Metal levels in some refuse dump soils and plants in Ghana

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ABSTRACT

Concentrations of Cd, Hg, Pb, Cr, Fe, Co, Ni, Cu, Zn, Mo and As were determined in soils and leaves of plants from refuse dumpsites and background soils in two cities, a municipality and a rural community in Ghana, using a ThermoFinnigan Element 2 high resolution inductively coupled plasma mass spectrometric (HR-ICP-MS) instrument. The refuse dump soils were classified between 'Uncontaminated to Moderate' and 'Strongly Contaminated'. Pollution levels for Cd (I_{geo} = 2.06–2.40) and Zn (I_{geo} = 2.95–3.36) were higher than of the other metals. The refuse dump soil from the rural community was the least polluted with the metals. Fe and Ni loads in plants from the refuse dump soils in the cities and the municipality were beyond the normal ranges of 40–500 μg/g (Fe) and 0.02–5.00 μg/g (Ni). Transfer ratios for Cd, Hg, Cu, Zn and Pb and Fe of plants from the background soils were higher than those from the refuse dump soils, which might be due to the higher levels of organic matter, pH, phosphate, Ca and Mg in the refuse dump soils.

Keywords: metal; refuse dump soil; Geoaccumulation index(I_{geo}); transfer ratio

The global rise in human population is impacting negatively on the availability of land for farming, especially in the urban and peri-urban settlements. Fertile lands in these settlements are being used for building and other industrial activities. Old dumpsites have become an ideal site for farming activities. In Ghana, it is observed that plants grown in these sites perform better compared to the surrounding areas. Dumpsites are known to be rich in soil nutrients for plant growth and development because decayed and composted wastes enhance soil fertility (Ogunyemi et al. 2003). Dumpsite soils are also used to fill poly-bags and nursery pots to grow seedlings. Dumpsites, especially in most third world countries, comprise of a higher proportion (50–90%) of organic materials (Asomani-Boateng and Murray 1999); however, a considerable proportions of plastic, paper, metal rubbish and batteries which are known to be sources of metals which may be hazardous to man and his environment are also present (Alloway and Ayres 1997, Pasquini and Alexander 2004, Woodbury 2005). These metals are not biodegradable and have toxic effects on living organisms at certain level of concentration. Exposure of man to such metals may cause blood and bone disorders, kidney damage and decreased mental capacity and neurological damage (NIEHS 2004).

Crops absorb whatever is present in the soil medium and therefore these hazardous metals are also absorbed and become bioaccumulated in the roots, stems, fruits, grains and leaves of the crops (Fatoki 2000), which may finally be transferred to man in the food chain.

Plants grown in some dumpsites of Nigeria were found to contain higher levels of metals (Oviasogie et al. 2007, Ebong et al. 2008); in Ghana, an experiment carried out on three waste dumpsites in Kumasi, where vegetable cultivation (cabbage, lettuce and spring onions) is practiced, found the levels of the two most toxic metals, i.e. cadmium and lead, to be far higher in the vegetables than the WHO/FAO recommended values (Odai et al. 2008).

The assessment of dumpsite soils for the concentration levels of hazardous metals is imperative for healthy crop production.

The current study was therefore carried out to assess the concentration levels of some hazardous metals in soils and some plants in selected urban and rural dumpsites in Ghana.

MATERIALS AND METHODS

Study area. Dumpsites located at four different parts of Ghana were used for the study. The dumpsites were located at Medina in Accra – the capital of Ghana, Medoma in Kumasi – the second largest city in Ghana, Tunsuom in Mampong – a municipal capital and Adidwan a rural setting about 24 km from Mampong (Figure 1). All the dumpsites were semi-abandoned. Soil and plant samples were collected from these dumpsites between February and April, 2007.

Sample collection. Soil samples were picked at 0–15 cm depth with a soil auger. At each of the dumpsites ten representative soil cores were picked and placed in poly-bags. The leaves and branches of two common plants at the dumpsites, *Eleusine indica* (L.) Gaertn. and *Sida acuta* Burm. F. were also sampled. The procedure was repeated for soil and plant samples taken in about 1 km from the dumpsites with no dumping activities; these represented the background samples. The samples were shade-dried and crushed in a porcelain mortar to pass through a 2 mm mesh and placed in drug poly-bags of 7 cm × 10 cm size, labeled and sealed. These prepared samples were sent to Norway for the analyses of some metals.

Analyses of some chemical properties of soil samples. Prior to the assessment of the metals, some chemical properties of the samples were determined at the Soil Research Institute at Kwadaso – Kumasi, Ghana. Organic matter was determined using the wet oxidation method (Walkley-Black 1934). The total nitrogen was determined by the Micro Kjeldahl (Anderson and Ingram 1989). Available P was determined by the Bray 1 method, and the total exchangeable calcium and magnesium were determined by EDTA titration method, while potassium and sodium were assessed using a flame photometer (IITA 1985). The pH (H_2O) of the soil samples was also measured (Rowel 1994).

Sample preparation and analyses of metals. The sample preparation was carried out at the Norwegian Institute of Life Sciences, Department of Plant and Environmental Science, Ås.

Both plant and soil samples were ground into fine powder. 0.3 g portions of the samples were weighed accurately and 3.0 cm^3 concentrated HNO_3 and 0.1 cm^3 internal standard solution containing 1.0 mg/dm^3 of Rh, Ir, Ga and Y were added to each. The samples were digested in a Milestone UltraClave High Performance Microwave Reactor (Shelton, USA) system and diluted to 70 cm^3 with deionized water (18.2 MΩ cm). External calibration was made with acid-matrix matched multi-elemental standard solutions.

The analyses were carried out at the National Institute of Occupational Health, NIOH, Oslo, Norway. The samples were analysed to determine Cd, Hg, Pb, Cr, Fe, Co, Ni, Cu, Zn, Mo and As by a ThermoFinnigan Element 2 (Bremen, Germany) high resolution inductively coupled plasma mass spectrometric (HR-ICP-MS) instrument.

For quality of the analytical procedure used for assessing the elemental composition of plant and soil samples, three different certified reference materials were used: (1) Bush and Leaves, NCS DC 73348. (2) Poplar, NCS DC 73348. (3) Energy Grass, NJV 944.

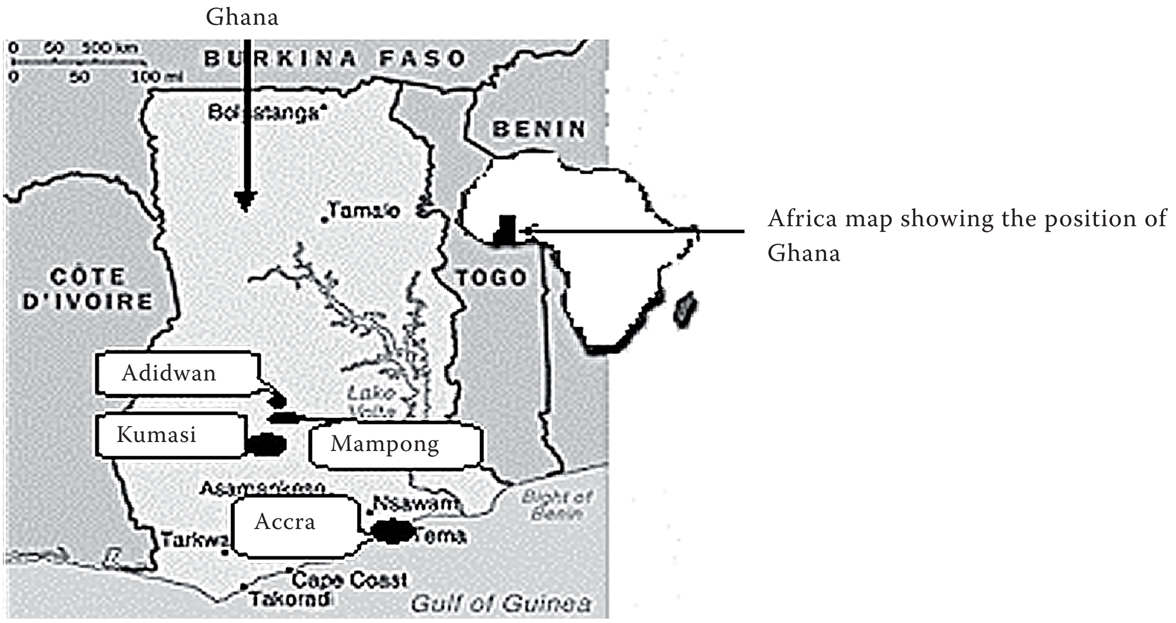

Figure 1. The map of Ghana showing the four dumpsite areas

Table 1. Metal levels of background soils and refuse dump soils from four locations in Ghana

Location and soil	Heavy metal (μg/g)										
	Cd	Hg	Pb	Cr	Fe	Co	Ni	Cu	Zn	Mo	As
ACCRA											
Refuse soil	0.90	0.04	59.20	17.90	1180.00	2.92	5.10	27.00	297.10	0.95	1.20
Background soil	0.05	0.02	22.95	8.80	700.00	1.73	3.30	3.70	9.60	0.10	0.33
KUMASI											
Refuse soil	0.29	0.09	26.23	13.00	3710.00	0.70	3.60	11.30	236.50	0.27	1.54
Background soil	0.03	0.04	6.62	8.90	1320.00	0.60	2.80	1.90	5.50	0.07	0.91
MAMPONG											
Refuse soil	0.56	0.21	26.55	16.50	4220.00	1.00	5.10	6.50	166.50	0.39	1.28
Background soil	0.05	0.03	7.82	12.60	2880.00	1.11	3.70	2.80	5.80	0.08	0.97
ADIDWAN											
Refuse soil	0.14	0.04	8.59	24.20	4230.00	1.27	4.10	5.70	105.40	0.19	0.65
Background soil	0.02	0.02	4.89	25.30	4130.00	2.30	3.40	2.80	3.70	0.06	0.46

Data analysis. To quantify the degree of pollution in the refuse dump soils the Geoaccumulation index, I_{geo}, was used (Förstner et al. 1993):

$$I_{geo} = \ln(C_n/1.5 \times B_n)$$

Where: C_n – measured concentration of metal in the refuse dump soil (μg/g); B_n – background value of heavy metal (μg/g); and 1.5 – background matrix correction factor.

The transfer factor (TF) of all the eleven metals in different samples was quantified. The TF is defined as the ratio of the concentration of a specific metal in the plant to the concentration of that metal in the background soil (Hasan et al. 2003).

RESULTS AND DISCUSSIONS

Metal levels in soils. Concentration levels of metals from soils collected from the background and refuse dump soils at four locations in Ghana; Medina in Accra – the capital of Ghana, Medoma in Kumasi – the second largest city in Ghana, Tunsuom in Mampong – a

Table 2. Concentration ranges of metals (μg/g) in soils and plants and critical concentrations in plants

Metal	Normal range in soils	Normal range in plants	Critical plant concentration
Cd*	0.01–2	0.1–2.4	5–30
Hg*	0.01–0.5	0.005–0.17	1–3
Pb*	2–300	0.2–20	30–300
Cr*	5–1500	0.03–14	5–30
Fe#	5000–100 000	40–500	–
Co*	0.5–65	0.02–1	15–50
Ni*	2–750	0.02–5	10–100
Cu*	2–250	5–20	20–100
Zn*	1–900	1–400	100–400
Mo*	0.1–40	0.03–5	10–50
As*	0.1–40	0.02–7	5–20

*Radojevic and Bashkin (2006); #Stewart et al. (1974)

Table 3. Geoaccumulation index (I_{geo}) and classification

Location		I_{geo}									
	Cd	Hg	Pb	Cr	Fe	Co	Ni	Cu	Zn	Mo	As
ACCRA	2.40	0.06	0.54	0.30	0.12	0.12	0.03	1.58	3.03	1.85	0.89
	Moderate to strong	Uncontamin. to moderate	Uncontamin. to moderate	Uncontamin. to moderate	Uncontamin. to moderate	Uncontamin. to moderate	Uncontamin. to moderate	Moderate	Strong	Moderate	Uncontamin. to moderate
KUMASI	2.06	0.52	0.97	−0.03	0.63	−0.25	−0.15	1.38	3.36	0.94	0.12
	Moderate to strong	Uncontamin. to moderate	Uncontamin. to moderate	Practically uncontamin.	Uncontamin. to moderate	Practically uncontamin.	Practically uncontamin.	Moderate	Strong	Uncontamin. to moderate	Uncontamin. to moderate
MAMPONG	2.06	1.67	0.82	−0.14	−0.02	−0.51	−0.08	0.44	2.95	1.18	−0.13
	Moderate to strong	Moderate	Uncontamin. to moderate	Practically uncontamin.	Practically uncontamin.	Practically uncontamin.	Practically uncontamin.	Uncontamin. to moderate	Moderate to strong	Moderate	Practically uncontamin.
ADIDWAN	1.57	0.52	0.15	−0.45	−0.38	−1.00	−0.22	0.31	2.94	0.75	−0.06
	Moderate	Uncontamin. to moderate	Uncontamin. to moderate	Practically uncontamin.	Practically uncontamin.	Practically uncontamin.	Practically uncontamin.	Uncontamin. to moderate	Moderate to strong	Uncontamin. to moderate	Practically uncontamin.

municipal capital and Adidwan a rural setting about 24 km from Mampong are shown in Table 1.

Differences in metal concentration of the background values were observed; Cr, Fe, Ni, Cu and Zn had higher values than the remaining metals. This pattern bears a resemblance of the normal concentration trends of metals in soils as observed by Stewart et al. (1974) and Radojevic and Bashkin (2006) in Table 2. The metal loads from the background samples with the exception of the Pb concentration (22.95 μg/g) from the Accra sample fell within the normal metal concentrations in soils (Table 2). The said background sample from Accra may be considered to be polluted with Pb, probably due to high vehicular emissions coupled with high population and industrial growth that led to increasing production of domestic, municipal and industrial wastes which at times are disposed haphazardly, making even the so called 'background soil' having high load of the metal.

The metal loads from the refuse dump soils were found to be higher than the background values with the exception of Cr and Co from Adidwan and Co from Mampong soils. It was expected because refuse dumps receive considerable waste proportions of product packaging, waste cloths, glass and bottles, newspapers, paints, batteries, industrial dust, ash, tyres, metal cans and containers, medical waste, abandoned vehicles and insulations which are known to be sources of metals (Zhang et al. 2002, Pasquini and Alexander 2004, Woodbury 2005).

The concentrations of most of the metals, Cd, Hg, Pb, Cu, Zn, Mo and As at the refuse dump soils from the cities (Accra and Kumasi) and Mampong – a municipal capital, were higher than those from Adidwan – a rural settlement. Such differences are observed as a result of higher population and industrial activities in cities and municipalities which lead to higher production of assorted waste than in the rural settlements. Ebong et al. (2008) also attributed the differences to the differences in the living standards, consumption patterns and level of industrial development between cities and rural communities.

The metal loads from the refuse dump soils were, however, within the normal concentration ranges in soils (Table 2); with the exception of concentration levels of Cd and Pb from Accra, Kumasi and Mampong refuse dump soils which were beyond the normal range in soils.

The degree of pollution of the refuse dumps by the metals was assessed (Table 3) using the Geoaccumulation Index (I_{geo}) classification (Table 4) by Förstner et al. (1993). Based on the

Table 4. Geoaccumulation index classification (Förstner et al. 1993)

Geoaccumulation index, I_{geo}	I_{geo} class	Contamination intensity
> 5	6	very strong
> 4–5	5	strong to very strong
> 3–4	4	strong
> 2–3	3	moderate to strong
> 1–2	2	moderate
> 0–1	1	incontaminated to moderate
< 0	0	practically uncontaminated

classification the refuse dump soils from Mampong and Adidwan were found practically not contaminated/polluted with Cr, Fe, Co, Ni and As. The refuse dump soil from Kumasi was also found not polluted with Cr, Co and Ni. Apart from these exceptions the refuse dump soils were found to be polluted somehow, and may be classified between 'Uncontaminated to Moderate' and 'Strongly Contaminated'. The pollution levels for Cd (I_{geo} = 2.06–2.40) and Zn (I_{geo} = 2.95–3.36) were stronger than the other metals in the Accra, Kumasi and Mampong refuse dump soils. The classifications show that the refuse dump soil from Adidwan was the least polluted with the metals, which may be due to the low population and industrial activities in the area as compared to the other study areas.

Metal levels in plants. The metal levels in the leaves of *Eleusine indica* (L.) Gaertn and *Sida acuta* Burm. (F.) sampled from both the background and refuse dump soils from the four locations are shown in Table 5. Ni concentrations in *Eleusine indica* (L.) Gaertn leaves (8.10 μg/g) from the Accra refuse dump soil and in *Sida acuta* Burm. (F.) leaves from Accra (6.10 μg/g) and Mampong (7.80 μg/g) refuse dump soils were beyond the normal Ni concentrations range (0.02–5.00 μg/g) in leaves (Table 2). The Ni concentrations were below the critical plant concentration range of 10–100 μg/g (Table 2) above which

Table 5. Metal levels of leaves of *Eleusine indica* and *Sida acuta* from soils of the four locations of study

Location and plant	Heavy metal concentration in plant (μg/g)										
	Cd	Hg	Pb	Cr	Fe	Co	Ni	Cu	Zn	Mo	As
ACCRA											
Refuse soil *Eleusine indica*	0.15	0.01	1.00	9.40	710.00	0.76	8.10	10.80	84.20	1.99	0.13
Background soil *Eleusine indica*	0.03	0.01	0.36	4.40	130.00	0.10	1.80	3.90	48.40	0.17	0.02
Refuse soil *Sida acuta*	0.08	0.02	1.43	6.50	430.00	0.52	6.10	9.50	58.20	0.76	0.08
Background soil *Sida acuta*	0.07	0.01	0.21	2.00	130.00	0.27	2.30	6.80	65.90	0.51	0.02
KUMASI											
Refuse soil *Eleusine indica*	0.01	0.01	0.31	8.60	250.00	0.13	4.60	3.60	35.40	2.81	0.12
Background soil *Eleusine indica*	0.01	0.01	0.23	4.10	200.00	0.11	2.70	3.80	34.50	0.69	0.07
Refuse soil *Sida acuta*	0.06	0.01	0.75	2.10	330.00	0.22	2.00	4.80	57.00	0.34	0.14
Background soil *Sida acuta*	0.03	0.01	0.25	1.30	280.00	0.16	1.00	4.10	36.10	0.14	0.10
MAMPONG											
Refuse soil *Eleusine indica*	0.05	0.02	0.35	2.50	520.00	0.17	1.20	7.00	244.10	1.43	0.16
Background soil *Eleusine indica*	0.01	0.01	0.28	2.10	320.00	0.21	1.10	5.10	64.80	0.20	0.11
Refuse soil *Sida acuta*	0.10	0.02	0.58	2.60	630.00	0.13	7.80	5.00	114.30	1.52	0.22
Background soil *Sida acuta*	0.01	0.01	0.09	1.60	410.00	0.71	1.60	5.00	32.50	0.65	0.04
ADIDWAN											
Refuse soil *Eleusine indica*	0.05	0.01	0.36	2.70	410.00	0.69	2.90	9.30	392.90	0.44	0.11
Background soil *Eleusine indica*	0.01	0.01	0.20	5.80	280.00	0.96	1.90	3.00	60.30	0.24	0.06
Refuse soil *Sida acuta*	0.06	0.02	0.50	1.60	390.00	0.24	2.40	5.20	46.50	1.41	0.36
Background soil *Sida acuta*	0.01	0.01	0.16	4.10	230.00	0.27	0.90	2.40	41.80	0.18	0.05

Table 6. Transfer ratio

Location and plant	Transfer ratio										
	Cd	Hg	Pb	Cr	Fe	Co	Ni	Cu	Zn	Mo	As
ACCRA											
Refuse soil *Eleusine indica*	0.17	0.20	0.07	0.53	0.60	0.26	1.59	0.40	0.28	2.09	0.11
Background soil *Eleusine indica*	0.48	0.23	0.02	0.50	0.19	0.06	0.55	1.05	5.04	1.70	0.06
Refuse soil *Sida acuta*	0.09	0.46	0.02	0.36	0.61	0.18	1.20	0.36	0.20	0.80	0.07
Background soil *Sida acuta*	1.33	0.41	0.01	0.23	0.19	0.16	0.70	1.84	6.87	5.1	0.06
KUMASI											
Refuse soil *Eleusine indica*	0.04	0.10	0.01	0.66	0.07	0.19	1.28	0.32	0.15	10.41	0.08
Background soil *Eleusine indica*	0.28	0.20	0.03	0.46	0.15	0.18	0.96	2.00	6.27	9.88	0.08
Refuse soil *Sida acuta*	0.20	0.15	0.03	0.16	0.09	0.31	0.56	0.42	0.24	1.26	0.15
Background soil *Sida acuta*	1.32	0.29	0.04	0.15	0.21	0.27	0.36	2.15	6.56	2.00	0.11
MAMPONG											
Refuse soil *Eleusine indica*	0.09	0.08	0.01	0.15	0.12	0.17	0.24	0.62	1.47	3.67	0.13
Background soil *Eleusine indica*	0.24	0.27	0.04	0.17	0.11	0.19	0.30	1.82	11.17	2.50	0.11
Refuse soil *Sida acuta*	0.17	0.11	0.02	0.16	0.15	0.13	1.53	0.44	0.69	3.90	0.17
Background soil *Sida acuta*	0.24	0.31	0.01	0.13	0.14	0.64	0.43	1.79	5.52	8.13	0.04
ADIDWAN											
Refuse soil *Eleusine indic*	0.34	0.21	0.04	0.11	1.36	0.16	0.38	1.63	1.66	2.32	0.17
Background soil *Eleusine indica*	0.35	0.40	0.04	0.22	1.51	0.23	0.56	1.07	16.30	4.00	0.13
Refuse soil *Sida acuta*	0.39	0.45	0.06	0.07	1.29	0.06	0.32	0.91	0.20	7.42	0.53
Background soil *Sida acuta*	0.55	0.53	0.03	0.16	1.24	0.07	0.26	0.86	11.30	3.00	0.11

plant toxicity is likely, however, the concentrations were above the acceptable limits (1.00–5.00 μg/g) in food (Awashthi 2000). These weeds from the said refuse dump sites may be therefore toxic to grazing animals and humans using these plants for food/medicinal purposes.

The Fe concentrations in *Eleusine indica* (L.) Gaertn leaves of 710 μg/g and 520 μg/g from the Accra and Mampong refuse dump soils, respectively, and in *Sida acuta* Burm. (F.) leaves (630 μg/g) from the Mampong refuse dump soil were beyond the normal range of Fe (40–500 μg/g) in plants (Table 2). These Fe concentrations fall beyond the toxic level for Fe in plant leaves (300–500 μg/g) (Dobermann and Fairhurst 2000). The leaves of these weeds may pose danger to grazing animals and humans using them for food/medicinal purposes.

Apart from the above exceptions, the rest of the metal concentrations in the plants were within the normal ranges (Table 2).

In almost all situations the concentration of the metals in the plants bore a resemblance proportion with the metal concentration in the soil (Tables 1 and 5) and therefore in most cases the metal loads of the plants from the refuse dump soils were higher than those from the background soils. This is in agreement with the findings of Ebong et al. (2008) who attributed the situation to the high metal contents of dumpsite soils which are eventually accumulated by the plants grown on them.

The transfer ratio (Table 6), which is the ratio of the concentration of the metal in the leaves of the plant to the concentration of the metal in soil, however, did not follow the pattern above (Tables 1 and 5). The transfer ratios of Cd, Hg, Cu and Zn, and to some degree Pb and Fe, in plants from the background soils with lower concentrations of the metals were higher than those from the refuse dump soils with higher metal loads. This indicates that some soil factors apart from the total soil content of the metals also affect the rate of metal uptake by plants. The application of some materials as dolomite, phosphates or organic matter into soils were found to reduce the concentration of metals by precipita-

Table 7. Some chemical properties of the soil samples used for the study

Location and soil	pH	Organic matter (%)	Total N (%)	Available P (mg/kg)	Exchangeable cations Ca (cmol/kg)	Mg	K	Na	Exchangeable acidity	ECEC	Base saturation (%)
ACCRA											
Refuse soil	7.48	3.84	0.22	53.41	36.58	5.07	2.25	0.65	0.05	44.60	99.88
Background soil	5.64	3.45	0.21	16.67	4.94	4.14	0.65	0.24	0.75	10.32	93.22
KUMASI											
Refuse soil	7.18	6.79	0.42	165.06	28.04	8.01	2.00	0.34	0.10	38.44	99.74
Background soil	6.09	2.95	0.20	18.82	4.81	2.67	0.34	0.08	0.35	8.00	95.80
MAMPONG											
Refuse soil	7.26	6.02	0.34	271.60	28.57	6.41	3.05	0.39	0.08	38.47	99.79
Background soil	6.98	2.43	0.17	225.68	5.34	2.40	1.03	0.08	0.15	8.95	98.35
ADIDWAN											
Refuse soil	6.75	6.14	0.36	73.36	12.00	9.77	2.11	0.29	0.20	24.27	98.26
Background soil	5.84	3.17	0.15	15.79	8.21	5.08	1.26	0.19	0.85	14.74	94.54

tion, adsorption, or complexation (Mench et al. 1994, Chen and Lee 1997) and thereby making them unavailable to plants. In the present study the refuse dump soils were observed to have higher levels of organic matter, available phosphorus (phosphates) and exchangeable cations such as Ca and Mg (Table 7) which might have had similar effects on the metals as observed by Mench et al. (1994) and Chen and Lee (1997) and therefore resulting in the lower transfer ratios of the metals in the refuse dump soils than the background soils as observed.

A crucial factor which affects metal availability in the soil is soil pH. According to Smith (1996), metal mobility decreases with increasing soil pH due to precipitation of hydroxides, carbonates or formation of insoluble organic complexes. All the refuse dump soils recorded higher pH values (6.75–7.48) than their background soils (Table 7). These high pH values might have decreased the mobility of the metals in the soil as stated by Smith (1996) and consequently might have contributed to the lower transfer ratios of the metals in the refuse dump soils.

REFERENCES

Alloway B.J., Ayres D.C. (1997): Chemical Principles of Environmental Pollution. 2nd Edition. Blackie Academic and Professional, Chapman and Hall, London, 190–242.

Anderson J.M., Ingram J.S.I. (1989): Tropical Soil Biology and Fertility: a Handbook of Methods. CAB International, Wallingford.

Asomani-Boateng R., Murray H. (1999): Reusing organic solid waste in urban farming in African cities: a challenge for urban planners. In: Olanrewaju B.S. (ed.): Urban Agriculture in West Africa, Canada, 210.

Awasthi S.K. (2000): Prevention of food Adulteration Act No. 37 of 1954. Central and State Rules as Amended for 1999. 3rd Edition. Ashoka Law House, New Delhi.

Chen Z.S., Lee D.Y. (1997): Evaluation of remediation techniques on two cadmium polluted soils in Taiwan. In: Iskandar A., Adriano D.C. (eds.): Remediation of Soils Contaminated with Metals. Science Reviews, Northwood, 209–223.

Dobermann A., Fairhurst T. (2000): Rice, nutrient disorders and nutrient management. Handbook series. Potash and Phosphate Institute of Canada, 191.

Ebong G.A., Akpan M.M., Mkpenie V.N. (2008): Heavy metal contents of municipal and rural dumpsite soils and rate of accumulation by *Carica papaya* and *Talinum triangulare* in Uyo, Nigeria. E-Journal of Chemistry http://www.e-journals.net, *5*: 281–290.

Fatoki O.S. (2000): Trace zinc and copper concentration in road side vegetation and surface soils: a measurement of local atmospheric pollution in Alice, South Africa. International Journal of Environmental Studies, *57*: 501–513.

Förstner U., Ahlf W., Calmano W. (1993): Sediment quality objectives and criteria development in Germany. Water Science and Technology, *28*: 307.

Hasan S.H., Ra S., Rupainwar D.C. (2003): Removal of zinc from wastewater by water hyacinth. Indian Journal of Chemical Technology, *10*: 274–280.

ITTA International Institute of Tropical Agriculture (1985): Laboratory Manual of Selected Methods for Soil and Plant Analysis. Ibadan, Nigeria.

Mench M., Didier V.L., Loffler M., Gomez A., Masson P. (1994): A mimicked in-situ remediation study of metal-contaminated soils with emphasis on cadmium and lead. Journal of Environmental Quality, *23*: 58–63.

NIEHS National Institute of Environmental Health Services (2004): 'Waste: Landfill.' Available at: http://www.niehs.nih.gov/external/faq/landfill.htm

Odai S.N., Mensah E., Sipitey D., Ryo S., Awuah E. (2008): Heavy metals uptake by vegetables cultivated on urban waste dumpsites: case study of Kumasi, Ghana. Research Journal of Environmental Toxicology, *2*: 92–99.

Ogunyemi S., Awodoyin R.O., Opadeji T. (2003): Urban agricultural production: heavy metal contamination of *Amaranthus cruenties* L. grown on domestic refuse landfill soil in Ibadan, Nigeria. Emirates Journal of Agricultural Sciences, *15*: 87–94.

Oviasogie P.O., Oshodi A.A., Omoruyi E. (2007): Levels of essential micronutrients in soils and growing plants around refuse dumpsites in Akure, Nigeria. International Journal of Physical Sciences, *2*: 159–162.

Pasquini M.W., Alexander M.J. (2004): Chemical properties of urban waste ash produced by open burning on the Jos Plateau: implications for agriculture. The Science of the Total Environment, *319*: 225–240.

Radojevic M., Bashkin V.N. (2006): Practical Environmental Analysis. Royal Society of Chemistry, Cambridge, 389.

Rowel D.L. (1994): Soil Science: Methods and Applications. Longman Group Ltd, London.

Smith S.R. (1996): Agricultural Recycling of Sewage Sludge and the Environment. CAB International, Wallingford, 382.

Stewart E.A., Max Grimshaw H., Parkinson J.A., Quarmby C. (1974): Chemical Analysis of Ecological Materials. Blackwell Scientific Publications, Osney Mead, Oxford, 165.

Walkley A., Black I.A. (1934): An examination of the Degtjareff method for soil organic matter determination and a proposed modification of the chronic acid titration. Soil Science, *37*: 29–38.

Woodbury P.B. (2005): Municipal solid waste composting: potential effects of heavy metals in municipal solid waste composts on plants and the environment. Available at: http://www.css.cornell.edu/compost/mswfactsheets/msw.fs5.html

Zhang F.S., Yamasaki S., Nanzyo M. (2002): Waste ashes for use in agricultural production: I. Liming effect, contents of plant nutrients and chemical characteristics of some metals. Science of the Total Environment, *284*: 215–225.

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