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Full Length Research Paper

Metal tolerant species distribution and richness in and around the metal based industries: Possible candidates for phytoremediation

Anoliefo, G. O[1], Ikhajiagbe, B[2], Okonokhua, B. O[3], Edegbai, B. O[1] and Obasuyi, D. C[1].

[1]Department of Botany, University of Benin, Benin City, Nigeria.
[2]Raw Materials Research and Development Council, Abuja, Nigeria.
[3]Department of Agricultural and Environmental Science, University of Newcastle, Newcastle upon Tyne.

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Plant species growing in and around 38 metal welding workshops in Benin City, Nigeria, were surveyed. *Eragrostis tenella* occurred most frequently in all the sites, followed by *Amaranthus spinosus, Eleusine indica,* while *Cucurbita pepo* occurred least. The family Poaceae, was identified in all the sites visited. The frequency of occurrence of any particular plant species was used as an indicator of tolerance to heavy metals. Margalef index (R_1) showed the richest locations in the study to be workshops at Ekenwan Road Quarters with a value of 2.87, followed by those at Ikpoba Hill (2.75). Shannon -Weiner's diversity index (H) which reveals the location with the most species diversity, showed that Ekenwan Road gave the most diverse with a value of 2.43, followed by Ikpoba Hill (2.17). Wire Road was least diverse in plant species (1.33) . Ugbowo quarters had the highest evenness index of 0.96, followed by Sapele Road (0.95), with Wire Road being the location with least evenness (0.82). Cadmium (Cd) and lead (Pb) occurred in soil samples obtained from the sites. Six of the ten locations (Ekenwan, Plymouth, Siluko, Sapele, Sakponba and Ikpoba Hill Road Quarters) had elevated cadmium in soil samples obtained outside the workshops, with the highest concentration of 1.2 mg/kg detected at Ikpoba. Lead concentration was highest at Ugbowo (53 mg/kg). Metal-tolerant plants obtained in the present study are suggested as possible phytoremediating agents.

Key words: Welding workshops, metal tolerant plants, cadmium, lead, phytoremediation.

INTRODUCTION

Human activities constitute one of the major means of introduction of heavy metals into the soil. Ghosh and Singh (2005) reported that controlled and uncontrolled disposal of wastes, accidental and process spillage, min-ing and smelting of metalliferous ores and sewage sludge application to agricultural soils are responsible for the migration of contaminants into the soil. Other sources of anthropogenic metal contamination include electroplating, gas exhaust, energy and fuel production as well as the application of fertilizer and industrial manufacturing (Blay-lock and Huang, 2000).

Nigeria's quest to develop has necessitated the mas-sive building of industries by private entrepreneurs and multinational conglomerates. Land as a resource is sud-denly becoming scarce and one of the reasons is that the Governments at the Federal, State and Local levels take up lots of land for infrastructure. Small and medium scale industrialists are also in the land acquisition and farmers are not left out. Anoliefo and Umweni (2004) reported that undisturbed and pristine arable lands are hard to come by in Nigeria, such that abandoned mine fields, dump sites and most available plots are being cultivated to meet the ever increasing demand for food. Naidu et al. (2001) reported that one of the consequences of using dumpsites and exposing the 'clean' soil in the unpopu-lated areas to external nutrient sources such as fertilizer and sewage sludge is the incidence of pollution by heavy metals. Excessive metal concentrations in contaminated soils can result in decreased soil microbial activity, soil fertility and yield losses (McGrath et al., 1997).

Unlike many organic contaminants, most metals cannot

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

be eliminated from the environment by physico-chemical means (Neilson et al., 2003). They do not degrade and are persistent in the environment (Thangavel and Subbhuraam, 2004), though it may however be possible to reduce the toxicity by influencing their speciation (NRC-National Research Council, 1999). In soil these pollutants (metal concentrations) might accumulate in plants to unacceptable levels, causing reduction in crop yields and toxic effects in soil microorganisms.

Thangavel and Subbhuraam, 2004 reported that physico-chemical technologies for soil remediation render the land useless as a medium for plant growth because the technique removes all the biological activities include-ing useful microbes such as nitrogen fixing bacteria, mycorrhizal-fungi and the fauna thus decreasing biodiversity. Lombi et al. (2001) reported that traditional solutions such as disposal of contaminated soil in landfills presently account for a large proportion of the remediation operations. It becomes imperative that new technologies based on environmentally friendly and low-cost processes be employed.

A promising cost-effective plant-based technology for the cleanup of heavy metal pollution is phytoremediation. Lombi et al. (2001) stated that this technology has attracted attention in recent years because of the low cost of implementation and is particularly attractive in the tropics, where normal climatic conditions favour plant growth and microbial activity.

The present study employed the phytoextraction technique, a type of phytoremediation. This method, also referred to as phytoaccumulation, involves plant roots taking up and translocating contaminants in the soil to the shoot. The plants that are most preferred are usually short duration annual crops having highly branched roots, high root/shoot ratio, high specific root length, extremely long root hairs and high transpiration rate (Thangavel and Subbhuraam, 2004). Prasad, 2001 reported that the leafy vegetable-producing species like *Amaranthus spinosus, Alternanthera philoxeroides* and *Amaranthus sessile* have the ability to bioconcentrate cadmium, zinc and iron in leaf tissues. However, Siedlecka (1995) divided metal accumulating plants into three categories based on metal accumulation in plant parts. The first category accumulates more metals (Al, Cd, Co, Cr, Cu, Fe, Mo, Pb and Zn) in roots/rhizome, including beetroot, carrot, radish, Jerusalem artichoke, *T. caerulescence* and potato. The second accumulates more Ag, Sn and V in shoots (stems/leaves) and include cabbage, cauliflower, tomato, rice, barley, oats, wheat, corn, pigeon pea, chick pea, soybean, peanut, broccoli, lettuce, spinach and amaranthus. The third category accumulates metals (Mn and Ni) uniformly in roots and shoots, including bush bean, broad bean, mung bean and cucumber. In Nigeria, where farmers lack adequate funds and knowledge, a low cost technology devoid of any complications in application is highly recommended for the decontamination of metal polluted soils. Assessment of indigenous metal tolerant plants becomes necessary, especially in urban and Industrial soils. Robinson et al. (2003) reported that the soils in these areas are usually more heterogenous with high metal concentration ‘hot spots’ occurring at depth. The present study thus documents plant species growing in and around metal welding workshops in Benin City, Nigeria using Frequency of occurrence.

MATERIALS AND METHODS

Thirty-eight (38) different metal welding workshops, evenly distributed among 10 experimental locations (Figure 1), were visited. The number of workshops included in the 10 locations were: Ugbowo (3), Uselu Quarters (4), Siluko Quarters (3), Evbuotubu Quarters (4), Ekenwan Road Quarters (4), Wire Road Quarters (3), Plymouth Road Quarters (5), Sapele Road Quarters (3), Sakponba Quarters (5) and Ikpoba Quarters (4) (Table 1). At each workshop, quadrants were used and in each the different plant species were identified and counted. A representative plant from each species was carefully obtained, placed inside a polythene bag and later pressed. All collections were made from within and around the workshops. The term “around” for the purpose of the present study meant “up to 5 meter radius of the workshop”. The composition and distribution of each plant species was calculated. Species richness was determined using the number of species (N_0), Margalef index (R_1) and Menhinick’s index (R_2). Diversity was determined using Simpson’s diversity index (Lambala), Shannon-Weiner’s index (H) and Hills number of abundant species (N_1) and very abundant species (N_2). Evenness index (E), used to determine evenly distributed species, was calculated according to Ludwig and Reynolds (1988).

$$H = - \; pi \; \ln pi \text{------------------------------(i) Shannon-Weiner index}$$

Where pi = proportion of species = ni/N
ni = Number of individuals in each
N = Species total number of individuals in the population.

1. $R_1 = \frac{S-1}{\ln (N)}$ --------------------------------------(ii) Margalef index
2. $R_2 = \frac{S}{\sqrt{n}}$ --(iii) Menhinick’s index

Where S = Total number of species
n = Total number of individual observed

3. $E = \frac{H}{\ln S}$ ---(iv) Evenness index

Soil samples were also collected (0 - 10 cm depth) and analyzed for pH, Cd and Pb contents. The pH was determined on a 1:1 ratio of soil and water and read using the Jenway 3020 pH meter. For the metal analysis, extraction from the soil was by nitric-perchloric acid digestion procedure. The concentrations of cadmium and lead in the extract were analyzed by atomic absorption spectrophotometry.

RESULTS AND DISCUSSION

In all the experimental locations sampled (Figure 1 and Table 1), a total of 725 plants were obtained, comprising 12 families and 30 different species. The most prevalent plant species was *Eragrostis tenella* (Poaceae) with

Table 1. Thirty eight metal welding workshops distributed among 10 experimental locations in Benin City from where plant and soil samples were obtained.

S/N	Location	Number of workshops sampled	Specific locations
1	Ugbowo	3	*Ugb1: Federal Government Girls College* *Ugb 2: Aburhimen Str, Ugbowo,* *Ugb 3:Aideyan Str, Ugbowo,*
2	Uselu Quarters	4	*Us1:Technical College Rd,Uselu* *Us 2: Uselu Market Area,* *Us 3: Anigboro Str,Uselu Quarters* *Us 4: Iyobanosa Str Uselu Quarters*
3	Siluko Quarters	3	*Sil1: Garrick Memorial Junction, Siluko* *Sil2: Oliha Market Area, Siluko* *Sil3: By Textile Mill Rd Junction Siluko*
4	Evbuotubu Quarters	4	*Evb1: Edigi Str, Evbuotubu Quarters* *Evb2:Off Ekenwan Rd, Evbuotubu Quarters* *Evb3:Edogiawere Str, Evbuotubu Quarters* *Evb4:Osagiede Str, Evbuotubu Quarters*
5	Ekehuan Quarters	4	*Ek 1: Osaghae Avenue, Ekenwan Rd* *Ek. 2. Ozolua Avenue, Ekenwan Rd* *Ek 3: Joromi Str Junctio, Ekenwan Rd,* *Ek 4: Erediauwa Str, Ekenwan Rd*
6	Wire Road Quarters	3	*Wire Rd 1: Off Isekhere Str* *Wire Rd 2: Emotan College area* *Wire Rd 3:Triangle Avenue*
7	Plymouth Road Quarters	5	*Ply1: Oguanogbe Str, Plymouth Rd* *Ply 2: Obakharbaye Str Plymouth Rd,* *Ply 3: Basimi Str Plymouth Rd,* *Ply 4: Akenzua Str Plymouth Rd,* *Ply 5: Ekpenede Str Plymouth Rd*
8	Sapele Road Quarters	3	*Sap Rd 1: Ohuoba Str, Sapele Rd* *Sap Rd 2: Ezoti Lane, Sapele Rd* *Sap Rd 3: Obasohan Lane, Sapele Rd*
9	Sakponba Quarters	5	*Sakp Rd 1:Ogbelaka Str, Sakponba Rd* *Sakp Rd 2:Aruosa Str, Sakponba Rd* *Sakp Rd 3:Behind Hausa Quarters, Sakponba Rd,* *Sakp Rd 4:Nosakhare Str, Sakponba Rd* *Sakp Rd 5: Igun Str Sakponba Rd*
10	Ikpoba Quarters	4	*Ikpoba Hill 1: Ewa Road Junction* *Ikpoba Hill 2: Igbinedion Way, Iwogban* *Ikpoba Hill 3:Army Barracks,* *Ikpoba Hill 4:BDPA Estate*
Total number of workshops sampled: 38			

15.31% frequency of occurrence (FO). This was followed by *Amaranthus spinosus* (Amaranthaceae, 15.17% FO), *Eleusine indica* (Poaceae, 14.9% FO) and *Panicum maximum* (Poaceae, 10.07 % FO) in that order (Table 2). Baker et al. (1998) reported that more than 400 species are found to be capable of hyperaccumulation so far throughout the world covering at least 45 plant families including flowering plants, herbaceous species as well as shrubs and trees. The first hyperacccumulators characterized were members of the Brassicaceae and Fabaceae families (Thangavel and Subburam, 2004). The largest numbers of temperate climate hyperaccumulating species belong to the Brassicaceae (Baker and Brooks, 1989), in the tropics the Euphorbiaceae is the best represented group (Ensley et al., 1997). Along with Brassicaceae, Fabaceae and Euphorbiaceae, Duchenkov (2003), added the families Asteraceae, Lamiaceae and Scrophulariaceae. A hyperaccumulator plant has been

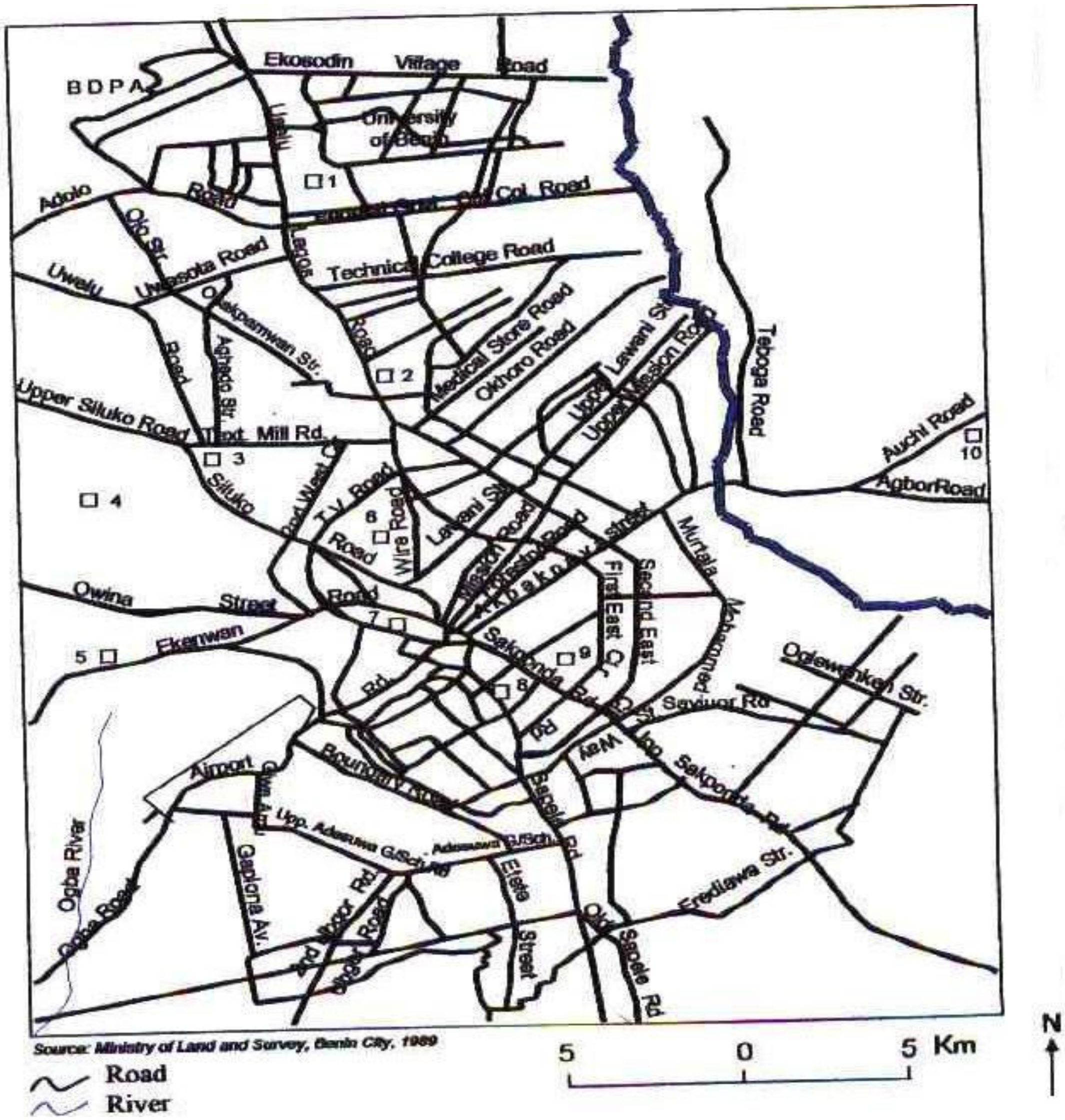

Figure 1. The topographic map of Benin city showing metal welding workshop locations.
Key: 1. Ugbowo; 2, Uselu Quarters 3, Siluko Road 4, Evbuotubu Quarters 5, Ekenwan Road 6, Wire Road .7, Plymouth Road 8, Sapele Road 9, Sakponba Road 10, Ikpoba Hill.

shown as the one whose metal accumulation exceeds a threshold value of shoot metal concentration of 1% (Zn, Mn), 0.1% (Ni, Co, Cr, Cu, Pb and Al), 0.01% (Cd and Se) or 0.001% (Hg) of the dry weight shoot biomass (McGrath, 1998).

The present study sought to identify hyperaccumulator plants based on their percent prevalence in locations sampled. *E. tenella* and *E. indica* of the family Poaceae, *Amaranthus spinosus* (Amaranthaceae) and *Peperomia pellucida* (Piperaceae) occurred in at least 9 of the 10 experimental locations sampled. Although *P. maximum* had a high frequency of occurrence, it was found only in 5 of the 10 locations. Ghosh and Singh (2005) reported that certain plants in the natural setting have the potential to take up heavy metals. *P. maximum* was the predominant vegetation in a derelict Pb- Zn mine in Nigeria (Chukwuma, 1995). Wong and Lau (1985) on their own part reported *E. indica* to be tolerant to Pb in roadside emissions.

In the present study, poorly distributed plant species (those that occurred in 2 or less out of 10 locations) include *Andropogon gayanus, Mariscus longibracteatus, Cyperus rotundus, Portulaca quadrifida, Curcubita pepo, Chromolaena odorata, Cyperus esculentus, Mariscus flabelliformis, Ixora coccinea, Sida corymbosa* and *Talinum triangulare* (Table 2). The low frequency of occurrence of some of the plant species around motor mechanic workshops does not necessarily imply that these plants have low tolerance to metals. Low frequency of occurrence may result from constant clearing/weeding by humans due to the shrubby or herbaceous perennial nature of the plants. Ridding the area of invasive plants like *C. odorata* becomes necessary in order for the Mechanic (Workshop owner) to meet with sanitary requirements of the Local Government authorities. This weed (*C. odorata*) has been confirmed in a number of studies to be tolerant to soil acidity, aluminium saturation (Olaoye, 1982) and oil (Anoliefo and Vwioko, 2001). It also establishes itself before any other plants on a cleared ground. Another poorly distributed plant is *Talinum triangulare,* a locally edible vegetable. Adeniyi (1996) and Yusuf et al. (2003) had earlier reported that *T. triangulare* showed tolerance when exposed to soil polluted with Cd, Cu, Ni, Fe, Mn and Zn. The plant is used as vegetable for cooking and as such is constantly removed from the field (site); accounting for its low occurrence.

In all the sites visited, plant species of the family Poaceae was most prevalent (Table 3). This was followed in a decreasing order by the families Amaranthaceae, Portulacaceae, Cyperaceae, Piperaceae, Malvaceae, Euphorbiaceae and Asteraceae. Gibson and Polard (1988) reported that heavy metal tolerance is common in the Poaceae family. Anoliefo et al. (2006) also reported abundance of plant species of the families Poaceae, Asteraceae and Euphorbiaceae in oily workshops of motor mechanics. Prasad and Freistas (2003) identified plants in the families; Asteraceae, Poaceae, Cyperaceae and Euphorbiaceae as having the ability to hyperaccumulate heavy metals.

Plant biodiversity is increasingly being considered in the study of clean up of metal contaminated and polluted systems (Prasad and Freitas, 2003) . Table 4 presents the composition and distribution of plant species in the workshops visited. Margalef index (R_1) shows the richest locations in the study to be Ekenwan Road Quarters with a value of 2.87, followed by those at Ikpoba Hill (2.75). Shannon-Weiner's diversity index (H) which reveals the location with the most species diversity, showed that Ekenwan Road gave the most diverse with a value of 2.43, followed by Ikpoba Hill location (2.17). Wire Road location was least diverse in plant species (1.33). Ugbowo quarters had the highest evenness index of 0.96, followed by Sapele Road (0.95), with Wire Road being the location with least evenness (0.82).

In all, the metal welding workshops within Ekenwan Road showed the richest and most diverse set of plant species sampled including *P. pellucida, A. spinosus, E. indica, E. tenella, C. pilosa, T. triangulare, M. alternifolius, G. celosioides, P. africana, P. oleracea, S. acuta, P. amarus, P. maximum* and *C. benghalensis.* These plant species may possess capabilities for tolerance to heavy metals particularly Cd. This is because more than 50% of the metal welding workshops sampled along Ekenwan Road had Cd beyond the recommended limit of the Interdepartmental Committee on Reclamation of Contaminated land (ICRCL, 1987). Gleba et al. (1999) proposed that hyperaccummulator species can be identified by collecting plants from the areas where soil contains greater than usual amount of metals as in the case of polluted areas or places that are geographically rich in a particular element. Prasad (1995) had reported that some of the prevalent mechanisms of Cd-tolerance were accumulation, sequestration, synthesis of Cd-binding complexes and their stabilization by sulphide ions.

Prevalence of some plant species in one location but not in the other may be attributed to environmental factors. Some of these factors affect plant growth including the topography of the land, soil type, drainage characterristics, climate and the level of contaminants present in the environment (Imevbore and Adeyemi, 1981). Plants growing in metal contaminated soils need to develop some degree of tolerance to metal toxicity in order to survive (Patra et al*.,* 2004). Since all plants contain at least some metal in their tissues, they clearly are incapable of completely excluding potentially toxic elements, but simply of restricting their uptake and/or translocation (Patra et al*.,* 2004). Heavy metal tolerance in plants is made possible through metal sequestration by specially produced organic compounds, compartmentalization in cell compartments, metal ion efflux and organic ligand exudation. A relatively small group of hyperaccumulator plants are capable of sequestering heavy metals in their shoot tissues at high concentrations (Yang et al*.,* 2005).

Heavy metal tolerance, as observed in the present study using frequency of occurrence of plants in heavy metal polluted soils identified several plant species and families which have also been shown to have hyperaccumulator ability (Prasad and Feitas, 2003). This phenome-non has implications in phytoremediation. Six of the ten locations (Ekenwan Road Quarters, Plymouth Road Quarters, Siluko Road Quarters, Sapele Road Quarters, Sakponba Road Quarters and Ikpoba Hill Quarters) had elevated cadmium in soil samples obtained outside the workshops (Table 5). This may indicate the points of disposal of the workshop wastes. Lead concentration was generally high. Jaradat and Momani (1999) reported that metals such as Cu, Fe, Zn and Cd are essential components of many alloys, wires and tires and Andrews (1992) added that lead occurs in soils near roads and smelters.

Soil pH affects metal concentration. Decrease in pH causes metal desorption from organic and clay particles thus making the metals to enter the soil solution. However at high pH, metals remain adsorbed and the ones in solution precipitate out in the form of salts (Chen et al., 1996).

Metal clean-up using plants would be of immense benefit to a developing country because of the cheap-but-efficient technology. The only hurdle would be on what to do with the metals accumulated in the plants. Several authors have suggested composting and compaction as post harvest biomass treatment (Kumar et al., 1995; Raskin et al., 1997; Garbisu and Alkorta, 2001). Leaching tests for the composted materials showed that the com-

Table 2. Plant species distribution in metal welding workshop in Benin City, Nigeria.

Name of plant species	Families	Class	Types	Ikpoba Hill	Ekenwan Road	Evbuotubu Qtrs	Plymouth Road	Uselu Qtrs	Ugbowo Qtrs	Wire Road	Siluko Road	Sapele Road	Sakponba Road	SUM	% Frequency ofOccurrence
Eragrostis tenella	Poaceae	Monocot	Grass	14	4	9	40	7	4	12	10	7	4	111	15.31
Amaranthus spinosus	Amaranthaceae	Dicot	Herb	13	9	17	34	3	8	10	6	2	8	110	15.17
Eleusine indica	Poaceae	Monocot	Grass	0	8	4	25	9	3	18	16	7	18	108	14.9
Panicum maximum	Poaceae	Monocot	Grass	21	20	6	16	0	10	0	0	0	0	73	10.07
Chloris pilosa	Poaceae	Monocot	Grass	0	8	16	9	9	4	3	0	2	2	53	7.31
Portulaca oleracea	Portulacaceae	Dicot	Herb	2	6	2	26	2	4	0	0	3	5	50	6.90
Peperomia pellucida	Piperacea	Dicot	Herb	1	7	2	2	5	0	1	10	4	1	33	4.55
Cynodon dactylon	Poaceae	Monocot	Grass	4	0	7	0	0	9	0	0	0	3	23	3.17
Sida acuta	Malvaceae	Dicot	Shrub	4	2	4	0	0	0	0	1	6	6	23	3.17
Gomphrena celosioidas	Amaranthaceae	Dicot	Herb	0	3	6	0	0	0	0	8	0	0	17	2.34
Cyperus haspan	Cyperaceae	Monocot	Sedge	0	0	0	14	0	0	0	0	0	0	14	1.93
Phyllanthus amarus	Euphorbiaceae	Dicot	Herb	2	10	0	0	0	0	0	0	0	0	12	1.66
Fleurya aestuans	Urticaceae	Dicot	Herb	0	0	0	5	1	0	0	0	4	0	10	1.38
Cyperus esculentus	Cyperaceae	Monocot	Sedge	0	0	0	0	0	9	0	0	0	0	9	1.24
Platostoma Africana	Lamiaceae	Dicot	Herb	0	5	0	0	0	0	0	4	0	0	9	1.24
Chromolaena odorata	Asteracea	Dicot	Shrub	0	0	0	0	0	0	0	1	0	8	9	1.24
Commelina benghalensis	Commelinacea	Monocot	Herb	0	3	0	0	0	0	0	0	0	4	7	0.97
Mariscus longibracteatus	Cyperaceae	Monocot	Sedge	0	0	0	7	0	0	0	0	0	0	7	0.97
Cyperus rotundus	Cyperaceae	Monocot	Sedge	0	0	0	0	0	7	0	0	0	0	7	0.97
Portulaca quadrifida	Portulacaceae	Dicot	Herb	0	0	0	0	0	0	0	0	0	7	7	0.97
Mariscus alternifolius	Cyperaceae	Monocot	Sedge	0	6	0	0	0	0	0	0	0	0	6	0.83
Aspilia Africana	Asteraceae	Dicot	Herb	6	0	0	0	0	0	0	0	0	0	6	0.83
Talinum triangulare	Portulacaceae	Dicot	Herb	3	1	0	0	0	0	0	0	0	0	4	0.55
Ixora coccinea	Euphorbiaceae	Dicot	Shrub	0	0	0	0	4	0	0	0	0	0	4	0.55
Sida corymbosa	Malvaceae	Dicot	Shrub	4	0	0	0	0	0	0	0	0	0	4	0.55
Andropogon gayanus	Poaceae	Monocot	Grass	0	0	0	2	0	0	0	0	0	0	2	0.28
Andropogon tectorum	Poaceae	Monocot	Grass	2	0	0	0	0	0	0	0	0	0	2	0.28
Paspalum conjugatum	Poaceae	Monocot	Grass	2	0	0	0	0	0	0	0	0	0	2	0.28
Mariscus flabelliformis	Cyperaceae	Monocot	Sedge	0	0	0	0	0	0	0	2	0	0	2	0.28
Cucurbita pepo	Curcubitaceae	Dicot	Herb	0	0	0	0	0	0	0	0	0	1	1	0.14
														725	100.00.

Table 3. Distribution of plant families in metal welding workshops in Benin City, Nigeria.

Families	Number of plant species	Total Individual plants	% Frequency of occurrence
Poaceae	8	374	51.59
Amaranthaceae	2	127	17.52
Portulacaceae	3	61	8.41
Cyperaceae	6	45	6.21
Piperaceae	1	33	4.55
Malvaceae	2	27	3.72
Euphorbiaceae	2	16	2.21
Asteraceae	2	15	2.07
Urticaceae	1	10	1.38
Lamiaceae	1	9	1.24
Commelinaceae	1	7	0.97
Curcubitaceae	1	1	0.14

Table 4. Composition and distribution of plant species found in metal welding workshops in Benin City, Nigeria.

		Ikpoba Hill	Ekenwan Road	Evbutubu Qtrs	PlymouthRoad	Uselu Qtrs	Ugbowo Qtrs	Wire Road	Siluko Road	Sapele Road	SakponbaRoad
RICHNESS											
	No	13	14	10	11	8	9	5	9	8	12
	R_1	2.75	2.87	2.1	1.93	1.9	1.97	1.06	1.97	1.97	2.62
	R_2	1.47	1.46	1.17	0.82	1.26	1.18	0.75	1.18	1.35	1.47
DIVERSITY											
	Lambda	0.14	0.1	0.14	0.14	0.14	0.11	0.28	0.16	0.12	0.12
	H^1	2.17	2.43	2.08	2.09	1.9	2.12	1.33	1.91	1.98	2.21
	N_1	8.77	11.3	8.1	8.1	6.7	8.3	3.77	6.75	7.24	9.14
	N_2	7.17	10.4	7.12	7.12	6.9	8.84	3.54	6.36	8.04	8.16
EVENNESS											
	E_1	0.85	0.92	0.9	0.87	0.91	0.96	0.82	0.87	0.95	0.89
	E_2	0.67	0.81	0.8	0.74	0.84	0.92	0.75	0.75	0.9	0.76
	E_3	0.65	0.79	0.78	0.71	0.81	0.91	0.69	0.72	0.89	0.74
	E_4	0.82	0.92	0.92	0.89	1.03	1.06	0.94	0.94	1.11	0.89
	E_5	0.79	0.91	0.91	0.87	1.03	0.07	0.93	0.92	1.12	0.88

No = Number of species; H^1 = Shannon-Weiner Diversity Index; $E_{1\text{-}5}$ = Evenness Indices
R_1 = Margalef Index; N_1 = Number of abundant species
R_2 = Menhinick Index; N_2 = Very abundant species

posting process formed soluble organic compounds that enhanced metal (Pb) solubility (Ghosh and Singh, 2005). Composting is a process that is much in use in Africa especially by farmers. However phytomining seem to be one of the 'best' means of disposal of the heavy metals. Brooks et al. (1998) proposed that the ash obtained from combustion and gasification of the biomass removed from metal polluted sites can be used as bio-ore. Production of the ore should be encouraged by governments in the developing countries through funding of research into its development.

Conclusion

Observations from the present study provide a list of plants that sprout and grow in metal laden soils. These

Table 5. Soil pH, lead (Pb) and cadmium (Cd) concentration in mg/kg obtained within (A) and around (B) metal welding workshops in different locations in Benin City

[A1]			
Workshop location	**pH**	**Pb**	**Cd**
		<======== mg/kg ========>	
Ugbowo 1	5.7	13.10	1.07*
Ugbowo 2	6.1	47.94	0.98
Ugbowo 3	5.6	10.12	0.10
[B1]			
Ugbowo 1	5.6	52.71**	0.42
Ugbowo 2	6.5	11.45	0.75
Ugbowo 3	5.8	15.12	0.18
[A2]			
Workshop location	**pH**	**Pb**	**Cd**
		<======== mg/kg ========>	
Uselu 1	5.9	10.97	0.54
Uselu 2	5.5	10.48	0.30
Uselu 3	5.4	10.21	0.10
Uselu 4	6.5	12.34	0.29
[B2]			
Uselu 1	5.7	12.05	0.13
Uselu 2	5.5	10.52	0.11
Uselu 3	5.7	10.87	0.05
Uselu 4	5.4	12.41	0.65
[A3]			
Workshop location	**pH**	**Pb**	**Cd**
		<======== mg/kg ========>	
Siluko 1	5.4	12.40	0.45
Siluko 2	5.7	10.69	0.17
Siluko 3	5.9	12.14	0.87*
[B3]			
Siluko 1	5.5	10.73	0.13
Siluko 2	5.8	11.95	1.05*
Siluko 3	5.8	10.62	0.31
[A4]			
Workshop location	**pH**	**Pb**	**Cd**
		<======== mg/kg ========>	
Evbuotubu 1	4.9	11.38	0.68
Evbuotubu 2	5.8	21.75	0.15
Evbuotubu 3	5.4	10.85	0.33
Evbuotubu 4	6.2	11.24	0.11
[B4]			
Evbuotubu 1	6.4	10.95	0.04
Evbuotubu 2	5.2	11.05	0.50
Evbuotubu 3	5.8	10.08	0.10
Evbuotubu 4	5.9	11.63	0.29
[A5]			
Workshop location	**pH**	**Pb**	**Cd**
		<======== mg/kg ========>	
Ekenwan 1	5.8	10.78	1.36*
Ekenwan 2	6.4	12.15	0.13

Table 5 cont.

Ekenwan 3	5.6	11.66	0.41
Ekenwan 4	6.2	14.69	0.89
[B5]			
Ekenwan 1	5.3	10.92	0.74
Ekenwan 2	5.9	12.23	0.63
Ekenwan 3	5.5	11.11	1.10*
Ekenwan 4	6.1	11.02	0.15
		[A6]	
Workshop location	**pH**	**Pb**	**Cd**
		<======== mg/kg ========>	
Wire Road 1	5.9	11.46	0.17
Wire Road 2	5.7	10.01	0.10
Wire Road 3	5.3	11.35	0.06
[B6]			
Wire Road 1	5.7	13.91	0.04
Wire Road 2	5.7	12.43	0.15
Wire Road 3	5.5	14.51	0.20
[A7]			
Workshop location	**pH**	**Pb**	**Cd**
		<======== mg/kg ========>	
Plymouth 1	5.6	11.15	0.10
Plymouth 2	5.5	11.06	0.11
Plymouth 3	5.4	13.09	0.32
Plymouth 4	5.6	15.38	0.11
Plymouth 5	5.6	10.05	0.09
[B7]			
Plymouth 1	5.6	11.10	0.77
Plymouth 2	5.6	21.20	0.21
Plymouth 3	6.5	11.45	0.75
Plymouth 4	6.7	22.10	1.06*
Plymouth 5	6.5	22.18	1.11*
[A8]			
Workshop location	**pH**	**Pb**	**Cd**
		<======== mg/kg ========>	
Sapele 1	5.4	21.43	0.66
Sapele 2	5.2	32.81	0.76
Sapele 3	5.9	15.01	0.55
[B8]			
Sapele 1	5.6	15.60	0.10
Sapele 2	5.5	40.86	1.03*
Sapele 3	6.3	10.74	0.61
[A9]			
Workshop location	**pH**	**Pb**	**Cd**
		<======== mg/kg ========>	
Sakponba 1	5.8	10.21	0.11
Sakponba 2	5.2	16.01	0.09
Sakponba 3	5.8	13.98	0.89
Sakponba 4	5.5	10.61	0.14
Sakponba 5	5.2	10.21	0.10
B9]			

Table 5 cont.

Sakponba 1	6.2	11.78	0.35
Sakponba 2	5.8	23.10	1.08*
Sakponba 3	5.6	22.18	1.11*
Sakponba 4	5.7	11.52	0.10
Sakponba 5	5.5	15.02	0.81
[A10]			
Workshop location	**pH**	**Pb** <======== mg/kg	========> **Cd**
Ikpoba 1	5.6	11.54	0.21
Ikpoba 2	5.8	10.12	0.11
Ikpoba 3	5.7	20.09	1.08*
Ikpoba 4	5.5	11.25	0.14
[B10]			
Ikpoba 1	6.3	11.61	0.33
Ikpoba 2	6.1	10.46	1.20*
Ikpoba 3	5.3	11.45	0.62
Ikpoba 4	5.3	16.12	0.12

*Total cadmium (Cd) content in soil above maximum recommended limit
**Total lead (Pb) content in soil above maximum recommended limit
The Interdepartmental Committee on Reclamation of Contaminated Land (ICRCL) limits for heavy metals in soil used for agriculture and recreation are;
Cd= 0-1 mg/kg, Pb= 1-500 mg/kg and 0-250 mg/kg (average for lead = 50 mg/kg).

plants are tolerant to metal pollution in soil and are 'candidates' for remediation strategies and management for heavy metals contaminated soils.

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