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EVALUATION OF HEAVY METALS CONCENTRATIONS IN PLANTS OF BIOSTIMULATED CONTAMINATED SOILS IN PORT HARCOURT, SOUTHERN NIGERIA

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ABSTRACT

Pot experiments were carried out in the Teaching and Research Farm and in the green house of Crop/Soil Science Department, Faculty of Agriculture, Rivers State University of Science and Technology, Port Harcourt to evaluate heavy metals (lead, zinc, copper, cadmium and Chromium) concentrations in maize *(Zea mays L.),* pumpkin *(Telfairia occidentalis L.), okra (Abelmoschus esculentus L.)* and vertivar tillers (*Vetiveria zizanioides*) in automobile and industrial waste dump soils amended with 5 t ha^{-1} poultry dung (PD) and fresh water hyacinth organic matter (WH). Treatments were replicated six (6) times; (3) replicates in the green house and in the field respectively in order to simulate different environmental conditions for the experiments. Results showed that pumpkin field plants for the Automobile dump soil had the highest lead contents (0.67, 1.57, and 1.03 mg/kg) in the un-amended, PD and WH amended soil respectively while in the industrial waste dump soil, vertivar, pumpkin, okra field plants had 0.52, 0.82 and 0.74mg/kg in the soil without amendment, PD and WH amended soil respectively. Highest copper contents (13.53, 22.48, 21.29 and 9.40, 19.09, 15.49 mg/kg) were obtained in the field maize plants of Automobile and industrial waste dump soils without amendment, amended with PD and WH respectively. Highest zinc concentrations (4.67, 10.40, 8.41 and 4.52, 7.78, 4.89 mg/kg) were obtained in field pumpkin plants of Automobile and industrial waste dump soil respectively. Cadmium and chromium values were also higher in the pumpkin plants of both Automobile and in the industrial waste dump soil treatment options in the field.

Key words: *Biostimulate, phytofiltration, phytovolatilization, phytostimulation, phytoremediation.*

INTRODUCTION

Industrial activities and urbanization in developing countries including Nigeria especially in the Niger Delta regions has led to the deterioration and contamination or pollution of the natural environment in recent years. Environment pollution is identified when the carrying capacity i.e. the optimum ability of environment to assimilate waste and residues at any level is exceeded (Isirimah, 2000). As a result, the productivity and dynamics of the ecosystem are affected by excess manmade waste/residue in spite of advanced waste purification technology. Surprisingly, a large percent of the sewage sludge from cities are released into soil and waterways untreated as well as from abattoirs, automobile mechanics, mining and industrial wastes. This resulted not only in direct degradation of soil and water quality, but also contributes to eutrophication and heavy metals pollution which poses serious threats to the management of natural ecosystems. Pollution of soil enhances plant uptake and accumulation of heavy metals in plants tissues and eventual phytotoxicity and change of plant Community (Sposito, 1982). He also pointed out that heavy metals pollution, not only affects the production and quality of crops, but also influenced the quality of atmosphere, contaminates ground water bodies, inhibits plant growth, threatens the health and life of animals due to it toxicity (Sposito, *et al.,* 1982).

Thus, it is now fully recognized that no country can afford to ignore sound management and protection of her environment and resource which form the basis of development. At present, heavy metals contaminated soil remediation technologies consisted primarily of removal and replacement of contaminated soils (Gisbert *et al.* 2003), which required millions of tons of soil to be disposed of. Such a process is expensive and environmentally-unfriendly, used scarce land fill space and require additional site, restoration, hence the need for the development of cost effective and *in-situ* environmental friendly technologies. Thus, phytoremediation technique – the use of natural plants to bioaccumulate, degrade or render harmless harmful substances in the soil, water or air. This is a cost effective, simple sustainable and beneficiary technique to purify polluted environment both *in-situ* and *ex-situ* (Jones and Greenfield, 1991).

Several subjects of phytoremediation have been developed and these include: phytostabilization, in which plants stabilize the pollutants in the soil; phytoextraction, metal accumulating plants and appropriate soil amendments are used to transport and concentrate metals from the soil into the above ground shoots; which are harvested with conventional agricultural methods: phytofiltration or rhizofiltration, in which plants root grown in aerated water, precipitate and concentrate toxic metals from polluted effluents, and phytovolatilization in which plants extract volatile metals (Eg. Hg and Se) from soil and volatize them, from the foliage (Raskin *et al.,* 1997).

These and others need to be evaluated in order to choose the most efficient techniques. Therefore, the objectives of this study were to: (1) determine the uptake and concentrations of heavy metals by maize, pumpkin, and vertivar grass in the automobile and industrial waste dump soil, and to (2) determine the effective bioremediation materials and the prefer plant to use for the remediation of heavy metals contaminated soils.

MATERIALS AND METHODS

Pot experiments were conducted between 1st March – 31st April, 2011 in the Teaching and Research Farm of the Rivers State University of Science and Technology, Port Harcourt, in the Niger Delta area of Nigeria which lies at Lat. 4'15^0 N and 7'05^0 N and long. 5'32^0 E to 9'16^0 E, 18 metres above sea level in rainforest zone. The mean annual rainfall of these areas ranges from 2000 – 2484 mm

Top soil (0 – 15cm) samples were randomly collected from Automobile mechanic and industrial waste dump site at Mile 3, Diobu and trans Amadi Industrial layout using auger for the experiments. Soils were homogenized, dried, sieved and passed through 2mm mesh and respectively amended with 5 t ha^{-1} air dried and crushed poultry manure and fresh water hyacinth *(Eichhornia crassipes)* organic material. The soils were left for fourteen (14) days to settle, then 3 kg of each treatment soils were transferred into perforated polythene bags measuring 20 x 25 x 25 cm^3 and replicated six times. Three (3) replicates of each treatment options were arranged in the field and in the green house respectively and Completely Randomized.

Five (5) seeds of maize (*Zea mays* L.) pumpkin (*Telfairia occidentalis* L.), vertivar grass (*Vetiveria zizanioides*) and okra (*Abelmoschus esculentus*) were respectively planted in each bag. Ten days after crops emergence, the seedlings were thinned to three per bag. The experiments were moistened at field capacity during the study period.

Eight (8) weeks after crops emergence, plant leaves were harvested and cleaned with distilled water, dried and ground with hammer mill and analyzed for Zinc, Lead, Cadmium, Copper and Chromium concentration using atomic Absorption Spectrophometer (Spectronic 20) at wave length of 217, 225, 213.90, 228 and 232nm respectively. Soil pH was determined in water with glass electrodes in the 1:2.5 soil water ratio. Mechanical analysis was determined by modified hydrometer method. Analysis of variance according to the conventional Complete Randomized Design at 0.05 probability level was used to test the treatments effects.

RESULTS

Physicochemical properties of the studied soils are presented in Table 1. Automobile and industrial waste dump soils pH were slightly alkaline and acidic in natures with mean values of 7.55 and 5.60 respectively. After application of soil amendment, pH decreased to 6,40, 6.30 and 5.55, 5.40 in the Automobile and in the industrial wastes dump soil respectively amended with poultry manure (PD) and water hyacinth organic material (WH). Lead (Pb), Zinc (Zn), Cadmium (Cd) and Chromium (Cr) also increased with the application of soil amendment. Highest heavy metals ranges were noted in the Automobile waste dump as compared to those of the industrial waste dump soil.

Percent sand, silt and clay mean values were 88.30, 4.70,700 and 86.30, 2.64, 10.06 in the Automobile and in the industrial waste dump soil respectively.

Chemical properties of organic amendments applied are presented in Table 2. Poultry manure had a neutral pH mean value of 7.03, while water hyacinth had 6.20.Mean value of Pb, Cu, Zn, Cd and Cr in the PD were slightly higher in poultry manure than those of the water hyacinth organic material.

Table 1: Physicochemical Properties of the Studied Soils at zero (before) and after treatment application.

	Site						
Parameter		AWD			IWD		
	X	Y	Z	X	Y	Z	
pH (H20)	1:2.5	7.55	6.40	6.30	5.60	5.55	5.40
Lead (mg/kg)	152.65	155.14	156.94	14.52	16.23	10.49	
Copper (mg/kg)	481.66	483.10	482.84	48.54	49.30	49.27	
Zinc (Mg/Kg)	88.28	89.81	88.98	39.80	39.83	39.84	
Cadmium (Mg/Kg)	20.40	20.36	20.43	5.16	5.31	5.18	
Chromium (mg/kg)	2.54	2.56	2.56	0.19	0.20	0.21	
Sand (%)	88.30			86.30			
Silt (%)	4.70			2.64			
Clay (%)	7.00			10.06			
Textural class: Sandy loam							

Key : AWD = Automobile waste dump soil
: IWD = Industrial waste dump soil
: X = Unamended soil
: Y = Soil amended with poultry manure
: Z = Soil amended with fresh water hyacinth organic materials

Table 2: Chemical properties of the soil amendments used.

	Amendment	
Parameter	**Poultry dung**	**Fresh water Hyacinth**
pH (H_20) 1:2.50	7.03	6.20
Pb (mg/Kg)	4.24	4.17
Cu (mg/kg)	0.29	0.28
Zn (mg/kg)	1.74	1.49
Cd (mg/kg0	0.025	0.002
Cr (mg/kg)	0.003	0.002

Key: Lead (Pb), Copper (Cu), Zinc (Zn), Cadmium (Cd), Chromium (Cr).

Heavy Metal Contents

Pumpkin plants in the field had the highest Pb contents (0.67, 1.54 and 1.03 mg/kg) in the unamended, PD and in the WH amended soil respectively. These were followed by 0.53, 1.46 and 0.97 mg/kg observed in maize plant of the same treatment options. In industrial waste dump soil, similar result in which pumpkin followed by vertivar field plants had the highest Pb contents were obtained

Copper (Cu)

Copper contents in test crops planted in the Automobile waste dump soil indicate that plants in the field had the highest Cu contents (13.53 and 21.29 mg/kg) in the unamended and in the WH amended soil, while 22.95 was obtained in the pumpkin filed plant in the PD amended soil. These were followed by 22.48, 21.93 and 21.66 mg/kg obtained in maize plant and vertivar grass respectively in field in the PD amended soil. In the industrial waste dump soil, maize plant in the field had the highest Cu contents (9.40 and 19.09 mg/kg) in the unamended and PD amended soil while in the WH amended soil, vertivar grass had the highest (15.65 mg/kg). These were followed by 9.38 and 18.72, 15.49 mg/kg obtained in pumpkin and maize plants in the field of the unamended PD and WH amended soil respectively.

Zinc (Zn)

In the unamended soil highest Zn content of 10.4 mg/kg was obtained in field pumpkin., followed by field okra (10.0) and vertivar (9.6). In WH amended soil, filed pumpkin, okra and vetivar had value of 8.4, 8.3 and 7.8 respectively. Poultry manure amended plant had least Zn less than 5.0 mg/kg. The unamended soil had highest Zn value which varied from 6.0 to 7.5 mg/kg, poultry amended soil had between 4 to 5, and wastes hyacinth soil had 2.8 to 4.5

Cadmium (Cd)

In the unamended soil, the highest Cd content was 0.02 mg/kg obtained in green house maize plant followed by 0.005 mg/kg obtained in pumpkin plant in the field of the Automobile waste dump soil. In the PD amended soil, 0.030 mg/kg followed by 0.026 mg/kg Cd were obtained in field and greenhouse vertivar grass respectively. In WH amended soil, 0.033 followed by 0.028 mg/kg were observed in the maize and pumpkin plants in the field respectively

Chromium (Cr)

The Highest Cr. Contents (0.08, 0.40 and 0.30 mg/kg) were obtained in the field pumpkin plant in the unamended, PD and WH amended soil respectively. In the industrial waste dump soil, similar results in which field pumpkin had the highest Cr contents in all the treatments. In general, heavy metals were more available to plants in the PD amended soil options.

DISCUSSION

Soil pH value of Automobile waste was higher than that of the industrial waste dump soil. This indicated that industrial waste dump soil contained more organic matter than the automobile waste dump soil. Decrease in the soils pH after application of soil amendments

may be due to the utilization of amendments by the soil microorganisms. According to Itah and Essien (2001), utilization may have resulted in the microbial growth and concomitant products. It may also be due to immobilization of basic cations by teaming soil microorganisms. This supports Ano and Agwu (2005), who observed decreased in soil pH after application of animal manure and spent mushroom substrate. They also attributed decrease in soil pH after organic material application to the degradation of hydrocarbons which may have resulted in the release of acidic intermediates.
Mechanical analysis showed that the soil contained more than 50 % less than 15 % silt and clay. It is described as sandy loam (Esu, 1999).

Higher heavy metals contents in plants were obtained in the PD amended soil. This was followed by plants in the WH amended soil. This concurred Yang *et al.* (2005), report that application of compost, fertilizer or manure can increase bioavailability of heavy metals. Higher values obtained in plants of the PD as compared to that of the WH amended soil suggests that WH material would have been in a lower degree of decomposition as compared to PD.

Least amount of heavy metals contents in test crops in the unamended soil may be due to lack of feed stuffs and increase in bacterial activities due to the present of contaminants. Itah and Essien *et al.* (2002), reported that in a contaminated soil, soil microbes are attracted, and their increase stimulated more than in the uncontaminated environment.

Application of organic materials may have improved soil aeration and influenced the vigour of mineralization thereby making more nutrients (including heavy metals) available to plants while in the unamended soil, microbial vital functions may have been inhibited due to toxicity of pollutants as earlier reported by Xu and Schurri (1990). Higher heavy metals contents in the plants planted in the amended soils further point to the fact that biodegradation of contaminants in natural environment is slow to bio-stimulate a contaminated soil.

Finally, higher heavy metals contents in field plants of the Automobile waste dump soil in all the treatment options supports Ita Essien (2002), reports that the degradation and mineralization of plant nutrients out of hazardous substance depended on the nature and amount of pollutant present.

CONCLUSION

The study indicated that Automobile and industrial waste dump site in Port Harcourt, Rivers State in the Niger-Delta Area of Nigeria are highly polluted with Pb, Cu, Zn, Cd and Cr. Application of PS made more heavy metals available to plants in the field as compared to green house plants in all the treatment options. Heavy metals concentrations were higher in pumpkin plants. Therefore, pumpkin plant in the automobile and industrial waste dump soil respectively amended with PD is recommended as the most phyto-remediating plant.

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