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Full Length Research Paper

Seasonal variations in heavy metal concentrations in soil and some selected crops at a landfill in Nigeria

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In this study, the seasonal variations in concentrations of the heavy metals - As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn - in soil and crops from a farm near the refuse dump site of Obafemi Awolowo University, Ile-Ife, Nigeria were investigated during the two major seasons of Nigeria. This was done to assess the pollution status of the farm and hence the safety levels of the crops produced. Soil and crop samples collected during the 2005/2006 rainy and dry seasons were treated and digested using standard wet digestion methods. Heavy metals were determined with Atomic Absorption Spectrophotometer (AAS). Analytical results of soil from landfill indicated that in the wet and dry seasons, values for Cd, Cu, Fe, Ni, Cr, Zn, Co and Pb were higher than normal levels of a typical agricultural soil, but As (3.20 and 4.13 mg/kg) was found to be within the acceptable range while Mn values of 597.00 - 828.37 mgkg^{-1} were slightly above the usual background levels. The study showed highest concentrations of As (8.31 mg/kg), Cr (9.00 mg/kg) and Ni (40.00 mg/kg) in *Manihot esculenta* leaves; Cu (25.0 0 mg/kg) and Fe (176.00 mg/kg) in *Xantosoma mafaffa* tuber; Cd (14.50 mg/kg), Co (22.50 mg/kg), Mn (189.50 mg/kg), Pb (680.00 mg/kg) and Zn (440.59 mg/kg) in *Talinum triangulare*. In general, the levels of heavy metals in soil and crops were higher in the dry season than in the wet season, but this difference is not statistically significant. Particularly, the levels of As, Cd, Cr, Ni, and Pb were above the critical toxic level in plant leaves in both dry and wet seasons while Zn and Cu occurred at toxic levels only in the dry season.

Key words: Contamination, heavy metals, landfill, refuse dump, transfer factor.

INTRODUCTION

Heavy metal pollution of the environment, even at low-levels, and their resulting long-term cumulative health effects are among the leading health concerns all over the world. For example, bioaccumulation of Pb in human body interferes with the functioning of mitochondria, thereby impairing respiration, and also causes constipation, swelling of the brain, paralysis and eventual death (Chang, 1992).

The situation is even more worrisome in the developing countries where research efforts towards monitoring the environment have not been given the desired attention by the stake holders.

Heavy metals concentration in the environment cannot be attributed to geological factors alone, but human activities do modify considerably the mineral composition of soils, crops and water. The recent population and industrial growth has led to increasing production of domestic, municipal and industrial wastes, which are indiscriminately dumped in landfill and water bodies without treat-ment. The use of dumpsites as farm land is a com-mon practice in urban and sub-urban centers in Nigeria because of the fact that decayed and composted wastes enhance soil fertility (Ogunyemi et al., 2003). These wastes often contain heavy metals in various forms and at different contamination levels. Some heavy metals like As, Cd, Hg and Pb are particularly hazardous to plants, animals and humans (Alloway and Ayres, 1997). Municipal waste contains such heavy metals as As, Cd, Co, Cu, Fe, Hg, Mn, Pb, Ni, and Zn which end up in the soil as the sink when they are

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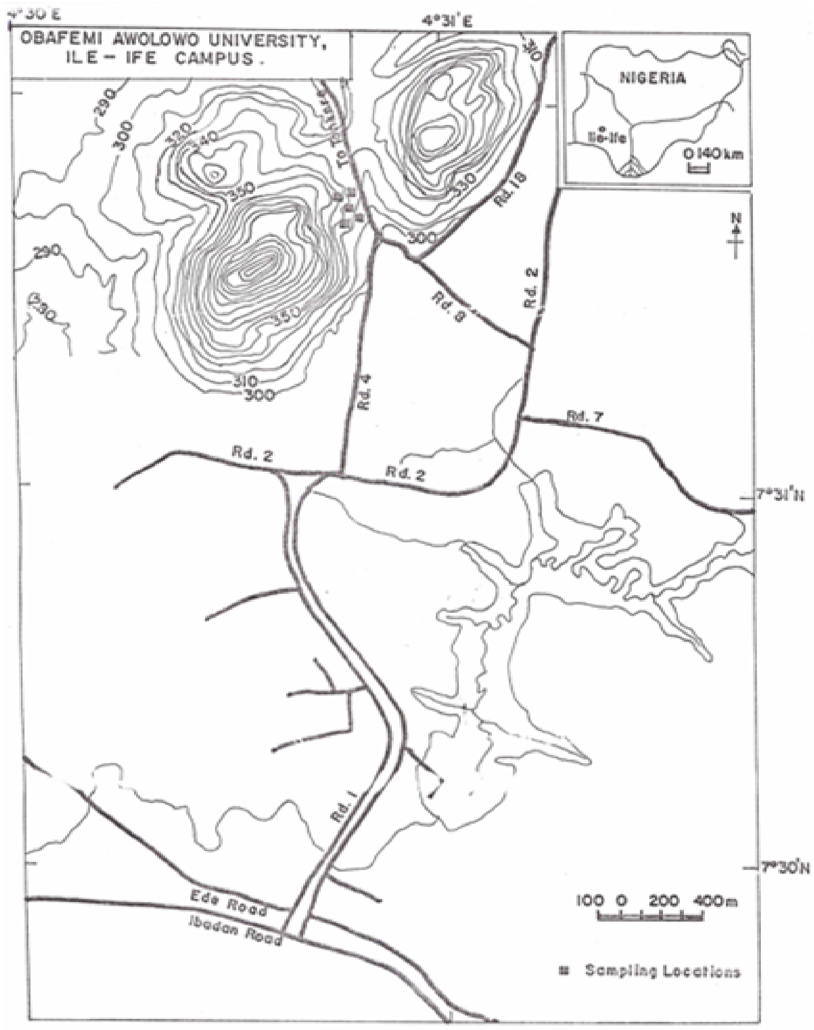

Figure 1. Map of Obafemi Awolowo University, Ile-Ife campus showing the sampling locations

leached out from the dump sites. Soil is a vital resource for sustaining two human needs of quality food supply and quality environment. Plants grown on a land polluted with municipal, domestic or industrial wastes can absorb heavy metals inform of mobile ions present in the soil solution through their roots or through foliar absorption. These absorbed metals get bioaccumulated in the roots, stems, fruits, grains and leaves of plants (Fatoki, 2000).

The present study was carried out to assess the pollution status of the farm land under study, the extent to which the crop plants grown on the land were exposed to heavy metals, and hence, the safety levels of the crops produced.

MATERIALS AND METHODS

Five sampling spots at a distance of 50 m from each other were mapped out for soil samples collection within the sampling site. Samples were collected during the rainy season of 2005 and in the dry season of 2006 using clean stainless steel trowel from 0 – 15 cm depth. A soil sample for each season to serve as control was also collected from a site about 2 km away from the polluted land site.

Five edible plant samples - cocoyam tuber and leaves (*Xanthosoma mafaffa*), cassava tuber and leaves (*Manihot esculenta*), maize (*Zea mais*), plantain (*Musa sapientum*) and water leaves (*Talinum triangulare*) – grown within the vicinity of the refuse dump site were randomly collected with a stainless steel trowel and knife. Plant samples of the same species were also collected as control from the unpolluted site chosen as control. The map of the University showing sampling sites is presented in Figure 1.

The collected dried soil samples were thoroughly mixed in clean plastic bucket to obtain a representative sample, crushed and sieved with 2 mm mesh before stored in labeled polythene bags prior to analysis. Plant leaves were rinsed in doubly distilled water and dried to a constant weight in an oven at a temperature of 70°C. These were then crushed into fine powders and then stored in poly-

Table 1. Soil properties

Soil	Soil depth (cm)	% Sand	% Silt	% Clay	pH	% Organic matter
Wet Season	0-15	42.96	15.28	41.76	7.4	6.94
Control	0-15	56.96	15.28	27.76	6.1	0.67
Dry Season	0-15	41.96	14.28	43.76	7.0	4.06
Control	0-15	55.54	16.32	28.14	6.3	0.62

thene bags prior to further laboratory analysis. The tubers were washed with water, sliced and dried to a constant weight in an oven also at a temperature of 70°C. The dried sample was pulverized using an agate pestle and mortar and kept in polythene bags.

The pH of the soil samples was determined with Orion Research Analog pH meter/model 30l according to standard analytical methods. Organic matter was determined using the chromic acid oxidation method (Walkey and Black, 1934).

Soil samples were digested in Teflon beakers with a mixture of HNO_3, HCl and HF. Similarly, dry powdered crop samples were digested with a mixture of 60% $HClO_4$, concentrated HNO_3 and H_2SO_4. Blanks were prepared to check for background contamination by the reagents used.

The digested samples were analyzed for heavy metals using Atomic Absorption Spectrophotometer, Alpha Star model 4 (Chem Tech Analytical) at the Center for Energy Research and Development (CERD) of the Obafemi Awolowo University Ile-Ife, Nigeria. Instrumental conditions are as reported earlier (Oladipo et al., 2005).

RESULTS AND DISCUSSION

Soil properties determined in the present study are shown in Table 1. Sand and clay fractions were dominant in the landfill soil and in the control. In the latter, sand is the predominant fraction while in the former, no fraction is predominant. The soil in the landfill is sandy clay loam in texture while soil for control is sandy clay in texture. Soil pH of the landfill was neutral with higher organic matter content in the wet than dry season while the soil pH for control showed a slightly acidic level with low organic matter content. Statistical analysis using Student's t-test showed that the soil texture, pH and organic matter content of the landfill soil were not significantly different from one season to another. The pH of the landfill soil in both the dry season (7.0) and the wet season (7.4) was higher than the control 6.1 and 6.3 respectively. This was probably due to the presence of broken floor tiles and blocks in the landfill that were the source of calcium carbonate ($CaCO_3$) buffer and also to the rainfall event during the wet season which dilutes the soil solution the more thus leading to pH increase. At low pH metals are more soluble in the soil solution, hence more bioavailable to plants. Hence, toxicity problems are more severe in acidic soils than in alkaline soils.

Higher organic matter content in the landfill than that of the control may be due to the presence of garden waste, food waste and the higher proportions of paper and packaging materials since more than half of municipal waste usually consists of paper, while the remaining half consists of garden waste, metals, glass and ash. Organic matter plays an important role in soil structure, water retention, cation exchange and in the formation of complexes (Alloway and Ayres, 1997).

Tables 2 and 3 represent the heavy metals concentrations in soils and plants in wet and dry seasons respectively. Except for Cr and Mn, the concentrations of metals in the dry season were higher than those in the wet season. This might be due to the runoff effect that is capable of removing heavy metals from the farmland and the effect of rainfall which may facilitate the leaching of the soil and contributes to the dilution of soil solution during the wet season.

During the dry season, open dumping and burning of wastes are a common place at the dumpsite. The farmland being too close to the refuse dump, fly ash and atmospheric particulates loaded with heavy metals might be readily deposited on the plants' leaves and get translocated into the plants' system through foliar absorption. This process of foliar absorption is more pronounced in the dry season due to the persistence of these fly ash and particulates on the plants' leaves and the total absence of the washing of the leaves by rainfall. This may also contribute to increasing metal concentration in crops during dry season. Furthermore, evaporation of water from soil together with the dehydration of plant leaves by transpiration increase the metal concentration in the roots and leaves. In addition, evaporation is more intense in dry season, thus, soil solution is more concentrated.

The sequence of metal concentrations in the landfill soil was Fe > Cu > Mn > Pb > Zn >Cr > Ni > Co > Cd > As in the wet season (Figure 2) while it was Fe > Cu > Mn > Zn > Pb > Ni > Cr > Co > Cd > As in the dry season (Figure 3). The heavy metal concentrations in soil and crops in the landfill are higher than those in the soil and crops for control. Generally, higher mean heavy metal concentrations were recorded in the soil during the dry season than in the wet season as illustrated by Figure 4. In the landfill soil, as has the least concentration of 3.20 $mgkg^{-1}$ while Fe has the highest concentration of 51584.03 $mgkg^{-1}$. In crops grown in the landfill area, the concentration of heavy metals ranged from not detectable (ND) to 680.0 $mgkg^{-1}$ recorded for Pb in *T. triangulare* in the

Table 2. Heavy metal concentrations in soils and plants in the wet season (mg/kg)

		As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Soil, 0 – 15 cm		3.20 ±0.01	10.35 ±0.00	23.00 ±0.01	181.25 ±0.01	844.00 ±0.01	48947.50 ±2.04	828.37 ±0.05	117.60 ±0.03	304.50 ±0.07	206.61 ±0.01
Soil (Control) 0 - 15 cm		1.80 ±0.01	0.10 ±0.00	14.00 ±0.03	8.75 ±0.01	30.50 ±0.01	15933.50 ±1.75	323.62 ±0.03	31.25 ±0.01	18.50 ±0.03	99.25 ±0.01
Elemental concentration of a typical soil *		7.2	0.35	9.1	54	25	26000	550	19	19	60
Manihot esculanta	Tuber	6.61 ±0.02	5.20 ±0.01	ND	ND	8.00 ±0.00	34.00 ±0.00	ND	ND	57.00 ±0.02	32.60 ±0.01
	Leaves	1.83 ±0.02	4.90 ±0.01	1.00 ±0.01	9.00 ±0.00	15.00 ±0.00	27.00 ±0.00	84.30 ±0.04	8.00 ±0.00	456 ±0.04	16.30 ±0.01
Control	Tuber	0.10 ±0.00	0.02 ±0.00	ND	ND	6.00 ±0.00	3.20 ±0.00	ND	ND	0.50 ±0.00	1.60 ±0.00
	Leaves	ND	0.03 ±0.00	0.21 ±0.00	ND	2.00 ±0.00	14.26 ±0.01	65.90 ±0.01	2.00 ±0.00	0.60 ±0.00	3.47 ±0.01
Xanthosoma mafaffa	Tuber	3.30 ±0.01	5.10 ±0.01	ND	ND	14.00 ±0.00	46.00 ±0.01	19.51 ±0.03	ND	10.00 ±0.00	107.30 ±0.02
	Leaves	1.65 ±0.01	7.90 ±0.01	4.00 ±0.02	5.00 ±0.01	7.00 ±0.00	9.07 ±0.01	49.40 ±0.01	10.00 ±0.00	12.10 ±0.04	39.70 ±0.01
Control	Tuber	0.14 ±0.01	0.05 ±0.00	ND	ND	6.00 ±0.00	2.36 ±0.00	10.40 ±0.01	ND	0.26 ±0.00	40.21 ±0.01
	Leaves	0.60 ±0.01	0.03 ±0.00	ND	ND	2.10 ±0.00	18.13 ±0.00	44.70 ±0.01	1.50 ±0.00	0.40 ±0.00	4.01 ±0.01
Zea mais	Grains	4.96 ±0.01	3.80 ±0.01	5.00 ±0.02	4.00 ±0.01	7.00 ±0.00	8.30 ±0.01	24.20 ±0.01	ND	16.10 ±0.01	17.20 ±0.01
Control	Grains	0.21 ±0.00	0.02 ±0.00	ND	ND	2.91 ±0.00	4.54 ±0.00	15.70 ±0.01	ND	0.36 ±0.00	3.00 ±0.01
Musa sapientum	Fruits	1.67 ±0.01	4.40 ±0.01	1.00 ±0.00	ND	2.00 ±0.00	47.00 ±0.00	10.90 ±0.01	ND	14.30 ±0.00	11.90 ±0.01
Control	Fruits	0.17 ±0.00	0.02 ±0.00	ND	ND	1.10 ±0.00	7.60 ±0.02	6.60 ±0.01	ND	0.21 ±0.01	3.21 ±0.01
Talinum triangulare	Leaves	1.67 ±0.01	4.70 ±0.03	9.00 ±0.01	ND	10.00 ±0.00	13.61 ±0.01	189.90 ±0.01	15.00 ±0.02	680.00 ±0.06	41.00 ±0.01
Control	Leaves	0.12 ±0.00	0.02 ±0.00	ND	ND	2.00 ±0.00	5.37 ±0.00	ND	ND	0.61 ±0.01	2.74 ±0.00

*Source: Brady (1984)

wet season. The results also showed the highest level of As (8.31 mgkg^{-1}) and Fe (168.7 mgkg^{-1}) in *M. esculanta* tuber; Cr (9.0 mgkg^{-1}) and Ni (40.0 mgkg^{-1}) in *M. esculanta* leaves; Cu (25.0 mgkg^{-1}) in *X. mafaffa* tuber; Cd (14.50 mgkg^{-1}), Co (22.0 mgkg^{-1}), Mn (189.90 mgkg^{-1}), Pb (680.0 mgkg^{-1}) and Zn (440.59 mgkg^{-1}) in *T. triangulare*. The variation of the various heavy metal concentrations in the plants was observed to. Be according to plant and metal species and from
one season to another.

The concentrations of heavy metals in the landfill soil varied according to the metal species and the season. They are higher in the landfill soil than in the control. The heavy metal levels in the control were within the background level range for farming. Analytical results indicated that in the wet and dry seasons, values for Cd, Cu, Ni, Cr, Zn, Co and Pb were grossly above the literature levels of a typical soil (Brady, 1984). The high level for Pb (304.5 - 317.5 mgkg^{-1}) conforms to a similar finding where a value of 678.5mgkg^{-1} was reported for Pb in landfill soil in Ibadan in South-West Nigeria (Ogunyemi et al., 2003). In the wet and dry season, as (3.20 and 4.13 mgkg^{-1}) was found to be within the recommended levels of heavy metals for agricultural practices by EEC while Mn (597.0 -82837 mgkg^{-1}) was slightly above the usual recommended level. Fe (48947.5 - 51584.03 mgkg^{-1}) was also a bit high (McGrath et al., 1994). The results showed that the concentration of heavy metals in the crops varied with plant species, plant parts and metal species (Tables 2 and 3). The levels of heavy metals in the crops harvested from the landfill were higher than those for control and this is in good agreement with earlier reports (Madejon et al., 2003; Oyedele et al., 1995). The concentrations of heavy metals in the crops from the control sites were within the reported range of elemental content of plants (Fifield and

Table 3. Heavy metal concentrations in soils and plants in the dry season (mg/kg)

		As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Soil, 0 - 15cm		4.13 ±0.01	11.30 ±65.00	65.00 ±0.06	107.50 ±0.01	875.00 ±0.01	51584.03 ±2.16	597.00 ±0.01	128.10 ±0.03	317.50 ±0.03	366.24 ±0.01
Soil (Control) 0-15cm		1.92 ±0.02	0.14 ±0.01	16.00 ±0.02	10.04 ±0.01	34.25 ±0.01	26529 ±1.54	298.36 ±0.02	35.64 ±0.01	20.81 ±0.02	101.05 ±0.01
Manihot esculenta	Tuber	4.18 ±0.01	14.00 ±0.01	2.50 ±0.02	ND	16.00 ±0.01	168.71 ±0.01	13.00 ±0.00	ND	87.50 ±0.01	36.14 ±0.01
	Leaves	8.31 ±0.01	1.25 ±0.01	ND	ND	22.50 ±0.01	81.67 ±0.02	68.00 ±0.01	40.00 ±0.01	132.50 ±0.03	44.55 ±0.01
Control	Tuber	0.08 ±0.01	0.01 ±0.00	ND	ND	7.02 ±0.01	5.61 ±0.01	ND	ND	0.30 ±0.01	1.85 ±0.01
	Leaves	ND	0.03 ±0.01	ND	ND	2.60 ±0.01	17.41 ±0.01	70.12 ±0.01	3.05 ±0.01	0.72 ±0.01	4.52 ±0.01
Xanthosoma mafaffa	Tuber	8.26 ±0.01	6.00 ±0.01	ND	ND	25.00 ±0.01	176.00 ±0.01	14.75 ±0.01	ND	50.00 ±0.01	112.83 ±0.01
	Leaves	4.34 ±0.01	8.75 ±0.01	ND	5.00 ± 0.02	14.00 ±0.01	72.59 ±0.10	50.00 ±0.01	7.50 ±0.04	38.75 ±0.01	69.30 ±0.01
Control	Tuber	0.12 ±0.01	0.02 ±0.01	ND	ND	7.40 ±0.00	5.32 ±0.01	13.61 ±0.01	ND	0.30 ±0.02	45.18 ±0.01
	Leaves	0.69 ±0.01	0.05 ±0.01	ND	ND	3.17 ±0.01	22.60 ±0.01	41.27 ±0.01	0.95 ±0.01	0.76 ±0.01	6.51 ±0.01
Zea mays	Grains	4.15 ±0.01	1.75 ±0.01	ND	ND	13.01 ±0.01	24.00 ±0.01	ND	ND	65.00 ±0.01	19.23 ±0.01
Control	Grains	0.18 ±0.01	0.02 ±0.01	ND	ND	3.01 ±0.01	6.58 ±0.01	20.35 ±0.01	ND	0.31 ±0.01	4.26 ±0.01
Musa sapientum	Fruits	4.36 ±0.01	4.25 ±0.01	ND	ND	11.50 ±0.01	127.00 ±0.03	15.75 ±0.01	ND	62.50 ±0.01	14.85 ±0.01
Control	Fruits	0.23 ±0.01	0.03 ±0.01	ND	ND	2.67 ±0.00	9.25 ±0.01	10.07 ±0.01	ND	0.26 ±0.01	5.37 ±0.01
Talinum triangulare	Leaves	5.41 ±0.01	14.50 ±0.01	22.50 ±0.02	ND	14.50 ±0.01	82.50 ±0.01	174.25 ±0.01	ND	500.00 ±0.07	440.59 ±0.02
Control	Leaves	0.15 ±0.01	0.01 ±0.00	ND	ND	3.10 ±0.01	8.23 ±0.00	ND	ND	0.82 ±0.01	3.41 ±0.01

Haines, 2002).

In crops from the landfill, the concentrations of As, Cd and Pb were above the acceptable range in plants and plant foodstuffs. Except for Pb in *X. maffa* leaves during the wet season, the levels of As, Cd and Pb were above the toxic levels in plant leaves which are: As (1 - 4 $mgkg^{-1}$), Cd (5.30 $mgkg^{-1}$) and Pb (30 - 300 $mgkg^{-1}$) (Alloway, 1995). Co, Cr and Ni were not in many crop samples particularly tubers. This might be due to the selective absorption of the metals by various crops. However they were detected at elevated concentration levels, which could be hazardous to human health, in the leaves of most crop samples.

The level of Cr was 9.0, 5.0 and 4.0 $mgkg^{-1}$ in the leaves of *M. esculenta*, *X. mafaffa* and in *Z. mais* respectively in the wet season while it was 5.00 $mgkg^{-1}$ only in *X. mafaffa* in the dry season. The concentration of Cr fell within the natural occurrence in plant foodstuffs which is 0.01 - 14 $mgkg^{-1}$ (Fifield and Haines, 2000). Ni was found only in the leaves and its level varied between 7.5 and 40.0 $mgkg^{-1}$. The concentration of Ni in *T. triangulare* (15.0 $mgkg^{-1}$), *X. mafaffa* leaves (10.0 $mgkg^{-1}$) and *M. esculenta* (40.0 $mgkg^{-1}$) during the wet season were within the toxicity level in plant leaves which is 10 - 100 $mgkg^{-1}$.

The level of Cu in the roots, grains and fruits ranged from 2.0 to 14.0 $mgkg^{-1}$ in the wet season and from 11.0 to 25.0 $mgkg^{-1}$ in the dry season while it ranged in the leaves from 7.0 to15 $mgkg^{-1}$ in the wet season and from 14.5 to 25 $mgkg^{-1}$ in the dry season. Some of these concentrations are above the usual Cu concentration levels in plants and plant foodstuffs which are 5 – 12 $mgkg^{-1}$ and 0.008 – 9 $mgkg^{-1}$. Moreover in the dry season 22.5 $mgkg^{-1}$ recorded for Cu in *Manihot esculenta* was above the toxicity limit in plant leaves which is 20 – 100 $mgkg^{-1}$.

The level of Zn in the roots, grains and fruits ranged from 11.90 to 107.3 $mgkg^{-1}$ in the wet season and from 14.85 to 116.25 $mgkg^{-1}$ in the dry season while it ranged in the leaves from 16.3 to 41.0 $mgkg^{-1}$ in the wet season and from 44.55 to 440.59 $mgkg^{-1}$ in the dry season. The level of 107.3 $mgkg^{-1}$ in *X. mafaffa* tuber in the wet season, 116.25 $mgkg^{-1}$ in *M. esculenta* tuber, 112.83 $mgkg^{-1}$ in *X. mafaffa* tuber, 69.3 $mgkg^{-1}$ in *X. mafaffa* leaves and 440.59 $mgkg^{-1}$ in *T. triangulare* in the dry season were above the normal range of 12 – 60 $mgkg^{-1}$ in plants. However only 440.5 $mgkg^{-1}$ recorded in *T. triangulare* was above the toxic level in plant

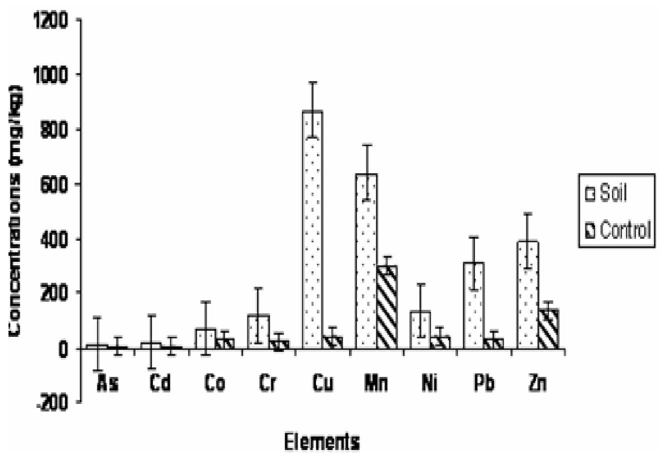

Figure 2. Mean concentrations of metals in the dump site and control soil samples in the wet

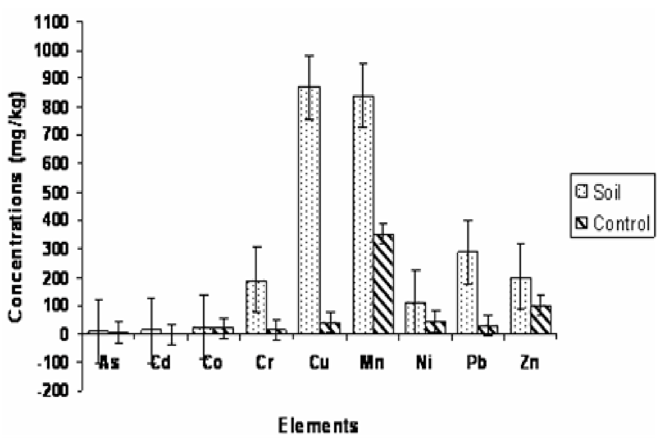

Figure 3. Mean concentrations of metals in the dump site and control soil samples in the dry

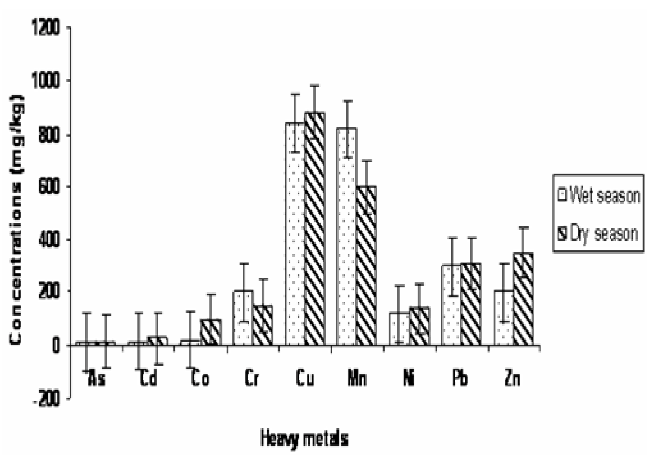

Figure 4. Seasonal variation of heavy metals in the dump site soil.

leaves which is 100 – 400 mgkg $^{-1}$ (Alloway, 1995; Fifield and Haines, 2000). In a previous study, Zn level in the leaves of spinach grown on a soil treated with sewage sludge was found to be 455.50 mg.kg^{-1} (Hooda et al., 1997). This is in agreement with our findings.

In crops from the landfill, the levels of Fe ranged from 9.07 to 176.0 mgkg^{-1} and Mn from 10.90 to 189.9 mgkg^{-1}. These values were within the normal ranges in plants (30 – 920 mgkg^{-1} and 20 – 240 mgkg^{-1} for Fe and Mn respectively). The toxic level for Fe in plant leaves is 300 - 500 mgkg^{-1} (Dobermann and Fairhurst, 2000). The higher level of 168.71 mgkg^{-1} for Fe recorded in *M. esculenta* tuber agrees with 131.87 mgkg $^{-1}$ obtained for Fe in cassava tuber from a farmland polluted by a textile industry effluent (Adeyeye and Ayejuyo, 2002).

The transfer factor (TF), which is the ratio of the concentration of metal in the aerial portion of the plant to the total concentration in the soil, is shown in Table 4. The TF for the same metal in the farmland were significantly different from those for control according to plant species and the season. Pb, As, Cd and Zn had the higher TFs which are 2.23; 2.01; 1.31 and 1.2 respectively. The highest TF value obtained for *M. exculenta* were As (2.01) and Ni (0.3); for *T. triangulare* Cd (1.31), Co (0.39), Cr (0.35), Mn (0.29), Pb (2.23) and Zn (1.2) while the highest TF for Cu (0.09) was recorded in *Z. mays***.**

A study gave a generalized transfer coefficient in the soil-plant system as: As, Co, Cr, Cu and Pb (0.01 - 0.1), Cd and Zn (1 - 10), Ni (0.1-1) (Kloke et al., 1984). The TF of As, Co, Cr, Ni and Pb are above the normal range in some plants species (Table 4). The main concern is As, Cd, Pb, and Zn with high transfer factor since As, Cd, Pb are non-essential toxic elements for plants, animals and humans. This study showed a TF>1 for Cd in *T. traingulare* which corroborated the works of Turner (1973) and Edwin and Howell (1993). TF>1 for Pb (1.57 and 2.23) in *T. triangulare* and in *Manihot esculenta* (1.41) agreed with earlier studies by Oyedele *et al.* (1995) and Hooda et al. (1997). The low TF value for Cu, despite its high contamination level in the landfill soil may be due to its strong adsorption onto the organic matter, which renders it less bioavailable to plants. In the dumpsite, refuse was burned continuously, thus the higher concentration of certain metals such as As, Cd, Pb and Zn in some plant species may be due to foliar absorption since plants can absorb heavy metals through leaves (Alloway and Ayres, 1997).

Conclusion

The study revealed that the landfill was polluted by Cd, Co, Cr, Cu, Ni, Pb and Zn while crops were contaminated with As, Cd, Cr, Cu, Ni, Pb and Zn. The level of Co, Fe and Mn was below the toxic level in plant leaves. This

Table 4. Transfer factor (TF) of heavy metals from soil to plants.

		As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Manihot esculenta	Wet Season	0.57	0.47	0.04	0.05	0.02	-	0.1	0.07	1.5	0.08
	Control	-	0.3	0.01	-	0.06	-	0.2	0.06	0.03	0.03
	Dry Season	2.01	0.11	-	-	0.03	-	0.11	0.3	0.37	0.12
	Control	-	0.21	-	-	0.07	-	0.23	0.08	0.03	0.04
Xanthosoma mafaffa	Wet Season	0.52	0.76	0.17	0.03	0.01	-	0.06	0.08	0.04	0.2
	Control	0.33	0.36	0.01	-	0.07	-	0.14	0.06	0.02	0.03
	Dry Season	1.05	0.79	-	0.05	0.02	-	0.08	0.06	0.11	0.19
	Control	0.36	0.21	-	-	0.09	-	0.14	0.02	0.04	0.06
Zea mays	Wet Season	1.55	0.37	0.22	0.02	0.01	-	0.03	-	0.05	0.08
	Control	0.12	0.2	-	-	0.09	-	0.05	-	0.02	0.03
	Dry Season	1.01	0.16	-	-	0.01	-	-	-	0.18	0.05
	Control	0.09	0.14	-	-	0.09	-	0.07	-	0.01	0.04
Musa sapientum	Wet Season	0.52	0.42	0.04	-	-	-	0.01	-	0.05	0.06
	Control	0.09	0.2	-	-	0.04	-	0.02	-	0.01	0.03
	Dry Season	1.06	0.38	-	-	0.01	-	0.03	-	0.17	0.04
	Control	0.12	0.21	-	-	0.08	-	0.03	-	0.01	0.05
Talinum triangulare	Wet Season	0.54	0.45	0.39	-	0.01	-	0.02	0.13	2.23	0.2
	Control	0.07	0.2	-	-	0.06	-	-	-	0.03	0.03
	Dry Season	1.31	1.31	-	0.35	0.02	-	0.29	-	1.57	1.2
	Control	0.08	0.07	-	-	0.09	-	-	-	0.04	0.03

study showed that the use of the landfill for agricultural purposes as at the time of the study was unsafe and the consumption of the crops from that landfill could be hazardous for animal and human health. This study particularly revealed that the landfill was polluted by Cd, Co, Cr, Cu, Ni, Zn, and Pb. This is therefore hazardous for agricultural purposes since plants are known to take up and accumulate heavy metals from contaminated soils (Madejon et al., 2003).

The consumption of *T. triangulare* from that farm could particularly be hazardous due to the high TF value recorded for Cd, Co, Cr, Ni, Pb, and Zn especially that the accumulated metals in edible plants may end up in human food chain with the adverse attendant effects on human health. It is noteworthy, from the result of this study, that *T. triangulare* can be used for phytoreme-diation of a soil polluted by the above mention-ed metals.

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