoots of plant species in the studied sites

	Plant species					
	Amaranthus hybridus		*Telfairia occidentalis*		*Talinum triangulare*	
Sites	Roots	Shoots	Roots	Shoots	Roots	Shoots
Cd						
EMD	21.50±0.13	38.74±0.03	39.15±0.05	66.18±0.04	34.67±0.09	76.25±0.11
AOD	18.36±0.05	37.42±0.07	36.94±0.05	60.23±0.17	30.11±0.03	47.75±0.03
EVD	20.63±0.01	32.71±0.03	27.82±0.03	58.65±0.06	25.86±0.03	56.89±0.13
CFA	2.94±0.01	6.11±0.02	1.21±0.03	4.08±0.07	3.06±0.03	4.89±0.07
Cu						
EMD	15.64±0.07	13.86±0.05	11.09±0.02	9.42±0.06	27.98±0.09	13.18±0.07
AOD	13.93±0.09	10.72±0.11	13.80±0.06	9.11±0.05	26.36±0.05	10.95±0.12
EVD	16.92±0.05	14.23±0.03	11.92±0.06	10.12±0.02	29.07±0.02	14.62±0.11
CFA	4.04±0.03	2.76±0.03	4.07±0.02	3.02±0.02	4.78±0.07	1.42±0.05
Mn						
EMD	3.68±0.11	8.44±0.09	4.96±0.03	9.12±0.07	4.76±0.06	9.87±0.9
AOD	3.16±0.07	7.64±0.03	3.14±0.11	7.09±0.05	3.66±0.07	9.54±0.05
EVD	37.24±0.02	8.26±0.01	5.67±0.09	8.13±0.03	5.69±0.07	10.65±0.11
CFA	1.21±0.01	3.88±0.01	0.96±0.03	1.85±0.03	0.74±0.11	1.94±0.04
Pb						
EMD	12.68±0.11	8.12±0.07	9.78±0.09	6.92±0.21	20.84±0.03	28.57±0.03
AOD	14.32±0.07	7.52±0.11	7.03±0.07	4.58±0.09	12.76±0.11	25.43±0.09
EVD	13.79±0.02	8.68±0.03	8.82±0.08	7.17±0.13	18.42±0.05	27.31±0.04
CFA	0.84±0.03	0.67±0.05	1.15±0.11	0.99±0.11	1.32±0.03	1.89±0.05

Values are mean of three (n = 3) replicates±standard deviation, EMD: Ezi Mba dumpsite, AOD: Amaozara dumpsite, EVD: Evoekpiri dumpsite, CFA: Control farmland Akpoha

Table 5: Total heavy metals (Zn, Fe and Ni) concentration (mg kg^{-1}) in roots and shoots of plant species in the studied sites

	Plant species					
	Amaranthus hybridus		*Telfairia occidentalis*		*Talinum triangulare*	
Sites	Roots	Shoots	Roots	Shoots	Roots	Shoots
Zn						
EMD	12.86±0.05	39.05±0.13	20.56±0.05	40.27±0.07	22.76±0.15	46.86±0.17
AOD	11.78±0.17	28.76±0.06	12.44±0.10	25.17±0.13	13.94±0.09	27.43±0.09
EVD	13.92±0.07	36.75±0.03	19.73±0.04	32.88±0.07	23.91±0.42	37.95±0.13
CFA	1.18±0.05	3.66±0.02	1.68±0.03	4.09±0.11	1.75±0.09	4.27±0.21
Fe						
EMD	82.97±0.05	137.99±0.05	63.65±0.05	96.89±0.13	80.68±0.13	141.45±0.21
AOD	88.65±0.11	133.54±0.11	69.18±0.06	129.87±0.11	89.75±0.11	142.77±0.17
EVD	92.14±0.03	146.27±0.07	84.17±0.03	142.11±0.07	93.59±0.05	157.13±0.09
CFA	1.12±0.05	2.94±0.03	1.03±0.05	2.94±0.07	1.34±0.05	3.57±0.09
Ni						
EMD	2.62±0.21	4.98±0.0.7	2.33±0.05	4.86±0.09	3.23±0.09	6.89±0.11
AOD	2.17±0.11	5.86±0.05	2.46±0.11	5.21±0.21	2.89±0.10	6.31±0.21
EVD	3.04±0.03	5.27±0.07	2.87±0.03	5.36±0.07	3.72±0.05	7.03±0.09
CFA	1.12±0.05	2.94±0.03	1.03±0.05	2.94±0.07	1.34±0.05	3.57±0.09
Cr						
EMD	6.87±0.11	14.55±0.17	10.15±0.10	17.88±0.05	8.98±0.07	18.73±0.11
AOD	6.13±0.08	13.98±0.21	8.34±0.13	14.44±0.13	11.56±0.05	23.94±0.21
EVD	7.18±0.17	14.66±0.06	10.84±0.10	16.87±0.13	10.94±0.09	21.63±0.09
CFA	0.74±0.13	2.07±0.05	1.79±0.05	3.05±0.09	0.92±0.03	2.45±0.05

Values are mean of three (n = 3) replicates±standard deviation, EMD: Ezi Mba dumpsite, AOD: Amaozara dumpsite, EVD: Evoekpiri dumpsite, CFA: Control farmland akpoha

The results (Fig. 1) indicated that Translocation Factor (TF) values vary from one plant species to another and from one heavy metal to another. The results indicated that *T. triangulare* had TF>1 for all the metals while *A. hybridus* and *T. occidentalis* had TF>1 for all the metals except Cu and Pb in all the sites (Fig. 1). Figure 2 shows the results of

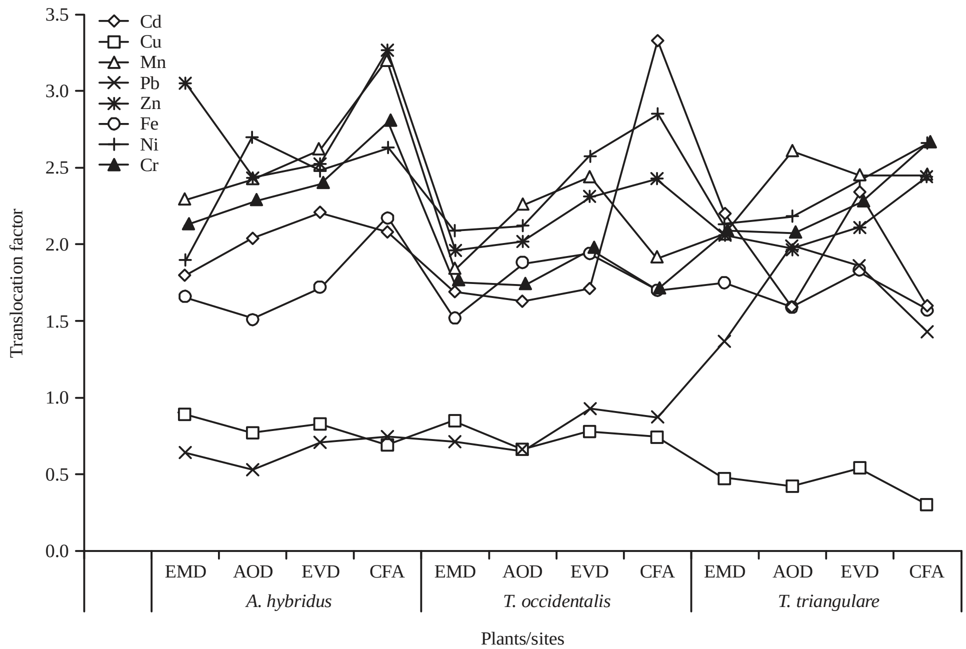

Fig. 1: Translocation factor of plants for all the metals in the studies sites

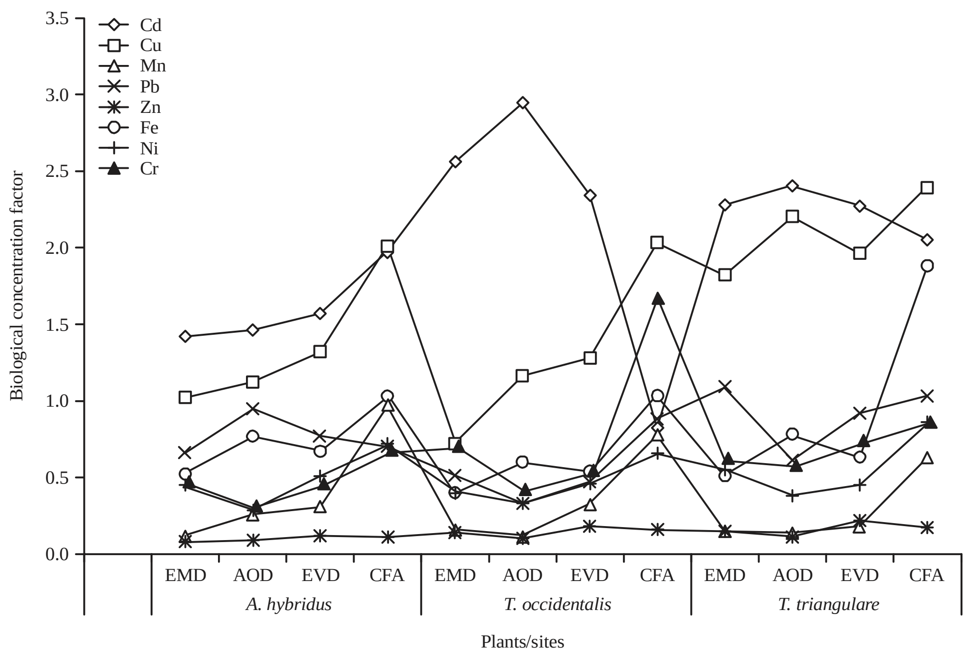

Fig. 2: Biological concentration factor of plant for all the metals in the studied sites

Biological Concentration Factor (BCF) of the three plant species for the different metals. The results (Fig. 2) showed that all the plants had BCF>1 for Cd and Cu only in all the sites and that the BCF of the plants was always higher in control sites than in dumpsites. The results of Biological Accumulation Coefficient (BAC) are shown in Fig. 3. The results (Fig. 3) showed that all the plants had BAC>1 for Cd in all the sites with the plants in the control sites having higher BAC values than those in the dumpsites in all cases.

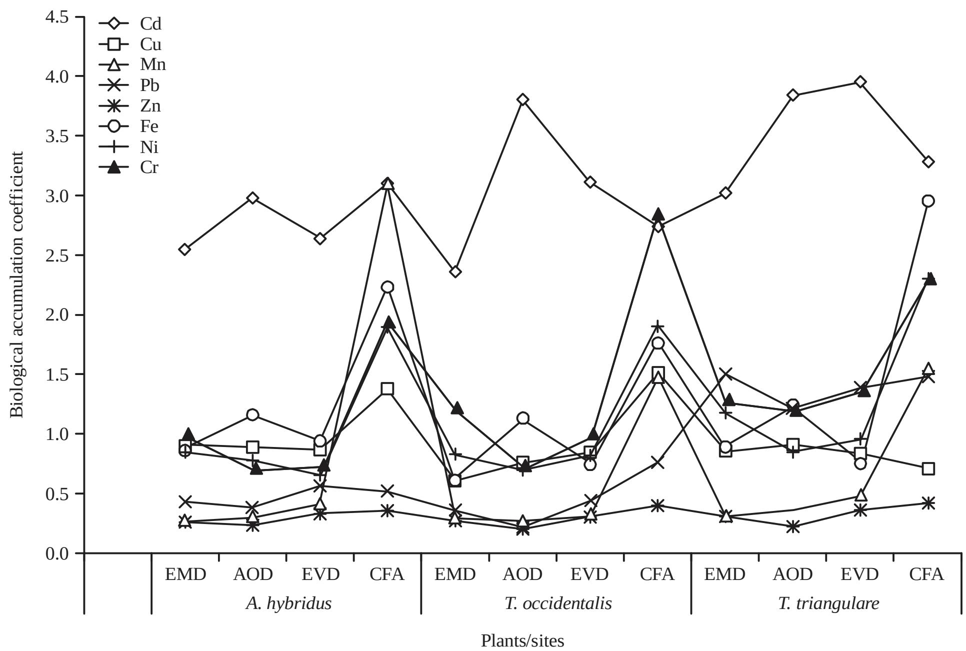

Fig. 3: Biological accumulation coefficient of plants for all the metals in the studies sites

DISCUSSION

The results indicated that the dumpsites soils were slightly alkaline (Table 1). This high pH may contribute to the properties exhibited by the soils as similarly reported for dumpsites[27,3,4]. The results are an indication that there were high soluble salts in the soil and this may be due to the presence of metal scraps in the refuse dumpsite[28-30]. The moisture content (Table 1) revealed the overall climatic condition of the area under study while the fertility of the soil may in part be attributed to the fact that the cation exchange capacity fall within permissible range for agricultural lands[31]. The results showed high mean percentages of Total Organic Carbon (TOC) and Total Organic Matter (TOM) comparable to those reported by De Araujo *et al*.[32] as such showed that the soils may serve as an important indicator of a rooting environment[33]. The relative high values of total nitrogen, PO_4^{3-}, SO_4^{2-} and the high ratio of carbon to nitrogen (C:N) (Table 1) implicated the overall fertility of the soils and as such indicated the soils would support plant species diversity and growth[33,34].

The high values of total extractable metals (Table 2, 3) may be attributed to different metals containing wastes such as cadmium and lead acid batteries, metal scraps among others in the dumpsites. However, these total extractable metals fell below the permissible limits allowable for agricultural lands except for Cd and Cr[35-38]. The high percentage of Fe and Zn in the mobile fractions suggests that these metals in these soils were potentially more bioavailable for plants uptake[30,39,40]. The strong association of Cu in the residual phase (i.e., bound to silicates and detrital materials) showed that they may be found in organic copper complexes as reported by Chinwe *et al*.[41]. High percentage of Fe, Zn, Mn, Cd and Pb, in the mobile phase (exchangeable and acid soluble phases) indicates high bio-availability and higher risks to the ecosystem[42]. High levels of Ni and Cr in the residual and oxidizable fractions (Table 2, 3) indicated alkaline stabilization process of the soils which may be due to the high pH and this may have led to formation of organic complex that may have impaired their mobility[43,44].

The results (Table 4, 5) showed that differences in plant species significantly ($p<0.05$) influenced the rate of their metal uptake, storage and distribution to various parts. This may be attributed to the genetic variability in the plant species[45-47] and the metal distribution in the environment[48,22]. The rate of metal uptake by plant species make them vary in their potentials for phytoaccumulation, photostabilization and phytoextarction[49,50] and those that accumulate high level of metals may have evolved mechanisms that could enhance its phyto-accumulation potentials and metal detoxification[51,52]. The accumulation of relatively high amount of metals (Table 4, 5) by these edible plants could be hazardous if the farmers depend on these plants as their source of food for a long period of time as the metals would be introduced to the ecosystem via food chain and food web. Although, observed metal accumulation value in this study did not exceed the established critical permissible limits, ecological and health risks may occur at the long run[53,54].

Translocation Factors (TF), Biological Concentration Factors (BCF) and Biological Accumulation Coefficient (BAC) are used to evaluate the potentials of plant species for phytoextraction, phytostabilization and phyto-remediation respectively when their critical values greater than one (>1)[23-25]. High root to shoot translocation (TF>1) (Fig. 1) is an indication that *Amaranthus hybridus*, *Telfairia occidentalis* and *Talinum triangulare* have vital characteristics to be used in phyto-extraction under the studied conditions[47,50]. These results (Fig. 1) may be attributed to the physicochemical properties of the dumpsite soils and the ability of the plants to developed metal detoxification mechanisms[47,23]. These plant species are able to translocate heavy metals to easily harvestable parts (shoots) and as such may be used for phyto extractions of these metals studied[23-25,30,40]. Previous study has shown that elevated concentration of heavy metals in roots of plants species and low translocation into above ground parts (BCF) make them suitable for phyto-stabilization[47]. The implication of the BCF values obtained in these study (Fig. 2) where the plant species had BCF>1 and TF<1 may be useful for phyto-stabilization of one, two or more of the metal contaminants in the study area. Plants that accumulate up to 1000 mg kg^{-1} of metal and above are said to be hyper-accumulators[46] and usually, they have well-developed cellular mechanisms for heavy metal detoxification and tolerance. The BAC>1 is used as an indicator to show plants species that accumulate high level of heavy metals[47]. The results of BAC values (Fig. 3) showed that the plants exhibited varying levels of phyto-accumulation potentials, although, none could be said to be a hyper-accumulator of any of the metals since they were all below threshold set limit of 1000 mg kg^{-1}. In general, this study revealed that the dumpsites were polluted fertile soils from where heavy metals can enter into the ecosystem via food chain and food web. The toxic effects of these metals may be encountered at the long run when animals including humans depend largely on edible vegetables and plants based food stuffs cultivated on these dumpsites. This study also showed that plants that grow and flourish in dumpsites soils are capable of transferring these heavy metals to their area parts. Thus, dumpsite plants could be used as phyto-extractors for heavy metals remediation purposes. The practices of using dumpsites and/or the wastes soils for arable farming due to their organic manure contents should be discouraged to avert the multiple effects of heavy metal toxicity. Further, enacting and/or enforcing policies on regulatory standards are needful. Further research should be focused on the communal health effects of long term consumption of plants based food stuff from farmlands in dumpsites vicinity.

CONCLUSION

The high level of metals in the Ezi Mba, Amaozara and Evoekpiri waste soils in Amata-Akpoha, Afikpo North, Ebonyi State, South-East, Nigeria indicated anthropogenic inputs and the soil-plants transfer coefficients for the edible plants indicated increased ecological and health risks implications. Hence, there is urgent need for enacting and enforcing policies on regulatory standards. Dependence on edible and medicinal plants cultivated on dumpsites as sources of plant-based foodstuff need further investigation to avert the multiple effects of metal toxicity since these results showed high level of soil-plants transfer coefficients for toxic metals.

SIGNIFICANCE STATEMENTS

This study discovered high anthropogenic input of Cd, Cu, Mn, Pb, Zn, Fe, Ni and Cr in farmlands within the vicinity of Ezi Mba, Amaozara and Evoekpiri dumpsites in Amata-Akpoha, Afikpo North L.G.A., Ebonyi State, Nigeria. This study also revealed that these heavy metals were taken up by cultivated edible plants (*Amaranthus hybridus*, *Telfairia occidentalis* and *Talinum triangulare*) in the farmlands at quantities above threshold their limits. Thus, the ecological and health effects of these heavy metals in populations consuming these vegetables around the study area can be estimated. The findings of this study will help policy makers and environmentalist in putting forward and enforcing legislations guiding the management and disposal of communal solid wastes and cultivation of edible food crops in farmlands near dumpsites.

ACKNOWLEDGMENTS

The authors are grateful to Prof. Emmanuel Iroha Akubugwo (Abia State University Uturu, Nigeria) for his technical assistance and to Venerable Dr Ogbonnia Ibe-Enwo (Rector, Akanu Ibiam Federal Polytechnic Unwana, Nigeria) for providing necessary facilities and reagent for carrying out this study.

REFERENCES

1. Ogwueleka, T.C., 2009. Municipal solid waste characteristics and management in Nigeria. Iran. J. Environ. Health Sci. Eng., 6: 173-180.
2. Salam, A., 2010. Environmental and Health Impact of Solid Waste Disposal at Mangwaneni Dumpsite in Manzini: Swaziland. J. Sustainable Dev. Afr., 12: 64-78.

3. Obasi, N.A., E.I. Akubugwo, O.C. Ugbogu and G.C. Chinyere, 2012. 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. Niger. J. Biochem. Mol. Biol., 27: 27-45.
4. Obasi, N.A., S.O. Elom, C.O. Edeogu, C.O. Alisa and S.E. Obasi, 2014. Soil environmental metals speciation and associated health risks in selected edible leafy plants on Amaechi and Four-corner dumpsites in Enugu of Enugu State, Nigeria. Int. J. Life Sci. Biotechnol. Pharm. Res., 3: 152-165.
5. Ebong, G.A., M.M. Akpan and V.N. Mkpenie, 2008. Heavy metal contents of municipal and rural dumpsite soils and rate of accumulation by *Carica Papaya* and *Talinum triangulare* in Uyo, Nigeria. E-J. Chem., 5: 281-290.
6. Krissanakriangkrai, O., W. Suparpacboon, S. Juwa, S. Chacwong and W. Swaddiwudhipong, 2009. Bioavailable cadmium in water, sediment and fish, in a highly contaminated area on the Thai-Myanmay border. Thammasat Int. J. Sci. Technol., 14: 60-68.
7. Ozturk, M., G. Ozozen, O. Minareci and E. Minareci, 2009. Determination of heavy metals in fish, water and sediments of Avsar dam lake in Turkey. Iran. J. Environ. Health Sci. Eng., 6: 73-80.
8. Bortey-Sam, N., S.M.M. Nakayama, Y. Ikenaka, O. Akoto, E. Baidoo, H. Mizukawa and M. Ishizuka, 2015. Health risk assessment of heavy metals and metalloid in drinking water from communities near gold mines in Tarkwa, Ghana. Environ. Monit. Assess., Vol. 187. 10.1007/s10661-015-4630-3.
9. Sun, H.F., Y.H. Li, Y.F. Ji, L.S. Yang, W.Y. Wang and H.R. Li, 2010. Environmental contamination and health hazard of lead and cadmium around Chatian mercury mining deposit in Western Hunan Province, China. Trans. Nonferrous Met. Soc. China, 20: 308-314.
10. Zhuang, P., B. Zou, N.Y. Li and Z.A. Li, 2009. Heavy metal contamination in soils and food crops around Dabaoshan mine in Guangdong, China: Implication for human health. Environ. Geochem. Health, 31: 707-715.
11. Ukpong, E.C., R.E. Antigha and E.O. Moses, 2013. Assessment of heavy metals content in soils and plants around waste dumpsites in Uyo Metropolis, Akwa Ibom State. Int. J. Eng. Sci., 2: 75-86.
12. Adelekan, B.A. and A.O. Alawode, 2011. Contributions of municipal refuse dumps to heavy metals concentrations in soil profile and groundwater in Ibadan Nigeria. J. Applied Biosci., 40: 2727-2737.
13. Bates, R.G., 1954. Electromeric pH determinations. John Willey and Sons Inc., New York.
14. Whitney, D.A., 1998. Micronutrients: Zinc, Iron, Manganese and Copper. In: Recommended Chemical Soil Test Procedures for the North Central Region, Brown, J.R. (Ed.). Missouri Agriculture Experiment Station, Missouri, pp: 41-44.
15. Rice, E.W., R.B. Baird, A.D. Eaton and L.S. Clesceri, 2012. Standard Methods of Examination of water and Wastewater. 22nd Edn., American Public Health Association, Washington, DC., USA., Pages: 1360.
16. Dewis, J. and F. Fertias, 1970. Physical and Chemical Methods of Soil and Water Analysis. Food and Agricultural Organizations of the United Nations, Rome, Italy, Pages: 275.
17. Osuji, L.C. and S.O. Adesiyan, 2005. The Isiokpo oil-pipeline leakage: Total organic carbon/organic matter contents of affected soils. Chem. Biodivers., 2: 1079-1085.
18. Yeomans, J.C. and J.M. Bremmer, 1991. Carbon and nitrogen analysis of soils by automated combustion techniques. Commun. Soil Sci. Plant Anal., 22: 843-850.
19. Butters, B. and E.M. Chenery, 1959. Determination of sulphate in soil, plant materials and water by the turbidimetric method. Anal. Lond., 84: 239-242.
20. Olsen, S.R. and L.E. Sommers, 1982. Determination of Available Phosphorus. In: Methods of Soil Analysis, Page, A.L., R.H. Miller and D.R. Keeney, (Eds.). American Society of Agronomy, Madison, USA., pp: 403-407.
21. Tessier, A., P.G.C. Campbel and M. Blisson, 1979. Sequential extraction procedure for the speciation of particulate trace metals. Anal. Chem., 51: 844-851.
22. Obasi, N.A., 2012. Biochemical studies on soil and air quality assessment of dumpsites on the Enugu-PortHarcourt Expressway, South-East, Nigeria. Ph.D. Thesis, Abia State University Uturu (ABSU), Nigeria.
23. Cui, S., Q. Zhou and L. Chao, 2007. Potential hyperaccumulation of Pb, Zn, Cu and Cd in endurant plants distributed in an old smeltery, Northeast China. Environ. Geol., 51: 1043-1048.
24. Yoon, J., X. Cao, Q. Zhou and L.Q. Ma, 2006. Accumulation of Pb, Cu and Zn in native plants growing on a contaminated Florida site. Sci. Total Environ., 368: 456-464.
25. Li, M.S., Y.P. Luo and Z.Y. Su, 2007. Heavy metal concentrations in soils and plant accumulation in a restored manganese mineland in Guangxi, South China. Environ. Pollut., 147: 168-175.
26. Zamani, A.A., M.R. Yaftian and A. Parizanganeh, 2012. Multivariate statistical assessment of heavy metal pollution sources of groundwater around a lead and zinc plant. Iranian J. Environ. Health Sci. Eng., Vol. 9. 10.1186/1735-2746-9-29.
27. Uba, S., A. Uzairu, G.F.S. Harrison, M.L. Balarabe and O.J. Okunola, 2008. Assessment of heavy metals bioavailability in dumpsites of Zaira Metropolis, Nigeria. Afr. J. Biotechnol., 7: 122-130.
28. Awokunmi, E.E., S.S. Asaolu and K.O. Ipinmoroti, 2010. Effect of leaching on heavy metals concentration of soil in some dumpsites. Afr. J. Environ. Sci. Technol., 4: 495-499.

29. Olayiwola, H.A., L. Abudulawal, G.K. Adewuyi and M.O. Azeez, 2017. Heavy metal contents in soil and plants at dumpsites: A case study of Awotan and Ajakanga dumpsite Ibadan, Oyo State, Nigeria. J. Environ. Earth Sci., 7: 11-24.
30. Obasi, S.E., N.A. Obasi, U.A. Dike and R.I. Igbolekwu, 2016. Assessment of physicochemical properties and heavy metals contents in selected dumpsites in Afikpo, Afikpo North, Ebonyi State, Nigeria. IRA-Int. J. Applied Sci., 4: 519-529.
31. Zhanbin, L., Z. Qinling and L. Peng, 2013. Distribution characteristics of available trace elements in soil from a reclaimed land in a mining area of north Shaanxi, China. Int. Soil Water Conserv. Res., 1: 65-75.
32. De Araujo, A.S.F., N. Eisenhauer, L.A.P.L. Nunes, L.F.C. Leite and S. Cesarz, 2015. Soil surface active fauna in degraded and restored lands of northeast Brazil. Land Degrad. Dev., 26: 1-8.
33. Sun, Q.B., C.Q. Yin, J.F. Deng and D.F. Zhang, 2013. Characteristics of soil-vegetable pollution of heavy metals and health risk assessment in Daye mining area. Environ. Chem., 32: 671-677.
34. Obute, G.C., B.C. Ndukwu and E. Eze, 2010. Changes in species diversity and physico-chemical properties of plants in abandoned dumpsites in parts of Por-Harcourt, Nigeria. Scient. Afr., 9: 181-193.
35. CCME., 1991. Interim Canadian environmental quality criteria for contaminated sites. Report CCME EPC-C534, September 1991, Canadian Council of Ministers of the Environment, Canada.
36. MAFF., 1992. Code of good agricultural practice for the protection of soil. Ministry of Agricultural, Forestry and Fisheries (MAFF) Welch Office Agriculture Department, Draft Consultation Document, London.
37. CEC., 1986. Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment and in particular of the soil, when sewage sludge is used in agriculture. Official J. Eur. Community, L181: 6-12.
38. USEPA., 1986. Test Methods of Evaluation of Solid Waste. In: Contaminated Land Policies in Some Industrialized Countries, Visser, W.J.F. (Ed.). United State Environmental Protection Agency, Washington, DC., USA.
39. Gupta, A.K. and S. Sinha, 2006. Chemical fractionation and heavy metal accumulation in the plant of *Sesamum indicum* (L.) var. T55 grown on soil amended with tannery sludge: Selection of single extractants. Chemosphere, 64: 161-173.
40. Obasi, N.A., S.E. Obasi, R.I. Igbolekwu, O.J. Nkama and S.O. Eluu, 2015. Health risk assessment of the quality of plants cultivated around Eluogo and Agboogo Ibii aged dumpsites in Ibii, Afikpo North L.G.A. of Ebonyi State, Nigeria. Am. J. Environ. Eng. Sci., 2: 100-108.
41. Chinwe, O.U., C.N. Obinna, A. Akeem and B.I. Alo, 2010. Assessment of heavy metals in urban highway runoff from Ikorodu expressway Lagos, Nigeria. J. Environ. Chem. Ecotoxicol., 2: 34-37.
42. Wang, Y., Q. Zhao, Y. Hu, X. Du, W. Ge and W. Liu, 2011. Survey and contamination assessment of heavy metals in soil and plants around the Pb/Zn mine in Shangyu, Zhengjiang province. Environ. Chem., 30: 1354-1360.
43. Luter, L., A. Terngu and S. Attah, 2011. Heavy metals in soils of auto-mechanic shops and refuse dumpsites in Makurdi Nigeria. J. Applied Sci. Environ. Manage., 15: 207-212.
44. Obasi, N.A., E.I. Akubugwo, K.M. Kalu, A.E. Ugbogu and U.C. Okorie, 2013. Toxicological assessment of various metals on selected edible leafy plants of Umuka and Ubahu dumpsites in Okigwe of Imo State, Nigeria. J. Exp. Biol. Agric. Sci., 1: 441-453.
45. Cao, H., J. Chen, J. Zhang, H. Zhang, L. Qiao and Y. Men, 2010. Heavy metals in rice and garden vegetables and their potential health risks to inhabitants in the vicinity of an industrial zone in Jiangsu, China. J. Environ. Sci., 22: 1792-1799.
46. Messou, A., L. Coulibaly, L. Doumbia and G. Gourene, 2013. Plants diversity and phytoaccumulators identification on the Akouedo landfill (Abidjan, Côte d'Ivoire). Afr. J. Biotechnol., 12: 253-264.
47. Jadia, C.D. and M.H. Fulekar, 2009. Phytoremediation of heavy metals: Recent techniques. Afr. J. Biotechnol., 8: 921-928.
48. Ebong, G.A., M.M. Akpan and V.N. Mkpenie, 2008. Heavy metal contents of municipal and rural dumpsite soils and rate of accumulation by *Carica Papaya* and *Talinum triangulare* in Uyo, Nigeria. E-J. Chem., 5: 281-290.
49. Ayari, F., H. Hamdi, N. Jedidi, N. Gharbi and R. Kossai, 2010. Heavy metal distribution in soil and plant in municipal solid waste compost amended plots. Int. J. Environ. Sci. Technol., 7: 465-472.
50. Malik, R.N., S.Z. Husain and I. Nazir, 2010. Heavy metal contamination and accumulation in soil and wild plant species from industrial area of Islamabad, Pakistan. Pak. J. Bot., 42: 291-301.
51. Vamerali, T., M. Bandiera and G. Mosca, 2010. Field crops for phytoremediation of metal-contaminated land. A review. Environ. Chem. Lett., 8: 1-17.
52. Oh, K., T. Cao, T. Li and H. Cheng, 2014. Study on application of phytoremediation technology in management and remediation of contaminated soils. J. Clean Energy Technol., 2: 216-220.
53. Li, Q.S., Y. Chen, H.B. Fu, Z.H. Cui, L. Shi, L.L. Wang and Z.F. Liu, 2012. Health risk of heavy metals in food crops grown on reclaimed tidal flat soil in the Pearl River Estuary, China. J. Hazard. Mater., 227: 148-154.
54. Su, C., L.Q. Jiang and W.J. Zhan, 2014. A review on heavy metal contamination in the soil worldwide: Situation, impact and remediation techniques. Environ. Skeptics Critics, 3: 24-38.