Phytoremediation of Lead Polluted Soils with Grass Species

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ABSTRACT

Heavy metals pollution, especially the lead (Pb), is caused by mining, industrial dumping and other anthropogenic activities which are corroding the environment. Efforts being made to control these pollutants include physical, chemical, biological and immunological methods. The failure of the aforementioned methods, are largely due to the fact that they are cumbersome, expensive and not eco-friendly. Some plant species however can be used for remediation in reclaiming the polluted environment. The objective of this work therefore is to evaluate the abilities of two native grass species to remediate two lead polluted soils: Battery dumpsite and naturally occurring lead mine. Soil samples were taken from two dominant sites of lead: Kumapayi in Ibadan, a battery dumpsite and Zamfara, a natural lead mine. A screen house factorial experiment laid out in a completely randomized design (CRD) replicated three times was carried out at the International Institute for Tropical Agriculture (IITA), Ibadan. Unpolluted soils were collected from the experimental site of the Department of Agronomy, University of Ibadan in Ibadan, Nigeria and polluted with varying Pb soil concentrations from Kumapayi and Zamfara at 0, 0.1, 0.2, and 0.5%. A thorough mixing of the two lead soils with unpolluted soil was done, respectively, and the seedlings of *Gomphrena celuosoides and Sporobolus pyramidalis* were planted directly after harvesting on the polluted soils. Plant growth parameters such as plant height, number of leaves, and dry matter were monitored for twelve weeks, after which the grass species were harvested. Dry weights were taken, while the uptake of Pb by the plant species was determined. Analysis of data was carried out using ANOVA ($p<0.05$) and descriptive statistics. Relative concentration of Pb in the stem and leaf, and root parts of *Gomphrena* c*eluosoides* revealed that a higher amount of Pb was taken up in the root compared to the shoots at different concentrations of Pb pollution. The Pb uptake was in this ordering 0.5% > 0.2% > 0.1% > Control. Phytoremediation ability of *G.* c*eluosoides* was highest at 0.5% Pb polluted soil and its retention was greater in the root than the shoot. In S. *pyramidalis*, soil retention ranged from 0.1% > 0.5% > 0.2% > control, while the Pb uptake was highest at 0.5% > 0.1% > 0.2% in shoot. Uptake of Pb heavy metal in leaves was highest at 0.2% concentration but none in the 0.5% pollution. This probably implies that rooting systems affect the amount and way different plant species absorb Pb (Gomphrena spp. rooting system is tap root, while that of *S .pyramidalis* is fibrous).

Key words: Lead pollution, grass species, phytoremediation

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INTRODUCTION

Environmental pollution continues to be a major problem in Nigeria (Ogunseitan and Smith, 2007), with soil contamination constituting a major source of exposure to heavy metal, lead. Heavy metals are among the most important contaminants in the environment. Several methods are already being used to clean up the environment from these contaminants, but most are costly and difficult to obtain optimum results. As a part of the urgent need for development of a comprehensive strategy for mopping up of lead in the environment, phytoremediation is currently being used as an effective and affordable technological solution (Flathman and Lanza, 1998; Tangahu *et al*., 2011).

Phytoremediation is a mitigation strategy for pollutant concentrations in contaminated soils, water or air, with plants able to contain, degrade, or eliminate metals, pesticides, solvents, explosives, crude oil and its derivatives and various other contaminants from the media that contain them (EPA, 2012.). The word Phytoremediation derives from the ancient Greek word phyto meaning "plant" and Latin remedium, meaning "restoring balance". It describes the treatment of environmental pollutants (bioremediation) through the use of plants that mitigate the pollutants without the need to excavate the containment material and dispose of it elsewhere (EPA, 2012).

Application of phytoremediators may be wherever the soil or static water environment has become polluted or is suffering ongoing chronic pollution (Talukder *et al*., 2015). Over the past 20 years, this technology has become increasingly popular and has been employed at sites with soils contaminated with heavy metals which include lead, uranium and arsenic (Naqvi *et al*., 2014).

Many plants such as mustard plants, alpine pennycress, hem and pigweed have proven to be successful at hyperaccumulating contaminants at toxic waste sites (Blaylock and Huang, 2000). However, in the literature, common lawn grasses and indigenous to the tropical environment were not considered to cleanse the soil of Pb pollution (Pshytorem). This study investigated the usefulness of two native grass species in Nigeria: *Gomphrena celuosoides* and *Sporobolus pyramidalis*, to effectively remediate lead polluted soils in Nigeria

MATERIALS AND METHODS

Site of the study and experimental materials

A screen house experiment was conducted in the Biosciences Center Screen house of the International Institute of Tropical Agriculture (IITA), Ibadan (Long:3.911079, Lat:7.499595) to determine the phytoremediation of two contaminated soils obtained from two locations in Nigeria; Zamfara (Long: 6.002428, Lat: 7.425123) and Ikumapayi, (Long:3.979552, Lat:7.425123) Ibadan.) using *Gomphrena celuosoides* and *Sporobolus pyramidalis* native plant species. These plants were obtained from the experimental field of the department of Agronomy (Long: 3.906199, Lat: 7.441260). They were seedlings at 3-4 leaf stages

Collection of the soil samples for the experiment

The polluted and unpolluted soils were collected with a spade from five cores 0-30 cm topsoil and mixed together in a plastic bucket, air-dried for 7 days and sieved through a 2.0 mm stainless steel sieve. Laboratory analyses were carried out on all the soils in order to determine the lead concentrations and routine parameters before and after the screen house investigations.

Preparation of the soils for the experiment

The two lead polluted soils separately in varying weights equivalent of 0, 23, 46 and 115g of the two lead contaminated soils was respectively mixed with the unpolluted soil to achieve different Pb concentrations (0, 0.1, 0.2, 0.5% pollution). A 2.0 kg mixed soil was put into 2 litre experimental plastic pots. The soils were watered to 60% field capacity and left for one week without the plants to equilibrate. Four plantlets obtained from the experimental field, Department of Agronomy, University of Ibadan were then introduced and later thinned to two after 2 weeks.

Experimental design

A Complete Randomized Design (CRD) in a factorial, replicated three times along with **a** control setup in Concentrations of 0, 0.1,0.2,0.5in each case, was carried out at the International Institute for Tropical Agriculture (IITA). Sets of 2 litre plastic pots were filled with 2kg fertile soil that was sieved through 4mm sized sieve. The treatment was applied and watered and planted immediately.

Planting of *Gomphrena celuosoides* and *Sporobolus pyramidalis* on polluted soil.

The plantlets of these plants species obtained from Agronomy Department, University of Ibadan., were planted into each pot to a depth of 3 cm.

Data collection

Plant height, number of leaves and stem girth were collected at two weeks intervals for the growing period of 12 weeks. After 12 weeks, the plants, partitioned into stem and leaf (above ground) and roots (below ground) parts, were harvested and fresh weight taken. Dry weights of dry matter accumulation were taken on an electronic balance.

Chemical analysis

Soil analysis was also carried out to determine the residual amount of Pb after harvesting. The soil samples were air dried for two days. The plants were oven dried at 68^0C for 48 hours. To 0.5 mls of samples is added 2:1mixture of Nitric Acid (HNO_3) and Perchloric Acid ($HCLO_4$) for 30mins on a hot plate under a Fume Cupboard and made up to 25mls with distilled water. The dried samples (stem and leaf and roots were subjected to laboratory analysis to determine the lead content using Atomic Absorption Spectrophotometer (AAS), at 418 nm.

Data analysis

All data collected in this study was analyzed using descriptive analysis and Genstat 12th edition statistical package. Mean uptake were obtained and graphically plotted, significance different between means were separated using Duncan multiple range test at 5% error probability level.

RESULTS

Results presented in Figure a showed the Pb distribution in *Gomphrena celuosoides* at different levels of pollution. The result showed that there was no significant difference ($p>0.05$) among the treatment rates. Much of the absorbed Pb was partitioned to the root at 0.2 and 0.5% pollution, while at 0.1% pollution much of the Pb was residual in the soil. After harvest, 85 and 65% of the Pb absorbed by *G. celuosoides* were concentrated in the root at 0.2 and 0.5 % pollution respectively. About 63% of the Pb remained in the soil after harvesting at the 0.1% pollution. At 0.2 and 0.5 % soil pollution, the distribution of Pb after harvest varied in the order: root >soil >stem >leaf. At 0.1%, the order was soil >root >stem >leaf.

The relative distribution of Pb in *Sporobolus pyramidalis* is shown in Figure b, there was no significant difference ($p>0.05$) among the other treatment levels. Much of the lead was partitioned to root and shoot at 0.5% pollution. At 0.2% pollution, Pb was most concentrated in the root, while at 0.1% pollution, the leaf and soil had equal distribution of Pb. However, there was a lower uptake of Pb at control level of pollution. At harvest, most of the Pb absorbed (46%) by *S. pyramidalis* was concentrated in the root at 0.2% level of pollution, 57% to the shoot at 0.5% pollution and 29% to both leaf and soil at 0.1% pollution. The distribution of Pb at harvest varied in the order: root > soil > stem > leaf at 0.2% pollution. At 0.5, the order was stem > root > soil > leaf and at 0.1%; leaf > soil > root > stem. The lead content of Ikumapayi soils is presented in Table 2. The extractable Pb in the two soils is very high, exceeding the tolerable level in an agronomic soil.

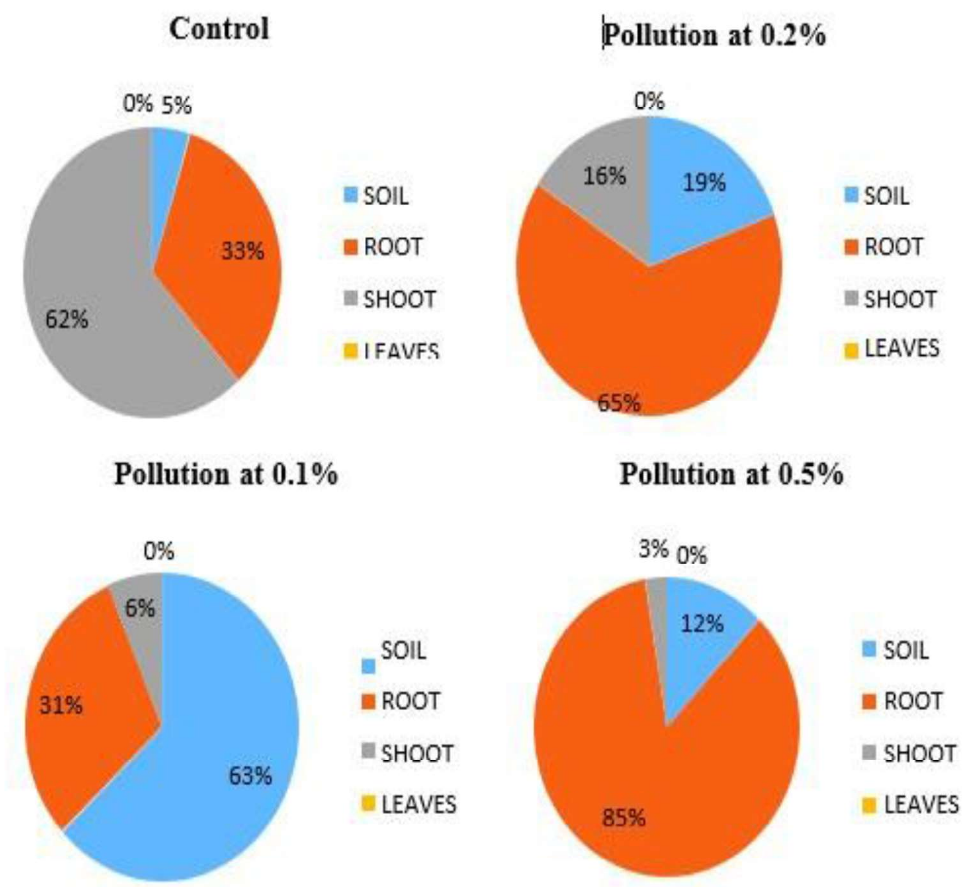

Figure a: Percentage Distribution of Pb concentration in *Gomphrena celuosoides* after harvesting at control, 0.5%, 0.1% and 0.2% rate of pollution

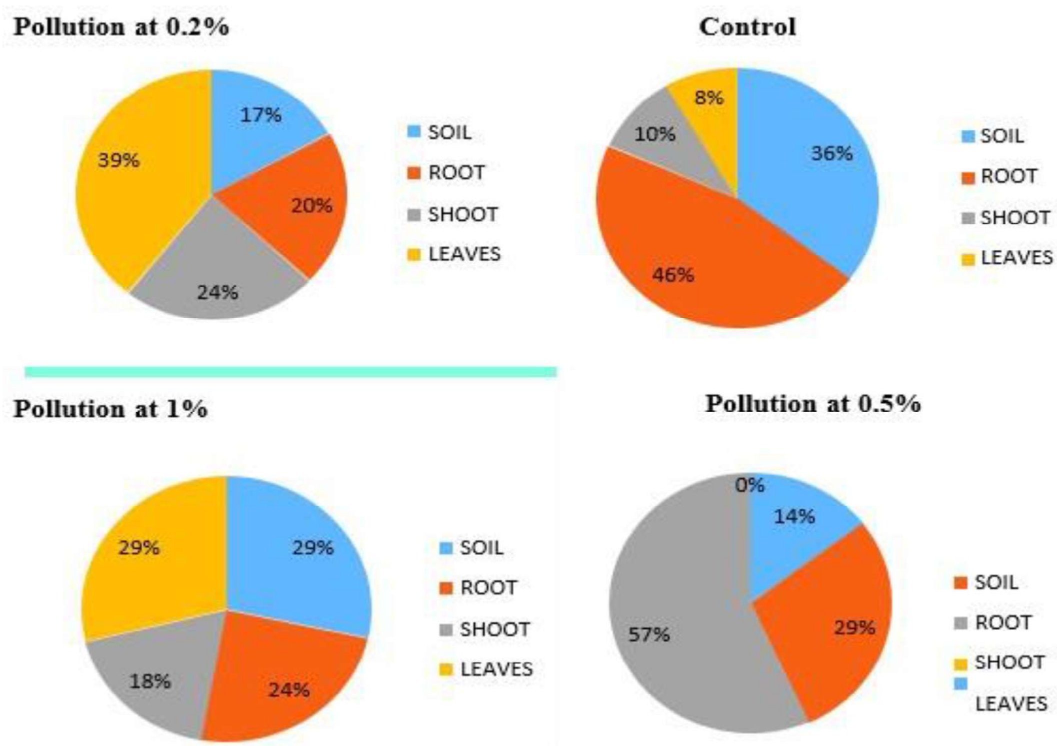

Figure b: Percentage distribution of Lead (Pb) in *Sporobolus pyramidalis* after harvesting at 0%, 0.0.1%, 0.2% and 0.5% rate of pollution

Table 1: Chemical properties of two Lead polluted soil samples

	Site	pH in H_20	T.N (g/kg)	T.O.C (g/kg)	Av.P (mg/kg)	Exchangeable Acid		Pb (mg/kg)
						H^+ Cmol/kg	Al^{3+} Cmol/kg	
1	Ikumapayi, Ibadan	5.5	1.91	24.02	55.89	5.4	1.0	20,355.00
2	Bagega Zamfara State	6.7	1.68	21.45	11.56	11.1	-	1545.50

Table 2: Exchangeable bases and micronutrients in Zamfara and Ikumapayi contaminated soil.

	Pb(mg/kg)	
FRACTIONS	Kumapayi	Zamfara
Water soluble	0	0
Exchangeable	1443.6	5.1
Bound to carbonate	16387.7	250.0
Fe/Mn Bound	7285.1	182.7
Bound to Org. C	2026.0	72.7
Residual	11.0	10.3
Total	20355.0	1545.5

DISCUSSION

The study showed that at low level of Pb pollution, the lead uptake by *G. celuosoides* was not significant. This implies that the remediating properties of *G. celuosoides* may be hampered, hence, the bulk of the Pb remains unabsorbed. As the concentration of Pb increased, much of it was translocated to the plant parts, principally the root and the shoot. This revealed dose-dependency or concentration as one of the factors for uptake. This tallies with findings by Deng et al. (2004), who found the factors affecting metal accumulation by wetland plats to be metal concentration, pH, and nutrient status in substrate. This result is informative because for a plant to be good for phytoremediation, the translocation factor or its bioaccumulation efficiency must be high. Therefore, at high level of Pb pollution, *G. celosoides* has a great potential for phytoremediation (Fig a).

In the case of *Sporobolus pyramidalis*, there was a different scenario. The root and shoots were the receptors of Pb, specifically at high levels of pollution. Unlike *G. celuosoides,* lower amount of absorbed Pb was translocated at all levels of pollution. Comparatively therefore, *G. celosoides* is superior to *S. pyramialis*, both in absolute absorption and relative phytoremediation and translocation (Flatman and Lanza (1998). This work is justifying the observation of Adeoye (2009) who screened out these two grasses in a battery dump site as potential phytoremediators (Adeoye and Eneji, 2016).

CONCLUSION

Sporobolus pyramidalis is suspected to be a hyper accumulator at 0.5 mg/kg Pb pollution, while *Gomphrena celuosoides* was less efficient at the various concentrations of Pb pollution. These differential potentials of the plant species have their advantages in Organic agriculture especially when land is going through conversion. These native plant species can be used to do phyto mopping and thereby shorten the period of land in conversion from conventional to organic. This is the current trend in Nigerian Agrarian system where scores of vegetable and arable crop farmers are imbibing the Federal Government of Nigerian policy of back to the land.

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