

Full Length Research Paper

Efficacy of *Moringa oleifera* as a phytoextraction plant in the remediation of heavy metals polluted soil

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The efficacy of *Moringa Oleifera*, for the phytoextraction of heavy metals (Zn, Fe and Pb) in tropical soil was investigated. A randomized complete block design (RCBD) consisting of 3 blocks was used. Each block (A, B and C) was polluted with 100 mg Zn, Pb and Fe, respectively. Each block was subdivided into treatment and control of 5 replicates each. Two seedlings of *M. Oleifera* were planted in each treatment plot (phytoextraction) while no planting was done in the control. Zn, Fe and Pb, were analyzed for the soil and plant parts. Results show that *M. oleifera* was able to extract and accumulate high concentration of these metals (Zn, Fe and Pb) in their roots and shoots. The percentage reductions of the heavy metals in the soil were Zn (20.1%), Fe (22.7%) and Pb (64%) after 3 months of phytoextraction. The transfer factor was in the order of Zn > Fe > Pb while translocation factors indicate that metals were largely retained in roots. On the basis of the result obtained, *M. oleifera*, can be classified as hyperaccumulator of some measured heavy metals and therefore, it is suitable for phytoextraction of heavy metal (Zn, Fe and Pb) contaminated soils.

Key words: Heavy metal, contamination, *Moringa oleifera*, phytoextraction, translocation factor, transfer factor.

INTRODUCTION

Heavy metals are natural constituents of the earth's crust. Heavy metals occur naturally in the ecosystem with large variations in concentrations. In modern times, anthropogenic sources of heavy metals have been introduced to the ecosystem. Heavy metals have an effect on the stability of colloids. Colloids are sensitive to change of ion or heavy metal concentration and it leads to violation of colloid stability and subsequent disintegration (Lane and Morel, 2010).

Heavy metal can occur in any ecosystem- terrestrial or

aquatic and when it occurs it affects all components of the ecosystem (biotic and abiotic). The effects range from physical and chemical contaminations of soil, air and water to deleterious impacts on flora and fauna.

Some metals such as Fe, Mn, Zn, Cu, Mg, Mo, and Ni are essential for plant growth in low concentration. However, high concentrations of these heavy metals in soil can negatively affect crop growth, as these metals interfere with metabolic functions in plants such as inhibition of photosynthesis, and respiration and

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degeneration of main cell organelles, even leading to death of plants (Garbisu and Alkorta, 2003; Schmidt, 2003; Schwartz et al., 2003). Soil contamination with heavy metals may also cause changes in the composition of soil microbial community, adversely affecting soil characteristics (Giller, 1998; Kozdrój and Van-Elsas, 2001).

Due to the negative effects of these heavy metals on the ecosystem especially at high concentration, it is imperative to apply some remedial measures. Several methods are already being used to clean up the environment from these kinds of contaminants, but most of them are costly and far away from their optimum performance. Conventionally, remediation of heavy-metal-contaminated soils involves either onsite management or excavation and subsequent disposal to a landfill site. This method of disposal solely shifts the contamination problem elsewhere along with the hazards associated with transportation of contaminated soil and migration of contaminants from landfill into an adjacent environment. Soil washing for removing contaminated soil is an alternative way to excavation and disposal to landfill. This method is very costly and produces a residue rich in heavy metals, which will require further treatment. Moreover, these physico-chemical technologies used for soil remediation render the land usage as a medium for plant growth, as they remove all biological activities (Gaur and Adholeya, 2004).

Recent concerns regarding the environmental contamination have initiated the development of appropriate technologies to assess the presence and mobility of metals in soil (Shtangeeva and Laiho, 2004). Presently, phytoextraction which is a form of phytoremediation has become an effective and affordable technological solution used to remove metal pollutants from contaminated soil. This technology is environmental friendly and potentially cost effective. Many species of plants have been successful in absorbing contaminants such as lead, cadmium, chromium, arsenic and various radionuclides from soils. One of phytoremediation categories, phytoextraction, can be used to remove heavy metals from soil using its ability to uptake metals (Fe, Mn, Zn, Cu, Mg, Mo and Ni) which are essential for plant growth.

This study attempts to determine the uptake and accumulation of heavy metals in different parts of the studied plant. It is expected that the findings obtained from this study will provide us with a clue on the efficacy of *M.oleifera* in the phytoextraction of heavy metal in the tropical soil.

MATERIALS AND METHODS

This study was carried out at the Ecological Centre, University of Port Harcourt. It is located in the Niger Delta area of Nigeria on geographical coordinates: latitude 4° 65' N and longitude 7° 5' E. The climate condition of the area is characterized by high temperature, high rainfall and high relative humidity.

A randomized complete block design (RCBD) was used for the experiment. Weighing balance (Setra 480S USA) calibrated in kilogram, was used to weigh 5 kg of soil into 40 polythene bags. The polythene bags were arranged in three blocks (designated as A, B and C) of 10 replicates each. Each block was polluted with 100 mg of a particular heavy metal solution. That is, block A was polluted with 100 mg of Zn; block B was with polluted 100 mg of Fe and block C was polluted with 100 mg of Pb.

The soil was thoroughly mixed in the bag to enhance the harmonization of the metal solution with the soil. The bags were allowed to stand for two weeks. After the two weeks of post-pollution treatment, each block (treatment) was subdivided into two subsets of five replicates each.

Two seedlings of *M.oleifera* were transplanted from the nursery into each bag of one subset for each block while the other subset acted as the control for each block with no planting. This was done for all the blocks (A, B and C). It was also ensured that the plants were of the same sizes. Watering was done three times a week. The quantity of water used for watering the planting bags was 50 cl per bag. Weeding was done when the need arose. The experiment lasted for 12 weeks.

Soil samples were collected from each bag after pollution (but before the plants were transplanted into them). This was done to ascertain the level of these metals present in the soil before phytoextraction. Soil sample collections were also done at the termination of the experiment. The heavy metals (Zn, Fe and Pb) were analyzed for the soil samples.

At the end of the 12 week period, the plants were carefully harvested from each bag. The shoots were separated from the root by cutting. All samples collected from each treatment were taken to the laboratory immediately for analysis. The plants parts and soil were analyzed for their heavy metal (Pb, Fe and Zn) content. This was done in accordance with their treatment. The plant concentration factor and translocation factor were also calculated.

Soil samples collected were analyzed by air-drying and all clods and clumps removed. Dried soil was sieved using 2 mm sieve to remove coarse particles before analysis. One gram (1 g) of the dried soil sample was 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 min before digestion by gently heating at low temperature on a hot plate and allowed to cool for 5 min. The digest was then filtered into 50 ml standard flask. The filtrate was analyzed for heavy metal using atomic absorption spectrophotometer (AAS).

Plant samples were analyzed by first rinsing with distilled water and oven-dried at 100°C for 48 h. The plant materials were ground to fine powder. One gram of the powder was digested as described above and analyzed for heavy metals AAS. Transfer factor or plant concentration factor (PCF) using metal concentration in the extracts of soils and plants were calculated. The plants concentration factor (PCF) was calculated as follows:

$$PCF = C_{\text{plant}}/C_{\text{soil}}$$

Where, C_{plant} and C_{soil} represents the heavy metal concentration in extracts of plants and soils respectively (Cui et al., 2005).

Translocation factor (TF) or mobilization ratio (Barman et al., 2000; Gupta et al., 2008) using the formula below.

$$TF = \frac{\text{concentration in shoot}}{\text{concentration in root}}$$

From the data generated, means and standard error mean (SEM) were calculated. The data obtained were also subjected to analysis of variance (ANOVA) using Microsoft Office Excel and least significant difference (LSD) was calculated using SPSS data analysis package (2007 version 9.1).

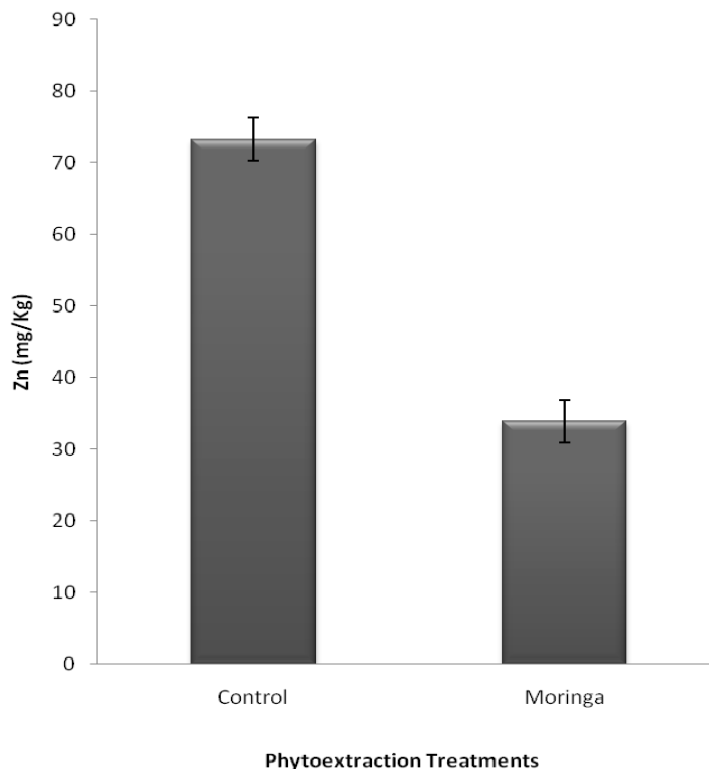


Figure 1. Soil Zn concentrations in phytoextraction treatment.

RESULTS

Figures 1 to 3 show the efficacy of the test plant (*M. oleifera*) for the phytoextraction of the heavy metal polluted soil. It was observed that there was a significant reduction in soil Zn in the polluted soil phytoextracted with the test plant species as compared to the control soil (no planting) (Figure 1). Similar results were observed in the Fe (Figure 2) and Pb (Figure 3) polluted soil phytoremediated with the test plant. These reductions were found to be significantly different ($p = 0.05$) from the control.

It was also observed that the reduction of the heavy metals in the soil differed considerably from metal to metal. Results show that the percentage reduction of Pb, Zn and Fe were 64, 20.1 and 22.7%, respectively.

Figures 4-6 showed the concentrations of the metals in both the above-ground and the below-ground parts of the test plant. Figure 4 shows the concentration of Zn in plant parts (roots and shoots) while Figures 5 and 6 shows the concentration of Fe and Pb in the plant parts of the test plant, respectively. It was observed that *M. oleifera* retained more of the heavy metals in its root than in the above-ground part (shoot). In other words, the concentration of Zn in plant's roots was significantly ($P = 0.05$) higher than the shoots. *M. oleifera* accumulation of zinc was significantly higher in root than shoot. Similar results were obtained for the concentration of Fe and Pb

in the plant's above-ground (shoot) and below-ground (root) parts.

The calculated result (Figure 7) showed the transfer values from soil to plant. It was observed that the transfer factors for the three (3) heavy metals studied were below one (1). The result indicates that transfer factor for heavy metals in the test plant species were in the orders Zn > Fe > Pb treatments. Reduction in transfer factor was lowest in Pb and highest in Zn polluted soil.

The translocation factor which is an indication of the ratio of heavy metal retention in the shoot over the root showed that the values for the 3 heavy metals studied were below one (1). This also buttress the fact that the phytoextracted plant (*M. oleifera*) accumulated and retained heavy metals (especially Fe, Zn and Pb) more in the root system than the shoot system (Figure 8). The order of translocation factor was: Zn > Pb > Fe.

DISCUSSION

It is a well established fact that some plants can extract heavy metals from the soil or water and accumulate or retain them in their body parts (roots, stems or leaves). This uptake and accumulation of metal ions by plants differ from plant to plant and in varying degrees. The bioavailability of the metals can also influence their uptake by plants which are in turn determined by both

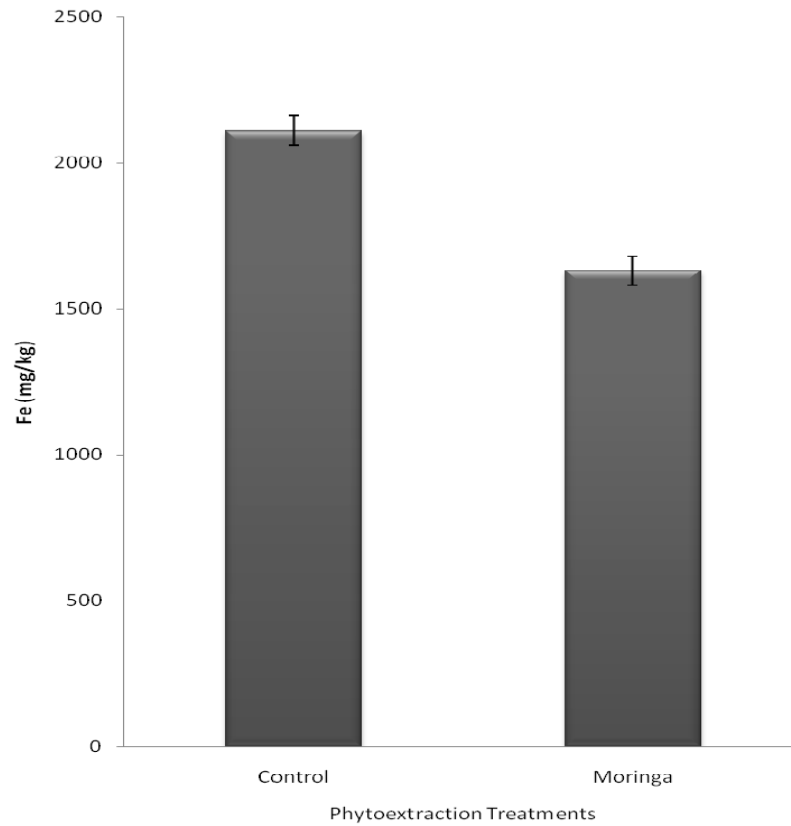


Figure 2. Soil Fe concentrations in phytoextraction treatment.

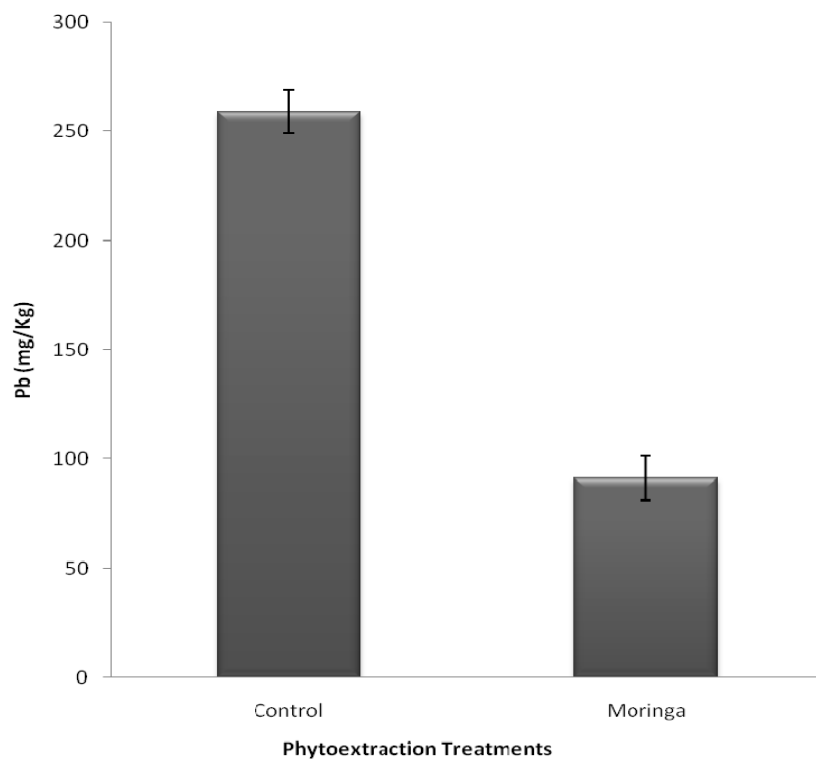


Figure 3. Soil Pb concentrations in phytoextraction treatment.

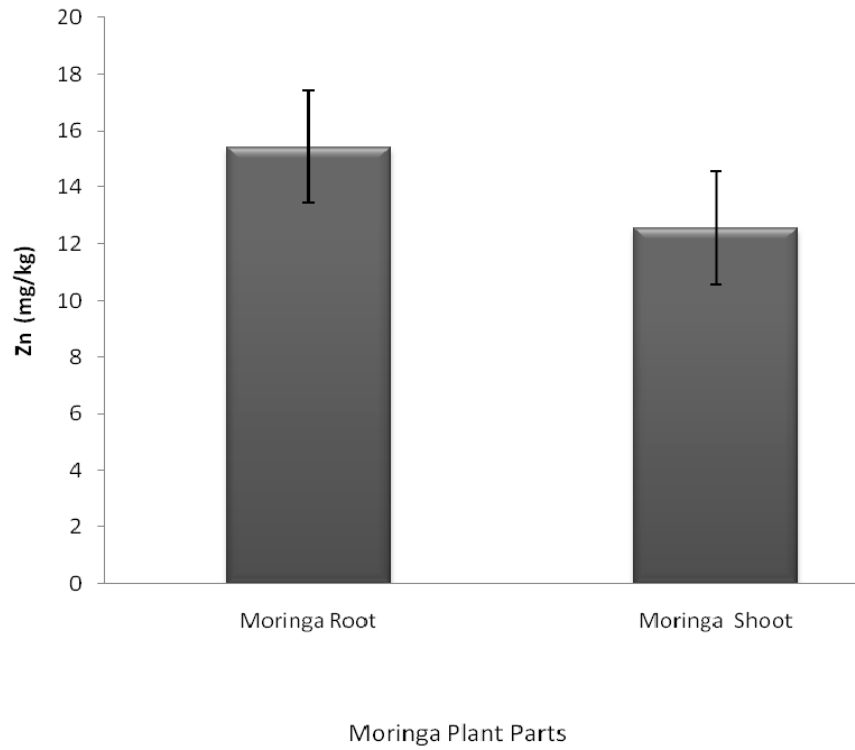


Figure 4. Zn concentration in plants part.

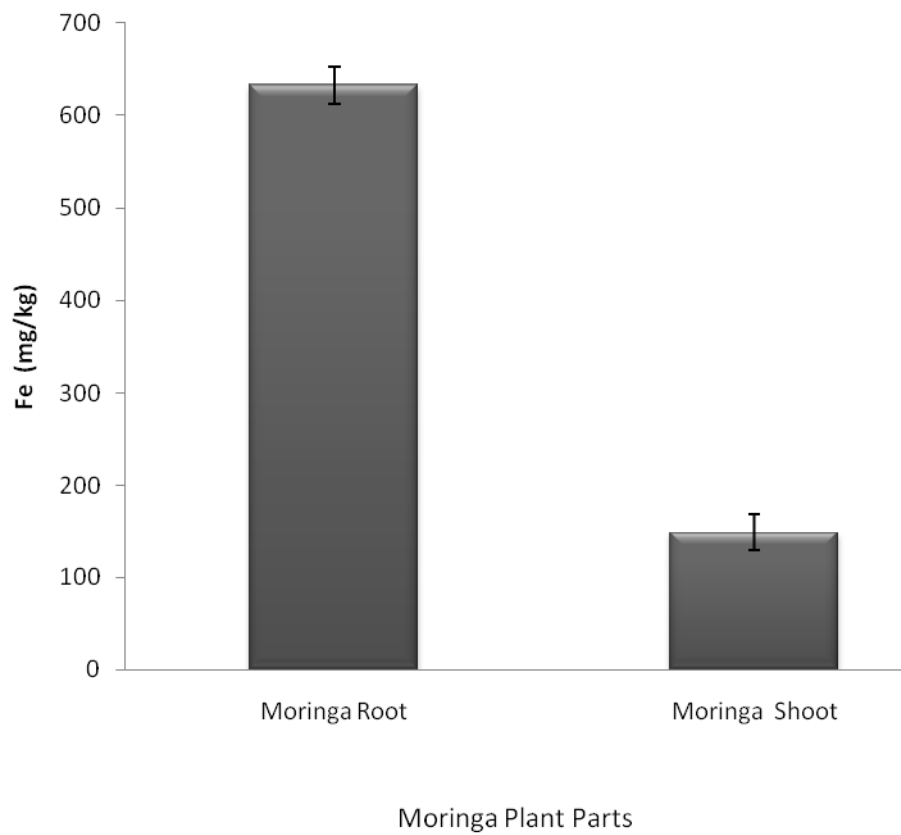


Figure 5. Fe concentration in plants parts.

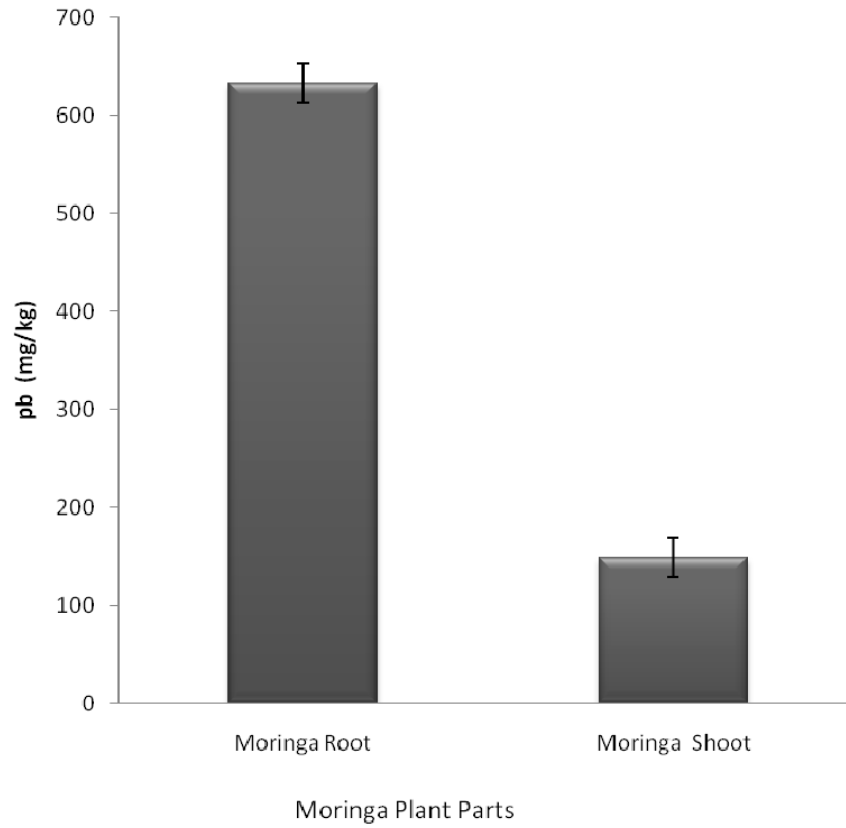


Figure 6. Pb concentration in plants parts.

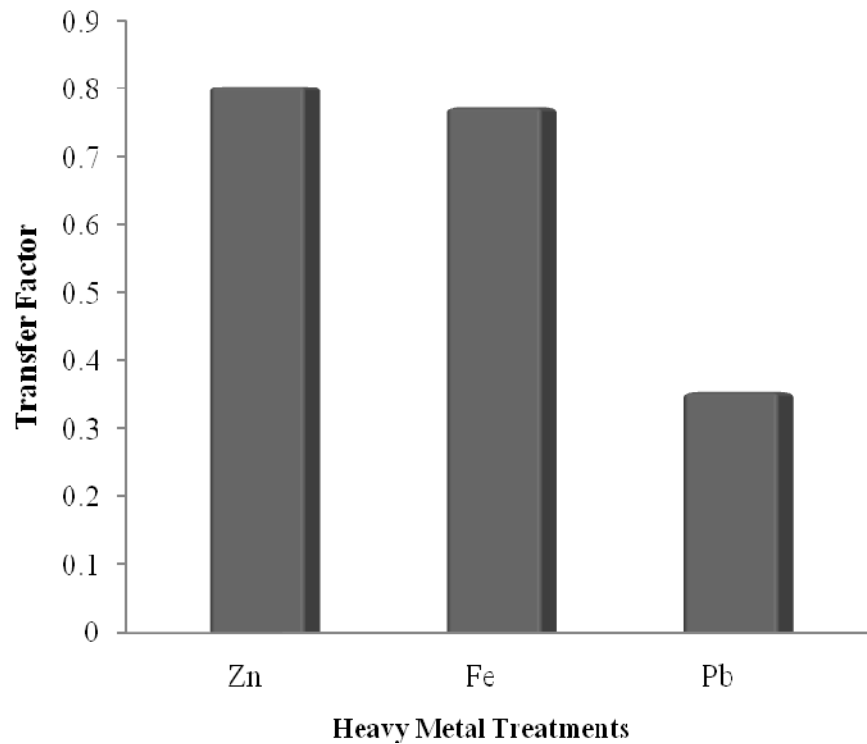


Figure 7. Transfer factor of different metals.

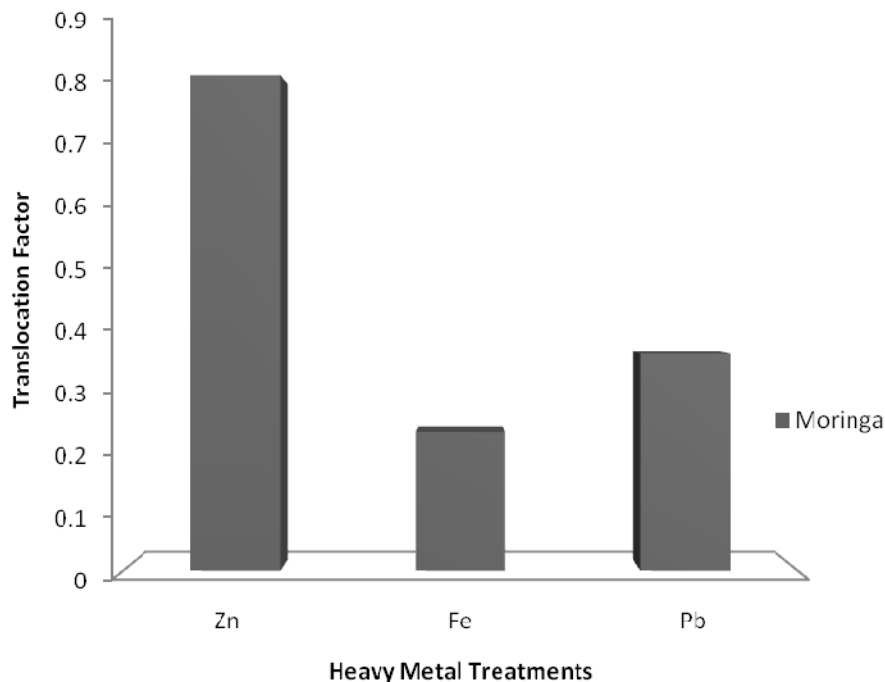


Figure 8. Translocation factors of different metals.

external (soil-associated) and internal (plant-associated) factors.

Results showed that *M. oleifera* plant has the ability to phytoextract heavy metals especially Fe, Zn and Pb and accumulate them in their body parts (below-ground and above-ground). Although, the strategy employed by *M. oleifera* plant for the uptake of heavy metal varies among heavy metal treatments as shown in the result in which the percentage reduction was in the order of Pb (64%) > Fe (22.7%) > Zn (20.1%). This is understandable since some plant exhibit selective absorption of metal ions from soil in which a particular plant may prefer a particular metal ion to another. Fleming and Parle (1977) reported that the uptake of heavy metal varies widely depending on the plant species being studied. It was long recognized that the uptake of metals by plants were plant species dependent (Adriano, 1986). Some plants release specific metal-chelating or reducing compounds into the rhizosphere to aid the absorption when availability of these micronutrients is low (Marschner, 1995).

Results in Figures 4, 5 and 6 show that the accumulation/retention of heavy metals (Zn, Fe and Pb) was more in root system than shoot system. This suggests that plant have different ability in accumulating particular heavy metals in different parts of their body. The accumulation of heavy metal contents in root and shoot varies from species to species (Salt et al., 1995). This is understandable since the breaking up of soil aggregates is a physical effect of root tips pushing through soil as the root tips grow. Fungi associated with some plant roots (mycorrhizae) can also influence the

chemical conditions within the soil, which could account for the accumulation of heavy metal more in root. Similar result has also been reported by Trusby (2003). This also suggests that a number of factors (including anatomical, biochemical and physiological factors) might contribute to heavy metal accumulation in the root than shoot. Although, Salt et al. (1995) reported a contrary observation of high accumulation of heavy metals in the upper vegetative parts of some plants.

The analysis of transfer factor indicates that the uptake capabilities of heavy metals from soil to *M. oleifera* is in the order of Zn > Fe > Pb. This could be attributed to the plant species used. Zurera et al. (1987) have reported that the mobility of metals from soil to plants is a function of the physical and chemical properties of the soil and of plants species, and is altered by innumerable environmental and human factors.

Translocation factor, the ratio of shoot to root metals, indicates internal metal transportation. The data presented indicate that metals accumulated by the test plant species (*M. oleifera*) were largely retained in roots, as shown by TF values (<1). Translocation factor (TF>1) showed that translocation of metals effectively was made to the shoot from root (Baker and Brooks, 1989; Fayiga and Ma, 2006).

Conclusion

It can be concluded that the ability of a plant species to phytoextract and accumulate heavy metals varies among

the heavy metals. There were drastic reductions in the heavy metal contents of soil phytoremediated with *M. oleifera*. Moreover, the level of accumulation of these metals studied (Zn, Fe and Pb) was more pronounced in roots than shoots. Therefore, *M. oleifera* is capable of phytoextracting these metals (Zn, Fe and Pb), but their accumulation rate is dependent on a particular metal.

Conflict of Interests

The author(s) have declared that there is no conflict of interests.

REFERENCES

- Adriano DC (1986). Utilization and disposal of fly ash and other coal residues in terrestrial ecosystems: A Review. *J. Environ. Qual.* 99:333-345.
- Baker JM, Brooks RR (1989). Terrestrial higher plants which hyper accumulate metallic elements. A review of their distribution, ecology and phytochemistry. *Biorecovery* 1: 81-26
- Barman SC, Sahu RK, Bhargava SK, Chatterjee C (2000). Distribution of heavy metals in wheat, mustard and weed grains irrigated with industrial effluents. *Bull. Environ. Contam. Toxicol.* 64:489-496.
- Cui C (2005). Junk-greedy greens: phytoremediation as a new option for soil decontamination. *Asian Pac. J. Environ. Biol.* 2:60-67.
- Fayiga AQ, Ma LQ (2006). Using phosphate rock to immobilize metals in soils and increase arsenic uptake in *Pteris vittata*. *Sci. Total Environ.* 359:17-25.
- Fleming G, Parle J (1977). Heavy metals in soils, herbage and vegetables from an industrialized area West of Dublin City. *Irish J. Agric. Res.* 16:48.
- Garbisu C, Alkorta I (2003). Basic concepts on heavy metal soil bioremediation. *Eur. J. Min. Process Environ. Prot.* 3(1):58-66.
- Gaur A, Adholeya A (2004). Prospects of arbuscular mycorrhizal fungi in phytoremediation of heavy metal contaminated soils. *Curr. Sci.* 86:528-534.
- Giller KE (1998). Toxicity of heavy metals to microorganism and microbial processes in agricultural soils: A Review. *Soil Biol. Biochem.* 30:10-11.
- Gupta S, Nayek S, Saha RN, Satpati S (2008). Assessment of heavy metal accumulation in macrophyte, agricultural soil and crop plants adjacent to discharge zone of sponge iron factory. *Environ. Geol.* 55:731-739.
- Kozdrój J, Val Elsa T (2001). Structural diversity of microbial communities in arable soils of a heavily industrialized area determined by PCR-DGGE finger printing and FAME profiling. *Appl. Soil Ecol.* 43:197-212.
- Lane TW, Morel FM (2010). A biological function for cadmium in marine diatoms. *Proc. Natl. Acad. Sci. U.S.A.* 97:4627-463.
- Marschner H (1995). Mineral nutrition of higher plants. 2nd Ed. Academic Press Inc., London
- Salt DE, Smith RD, Raskin L (1995). Phytoremediation: a novel strategy for removal of toxic metals from the environment using plants. *Biotechnol.* 13:468-474.
- Schmidt U (2003). Enhancing phytoextraction: The effect of chemical soil manipulation on mobility, plant accumulation and leaching of heavy metals. 87:212-229.
- Shtangeeva I, Laiho H (2004). Improvement of phytoremediation effects with help of different fertilizers. *Soil Sci. Plant Nutr.* 50:885-889.
- Schwartz C, Echevarria G, Morel J (2003). Phytoextraction of cadmium with *Th laspi caerulescens*. *Plant Soil* 249:27-35.
- Trusby P (2003). Impact of heavy metals on forest trees from mining areas. Proceedings of the International Conference on Mining and the Environment III, October 24, 2005, Sudbury, Ontario, Canada.
- Zurera G, Estrada B, Rincon F, Pozo R (1987). Lead and cadmium contamination levels in edible vegetables. *Bull. Environ. Contam. Toxicol.* 38:805-812.