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Screening of *Polyalthia longifolia* and *Aloe vera* for their phytoextractability of heavy metals in tropical soil of the Niger Delta

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ABSTRACT: The work focuses on the screening of *Polyalthia longifolia* and *Aloe vera* for their phytoextractability of heavy metal in soil of the Niger Delta. 5kg of soil was polluted with 100 mg of Zn, Fe and Pb each replicated 9 times. Each set was separated into 3 subgroups. The subgroups were phytoextracted with *Polyalthia longifolia* and *Aloe vera* alongside a control (no phytoextraction) respectively. After 12 weeks, the concentration of Lead, Iron and Zinc in soils, roots and shoots was determined. Results showed that the two plants have phytoextraction ability with reductions in Zn, Fe, and Pb in the phytoextraction soil . Metal transfer factor was PB: *Aloe vera* (0.881) > *P. longifolia* (0.315); Zn: *P. longifolia* (0.614) > *Aloe vera* (0.606); Fe: *Aloe vera* (0.812) > *P. longifolia* (0.774). Translocation factors for the two plants were in the order: **Zn:** *P. longifolia* (0.79) > *Aloe Vera* (0.36); **Fe:** *P. longifolia* (0.63) > *Aloe Vera* (0.05); **Pb:** *P. longifolia* (0.57) > *Aloe Vera* (0.23). Since the translocation factors were < 1, the plants can be classified as non- hyperaccumulators for these metals. © JASEM

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***KEYWORDS*:** Heavy metal, contamination, *Polyalthia longifolia*, *Aloe vera*, phytoextraction, translocation factor, transfer factor.

Introduction

The rise in civilization and increasing level of technology have been a source of concern all over the world due to the resultant effect of increasing chemical pollution especially heavy metal pollution. Majority of these problems come from human activities such as waste disposal (industrial and municipal wastes), fossil fuel burning, ore mining and smelting and agricultural activities (Adriano, 2001; Kratz and Schnug, 2006). Accumulation of heavy metals in soil especially agricultural soil posses dangers to the plants as well as to human health. This is because heavy metals bioaccumulate and biomagnified along food chains which can cause serious health risk to the final consumer such as man. Unlike organic pollutants, heavy metals are non-biodegradable and can only be transformed from one oxidation state or organic complex to another (Gisbert *et al*., 2003). Hence, they tend to persist in the environment for many years. Some of these metals such as copper (Cu), iron (Fe) and zinc (Zn) are used by plants as micro nutrients at low concentrations but others such as lead (Pb) has been known to have no biological importance to living organisms. All heavy metals are toxic to life at high concentration. Accumulation of toxic heavy metals has detrimental effects on the ecosystem functioning (Giller *et al*., 1998). It is also known to inhibit anatomical, physiological and biochemical functioning in plant and animals.

As humans continue to impact on the environment, metal contamination issues will become increasingly common (Fernandes and Henriques, 1991). Due to the adverse effects of these metals on plant, animal, microorganism as well as the entire ecosystem functioning especially at high concentration; it is therefore, imperative to apply some remedial measures. Several techniques have been adopted for the cleaning of heavy metal contaminated site which ranged from on-site management to excavation of contaminated soil and disposing it in land fill. Some of these methods only transfer contaminant from one site to another without clean up thereby shifting the contamination problem. It has also been observed that some of these methods are expensive with some high level of technology. Sometimes they cause more harm to the ecosystem than the pollutant. This is because these methods render the soil sterile of all biological activities (Gaur and Adholeya 2004). In other words, these methods are not eco-friendly technology.

The use of phytoremediation (an aspect of bioremediation) has been proven to be a viable, inexpensive, eco-friendly and easy to use technology

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in the remediation of polluted environment. Phytoremediation involves the growing of higher plants for the *in-situ* reduction of contaminant in soil or water. Phytoremediation uses approaches such as phytostabilization, phytodegradation, phytovolatilization, rhizofiltration and phyoextraction to decontaminate polluted environment. Phytoextraction (the uptake of contaminants by plant root and the translocation/accumulation of contaminants into the plant shoots and leaves) has been known to be an effective and affordable technological solution used to remove metal pollutants from contaminated soil (Salt and Kramer, 1997). Phyto-extraction can be continuous and induced (Anderson *et al*., 1993). Plants differ in their phytoremediation abilities. Phytoremediation plants must be able to tolerate the types and concentrations of contaminants present. They must also be native to the area.

Several works have been done on phytoremediation (phytoextraction) in the developed countries using foreign plants but not much work has been done in developing countries (Nigeria) especially in the Niger Delta region where pollution is a common phenomenon using indigenous plants such as *Polyalthia longifolia and Aloe vera,* hence the thrust of this investigation. *Polyalthia longifolia and Aloe vera* are two common plants grown in the Niger Delta area of Nigeria mainly for ornamental purpose. It is expected that results from this study will provide clues for the selection of these two plant species not just for ornamental purpose but also for their phytoextraction potential.

MATERIALS AND METHODS

The work was carried out at the University of Port Harcourt Ecological Centre, located in the south – south (Niger Delta) area of Nigeria on geographical coordinates: latitude 4^o 65' N and longitude 7^o 5' E. The area falls within the tropical climate type characterized by high temperature, high rainfall, and high relative humidity. A Randomized Complete Block Design (RCBD) was used for the experiment. Soil collected in bulk and homogenized from a fallow farm with no history of heavy metal pollution was used to fill 27 polythene bags. 5 kg of soil was filled into each bag. The bags were not perforated to avoid leakage out of the pollutants. The polythene bags were arranged in 3 sets (designated as Tz, Tf and Tp) of 9 replicates each. Each set was polluted with 100 mg of a particular heavy metal. That is Tz, Tf and Tp were polluted with 100mg of Zn, Fe and Pb respectively. The pollutants were thoroughly mixed with the soil in the bag to enhance homogeneity. The set-up was allowed to stand for 2 weeks for full acclimatization. After the 2 weeks of post- pollution treatment; each set (Tz, Tf and Tp) was subdivided into 3 subsets of 3 replicates each. That is Tz1, Tz2 and Tz3 for set Tz; Tf1, Tf2 and Tf3 for set Tf and; Tp1, Tp2 and Tp3 for set Tp. Two seedlings of *Polyalthia longifolia* and *Aloe vera* of equal size, age and vigour were transplanted from the nursery into the treatment plots. *Polyalthia longifolia* was transplanted into Tz1, Tf1 and Tp1; while *Aloe vera* was transplanted into Tz2, Tf2 and Tp2. Tz3, Tf3 and Tp3 received no planting and acted as the control. 50 cl of water was used to water each bag three times a week. Weeding was done when the need arose. The experiment was allowed for 12 weeks before harvesting the plants and analysis.

Soil samples analyses were done by air-drying the soil and the dried soil sieved with a 2 mm sieve to remove coarse particles. One gram (1 g) of the dried soil sample was collected and placed in 100 ml beaker and; 3 ml of perchloric acid and 5 ml of nitric acid were added. The mixture was allowed to stand for 15 minutes. After the 15 minutes, it was digested by gently heating at low temperature on a hot plate and allowed to cool for 5 minutes. The digest was then filtered into 50 ml standard flask. The filtrate was analyzed for heavy metals (Zn, Fe and Pb) using Atomic Absorption Spectrophotometer (AAS). This soil analysis was done before planting and at the termination of the experiment.

After the 12 weeks period, the plants were carefully harvested from each bag. Each of the plants was cut at the junction between the root and shoot as to separate the root from the shoot. All samples collected from each treatment were taken to the laboratory immediately for heavy metals analysis.

Plant samples were first rinsed with distilled water and oven-dried at 100^oC for 48 hours. After the drying, the plant materials were ground to fine powder. One gram of the powder was digested as described above for soil samples and analyzed for heavy metals (Zn, Fe, and Pb) using Atomic Absorption Spectrophotometer (AAS).

Metal transfer factor (MTF) and Translocation factor (TF) were calculated from the data collected. Metal transfer factor (MTF) was calculated according to the method of Cui (2005) using metal concentration in the extracts of soils and plants as in equation (1).

$$MTF = \frac{metal\ concentration\ in\ plant}{metal\ concentration\ in\ soil} \quad \text{…Equation 1}$$

Translocation factor (TF) was determined using the formula of Barman *et al*. (2000); and Gupta *et al*. (2008) as stated in equation 2.

$$TF = \frac{metal\ concentration\ in\ shoot}{metal\ concentration\ in\ root} \quad \ldots\ldots \text{ equation 2}$$

The data generated were analyzed statistically. Mean, standard error mean (SEM), Analysis of variance (ANOVA) and Least Significant Difference (LSD) were obtained using SPSS data analysis package (2007 version 9.1).

RESULTS AND DISCUSSION

In Fig. 1, it is observed that the two plant species showed the ability to absorb Zn metal from the soil. A significant reduction in soil Zn was observed in soil phytoextracted with the two plants as compared with the control (no phytoextraction). Between the two phytoextraction plants, no significant difference (p=0.05) occurred in their Zn absorption capacities.

In the Fe phytoextraction soil, there was also decrease in the soil Fe as compared with the control. Although, the reductions in the soil Fe by the two phytoextraction plants were not as much as the reductions in the Zn polluted soil (Fig. 2). There was no significant difference between the two plants in the extraction of Fe from the soil.

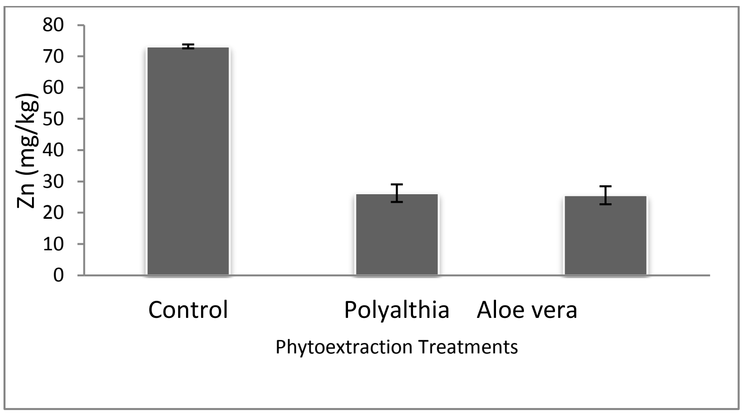

Fig. 1. Soil Zn concentrations in phytoextraction treatments

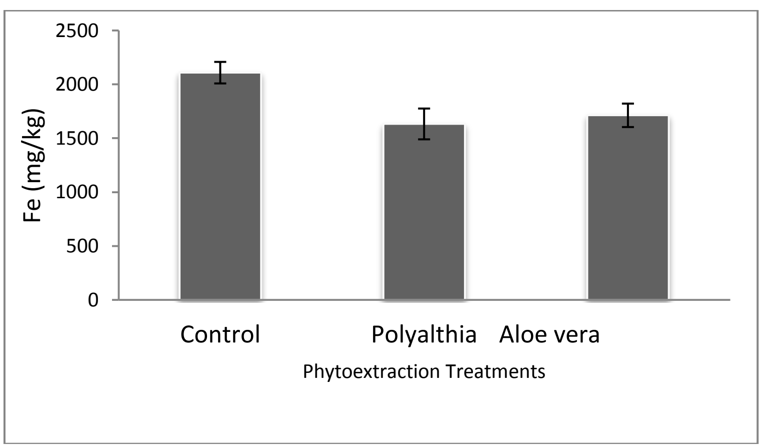

Fig. 2. Soil Fe concentrations in phytoextraction treatments

Fig. 3 showed the reduction of soil Pb in the different phytoextraction treatments. It was observed that the two phytoextraction plants significantly reduced the soil Pb when compare with the control. The reduction was significantly more in the Pb polluted soil phytoextracted with *Aloe vera* than *P. longifolia*. In other words, the Pb contents in the soils were in the order of: control > *P. longifolia* soil> *Aloe vera* soil.

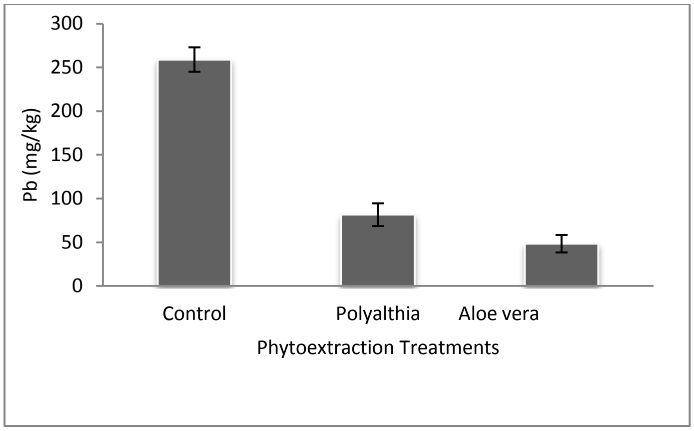

Fig. 3. Soil Pb concentrations in phytoextraction treatments

Figs 4-6 showed the concentrations of the metals (Zn, Fe, Pb) in the above-ground and below-ground parts of the phytoextracted plants. Results showed that the three metals were more concentrated in the roots of the plants than in their shoots (p=0.05). This was more pronounced in *Aloe vera* plants in which greater percentage of the metals were in the root as compared to *P. longifolia*. The concentration of Zn in the shoot of *P. longifolia* was found to be higher than the concentration in shoot of *Aloe vera* (Fig, 4). Similar results were obtained for Fe (Fig. 5) and Pb (Fig.6). Roots of *Aloe vera* significantly accumulated more Fe than the roots of *P. longifolia*.

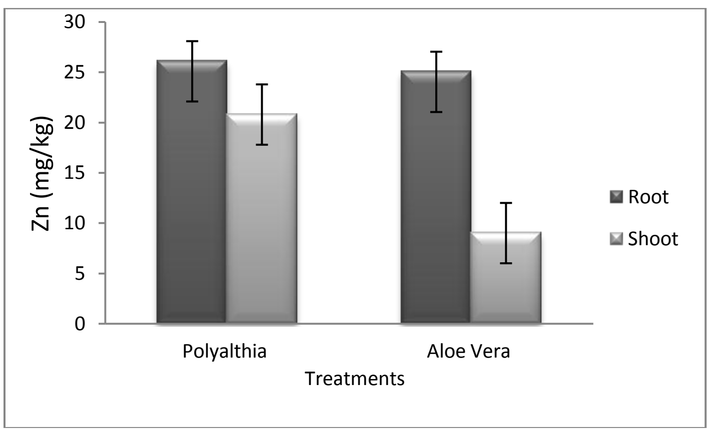

Fig. 4: Zn concentrations in plant parts

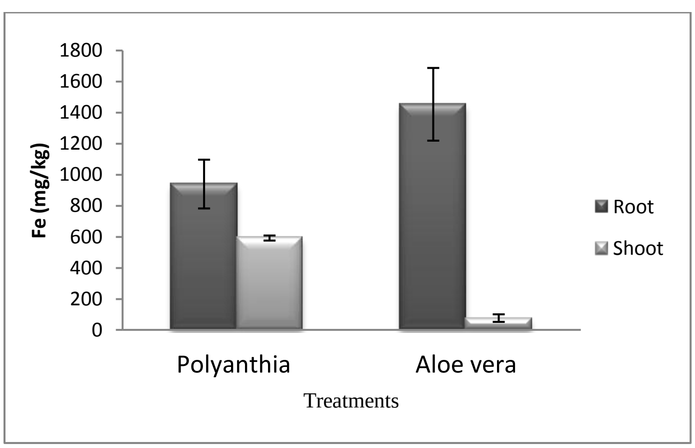

Fig. 5: Fe concentrations in plant parts

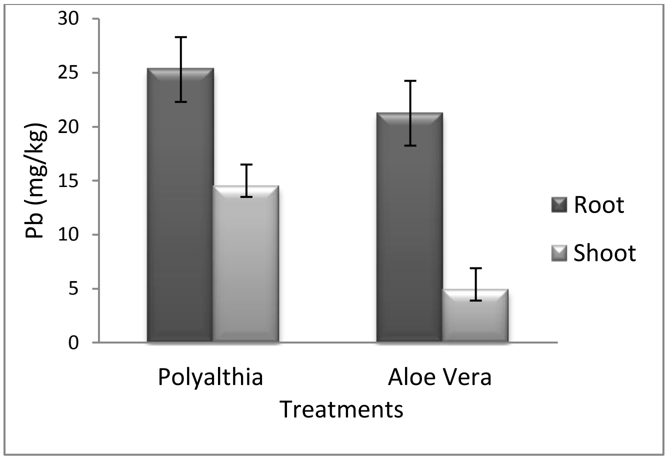

Fig. 6: Pb concentrations in plant parts

It is observed that the transfer factors for the three metals were below one. Results showed that the transfer factors of *Aloe vera* in Pb and Zn polluted soil were significantly higher than that of *P. longifolia* (Table 1). The highest transfer factor was in *Aloe vera* plant in Pb polluted soil while the least was recorded for *P. longifolia* in Pb polluted soil.

Similar results were recorded for translocation factors for the two phytoextraction plants in which all were below 1 (Table 2). *P. longifolia* recorded higher translocation factors in all the three metals pollution than *Aloe vera*. Highest translocation factor was recorded for *P. longifolia* and least in *Aloe vera* in Zn and Fe polluted soils respectively. Translocation factors for the two plants were in the order:
Zn: *P. longifolia* > Aloe Vera; **Fe:** *P. longifolia* > Aloe Vera; **Pb:** *P. longifolia* > Aloe Vera.

Table 1: Transfer factor of the phytoextraction plants

Metals	P. longifolia	Aloe vera
Pb	0.315	0.881
Zn	0.614	0.606
Fe	0.774	0.8123

Table 2 Translocation factors (TF = [Metal] Shoot/ [Metal] Root) of the phytoextraction plant species.

S/no.	Species	Translocation Factor		
		Zn	**Fe**	**Pb**
1.	***Polyalthia longifolia***	**0.79**	**0.63**	**0.57**
2.	***Aloe vera***	**0.36**	**0.05**	**0.23**

Plant can under normal condition absorb and accumulate certain metals into their system in quantity and magnitude greater than their immediate environment (Kim *et al*. 2003). Some of these metals are micronutrients to the plants (such as Fe, Zn, and Cu) needed for the normal growth and development while some like Pb has no known biological importance to plants. The accumulation of metals in plants involves many steps. These include the mobilization of the metal into soil solution phase, the uptake by the root system and the upward movement to the shoot system (Clemens *et al*. 2002). The amount accumulated depends on the phytoavailability of the metal which is a product of the quantity of the metal, the ionic ratios and the rate of transfer from the soil solution (Brummer *et al*. 1986).

Results showed that the two plants (*P. longifolia* and *Aloe vera*) were able to reduce the concentrations of the metals (Zn, Fe and Pb) in the soil. This is an indication that these plants have phytoextraction potential. There are two basic ways in which plants take up metals from the soil. It can be either with the mass flow of water (passive or apoplastic) or active (symplastic) movement trough the cell membrane of root cells (Lu *et al*.2009). In the active uptake, energy is expended and the non- essential metal ions compete with the essential metals for transmenbrane carrier. For instance, Clarkson and Luttge (1989) report that Cd and Ni compete with Cu and Zn for transmembrane carrier. In the apoplastic pathway, the metal ions enter through the intercellular spaces into the root.

Results showed that the percentage reduction in soil Zn and Pb by the phytoextraction plants was more than soil Fe. The low absorption of Fe may be attributed to its similarity with other plant nutrients. This other nutrients may have been absorbed in preference to Fe. It has been observed that phytotoxicity induced by the uptake of non-target metals may also limit the potential of phytoextraction. For instance, Lombi *et al*., (2001) report that Cd and Zn extraction potential was severely affected by Cu toxicity in sewage sludge contaminated agricultural soil.

There was difference in the accumulation capacities between the two phytoremediation plants especially in Pb polluted soil in which greater reduction was observed in soil phytoextracted with *P. longifolia* than *Aloe vera*. This shows that plants have preferences for accumulation of metal ions. Also the accumulation of metal ions by plants is plant species and metal dependent. Alloway *et al*. (1990) observed that plants take up metal ions in varying degree when grown in metal enriched soil. For example, some plants have been known to produce root exudates that help in increasing metal mobility and uptake. Muginic acid and avenic acid have been reported to mobilize Zn, Cu, and Mn (Romheld, 1991).

Accumulation of the three metals was found to be retained more in the roots than in the shoots in the two plants. This was more pronounced in *Aloe vera* than *P. longifolia*. The variability of metals retentions in roots and shoot has also been reported by Salt *et al*. (1995) and; Wenzel *et al*., (2003). This suggests that metal ions were stored within the root cells, thus becoming not available for xylem loading. This means that for metal ions to move into xylem, the metal ion must cross the casparian band and move symplastically. Clemens *et al.* (2002) observed that xylem loading process is highly mediated by membrane transport proteins. Xylem sap pH and redox potential can also affect the types, amount and movement of metals ions in the xylem (Liao *et al*. 2000).

The metal transfer factor and translocation factor for the metal and phytoextraction plants were below 1. The transfer factor of the three metals was higher in *Aloe vera* than in *P. longifolia* while the translocation factor was higher in *P.longifolia* than *Aloe vera*. A translocation factor (an indication of internal metal movement from root to shoot) < 1 showed that the metals were retained more in roots than in shoot. A translocation factor > 1 suggests that the plant is a hyper-accumulator while < 1 is a non-hyperaccumulator,

Conclusion: This study showed that the two plants have the abilities to phytoextract metals from soils polluted with metals such as Zn, Fe and Pb due to the great reduction of these metals in these phytoextraction soils with a demonstrated high level of tolerance to these metals. Since their translocation factors were < 1, showing their poor metal translocation abilities. Therefore, they cannot be regarded as hyper-accumulators but non-hyperaccumulators.

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