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Re-Establishment of Vegetation on Soil Contaminated by Battery Wastes in Response to Application of Mexican Sunflower and Cassava Peels Composts

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Abstract

Soil contamination by industrial wastes contributes greatly to poor soil fertility, ecological imbalance and phytotoxicity. To restore soil fertility and encourage plant growth, remediation of contaminated land becomes pertinent. The use of organic amendment has been reported to be effective for restoration of heavy metal contaminated soil. Effects of Mexican Sunflower (Tithonia diversifolia: MSC) and Cassava peels (Manihot esculentum: CPC) composts, each applied at 20 and 40 t/ha as well as inorganic fertilizer (NPK 20:10:10) applied at 100 kgN/ha were investigated for restoration and re-vegetation of a degraded battery wastes contaminated site. The experiment was laid out in a Randomized Complete Block Design (RCBD). Ordination method was used to measure flora diversity and abundance among treatments. The species importance in the ecosystem was determined using Relative Importance Values (RIV) before application of compost (BAC), at 4 weeks after compost application (4WACA) and at 8 weeks after compost application (8WACA). Also, the dominance and plant species distribution at the three periods were determined from the Dominance, Shannon and Equitabilty indices. Application of composts increased the number of individual plants on the contaminated site from 1177 at BAC to 2276 at 8 WACA. Species richness increased from 7 species at BAC to 15 species at 8 WACA. Gomphrena celosoides L. had the highest RIV value (72.4%) at BAC, 67.0% and 49.6% at 4 WACA and 8 WACA respectively. The dominance index (DI) decreased from 0.8557 at BAC to 0.6008 at 8 WACA. At 8 WACA the Shannon index (0.9976) and Equitability index (0.3684) were highest. Application of MSC at 40t/ha (MSC40) reduced Pb level in the soil by 71.6% followed by CPC40 (67.3%), MSC20 (66.1%) and least in CPC20 (49.5%). NPK fertilizer application had no effect on soil Pb level compared to control. Addition of compost significantly increased the plant nxutrients including phosphorus, nitrogen, calcium and magnesium in the soil compared to inorganic fertilizer. The use of compost reduced Pb contamination, improved soil fertility, enhanced re-vegetation and flora diversity of battery waste contaminated site more than inorganic fertilizer. The prevalence of G. celosioides may suggest that it has potentials for the phytoremediation of lead-acid battery polluted soil.

Keywords: *Compost, Flora diversity, heavy metals, pollution, remediation*

Introduction

Indiscriminate disposal of hazardous wastes arising from industrialization has been blamed for the continuous alteration of naturally balanced ecosystem, loss of plant diversity and reduced soil fertility as a result of contamination. Hundreds of tons of hazardous wastes from industrial activitiescontaining heavy metals are reportedlystored indumps,landfills, lagoons and underground tanks while some are indiscriminately dumped on land in many parts of the world (USEPA, 1997).

Soil contamination generally reduces the amount of cultivable land and crop yield, thus posing a threat to food security in terms of availability and quality. Activities such as mining, smelting of metaliferous ores and metal scraps, electroplating and municipal wastes have been identified as the principal sources of contamination by heavy metals (UNEP, 2000; Ogundiran and Osibanjo, 2009). Excessive amount of heavy metals in soils produces harmful effects on the ecosystem (Vishnu *et al.*, 2007).

Other ecological consequences include alterations of the physical landscape, destruction of natural habitat and biodiversity, soil degradation, air and water pollution (Aina and Adedipe, 1996). Heavy metals displace essential metal ions from biomolecules thereby causing deficiency symptoms in plant grown on heavy metal polluted soil (Seregin *et al.*, 2005). Their presence in food chain has been found to be detrimental to plant, animal and human health. Lead is especially toxic to children (Needleman *et al.*, 1982). It may enter plant through the root and leaves (Taiwo, 2007). It is an enzyme poison that disturbs normal biological reaction (Pallavi and Dubey, 2005). Cadmium has been reported to inhibit chloroplast activity with a decrease in total chlorophyll and in the chlorophyll a/chlorophyll b ratio (Govindjee, and Bazzaz, 1974). Discoloured foliage, reduction in visual appeal and marketability, wilting and eventual death are some of the effects of heavy metals on plants (Dale *et al.*, 2006; Vishnu *et al.*, 2007).

Due to the alteration in the ecosystem, there is the compelling need to clean up and restore heavy metal contaminated sites. Soil remediation is therefore needed to eliminate or reduce the risk to the ecosystem and restore the already degraded land so that it can be used for crop production. Considerable remediation of contaminated soils and sediments has been accomplished by composting (Chaney *et al.*, 2000; Ryan *et al.*, 2007). This method is said to be environment-friendly, and cost-effective. It avoids dramatic landscape disruptions, and preserves the ecosystem (USEPA, 1997). Organic matter is beneficial for the re-vegetation of barren soil The benefits derived from utilization of organic materials for improvement of soil fertility, crop production and binding of heavy metal have been well discussed (Chaney *et al.*, 2000; Cao *et al.*, 2003; Togun *et al.*, 2003; Rennevan *et al.*, 2007, Ryan *et al.*, 2007). This study was carried out to test for the effects of compost and inorganic fertilizer on vegetation re-establishment on a heavy metal contaminated site in Ibadan, Nigeria.

Materials and methods

Description of experimental site

Abandoned dumpsite of a lead-acid battery manufacturing company in Ibadan, Nigeria was used for the trial. The site was located at Ori-ile, Kumapayi village in Egbeda Local Government Area (near Ibadan), Oyo State in Southwestern Nigeria. It is located on latitude $7^{o}24.456'$ N; longitude $4^{o}00.876'$E and an elevation of 174 m above the sea level. The site lies within the transitional forest-savanna ecosystem of Nigeria. Several hectares of land in this area are no longer productive and almost denuded of vegetation.

Soil chemical analyses

Pre-treatment soil chemical analyses were carried out by taking soil samples at 0-15cm depth from the main contaminated site and its surroundings using standard procedure. Total bio-available concentrations ofPb (mg/kg) for plant uptake were determined using Atomic Absorption Spectrophotometer Bulk Scientific Model 210 (VGP) after digestion with 2M nitric acid (Smejikalova *et al.*, 2003). Post-treatment samples were also taken from different plots onthe main contaminated site for chemical analysis. Soil pH was measured using a pH meter-Electrometric Method in 1:1 w/v of soil to water. Total nitrogen and phosphorous were determined using Kjedahl (Bremmer, 1965) and Vanado-Molybdate yellow methods respectively, while dichromic acid digestion (IITA, 1979) was used for percentage organic carbon. Ammonium acetate (pH 7, 1N) was used to extract exchangeable bases from soil samples and the cations determined using the flame photometer. Soil Pb concentration was also determined using the method described above.

Preparation of compost

Composts were prepared separately from mexican sunflower (*Tithonia diversifolia* (Hemsl) A. Gray), cassava peels and poultry manure to give mexican sunflower compost (MSC) and cassava peel compost (CPC) respectively. The concrete surface heap method was adopted in the composting (Adediran *et al.*, 2001; Akanbi, 2002). Turning and watering were done fortnightly, after which the matured composts were evacuated from the heap, air dried, shredded and kept for use. Selected chemical properties of matured composts were determined according to the procedure of IITA (1979). The total N was determined by a semi-micro-kjeldahl digestion technique. The P was determined by colorimeter; K, Ca, and Mg by flame photometer and Zn, Cu, Pb, Cr and Cd were determined using Atomic Absorption Spectrophotometer Bulk Scientific Model 210 (VGP).

Experimental Procedure

Composts were applied at 0, 20 and 40 t / ha. NPK (20:10:10) while NPK (20:10:10) fertilizer was applied at the rate of 100 kg N / ha. The six treatments (MSC20, MSC40, CPC20, CPC40, NPK and control: No compost and inorganic fertilizer), were replicated four times in a randomized complete block design (RCBD). Plot size was 4 x 3 m leaving a space of 0.5 m as alley between plots and between replicates. The treatments were randomly allocated to plots in each block. The composts were applied to the plots using surface application method and worked into the soil by light hoeing. The NPK fertilizer was applied using drilling application method.

Vegetation survey

Vegetation survey was carried out before application of compost (BAC), four weeks after compost application (4WACA) and eight weeks after compost application (8WACA) using systematic sampling technique by enumerating the plant species on each of the 24 plots and five other points around the experimental site (at 10m and 50m away to the east and west, and 100 m away to the west of the dump-site) to have a total of 29 plots as described in Table 1. Plot size of 4m x 3m was used to represent quadrat due to sparse distribution of plants on the site. All the plants within each plot were identified up to species level and the number of each species recorded. A spreadsheet of species X quadrat matrix was prepared from the species data collated from the main dumpsite and its surrounding for ordination analysis and determination of relative importance values. Ordination method was used to determine the response of flora diversity and abundance among treatments. The plots were related by using the 1994 revised edition of DECORANA version 1.0, a computer program written to perform Detrended Correspondence Analysis (DCA) and Reciprocal Averaging.

Species Importance and diversity indices

The vegetation data were used to determine the Relative Importance Values (RIV) for each species as mean of the sum of relative density and relative frequency, following Kent and Coker (1996).

Relative Importance Value (RIV%) = [(RD+RF)/2] x 100; where RD = Relative density; RF = Relative frequency.

The diversity indices for the species distribution on the main polluted site were obtained for the three enumeration periods from the density values for the species using PAST software Version 1.10 developed by Hammer and Harper (2003; http://folk.uio.no.oharmmer/past).

Data Analysis

Data collected were subjected to analysis of variance (ANOVA) and means separated using Duncan Multiple Range Test (DMRT) at 5% level of probability.

Results

Pre-treatment lead concentrations of the main contaminated site and the surrounding shows that the concentration of lead (138,000 mg/kg) on the main site was higher than the concentrations in the surroundings (Table 1).

Table 1.Pb concentrations in the soil of the main plot and surroundings of a lead-battery dumping site in Kumapayi, Ibadan, Nigeria.

Quadrat number	1-24	25	26	27	28	29
Location	Main dumpsite	10m East	10m West	50m East	50m West	100m West
Soil Pb (mg/kg)	138000	129300	115310	16800	7500	756

As the distance from the dumpsite increased, Pb concentration decreased with the lowest (756 mg/kg) recorded at 100 m away (Table 1). The Pb concentrations at 10 and 50 m away to the East and West and 100 m away to the west sides of the dumpsite were 129000, 115000, 16800, 7500 and 756 mg/kg, respectively.

Effects of compost on soil physico-chemical analysis

Application of MSC at 40t/ha reduced the level of Pb on the site by 71.59% followed by CPC at 40t/ha that gave 67.33%. The two treatments reduced significantly the final Pb concentration in the soil more than those treated with MSC20 (66.06%) and CPC20 (49.47%). The final Pb concentration in the NPK fertilizer treatment was not significantly different from control (Table 2). Compost application improved the soil fertility by increasing the concentration of essential elements in the soil compared to control. MSC40 treatment had the highest concentration of phosphorus, magnesium, Nitrogen and calcium compared to other compost treatments. Addition of inorganic fertilizer also increased the phosphorus concentration of the site compared to control.The pH value was also increased in all the compost-amended plots (Table 2).

Table 2.Effects of compost and NPK fertilizer on the chemical composition of soil in a lead-battery dumping site in Kumapayi, Ibadan, Nigeria.

Treatment	P	Ca	Mg	Pb	K	N(%)	pH
mg/kg	⟶		⟵		(cmol/kg)		
Control	128^{d}	65.0^{d}	58^{d}	137000^{a}	1.18^{c}	0.14^{d}	4.59^{b}
MSC20	1160^{bc}	228^{c}	54^{d}	47000^{c}	1.31^{a}	0.25^{b}	6.76^{a}
MSC40	3630^{a}	3870^{a}	857^{a}	39000^{d}	1.14^{a}	0.57^{a}	6.90^{a}
CPC20	1500^{b}	519^{b}	312^{b}	69000^{b}	1.55^{c}	0.17^{c}	6.44^{a}
CPC40	1570^{b}	358^{c}	109^{c}	45000^{c}	1.14^{a}	0.28^{b}	5.99^{a}
NPK	980^{c}	65.0^{d}	62^{d}	125000^{a}	1.23^{a}	0.12^{d}	4.91^{b}

MSC20= Mexican sunflower compost at 20t/ha; MSC40= Mexican sunflower compost at 20t/ha; CPC20= Cassava peel compost at 20t/ha; CPC40= Cassava peel compost at 20t/ha; NPK=Inorganic nitrogen fertilizer

Means followed by the same letter in a column are not significantly different from each other at $p<0.05$.

Ordination analysis of vegetation data

Vegetation progressively responded to the compost applications (Figure 1).

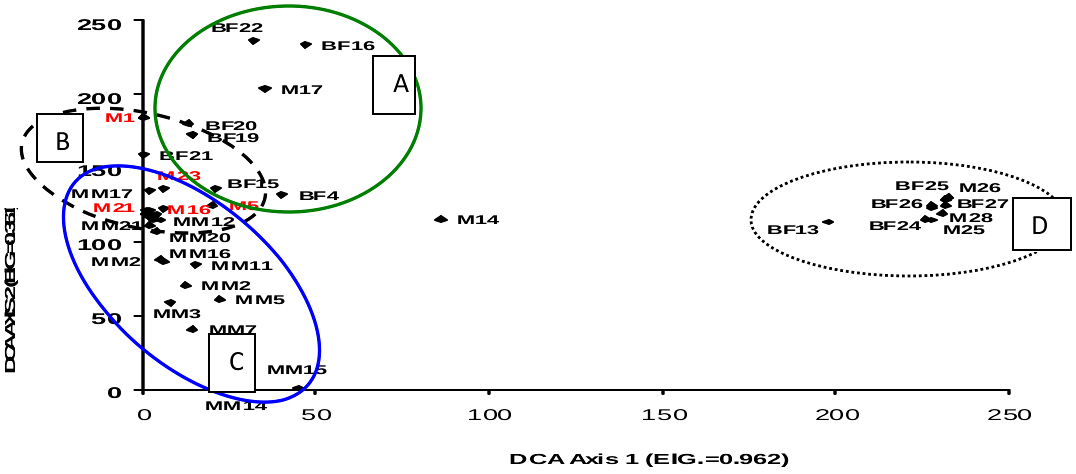

Figure1. DCA biplots of stands defining the response of vegetation of the main sites and surroundings at BAC (A) , 4WACA (B), 8WACA (C) and interaction of 4WACA and BAC (D). [BF = BAC ;M = 4WACA ; MM = 8WACA].

There were overlaps between the plot composition (in species abundance and type) before application of compost and at 4WACA, and between application at 4WACA and 8WACA. Cluster A shows the concentration of plots at BAC while cluster C represents the clustering of compost treated plots at 8WACA. Cluster B contains interaction between the plots treated with compost at 4WACA and those without the treatment (i.e control). There seemed to be an improved re-vegetation at 4WACA as shown in the overlapping of the clusters. There was progression of change as clearly seen along the axis 2. Cluster D contains interaction between the plots around the contaminated site at BAC and 4WACA. The two strongest axes (Axes 1 & 2) were used as indicated in their Eigen values. Some plots overlapped and as such, not all the stands could be depicted.

Effect of compost application and inorganic fertilizer on vegetation re-establishment

Overall, before compost application there was no difference among the plots and the vegetation density was low. Enumeration of floral diversity and density carried out at 4 and 8 weeks after compost application however revealed that compost application stimulated the emergence of vegetation on all the treated plots compared to control and inorganic fertilizer treatments with the vegetation density at 8WACA being superior to that of 4WACA (Table 3).

Table 3: Effects of Mexican sunflower and Cassava peel waste composts and inorganic fertilizer on vegetation re-establishment on the heavy metal contaminated field

TREATMENTS	BAC	4WACA	8WACA
CONTROL	6.3^{b}	5.0^{e}	2.5^{f}
MSC20	7.0^{b}	57.5^{a}	156.8^{b}
MSC40	6.5^{b}	58.5^{a}	198.5^{a}
CPC20	11.3^{a}	56.0^{b}	93.8^{d}
CPC40	6.8^{b}	38.3^{c}	102.5^{c}
F1	5.8^{b}	7.5^{d}	44.0^{e}

BAC=Before application of compost, 4WACA = 4weeks after compost application, 8WACA= 8weeks after compost application, MSC40=mexican sunflower compost at 40t/ha, MSC20=mexican sunflower compost at 20t/ha, CPC20=Cassava peel waste compost at 20t/ha, CPC40= Cassava peel waste compost at 40t/ha , F1= inorganic fertilizer at 100kgN/ha.

The result also showed that higher application rate of both types of compost performed better than lower rate with MSC having the highest species diversity and density.

Though lower than the compost treatments, the enumeration of vegetation carried out showed that at 8WACA, treatment with inorganic fertilizer also enhanced vegetation emergence on this site compared to control.

Species Importance

The enumeration conducted before the application of compost revealed 7 plant species on the main dump site plots and 26 plant species on the surrounding plots. The density of *Gomphrena celosioides* was highest (45.29 plants/plot) on the main plot while that of *Imperata cylindrica* was highest (72.20 plants/plot) on the surrounding plots (Table 4).

Table 4. Density (plants/plot) and plant species richness on the main and surrounding plots of lead-acid battery waste contaminated site at Kumapayi, Ibadan before application of treatments(BAC)

PLANT SPECIES	Density (plants/plot*)	
	Main Site	Surrounding
Acalypha fimbriata Schum and Thonn	-	1.6
Aspilia africana (Pers) C. O. Adams	-	1.6
Asystasia gangetica (Linn) T. Anders	-	2.2
Bidens pilosa Linn	-	10.8
Chromolaena odorata (L.) R. M. King and Robinson	0.04	4.8
Cleome rutidospermum O. C.	-	0.2
Cochorous olitorus L.	-	0.2
Commelina benghalensis L.	-	0.6
Conyza sumatrensis (Retz.) Walker.	-	0.6
Cynodon dactylon (Linn) Perse	0.42	-
Cyathula prostrata (L.) Blume	-	0.8
Desmodium scopiurus (W.) Desv	-	0.4
Euphorbia hirta (Linn)	-	0.6
Gomphrena celosioides Mart	45.29	-
Imperata cylindrica (Linn) R. V. A. Anders	0.33	72.2
Mariscus alternifolius Vahl	-	0.6
Mormordica charantia Linn	-	0.2
Phyllanthus amarus Schum and Thonn	-	1.0
Physalis angulata Linn	2.5	0.2
Portulaca oleraceae Linn	-	0.2
Schrankia leptocarpa D. C.	0.13	-
Scoparia dulcis Linn	-	3.2
Sida veronicifolia Lam	-	2.4
Spigelia anthelmia Linn	-	6.2
Sporobolus leptocarpa	0.33	-
Talinum fruticosum Jacq	-	0.2
Trianthema portulacastrum Linn	-	1.4
Tridax procumbens Linn	-	1.4
Urena lobata Linn	-	1.2
Vitex doniana Sweet	-	0.2
Species Richness	**7**	**26**

*A plot = 4 x 3 m; 24 plots were assessed on the main dumpsite and 5 plots assessed in the surroundings.

Compost application improved re-vegetation right from 4WACA and progressed into the 8WACA. The species richness increased from 7 species at BAC to 10 and 15 species at 4WACA and 8WACA respectively (Table 5).

Table 5. Plant species and their relative importance value (RIV%) on the main lead-battery dumpsite at Kumapayi, Ibadan before application of compost (BAC), at 4weeks after compost application (4 WACA) and at 8weeks after compost application (8 WACA).

PLANT SPECIES	BAC	4 WACA	8 WACA
Amaranthus spinosus	-	-	3.3
Centrosema pubescens	-	-	1.2
Chromolaena odorata	1.3	2.7	4.0
Cleome rutidospermum	-	1.0	0.6
Cochorous olitorius	-	-	0.6
Cynodon dactylon	8.8	5.5	2.3
Gomphrena celosoides	72.4	67.0	49.6
Imperata cylindrical	2.8	3.0	-
Physallis angulate	8.5	-	3.8
Schrankia leptocarpa	1.4	11.1	6.4
Sida veronicifolia	-	-	1.2
Sporobolus leptocarpa	-	3.7	5.2
Sporobolus pyramidalis	5.1	3.8	8.5
Talinum fruticosum	-	1.9	2.6
Tithonia diversifolia	-	3.7	8.0
Trianthema portulacastrum	-	-	3.5

The increase in number of individual species was most evident at 8WACA with 2276 plants (Table 6).

Table 6. Diversity indices of the flora composition in the main lead-battery dumpsite in Kumapayi, Ibadan before application of compost (BAC), at 4weeks after compost application (4 WACA) and at 8weeks after compost application (8 WACA).

Diversity Indices	**BAC**	**4WACA**	**8WACA**
Taxa/Species Richness	7	10	15
Number of Individuals	1177	1100	2276
Dominance	0.8557	0.8245	0.6008
Shannon-Wiener	0.3548	0.4570	0.9976
Equitability	0.1823	0.1985	0.3684

Gomphrena celosioides remained the most important plant species on the main plot at the three enumeration periods.

The relative importance values (RIV) however decreased from 72.4% at BAC to 67.0% and 49.6% at 4WACA and 8WACA respectively (Table 5), which indicated decreasing dominance.This decreasing dominance by a particular species was reflected in the decreasing

DominanceIndex values atthethree periods, which were 0.8557, 0.8245 and 0.6008 at BAC, 4WACA and 8WACA, respectively. The strongestdominance by*G.celosioides*at BAC (RIV=72.4%) was confirmed by the lowest Shannon index (0.3548) and the equitability index which tended towards zero (0.1823). At 8WACA, the Dominance index was lowest, the Shannon index was highest and Equitability index tended away from zero (Table 6).

Though *G. celosioides* was most prevalent, some other weed species have infested the site and were fast increasing in number. Examples are *Tithonia diversifolia*, *Centrosema pubescens*, *Sporobolus pyramidalis*, *Sporobolus leptocarpa*, *Amaranthus spinosus* and *Talinum fruticosum*.

Discussions

In normal soil, the common range of Pb is 2-300 mg/kg (Kabata-Pendias and Pendias, 2001; Hague *et al.*, 2008; Ogundiran and Osibanjo, 2009), therefore level of lead was extremely high both on the main site and the surrounding plots. The high level of lead in this soil might be due to the secondary smelting of Pb in the fabrication and production of Pb batteries (Liua *et al.*, 2005). The low pH of this soil might also be accountable for the high solubilization of this metal since heavy metals generally have been reported to become more mobile as acidity increases (Smejkalova *et al.*, 2003; Ogundiran and Osibanjo, 2009).

Compost-application reduced the Pb concentration and supported the regeneration of vegetation in all plots. The ordination revealed clusters that followed a progression of change, indicating change in flora diversity and species importance at the three enumeration periods. The increased species richness and relative importance values of species other than *G. celosioides* on this contaminated soil was probably due to the ability of compost to supply soil with all the essential nutrients needed for the plant growth (Togun *et a.l*, 2003; Dale *et al.*,2006; Rennevan *et al.*,2007). The presence of organic matter in the compost might also have acted as sorbent of cations thereby demobilizing the heavy metals in the contaminated soil (Chaney *et al.*, 2000). The result also agrees with the finding of Ryan *et al* (2007) that organic amendment decreased toxic bioavailable heavy metal concentrations thereby promoting plant growth. Therefore, compost amendment improved the vegetative growth probably by reducing the bioavailable heavy metal concentrations.

Compost prepared from Mexican sunflower however, performed better than those of Cassava peel waste compost and inorganic fertilizer in the reduction of Pb concentration in this contaminated soil, probably due to high concentration of Ca and P in Mexican sunflower as reported by Akanbi *et al.*, (2007) and *Adejumo et al.* (2011). The Ca and P have been reported to enhance metal precipitation in the soil with the formation of pyromorphite and chloro-pyromorphite (Chaney *et al.*, 2000; Ogundiran and Osibanjo, 2009). Low pH reportedly induces the solubility of Pb in the soil thereby enhancing plant uptake and vice versa. In this experiment however, addition of compost was found to increase the soil pH of the contaminated soil which in turn might be responsible for the reduction in the final concentration of lead in the compost amended plots. It has also been reported to have the tendency of increasing the soil capacity for metal binding (Chaney *et al.*, 2000; Sadovnikova, 2002). The wilting of vegetation on the plots treated with inorganic fertilizer according to Ryan *et al* (2007) was due to increased acidity of the substrate by fertilizer addition resulting in solubilization of heavy metals. The result also confirms the finding of Stefanov *et al* (1995) that fertilizer application increased the level of mobile forms of Pb in the soil thereby enhancing its uptake by the plants.

The lack of vegetation in the control plot could be attributed to the high concentration of Pb in this soil as excess Pb has been found to cause a number of toxicity symptoms in plants (Miller and Koeppe, 1970; Onianwa and Fakayode, 2000; Pallavi and Rama, 2005; Seregin *et al.*, 2005). The process of photosynthesis has also been reported to be adversely affected by Pb toxicity as a result of distorted chloroplast ultrastructure, restrained synthesis of chlorophyll, plastoquinone and carotenoids, obstructed electron transport, inhibited activities of Calvin cycle enzymes as well as deficiency of carbondioxide due to stomatal closure (Quentin and John, 2003; Pallavi and Rama, 2005).

The ordination revealed clusters that followed a progression of change, indicating change in flora diversity at the three enumeration periods. The decreasing Dominance index and the increasing Shannon and Equitabilty indices indicated that the ecosystem was infested bymore weed species, the species distribution became more random and their RIV increased as the soil environment became more conducive with the compost remediation (Olubode *et al.*,). Also, the strongest dominance by *G. celosioides* at BAC which was confirmed by the lowest Shannon index and the equitability index indicated that the plant species were not randomly distributed at BAC but at 8WACA, there was less dominance by a particular species and that the prevailing species were more randomly distributed as shown by lower Dominance index and the highest Shannon index and Equitability indices. The overlapping of the plots as revealed by the ordination analysis shows that many points used for the study responded similarly to give the trend observed.

Plant species differs in Pb tolerance as shown by the prevalence of *G. celosioides* on the main plots. This according to Igoshina and Kositsin (1990) was attributed to the activation of carboanhydrase enzyme activity by Pb in the tolerant plant thereby enhancing plant growth. Adequate rooting depth is an important factor in re-vegetation success (Ryan *et al.*, 2007). Amendments applied in a layer on the substrate surface have little impact on substrate properties at lower depth (Tordoff *et al.*, 2000). The prevalence of *Gomphrena celosioides* on this site before application of compost might probably be due to some kind of detoxifying ability in this plant while its survival after application of compost could be attributed to the concentration of its root in the layered compost treatments since it is a shallow-rooting and decumbent plant, with only a small proportion of its roots growing beyond the shallow compost interface. The phytoremediating ability of this plant can be tested further.

The compost might have remediated the polluted soil and made it more conducive for the establishment of more plant species. An increase in the number of species enumerated at 8WACA confirm the report of previous researchers (Tordoff *et al.*, 2000; Clemente *et al.*, 2006) that compost application on the contaminated soil encourages weed emergence. Other species that could not have withstood the toxic environment were enumerated on this site at 4 and 8WACA. This was also attributed to the reduction in the heavy metal concentration of all the treated plots. Some plant species that were initially present disappeared at 4 and 8WACA and new ones were re-established probably due to inter-specific competition resulting from improved soil environment that had ousted the species with low competitive abilities (Awodoyin *et al.*,).

The seedlings of *Tithonia diversifolia* that were enumerated on the plots treated with MSC could possibly be as a result of its seeds being transported to the site by the compost. This is in agreement with the finding of Malama (2001) that seeds of *Tithonia diversifolia* are capable of being dormant in an unfavourable condition and later germinate when the environmental conditions become favourable for the survival of their seedlings. This may explain the survival of the seeds even at the adverse conditions of high composting temperature (Malama, 2001).

Conclusion

Poor vegetation arising from the pollution of the soil by heavy metals especially Pb can be successfully corrected by remediating the land with the application of compost. However, compost obtained from Mexican sunflower can perform better than that of cassava peels and NPK inorganic fertilizer in the improvement of soil fertility and revegetation of lead battery polluted land. Gomphrena celosoides was the most predominant plant species on this site before application of compost while Imperata cylindrica dominated the surrounding vegetations. An implication for phytoremediation.

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