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Phytoextraction of heavy metals by *Vetivera zizanioides, Cymbopogon citrates and Helianthus annuls*

Yashim Zakka Israila*, Agbaji Edith Bola, Gimba Casimir Emmanuel, Idris Suleiman Ola

Department of Chemistry, Ahmadu Bello University, Zaria, Nigeria

Email address:
ziyashim@abu.edu.ng (Yashim Z. I.), bola.agbaji@gmail.com (Agbaji E. B.), gimbace@yahoo.com (Gimba C. E.), alhajisoidris@yahoo.com (Idris S. O.)

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Abstract: The research work under field conditions is to investigate the connection between the heavy metals concentration in soil and their bioaccumulation in *Vetivera zizanioides, Cymbopogon citrates* (Lemon grass) and *Helianthus annuls* (sunflower) collected from experimental site and a control area in Zaria-Nigeria. The collection was done by dividing the experimental and control sites each into four quadrants, five plants samples of each species and soil samples were collected from each quadrant in a diagonal basis. The concentrations of Cd, Co, Cu, Ni, Pb and Zn in different parts of each of the plant species collected from the experimental and control soils were determined using atomic absorption spectrophotometry. The experimental levels of the metals were higher ($P \leq 0.05$) than those at the control site and the limits recommended by Food and Agricultural Organisation/World Health Organisation (FAO/WHO). The heavy metal concentrations were higher in leaves ($P \leq 0.05$) than in roots of the plants tested. *Vetivera zizanioides* showed the bioaccumulation factor (BF) and translocation factor (TF) values for the studied metals greater than 1 (except Co and Pb that had their BF less than 1). *Cymbopogon citratus* showed BF values of Cd, Ni and Pb were greater than 1, but TF of all the metals studied were greater than 1. *Helianthus annus* plant had BF values for Cd, Cu and Zn greater than 1, but TF values for all the metals studied were greater than 1. This indicated that *Vetivera zizanioides, Cymbopogon citrates* and *Helianthus annuls* have good phytoextraction potentials for the removal of heavy metals from contaminated soils.

Keywords: *Vetivera Zizanioides, Cymbopogon Citrates, Helianthus Annuls,* Bioaccumulation Factor, Translocation Factor, Phytoextraction

1. Introduction

The global problem concerning contamination of the environment as a consequence of human activities is increasing. Contamination, however, has resulted from industrial activities, such as mining and smelting of metalliferous ores, electroplating, gas exhaust, energy and fuel production, fertilizer and pesticide application, and generation of municipal waste [1]. This has resulted in environmental build up of waste products of which heavy metals are of particular concern [2]. Excessive metal concentration in soils pose significant hazard to human, animal and plant health, and to the environment in general [3].

Plant uptake of trace elements is generally the first step of their entry into the agricultural food chain. After plant uptake, metals are available to herbivores and humans both directly and through the food chain. The limiting step for elemental entry to the food chain is usually from the soil to the root [4]. This critical step usually depends on element concentrations in soil pore solutions, which are controlled by local soil physical and chemical conditions including water content, pH, redox potentials and other factors.

Phytoextraction process involves plant roots removing metals from contaminated soils/sediments and transporting them to leaves and stems for harvesting and disposal without destroying the soil structure and fertility. The success of the phytoextraction process, whereby pollutants are effectively removed from soil, is dependent on an adequate yield of plants and/or the efficient transfer of contaminants from the roots of the plants into their aerial parts [5, 6]. Phytoextraction makes use of natural hyperaccumulators as well as high biomass producing plants [7].

The dumpsite at Dakace in Zaria, Nigeria (11° 07’ 51” N;

7° 43' 43" E) occupies an estimated area of 20 m x 6 m. Three different plant species namely *Vetivera zizanioides, Cymbopogon citrates* (Lemon grass) and *Helianthus annuls* (sunflower) were planted on the soil around the dumpsite.

The aim of this study is to investigate the connection between the heavy metals concentration in soil and their bioaccumulation in *Vetivera zizanioides, Cymbopogon citrates* (Lemon grass) and *Helianthus annuls* (sunflower) in order to assess the plants' phytoextraction potentials under field and natural agro-climatic conditions.

2. Materials and Methods

2.1. Experimental Design

The field experiment was carried out near a scrap-metal dumpsite at Dakace in Zaria-Nigeria from July to September of 2012. An experimental area of 3 m x 2 m was selected at the site where the studied plants were grown. The seedlings of the plants were obtained from farmlands not contaminated and transplanted to the field. Three different plant species- *Vetiveria zizanioides*, *Cymbopogon citratus* (Lemon grass) and *Helianthus annus* (sunflower) were planted in the designated field plot with spacing of 20cm x 20cm for all the tested plants as described by Zhuang *et al*.[8]. The plants were allowed to grow naturally under natural agro-climatic conditions and exposed to natural day and night temperatures, with neither fertilization nor optimum irrigation so as to assess the feasibility of the remediation process. Weeds were controlled by mechanical method.

2.2. Sample Collection

Whole plant samples of *Vetivera zizanioides, Cymbopogon citrates* (Lemon grass) and *Helianthus annuls* (sunflower) were harvested, while soil samples (150 g) were collected from the surface to a depth of 15 cm around each plant root zone, using hand trowel and then mixed together. Background soil (150 g) and plant samples were also obtained as control from an area 5 km distance away from the dumpsite. The collection was done by dividing the experimental and control sites each into four quadrants, five plants samples or soil samples were collected from each quadrant in a diagonal basis following the methods of Nuonom *et al*.[9].

2.3. Sample Treatment

The collected soil samples were air-dried at room temperature for 3 days, while the shoots and roots of the plant samples were washed, separated and air dried. The soil samples were ground and sieved (500µm sieve) and then dried in an oven at 65 ± 1°C for 16 hrs, and kept in clean polythene bags for further analysis.

One gram (1g) of each of the soil and plant samples was digested separately with 10 cm^3 of aqua regia (a mixture of 3 parts concentrated HCl to 1 part concentrated HNO_3) on a hot plate in a fume cupboard, until a clear solution was obtained. Distilled water was added periodically to avoid drying up of the digest. To the hot solution, 30 cm^3 of distilled water was then added and filtered through a Whatman No. 42 filter paper into a 50 cm^3 standard volumetric flask and then made up to the mark with distilled water [10].

Cadmium, cobalt, copper, nickel, lead and zinc were analyzed in the plant and soil samples using a D100XB4J atomic absorption spectrometer, with the analyses being done in triplicate.

The bioaccumulation factor (BF) and the transfer factor (TF) were calculated to determine the degree of metal accumulation in the plants grown at the farm site close to the metal-scrap dumpsite [11].

$$BF=\frac{\text{Concentration of metal inplant}}{\text{Concentration of metal in soil}}$$

$$TF=\frac{\text{Concentration of metal inplant shoot}}{\text{Concentration of metal in plant root}}$$

Replicates of the data obtained were subjected to one-way ANOVA using SPSS 20 software.

3. Results and Discussion

Figure 1a shows the result of the metal concentrations in different parts of *Vetivera zizanioides* plant grown at Dakace soil near the dumpsite. The metal concentrations at the experimental site were higher ($P \leq 0.05$) than the control and were above the standard limits as recommended by Food and Agricultural Organisation and World Health Organisation (FAO/WHO) [12]. The BF of the elements at the experimental site were in the order of Cu > Ni > Cd ≈ Zn > Pb > Co, while the TF was Zn > Cu > Ni > Cd ≈ Co ≈ Pb. Both the BF and TF (Figure 1b) for the metals were greater than 1 except cobalt and lead had their BF less than 1. *Vetivera zizanioides* plant has achieved a good phytoextraction process, whereby it has effectively removed from soil and translocated the heavy metal contaminants from the roots of the plants into their aerial parts [13]. They are plants that achieve a shoot- to- root (TF) metal concentration ratio greater than one. *Vetivera zizanioides* plant is a hyperaccumulator and has the potential to decontaminate metal-polluted soils [14].

The BF of the studied metals in *Cymbopogon citrates* (Lemon grass) as shown in Figure 2a were in the order of Ni > Cd > Pb > Zn > Co ≈ Cu, while the TF followed the order: Zn > Cu > Cd ≈ Co > Ni > Pb. The BF of Cd, Ni and Pb were greater than 1 while that of Co, Cu and Zn were less than 1. The TF of all the metals studied were greater than 1. Figure 3a shows the metal concentrations in different parts of *Helianthus annus* (sunflower) plant. The BF and TF followed the order: Cu > Cd > Zn > Co ≈ Pb > Ni, and Ni > Co > Cu > Pb > Zn > Cd respectively. *Helianthus annus* (sunflower) plant has a good phytoextraction potential for the removal of heavy metals from a contaminated soil [15]. The BF for Cd, Cu and Zn were greater than 1. The study showed that there was a general increase in metal concentration from the roots to the leaves for all the element studied at the experimental and control sites. The phytoextraction potential of each plant species is determined by its BF and TF. The metals were extracted by each of the plant species and then translocated from the roots to the shoot, hence TF for all the metals found to be greater than 1. This factor illustrates the efficiency of the internal transport of metals from roots to shoots, and a value > 1 indicates that plant is a metal accumulator appropriate for phytoextraction [16]. The TF values always lower than 1 suggested that Plants grown on highly metal contaminated soils behaved as tolerant plants, thus excluding metal toxicity by accumulation in roots. Where the BF is greater than 1, the plant species is a good accumulator, and where the TF is greater than 1 the plant species is a hyperaccumulator of the metal [17]. Studies have shown *Vetivera zizanioides, Cymbopogon citrates* (Lemon grass) and *Helianthus annuls* (sunflower) are hyperaccumulators . Paz-Ferreiro *et al*. [18] reported that uptake of heavy metals is higher in pot experiments than for the soils in the field experiments. This is due to differences in soil moisture or microclimate and to the fact that field-grown plants can reach down to less polluted soil.

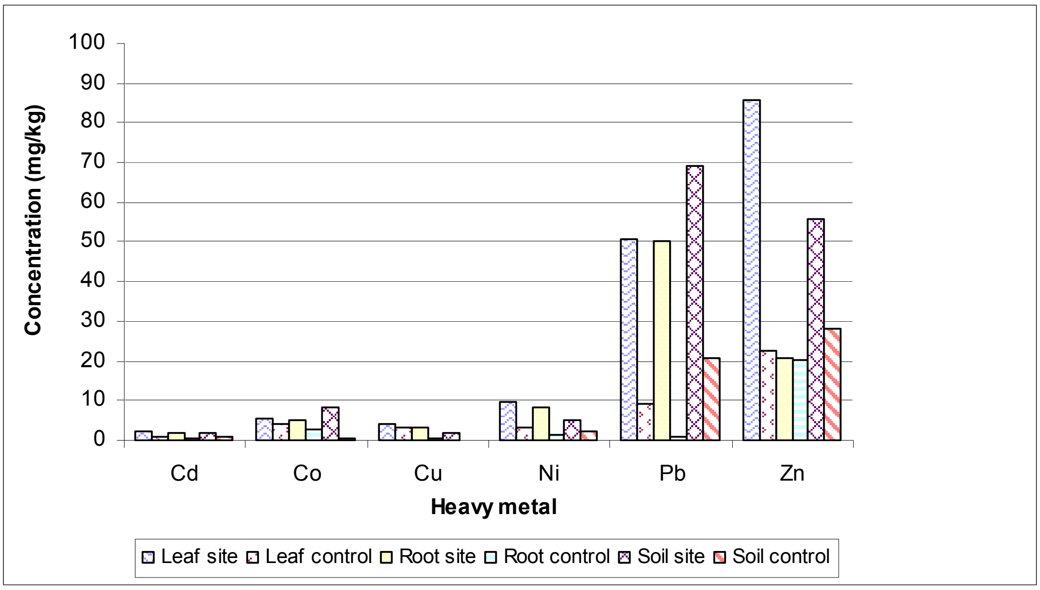

Figure 1a. *Concentration of Heavy metals (mg/kg) in different parts Vetivera zizanioides plant and the soil.*

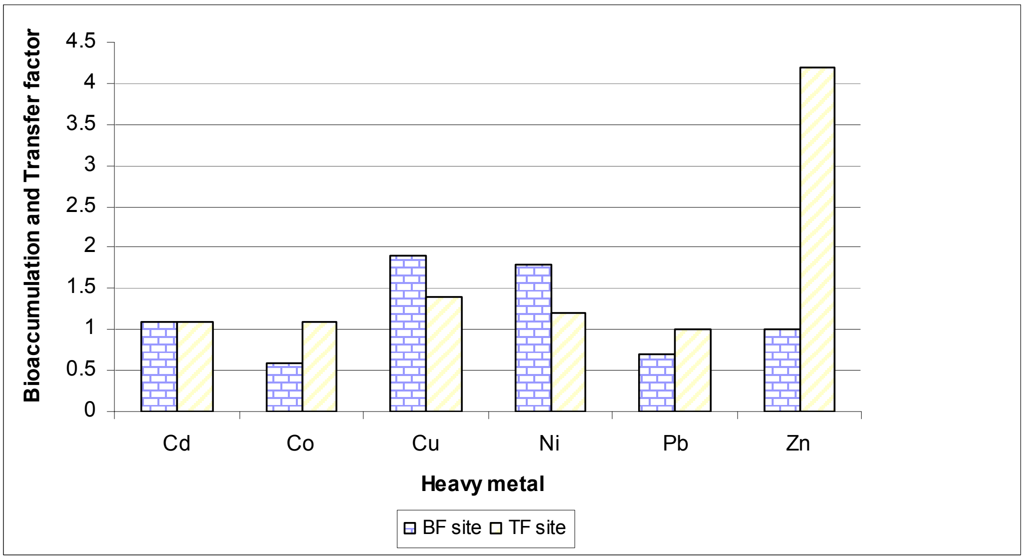

Figure 1b. *Bioaccumulation and Transfer factors for Vetivera zizanioides plant.*

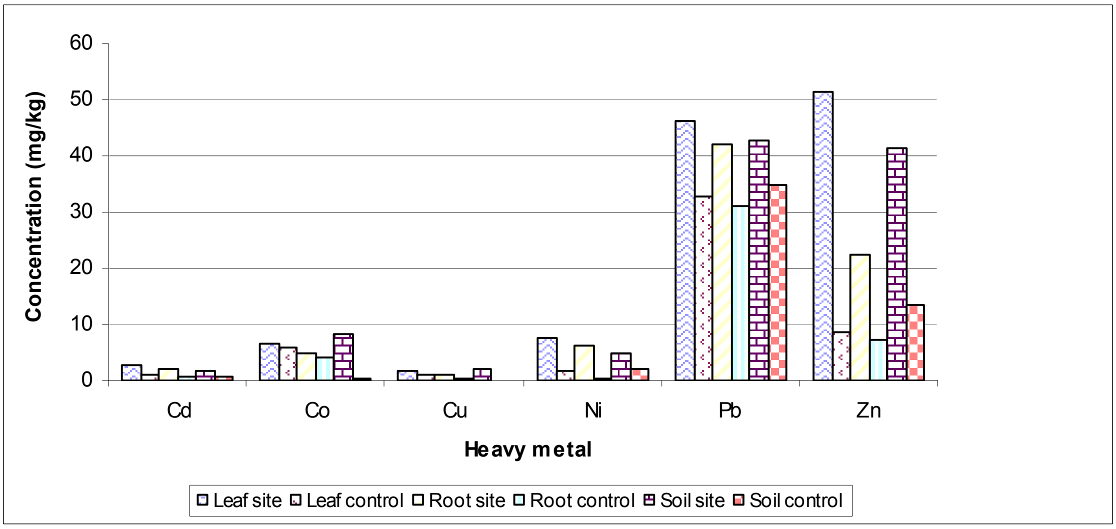

Figure 2a. *Concentration of Heavy metals (mg/kg) in different parts Cymbopogon citrates(Lemon grass) plant and the soil.*

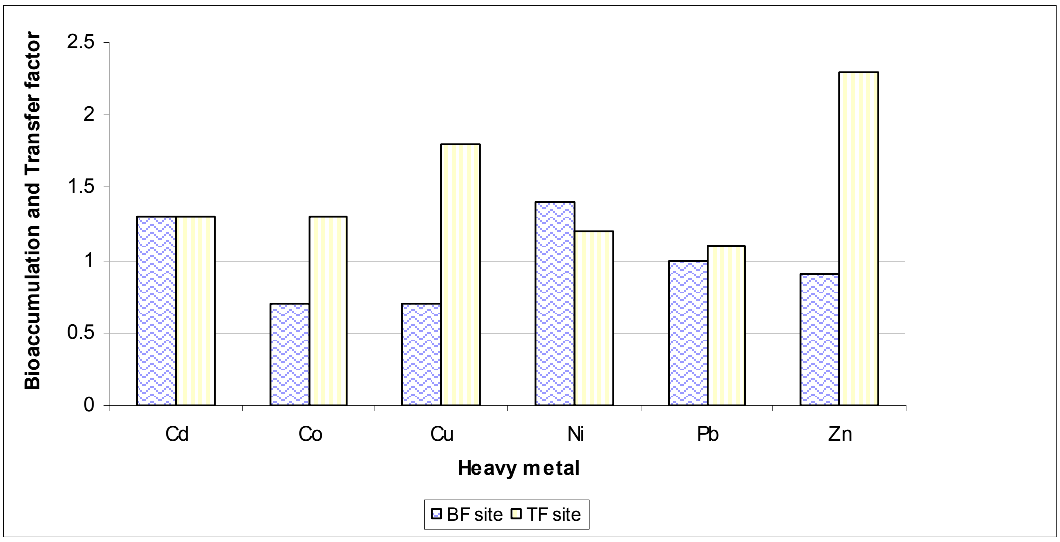

Figure 2b. *Bioaccumulation and Transfer factors for Cymbopogon citrates(Lemon grass) plant.*

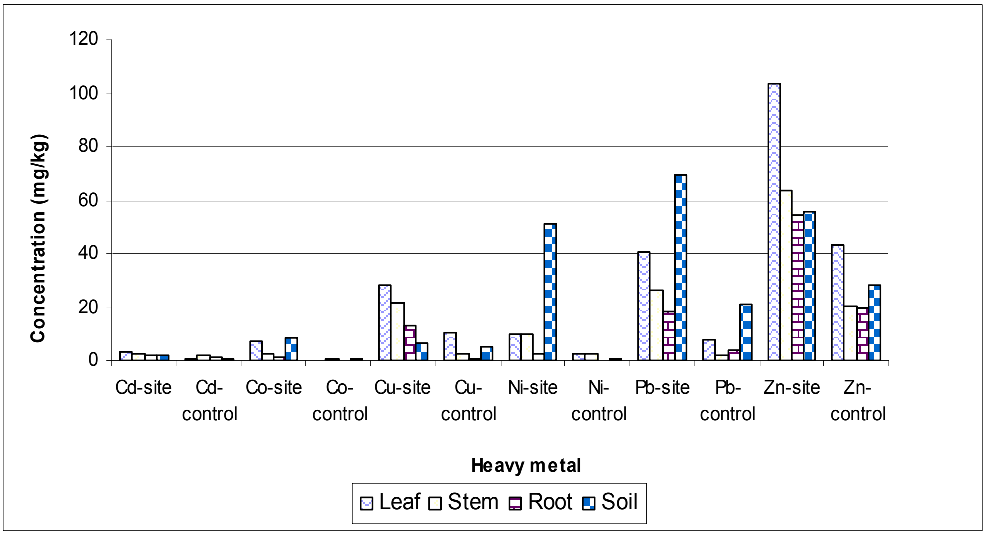

Figure 3a. *Concentration of Heavy metals (mg/kg) in different parts Helianthus annuls (sunflower) plant and soil.*

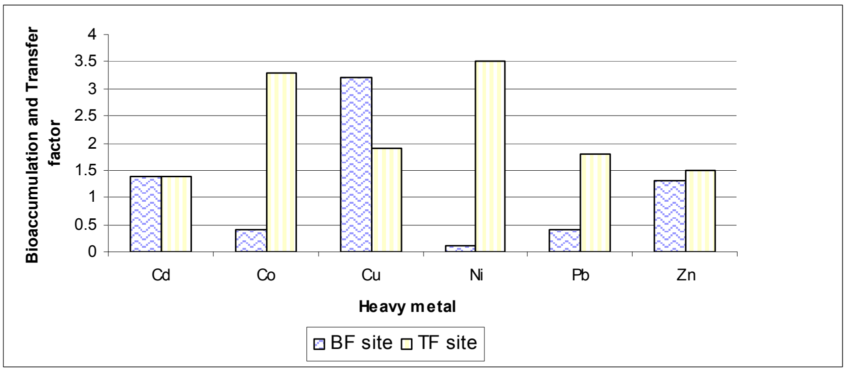

Figure 3b. *Bioaccumulation and Transfer factors for Helianthus annuls (sunflower) plant.*

4. Conclusion

Vetivera zizanioides, Cymbopogon citrates (Lemon grass) and *Helianthus annuls* (sunflower) plants planted near dumpsite at Dakace showed higher concentration of Cd, Co, Cu, Ni, Pb and Zn than the control. The concentration of Cd, Co, Cu, Ni, Pb and Zn were higher in their shoots as compared to their roots. For *Vetivera zizanioides,* both the BF and TF for the metals were greater than 1 except cobalt and lead had their BF less than 1. For *Cymbopogon citrates* (Lemon grass) the BF of Cd, Ni and Pb were greater than 1 while that of Co, Cu and Zn were less than 1. The TF of all the metals studied were greater than 1. For *Helianthus annus* (sunflower) plant the TF for all the metals were found to be greater than 1. All the plants studied have good phytoextraction potentials, hence can be used for the phytoremediation of soils contaminated with heavy metals.

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