African Journal of Biotechnology Vol. 7 (17), pp. 3053-3060, 3 September, 2008
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2008 Academic Journals

Full Length Research Paper

Heavy metal concentrations in soils and accumulation in plants growing in a deserted slag dumpsite in Nigeria

Mary B. Ogundiran* and Oladele Osibanjo

Department of Chemistry, University of Ibadan, Ibadan, Nigeria.

Accepted 28 July, 2008

Early detection and remediation of heavy metals in soil and vegetation will ameliorate serious threats posed to human existence. An auto battery manufacturing company dumped slag containing proportion of heavy metals in an hectare of land at Lalupon, Ibadan, Nigeria. The extent of contamination of soil by heavy metals and their accumulation in plants around the abandoned slag was studied. Plants and the surrounding soils were sampled from different directions at increasing distance from the vicinity of the waste pile and their concentrations of heavy metals were determined. The levels of Pb, Zn and Ni in mg/kg ranged from 34.8 – 41500, 16.3 – 849 and ND – 48.2; 9.2 – 9700, 16.0 – 271 and 2.83 – 36.9; 4.5-5670, 8.00 – 174 and ND – 322 in soil, plant root and plant shoot, respectively. The plant samples from the immediate environment of the waste were highly contaminated with Pb. Six plant species, particularly *Sporobolus pyramidalis*, met some of the conditions to be classified as hyperaccumulators for Pb, Ni and Zn, and three other plants fulfilled the criteria for heavy metal excluders. We conclude that the potential hyperaccumulators and excluders, under controlled conditions, can be used for phytoremediation of the site.

Key words: Heavy metals, contamination, hyperaccumulator, excluder, phytoremediation.

INTRODUCTION

Soil contamination by heavy metals as a result of human activities is a serious environmental issue all over the world. Mining, smelting of metalliferous ores and metal scraps, electroplating, application of fertilizer and pesticides, sludge dumping and generation of municipal waste have been identified as the principal sources of soil contamination by heavy metals. Failure to mitigate high heavy metal concentrations in soils may result in mobilization of heavy metal contaminants into the flora and fauna and subsequently into man with consequent deleterious health effects.

Once heavy metals get into the environment, whether in small or large quantities, they cannot be completely eliminated. However, their effects on the ecosystem can be mitigated through immobilization. Research continues on the effective, less expensive and environment friendly methods of immobilizing heavy metals in contaminated soil thereby making them less bioavailable. One of the currently researched soil decontamination methods for heavy metal polluted matter is phytoremediation which is the use of plants to accumulate heavy metal contaminants (phytoextraction) and also to restrict their dissemination from the polluting source (phytostabilization) (Smith and Bradshaw, 1979; Kumar et al., 1995). Low cost, little or no landscape disruption, preservation of ecosystem, generation of a recyclable metal-rich plant residue, applicability to a range of toxic metals and public acceptance, among others, have been identified as merits of phytoremediation.

Three important uses of plants in environmental studies have been investigated which are as indicators of pollution (Gabriella and Attila, 2002; Fatoki and Ayodele, 1991) as excluders and as accumulators. Excluders are plants that limit the levels of heavy metal translocation within them and maintain relatively low concentrations in their shoot over a wide range of soil concentrations. They are employed in regenerating heavy metal contaminated soils (Baker, 1981). Accumulators concentrate heavy metals in their shoots at both low and high soil metal concentrations and are utilized in extracting heavy metals from contaminated soils (Rotkittikhun et al., 2006).

*Corresponding author: E-mail: mbogundiran@yahoo.com.

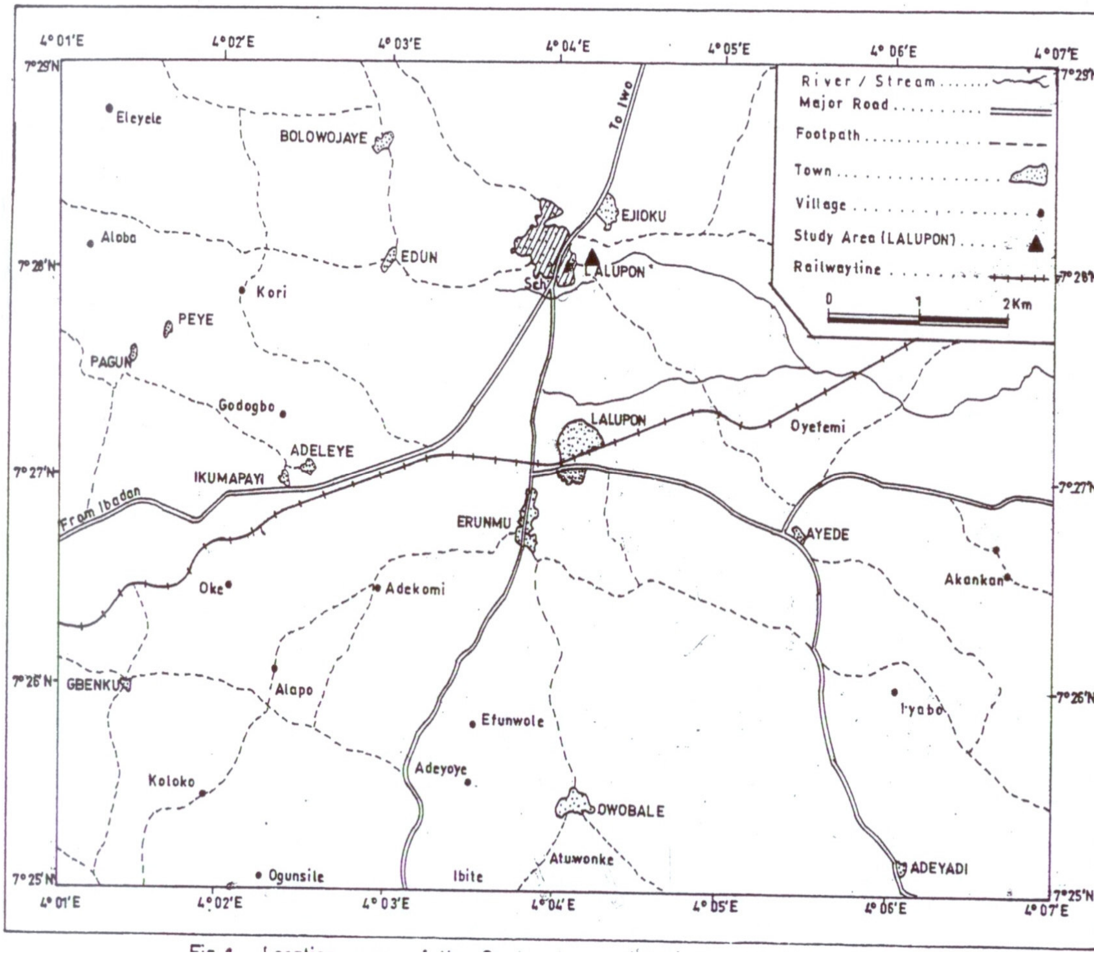

Figure 1. Map of Ibadan showing Lalupon, the sampling site.

Many field studies have investigated the accumulating capacity of plants that grew naturally on metalliferous wastes and on contaminated soils. It has been observed from such surveys that some plant species accumulate levels of heavy metals more than the normal levels encountered generally in plants (Boularbah et al., 2006; Kidd and Monterroso, 2005; Yanqun et al., 2004; Walter et al., 2003; Bunzl et al., 2001; Escarre et al., 2000; Smith and Bradshaw, 1979) thereby proposing that such plants can be used as decontaminants of heavy metal polluted soils. In Nigeria there is paucity of information about such metal tolerant plants locally. Hence in this study, we looked at the levels of Pb, Zn and Ni in soils and plants from a site contaminated by an abandoned Pb-acid battery waste in Lalupon, an outskirt of Ibadan, Nigeria.

MATERIALS AND METHODS

Site description

The study site was an abandoned auto battery waste dumpsite on an hectare of land owned by a defunct lead-acid battery manufacturing company located in Lalupon, Ibadan, Nigeria. Lalupon lies between longitude 7^o 28^1 N and latitude 4^o 04^1 E as shown in Figure 1. The area occupied by the waste is void of vegetation which may be a result of heavy metal toxicity while the adjacent land some distance away blossoms with different plant species.

Plants and soil sampling

Twenty six (26) plant samples consisting 15 different species were collected at different distances and along three different directions, west, north and north east from the centre of the waste pile and identified. These were directions suspected to be contaminated by run-off and other erosion agents from the waste-pile. Soils were sampled at the same locations as the plant samples at 15 cm depth rooting zone and mixed to form composite samples at each location. The choice of plant species collected was based on distance to the source of contamination and the availability at the point of collection as previously reported (Steinborn and Breen, 1999). For each plant species, depending on the biomass, two to six replicate samples were collected from each location within the area of 4 m^2. The samples were mixed to form a composite of the particular species, stored and transported in plastic bags to the laboratory for detailed analysis. Plant samples used for identification were collected separately and kept in a brown envelope. Sample identification was done at Forestry Research Institute of Nigeria (FRIN), Ibadan.

Plant and soil samples pretreatment

Plant samples collected from the field were washed under running tap water to remove adhered soils, and were then separated into parts including roots and shoots. The samples were dried in an oven for 48 h at 80°C. The dried samples were ground using agate mortal and pestle, sieved to < 2 mm and transferred to polyethylene bags for storage until later analysis. The soil samples were air-dried at room temperature for two weeks, mechanically ground and sieved to < 2 mm diameter size.

Soil analysis

The < 2 mm fraction soil samples were digested to determine the maximal environmentally available heavy metals. This was done using 2 M HNO_3 in centrifuge tubes which were placed in boiling water in a 1 L beaker on a hot plate for 2 h and shaken at 20 min intervals. The digested samples were filtered into 25, 50 or 100 mL standard flasks for varying distances of sampling points to the waste pile. The filtrates were diluted to the marks on the flasks with deionized water and stored in polyethylene tubes prior to instrumental analysis.

Composite sample

Seven composite soil sub-samples were obtained from the soil samples collected from the different locations in addition to one composite from the waste pile. Bulk soils were tested for basic physico-chemical properties including pH, potassium (K), calcium (Ca) and magnesium (Mg). Total K, Ca and Mg concentrations were determined using flame emission after digestion of the composite samples with boiling 2 M HNO_3 for 2 h. The pH of the soil was measured in water at ratio 1:1 soil/water.

Plant analysis

The roots and shoots of the different plants were analyzed separately for heavy metal content. 1 g of < 2 mm fraction plant samples was weighed into porcelain crucibles and was ignited in a muffle furnace for 6 h at a temperature between 450 - 500°C. Grey white ash was obtained at the completion of the ashing. The ash samples were allowed to cool and then 10 mL of 2 M HNO_3 was added to each sample. The solution was evaporated to near dryness on a hot plate and the cooled residues were re-dissolved in 10 mL 2 M HNO_3. The solutions were then filtered into 25 mL volumetric flasks. Both the crucible and the filter paper were washed into the flasks, made up with deionized water and then stored in polyethylene tubes for instrumental analysis. Atomic absorption spectrophotometer Buck Scientific 200 was used to analyse soil and plant digests for Pb, Zn and Ni.

Shoot/root quotient and extraction coefficient

Shoot/root quotient was determined by dividing the concentration of the heavy metals in the shoot by that of the root while the extraction coefficient was calculated by dividing the concentration of the heavy metals in the shoot by that of the soil as previously described (Rotkittikhun et al., 2006).

Quality control

The efficiency of digestion procedures for both soil and plant samples was tested by analyzing spiked samples (recovery studies) that were made from previously analyzed samples. Replicate analyses were performed on the spiked soil and plant samples to yield a mean which is used to determine trueness and also standard deviation of the mean to measure precision (Stanton 1966; Valcarcel, 2000).

10% duplicate samples were included to evaluate measurement precision. Procedural blanks and standard solutions were also included for analytical quality control to assure the accuracy and reproducibility of the results.

Statistical analysis

Pearson's correlation coefficient was used to determine the relationship between concentrations of soil Pb/Zn; soil Pb/Ni; soil Pb/plant Pb and between soil Zn/plant Zn using Statistical Package for Social Science (SPSS) version 14.0.

RESULTS

Chemical properties of composite soil samples

The soil physico-chemical properties of the composite samples are presented in Table 1. The pH of the soils ranged between moderately acidic (5.82) and slightly alkaline (7.58). The highest levels of Pb and Zn were found in the composite waste pile sample. The levels of Mg and K were much lower in the wastes when compared with their high levels in adjacent soils. All the soils were low in Ca content. The organic carbon content and the soil texture were reported elsewhere (Ogundiran, 2007).

Distribution of heavy metals in soils, roots and shoots of plant species

Chromolaena odorata and *Imperata cylindrical* were predominant plant species on the site followed by *Passiflora foetida*, *Sporobolus pyramidalis* and *Andropogon tectonum*. The presence of other plant species was sporadic. The concentration of heavy metals in plants and soils are as given in Table 2. Soil contamination with Pb and Zn was obvious in the west, north and north east directions of the site. Generally, the concentration of metals in soil and plants were found to decrease with distance from the waste pile to background levels as reported (Kabata-Pendias and Pendias, 2001). Pb and Zn concentrations in soil and plants were greatest at 40 m west and at 60 m north of the waste pile which happened to be in the immediate vicinity of the waste. At 40 m west, Pb and Zn levels in soils ranged from 1310 - 19600 mg/kg and 96.0 - 849 mg/kg, respectively; Pb and Zn levels in plants ranged from 18.7 - 15410 mg/kg and 73 - 1270 mg/kg, respectively. Also, at 60 m north Pb and Zn levels in soils ranged from 797 - 41500 mg/kg and 232 974 mg/kg, respectively; Pb and Zn levels in plants ranged from 317-693 mg/kg and 101 - 389 mg/kg, respectively. Heavy metals content in plants were ob-

Table 1. Chemical properties of composite soil and waste samples in abandoned auto battery waste dumpsite in Lalupon, Ibadan, Nigeria.

Location	Concentration (mg/Kg)							
	pH	Pb	Cd	Ni	Zn	Ca	Mg	K
40 mW	5.82	12600	ND	ND	131.2	10.0	1450	3620
60 mW	6.29	21.5	ND	ND	20.75	3.25	1730	1410
100 mW	7.05	44.5	ND	1.91	37.3	74.5	4820	8740
60 mN	5.86	18900	ND	10.3	182	27.0	3060	4020
100 mN	6.53	1140	ND	9.90	52.0	32.0	2720	4020
140 mN	7.58	1450	ND	ND	48.0	53.0	3640	3620
60 mNE	6.09	49.0	ND	ND	31.0	10.0	1130	4420
Waste pile	6.87	95700	ND	31.1	1670	75.0	974	804

ND = Not detectable.

Table 2. Concentration of Pb, Zn and Ni in soils and plants collected from auto battery waste dumpsite, Lalupon.

Location	Plant species	Pb concentration (mg/kg)			Zn concentration (mg/kg)			Ni concentration (mg/kg)		
		Soil	Root	Shoot	Soil	Root	Shoot	Soil	Root	Shoot
40 mW	*S. pyramidalis*	19600	9740	5670	849	197	174	4.11	16.2	322
	Py. polystachyos	23500	9640	94.8	817	1250	18.3	ND	18.6	35.5
	C. odorata	5540	275	95.5	270	275	23.5	15.6	20.9	ND
	I. cylindrical	1310	9.20	9.50	96.0	65.0	8.00	25.9	11.8	ND
60 mW	*C. odorata*	89.5	25.0	104	20.5	283	41.3	30.2	16.4	8.2
	P. foetida	182	15.0	29.5	18.5	83.8	12.0	30.0	16.0	7.25
	A. tectonum	44.8	42.5	22.0	19.8	27.5	41.3	31.4	9.71	3.83
	H. suaveolens	34.8	20.0	24.5	90.8	33.3	12.3	30.3	6.80	1.59
	I. cylindrical	149	22.5	19.5	1.70	88.3	25.0	31.3	9.77	1.82
100 mW	*C. mucunoids*	88.8	74.8	17.0	86.3	96.5	70.8	31.9	17.2	ND
	P. foetida	44.8	22.5	27.5	88.5	84.0	93.0	33.0	9.39	ND
60 mN	*P. foetida*	797	569	99.8	242	93	86	38.7	11.2	ND
	A. tectonum	5990	280	37.0	237	277	112	47.7	14.5	61.5
	C. odorata	4200	489	190	232	76.8	24.5	43.1	16.3	ND
	C. digitalis	41500	457	226	974	272	83.8	68.6	17.3	ND
100 mN	*Se. sesban*	3450	67.3	62.0	69.8	82.8	20.0	21.9	16.3	76.2
	T. platycarpa	2220	24.5	17.0	261	62.5	15.5	21.7	7.31	ND
	Cal. mucunoides	120	23.5	22.0	62.8	78.0	23.5	25.3	12.7	84.0
	I. cylindrical	3130	22.0	4.50	65.3	89.5	69.8	27.8	12.6	ND
140 mN	*T. platycarpa*	612	26.2	69.0	79.3	76.4	16.8	29.1	12.6	ND
	Ca. cajan	2950	79.8	39.3	81.5	83.8	13.3	23.4	15.9	ND
	C. odorata	291	50.0	37.0	16.3	16.0	16.0	25.9	8.52	ND
60 mNE	*D. aegypticum*	428	41.0	7.00	77.0	96.5	20.8	48.2	36.9	237
	Sc. dulcis	1490	14.5	9.50	208	82.5	91.8	13.1	17.0	ND
	C. odorata	209	49.0	64.7	48.8	82.5	23.8	22.2	12.9	118
	S. pyramidalis	431	399	17.0	71.0	82.5	16.8	15.2	2.83	137

ND = Not detectable.

tained by summation of the leves in roots and shoots at the locations considered. These levels fall within the concentrations of these metals in contaminated soils of other countries (Kabata-Pendias and Pendias, 2001) and also met remediation criteria for Pb and Zn contaminated soils (Ma and Rao, 1999; Vanik et al., 2005).

Variations in heavy metals concentration with plant species

By and large, *S. pyramidalis, Pycreus polystachyos, C. odorata, P. foetida, A. tectonum, Cajanus cajan* and *Cyperus digitals* accumulated Pb (Table 2). *S. pyramidalis* contained the highest concentrations of Pb in its roots (9740 mg/kg) and shoots (5670 mg/kg), followed by *Py. polystachyos* which had a high concentration in its roots (9640 mg/kg). Plants such as *I. cylindrical, Tephrosia platycarpa* and *Scoparia dulcis* sampled from a highly Pb-contaminated soil indicated low Pb concentrations in their morphologies in spite of the corresponding high soil Pb concentrations (Table 2). Some of the plants which showed high accumulation towards Pb also showed accumulation towards Zn particularly *S. pyramidalis, Py. polystachyos* and *C. odorata* (Table 2). Ni on the other hand indicated weak accumulation towards *C. odorata* but excessively towards *S. pyramidalis, Py. polystachyos* and *Calopogonum mucunoide* (Table 2).

Variations in heavy metals concentration in plants with levels in soil

Lead and Zn concentrations in plants varied with levels in soil. This was evident by the concentrations of heavy metals noticed in the roots of *C. odorata*, *P. foetida*, *S. pyramidalis* and *A. tectonum* collected at different locations. *C. odorata* indicated 275, 489, 50.0 and 49 and 25.0 mg/kg Pb in roots that grew on soils with 5540, 4200, 291, 209 and 89 mg/kg at 40 m W, 60 m N, 140 m N, 60 m NE and 60 m W respectively. Similar trends were also observed for *S. pyramidalis* at 40 m W and 60 m NE.

Pearson correlation analysis established that Pb concentrations in the plants were positively correlated with Pb concentrations in soil ($r = 0.93$, $p < 0.01$). The relationship between concentration of Zn in the soil and plant was weak.

Heavy metals accumulation in plants

S. pyramidalis showed noticeable levels of Pb in roots (9740 mg/kg) and shoots (5670 mg/kg shoot) followed by *C. odorata* (489 and 190 mg/kg), *Cy. digitals* (457 and 225 mg/kg) and *P. foetida* (569 and 100 mg/kg), while *Py. polystachyos* (9640 mg/kg) and *A. tectonum* (270 mg/kg) indicated high extraction of Pb only in their roots. Plants such as *I. cylindrical* {1310 mg/kg (soil), 9.20 mg/kg (root), 9.20 mg/kg (shoot)}, *T. platycarpa* {2220 mg/kg (soil), 24.5 mg/kg (root), 17.0 mg/kg (shoot)} and *Sc. dulcis* {1490 mg/kg (soil), 14.5 mg/kg (root), 9.50 mg/kg (shoot)} did not indicate Pb accumulation although they grew on highly Pb-contaminated soil (Table 2).

S. pyramidalis {197 mg/kg (root), 174 mg/kg (shoot)} and *A. tectonum* {277 mg/kg (root), 112 mg/kg (shoot)} accumulated substantial levels of Zn in roots and shoots. Unlike what was observed with Pb accumulation, *Py. polystachyos* {1250 mg/kg (root), 18.3 mg/kg (shoot)}, *C. odorata* {275 mg/kg (root), 23.5 mg/kg (shoot)} and *Cy. digitals* {272 mg/kg (root), 83.8 mg/kg (shoot)} accumulated high concentrations of Zn only in the root with very little transfer to the shoot.

The site did not show a considerable pollution with Ni. However, some of the plant species showed high levels of Ni in the shoots compared to the levels found in soils (Table 2). Ni extraction coefficients and shoots to roots quotients for *S. pyramidalis*, *Py. polystachyos*, *A. tectonum, Se. sesban, Cal. mucunoide* and *D. aegypticum* were greater than 1, with *S. pyramidalis* indicating the highest (78.3, 19.9)

Extraction coefficient and shoot/root quotient

None of the plants that were analyzed had extraction coefficient and shoot/root quotient greater than 1 for Pb. However *S. pyramidalis, Cal. mucunoide* and *Se. sesban* showed appreciable shoot/root quotients of 0.58, 0.94 and 0.92 respectively. *Sc. dulcis* (1.11), *C. odorata* (1.49) and *S. pyramidalis* (0.88) had their shoot/root quotients >1 for Zn (Table 3). Ni extraction coefficients and shoots to roots quotients for *S. pyramidalis*, *Py. polystachyos*, *A. tectonum, Se. sesban, Cal. mucunoide* and *D. aegypticum* were greater than 1 with *S. pyramidalis* indicating the highest (78.3, 19.9).

DISCUSSION

Chemical properties of composite soil samples

The highest levels of Pb and Zn were found in the composite soil from the waste indicating the waste as the source of soil pollution. The presence or absence of soil micronutrients and macronutrients determine the viability of plants on a particular soil. This necessitated the need to determine the levels of some of the important nutrients in the study area. Mg and K, which are important macronutrients for plant growth, were at much lower levels in the wastes when compared with their high levels in adjacent soils. This, in addition to the high Pb and Zn levels may explain the absence of plants on the waste pile. This may imply the need for nutrient enrichment of the waste prior to future experiments with the waste and regeneration of vegetations of the bared area with the discovered local metal tolerant plants. It is also obvious from the table as indicated by the pH 40 mW (5.82) and pH 140 m N (7.58) that *S. pyramidalis* and *C. odorata* can thrive both in slightly acidic and alkaline environments, suggesting that they can be potential materials for phytoremediation regardless of the pH of the contaminated area.

All the soil samples collected 40 m west and at 60 m north of the waste pile had higher levels of Pb than the

Table 3. Extraction coefficients and shoot/root quotient of plants that grew on highly lead-contaminated soils.

Plant species	Pb		Zn		Ni	
	Extraction coefficient = Shoot : soil	shoot/root quotients = Shoot : root	Extraction coefficient = Shoot : soil	shoot/root quotients = Shoot : root	Extraction coefficient = Shoot : soil	shoot/root quotients = Shoot : root
S. pyramidalis	0.29	0.58	0.23	0.88	78.3	19.9
Py. polystachyos	0.004	0.01	0.02	0.01	35.5	1.91
C. odorata	0.02	0.35	0.45	1.49	ND	ND
P. foetida	0.13	0.18	0.36	0.92	ND	ND
A. tectonum	0.01	0.13	0.47	0.40	1.29	4.26
C. digitalis	0.01	0.49	0.09	0.31	ND	ND
Sc. dulcis	0.01	0.7	0.44	1.11	ND	ND
Se. sesban	0.02	0.92	0.29	0.24	3.48	3.51
D. aegypticum	0.02	0.48	0.27	0.22	4.92	6.42
Cal. mucunoides	0.18	0.94	0.82	0.73	3.32	6.60

normal cleanup level of 400 mg/kg of Pb in soils (Chen et al., 2003). The levels of Zn were outside the range found in uncontaminated soils (20 - 300 mg/kg) (Steinborn and Breen, 1999). The levels of Ni found in the soil samples were within the normal range of 1-110 mg/kg reported for uncontaminated soils (Kabata-Pendias and Pendias, 2001). These levels impacted on the concentration of Ni observed in the plants.

The apparent diminishing of heavy metals concentration away from the waste pile almost certainly confirms the waste as the potential source of soil contamination and their concentrations in plants. About 58% of the soil samples analyzed indicated levels higher than the normal range (2 - 200 mg/kg) of Pb in soil (Kabata-Pendias and Pendias, 2001). Samples of plant collected from the immediate environment of the waste were grossly contaminated with Pb. The high levels of these metals present the site as potentially hazardous and highly inimical to food chain and biological life in the environment. This makes remediation of the site a matter of urgency for safe biological life and for a clean environment.

The results obtained showed that heavy metal concentrations in the plants varied with plant species, levels of heavy metals in the soils and heavy metal contaminants. Plant species such as *S. pyramidalis* and *Py. Polystachyos* accumulated Pb from the soil while *I. cylindrical, T. platycarpa* and *Sc. dulcis* sampled from highly Pb-contaminated soils contained very low levels of Pb (Table 2). This observation has been attributed to the differences in metal tolerance mechanisms. In actual fact, accumulation and exclusion have been viewed as the two fundamental mechanisms by which plants respond to high levels of heavy metals in soil (Steinborn and Breen, 1999; Yanqun et al., 2004). Excluders are plants that limit the levels of heavy metal translocation within them and maintain relatively low concentrations in their shoot over a wide range of soil concentrations. They are mostly employed in revegetating and stabilization of heavy metal contaminated soils (Baker, 1981). In plants that accumulate heavy metals, shoot/root quotients greater than 1 are commonly reported while shoot/root quotients less than 1 characterize heavy metal excluders. Based on this criterion, *I. cylindrical, T. platycarpa,* and *Sc. dulcis* could be regarded as potential Pb excluders or hypertolerant as described (Boularbah et al., 2006). Consequently these plants if found so in laboratory trials may be proposed for revegetation of the bare Pb-contaminated soils at Lalupon the site under consideration.

Lead and Zn concentrations in the plants varied with their levels in soil as demonstrated by the concentrations of heavy metals in *C. odorata*, *P. foetida, S. pyramidalis* and *A. tectonum* that were collected from different locations. Nevertheless, the degree at which a particular plant species accumulated Pb at the different locations in the present study differed, such that *S. pyramidalis* at 40 m W transferred 50% (i.e Pb in root/Pb in soil X 100) of the soil Pb to the root while the same plant transferred 92% of the soil Pb to its root at 60 m NE (Table 2). A similar trend was observed for *C. odorata* which transferred 5.0% soil Pb to the root at 40 m W (pH = 5.82) and 11.6% to its root at 60 m N. The lower levels of Pb in *S. pyramidalis* and *C. odorata* at 40 m W when compared to the level at 60 m N where the level in soil is lower may suggest that a few other soil factors may be responsible for the concentration of heavy metals in plant species apart from their levels in the soil. Some of such factors may be the form in which the metal exists in total soil, soil pH, soil organic matter and the degree of moisture in soil (Steinborn and Breen, 999; Xian, 1989). The implication is that the characteristics of the contaminated soil are also crucial to the effective field application of phytoremediation technique.

The extraction coefficient and shoot/root quotient have been used to demonstrate the ability of plants to accumulate heavy metals (Rotkittikhun et al., 2006). The extent of accumulation of heavy metals by the plants studied differed with the type of metal being considered. In the present study, *S. pyramidalis, Py. polystachyos, A. tectonum* and *Cal. mucunoide* accumulated the metals in the order Ni > Zn > Pb; *Se. sesban* and *D. aegypticum* in the order Ni > Pb > Zn as indicated by extraction coefficient and shoot/root quotient values (Table 3). Also, *C. odorata*, *P. foetida*, *Cy. digitals* and *Sc. dulcis* accumulated Zn and Pb whereas the values for Ni were undetectable. Criteria have been reported for a plant to be categorised as hyperaccumulator, that is, plant with exceptional ability to concentrate heavy metals in their shoots at both low and high soil metal concentrations. (Boularbah et al., 2006; Yanqun et al., 2004; Ginocchio and Baker, 2004) established that plant species which contained more than 0.1% (1,000 mg/kg) of copper, lead, nickel chromium or cobalt, cadmium >100 mg/kg, with an exception for zinc and Mn which have a threshold of 1% (10,000 mg/kg) in their dried tissues are hyperaccumulators. Hyperaccumulator was also defined (Shen and Liu, 1998) as concentrations of heavy metals in shoots by 10 – 500 times more than concentration in normal plants, if shoot/root quotient is greater than 1, and if extraction coefficient is greater than 1 (Rotkittikhun et al., 2006).

In this study, *S. pyramidalis* (5670 mg Pb/kg shoot) met the first two conditions as Pb hyperaccumulator since the concentrations of Pb in the shoot was > 1000 mg/kg and 10 - 500 times more than 0.5 - 10 mg/kg Pb levels in normal plants (Boularbah et al., 2006), *C. odorata* (190 mg Pb/kg shoot) and *Cy. digitals* (225 mg Pb/kg shoot) met the second condition where the levels of Pb in the shoot were more than 10 times what was obtainable in uncontaminated plants, suggesting that they are potential Pb hyperaccumulators. Similar observations were reported for *Sporobolus indicus, C. odorata* and *C. difformis* collected from a lead mine in Thailand (Rotkittikhun et al., 2006). Considering the last two conditions, none of the plants can be regarded as Pb hyperaccumulator *Se. sesban* (shoot/root quotients = 0.92) and *Dactyloctenium aegypticum* (shoot/root quotients = 0.94) are close to fulfilling the third and fourth conditions.

C. odorata and *Sc. dulcis* indicated shoot to root quotient greater than 1 for Zn although in unpolluted soil implying that this plant may likely accumulate Zn when planted on Zn polluted soils.

The soil samples from the site did not show any serious pollution with Ni and many of the plants analysed indicated little or no detectable concentrations of Ni in their shoots. This suggests that they did not accumulate Ni in their tissues above the ground. However, a few of the plants especially *S. pyramidalis*, *Py. polystachyos, A. tectonum, Cyperus digitalis*, *Cal. mucunoide* and *Dactyloctenium aegypticum* showed significant concentrations of Ni in the shoot even where the metal was below detection levels in the soil. Extraction coefficients were documented to be a key feature to be considered before a plant species can be listed as potential candidate for phytoremediation of heavy metal-contaminated soil (Yanqun et al., 2005). Accumulators concentrate heavy metals in their shoots at both low and high soil metal concentrations and are utilized in extracting heavy metals from contaminated soils (Rotkittikhun et al., 2006). In this study, *S. pyramidalis, Py. polystachyos, Se. sesban, D. aegypticum* and *Cal. mucunoides* showed extraction coefficients and shoot/root quotients > 1 for Ni, with *S. pyramidalis* showing the highest (78.3 and 19.9 respectively). Taylor et al. (1992) also observed excessive accumulation of Ni by cowpea (*Cal. mucunoide*). This presupposes that any of these plants, especially *S. pyramidalis,* may likely hyperaccumulate Ni when grown in Ni-contaminated soils. *Se. sesban* has been reported to accumulate Pb and Zn both in its root and shoot (Yang et al., 2003). In this work, the same plant species accumulated a reasonable level of Pb, had Zn plant levels higher than what was found in the soil and hyperaccumulated Ni.

The relative percent differences (RPD) for duplicate analyses for Pb, Zn and Ni included as quality control were less than 20% which is the control limit between duplicate as set by United States Environmental protecttion Agency (USEPA, 2002) indicating high precision. In the soils and plants used for recovery studies, Pb, Zn and Ni percent recoveries were within 100 ± 20% suggesting that errors attributable to total metal analysis were negligible. The coefficient of variations among replicate determinations was ≤ 5.0.

Conclusion

The results showed that some of the soils and plants studied were highly contaminated with Pb and Zn suggesting that the site poses potential hazards to grazing animals and the food chain. These findings suggest that there is need for urgent attention to proffer far reaching solutions to the problems of the exposed contaminated site.

On the other hand, some of the plants analyzed, particularly *S. pyramidalis,* showed high levels of metal tolerance to lead, zinc and nickel. These plants after establishing their accumulating abilities under laboratory and field studies can be utilized for the decontamination of the studied site and other polluted soils in Nigeria thereby reducing potential dangers of heavy metal toxicity to ecology.

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