EFFICIENCY IN PHYTOEXTRACTION OF HEAVY METALS FROM SOIL NEAR METAL DUMPSITES BY SOME SELECTED PLANTS IN ZARIA NIGERIA

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ABSTRACT

This research work is to investigate the efficiency ofphytoextraction of heavy metals from soils near scrap-metal dumpsites by *Vetiverazizanioide*, *Ipomoea asarifolia,Helianthusannus*, *Ricinuscommunis* L. and *Cymbopogoncitratus*at Dakace, Gaskiya and Hanwa in Zaria, Nigeria. Soil and grown plant samples were collected from each dumpsite. The samples were digested using aqua regia and the concentrations of Cd, Co, Cu, Ni, Pb and Zn were determined by atomic absorption spetrophotometric (AAS) method. The pollution index of the soil and the bioaccumulation factor of the heavy metals in the plants were calculated. The results obtained indicated that the concentrations of the heavy metals at the dumpsites were higher than those at the control site and the limits recommended by WHO. The bioaccumulation factors for all the metals were greater than 1.The percentage removal of the heavy metals by the five plant species were as follows: : Dakace site: Cd- 52.5%, Co – 0.6%, Cu – 44.3%, Ni – 88.4%, Pb – 13% and Zn – 28%; Gaskiya site: Cd – 45.7%, Co – 15.7%, Cu – 24.5%, Ni – 69.7%, Pb – 21.2% and Zn – 17.1%; Hanwa site: Cd – 36.7%, Co – 1.2%, Cu – 28.4%, Ni – 20.5%, Pb – 17.4% and Zn – 17.2%. The five studied plant speciess are very efficient in removing heavy metals from soil, thus can be used in the remediation process.

***Keywords**:* Bioaccumulation factor, Dumpsite, Heavy metal, Phytoextraction, Pollution index.

1.0 INTRODUCTION

Soils polluted with heavy metals pose significant hazard to human, animal and plant health, and to the ecosystem in general (Nascimento and Xing, 2006; Paz-Ferreiro*et al*.,2014). Due to the high cost of conventional technologies, the use of plants to clean up contaminated environments known as phytoremediation has emerged (Hosh and Ingh, 2005;). Phytoremediation takes the advantage of the unique and selective uptake capabilities of plant root systems, together with the translocation, bioaccumulation, and contaminant degradation abilities of the entire plant body.

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The method is comprised of phytoextraction, phytostabilization, phytovolatilization, phytodegradation and phytofiltration. However, only phytoextraction which can effectively remove contaminants from contaminated soils is the most promising for commercial application (Sun *et al.,* 2011). It is economically more viable and less disruptive to the environment.

Successful phytoextraction depends not only on metal concentration in shoots but also on high plant biomass. Selection of plant species is based on high tolerance and accumulation rate for several metals, adaptation to local climates, high biomass, depth of root structure, growth rate, ease of planting and maintenance, and ability to take up large quantities of water through the roots (*Zhao et al*.,2001). This can be an effective remediation method

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method at a variety of sites and on numerous contaminants. The success of the phytoextraction process, whereby pollutants are effectively removed from soil, is dependent on the adequate yield of plants and/or the efficient transfer of contaminants from the roots of the plants into their aerial parts (Luo*et a*l., 2005; Evangelou*et al*., 2007; Ahmad *et al*.,2017).

The metal dumpsites atGaskiya, Dakace and Hanwa in Zaria, Nigeria (11° 07' 51" N; 7° 43' 43" E) were selected (Figure 1) for the research work. Five different plant species namely: *Vetiverazizanioide*(Jema), *Ipomoea asarifolia*(dumankada),*Helianthus annus* (sunflower), *Ricinuscommunis* L. (Castor oil plant) and *Cymbopogoncitratus* (Lemon grass) were grown on the soil around the metal dumpsites.

The aim of the this study is to investigate the efficiency of the extraction of heavy metals by*Vetiverazizanioide*(Jema), *Ipomoea asarifolia*(dumankada)*Helianthus annus* (sunflower), *Ricinuscommunis* L. (Castor oil plant) and *Cymbopogoncitratus* (Lemon grass) so as to assess the feasibility of the remediation process.

2.0 MATERIALS AND METHODS

2.1 Experimental Design

The field experiment was carried out near scrap-metal dumpsites at Dakace, Hanwa and Gaskiyaareas in Zaria, Nigeria. An experimental area of 3 m x 2 m was selected at each site where the plants were grown. Five different plant species- *Vetiverazizanioide*(Jema), *Ipomoea asarifolia*(dumankada)*Helianthus annus* (sunflower), *Ricinuscommunis* L. (Castor oil plant) and *Cymbopogoncitratus* (Lemon grass) were planted in the designated field plots with spacing of 20cm x 20cm for all the tested plants as described by Zhuang*et al*.[2007]. 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.

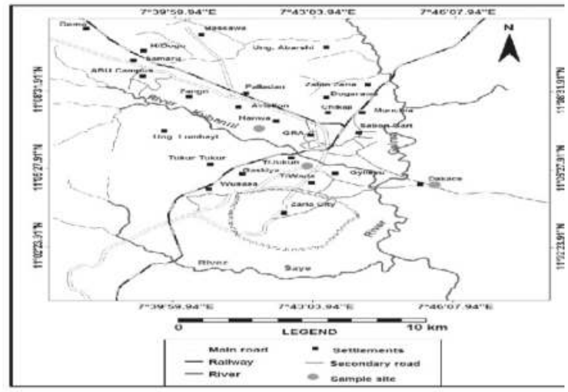

Figure: Map of Zaria Showing the Study Areas

2.2 Sample Collection

Soil samples were collected from the surface to a depth of 20 cm from each site (before planting) using hand trowel and then mixed together. Background soil 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 soil samples were collected from each quadrant in a diagonal basis following the methods reported byYashim*et al*.(2015).
After 10 weeks when the plants might have achieved maximum biomass production, the plants were harvested and the associated soil samples were collected following the procedure stated above.

2.3 Sample Treatment

The collected soil samples were air-dried at room temperature for 3 days, while the plant samples were washed, cut into pieces and air dried for 5 days. The dried soil and plant samples were ground, sieved (500µm sieve) and kept in clean polythene bags for further analysis.

One gram (1g) each of the sieved soil and plant samples were digested separately with 10 cm^3 of aqua regia (3:1 of conc. HCl andconc. HNO_3) on a hot plate in a fume cupboard, until a clear solution

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was obtained. To the hot solution, 30 cm^3 of distilled water was then added and filtered through AshlessWhatman No. 42 filter paper into a 50 cm^3 standard volumetric flask and then made up to the mark with distilled water (Yashim*et al*., 2015).

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 Nemero Pollution Index of the soil at each study site was obtained from the expression:

$$P_i = \sqrt{[(P_{jmax})^2 + (P_{jave.})^2]/2}$$

where P_i = Nemero Pollution Index , P_{jmax} = corresponding maximum value in the single contamination pollution index and $P_{jave.}$ = the corresponding average value in the single contamination pollution index **(Hong-gui *et al*., 2012**).

The bioaccumulation factor (BF) was calculated to determine the degree of metal accumulation in the plants grown at the dumpsite (Sun *et al*., 2011).

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

3.0 RESULTS AND DISCUSSION

3.1 Concentrations of Metals in the soil

The mean concentration of the studied metals in the soils at the three study areas and the control are represented in Figure 2. All the values for the studied metals were higher than the control. The values were also higher than the standard regulatory limits (except for Cu and Zn) as reported by Akpoveta*et al*.(2010). Using one-way ANOVA, there was a significant difference (*P < 0.05*) between the metal level at the experimental site and the control. This implies that the dumping of scrap metals on the soil has contributed significantly to the heavy metals contamination of the soil.
Soil atDakace had the lowest values of Co (8.30±0.04 mg/kg) and Pb (69.30±0.04 mg/kg), but highest values of Cd (8.00±0.03 mg/kg), Cu (6.50±0.03 mg/kg) and Zn (55.93±0.11 mg/kg) as compared to their corresponding values at Gaskiya and Hanwa soils. The soil at Gaskiya had lowest value of Cu (5.30±0.03 mg/kg) only, but highest values of Co (9.90±0.05 mg/kg) and Ni

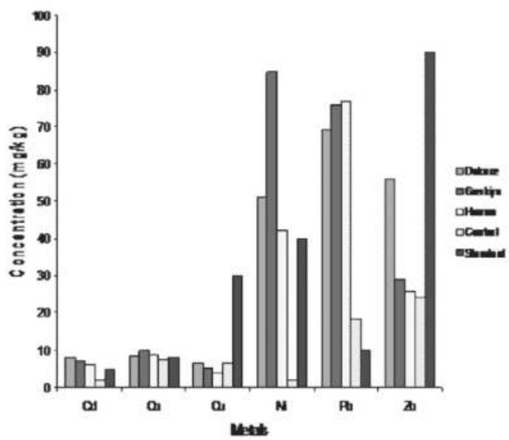

Figure 2: Concentrations of Metals at the Study Areas before Planting

(84.93±0.07 mg/kg). The soil at Hanwa showed lowest values of Cd (6.00±0.02 mg/kg), Ni (47.90±0.06 mg/kg) and Zn (25.58±0.06 mg/kg), but highest in Pb (76.90±0.05 mg/kg) when compared with those of Dakace and Gaskiya.

The grade standard of the Nemero Pollution Index presented in Table 1, shows that the soils at the dumpsites are clean in respect to Zn and Cu, slightly polluted with Cd, Co and Ni, and very heavily polluted with Pband Ni at Gaskiya. Therefore, phytoextraction technique could be a very promising method for the heavy metals remediation. It is best suited for the remediation of diffusely polluted areas, where pollutants occur only at relatively low concentration and superficially.Phytoextractioncan be an effective remediation method at a variety of sites and on numerous contaminants (Luo*et al*., 2005; Yashim*et al*., 2016).

3.2 Bioaccumulation Factor

The Bioaccumulation Factors (BF) for the studied metals in the different plant species harvested

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the three dumpsites are shown in Figures 3 – 5. The phytoextraction potential of each plant species is determined by its BF. The metals were extracted by each of the plant species and then translocated from the roots to the shoot. This factor illustrates the efficiency of the transport of metals from soil to roots and to the shoots, and a value > 1 indicates that plant is a good metal accumulator appropriate for phytoextraction (Gennaro*et al*., 2012). Studies have shown *Vetiverazizanioide*(Jema), *Ipomoea asarifolia*(dumankada)*Helianthus annus* (sunflower), *Ricinuscommunis* L. (Castor oil plant) and *Cymbopogoncitratus* (Lemon grass) are hyperaccumulators (Evangelou*et al*., 2007; Aremu*et al*., 2013; Yashim*et al*., 2015).

Table 1: The Grade Standard of the Nemero Pollution Index Method for Soils Before Planting

	I P≤ 0.7 Clean	II 0.7< P ≤ 1 warning	III 1 < P ≤ 2 slight	IV 2 < P ≤ 3 heavy	V P > 3 very heavy
Dakace	Zn, Cu	-	Cd, Co, Ni	-	Pb
Gaskiya	Zn, Cu	-	Cd, Co	-	Ni, Pb
Hanwa	Zn, Cu	-	Cd, Co, Ni	-	Pb
Control	Cd, Cu, Ni, Zn	-	Co, Pb	-	-

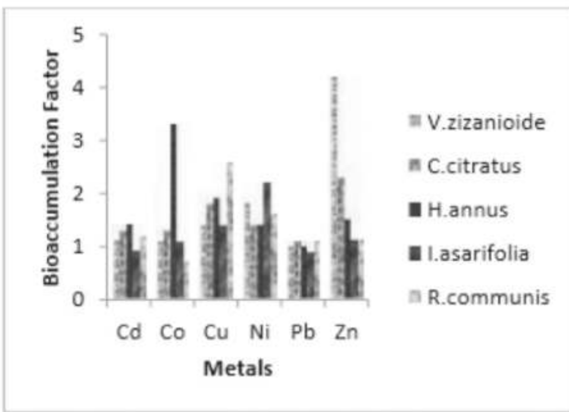

Figure 3: Bioaccumulation Factor for heavy Metals at Dakace Dumpsite

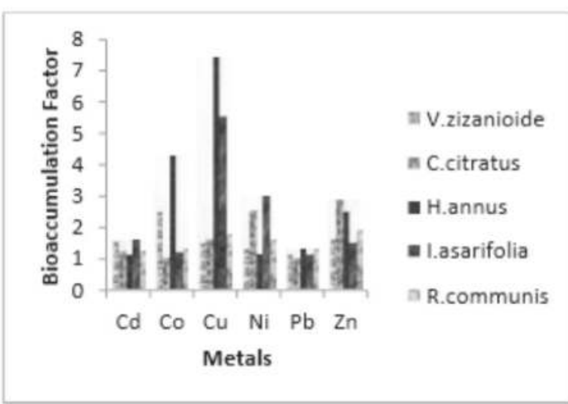

Figure 4: Bioaccumulation Factor for heavy Metals at Gaskiya Dumpsite

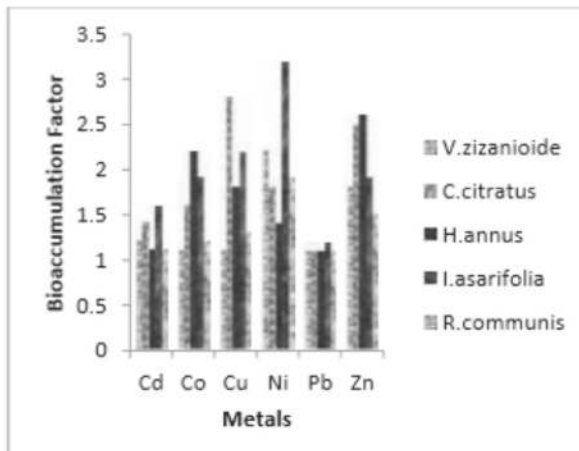

Figure 5: Bioaccumulation Factor for heavy Metals at Hanwa Dumpsite

Hyperaccumulators accumulate appreciable quantities of metal in their tissue regardless of the concentration of metal in the soil, as long as the metal in question is present (Prasad and Freitas, 2003). Paz-Ferreiro*et al*. (2014) reported that uptake of heavy metals is lower in field experiments than for the soils in the pot 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.

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3.3 Efficiency of the Phytoextraction

This study has shown that there was a decrease in the concentrations for all the studied metals in the soil after the plants were harvested from Dakace, Gaskiya and Hanwa dumpsites. At the Dakace and Hanwa sites, it was observed that the decrease in Co concentration was not significant ($P > 0.05$) as compared to other studied metals (Table 2). The percentages of the studied metals removed from the soils by the five plant species planted at the dumpsites (Figure 6) indicated that: Dakace site, Cd- 52.5%, Co – 0.6%, Cu – 44.3%, Ni – 88.4%, Pb – 13% and Zn – 28%; Gaskiya site, Cd – 45.7%, Co – 15.7%, Cu – 24.5%, Ni – 69.7%, Pb – 21.2% and Zn – 17.1%; Hanwa sit, Cd – 36.7%, Co – 1.2%, Cu – 28.4%, Ni – 20.5%, Pb – 17.4% and Zn – 17.2%.

Phytoextraction is an efficient method for decontamination of soils contaminated with heavy metals. The goal of the phytoextraction process is to reduce heavy metal concentrations in contaminated soil to acceptable levels within a reasonable time frame.

The data obtained in the experiment confirmed that all the plants were tolerant to heavy metals. Combining cropping or co-cropping system has enhanced the phytoextraction rates (Wei *et al*., 2011). Fuksova*et al*. (2009) reported that the remediation efficiency of the individual plant species in the co-cropping system did not differ from those obtained in separate cropping mode. It improved the survival rate of the individual plant/crop and reduced the time period to accomplish the decontamination of a polluted soil. It also induced competition for phytoavailable nutrients and pollutants in the shared soil solution with stronger effect on the hyperaccumulator plant when grown on moderately contaminated soil (Jenna, 2012). Metal uptake by plant species is metal specific (Almas *et al*., 2012).

Table 2: Mean Concentration of Metals (mg/kg) in Soils at the Sites before Planting and after Harvest

	Before Planting			**After Harvest**		
	Dakace	Gaskiya	Hanwa	Dakace	Gaskiya	Hanwa
Cd	8.00±0.03	7.00±0.02	6.00±0.02	3.80±0.02	3.80±0.01	3.80±0.03
Co	8.30±0.04	9.90±0.05	8.70±0.05	8.25±0.04	8.35±0.04	8.60±0.04
Cu	6.50±0.03	5.30±0.03	47.90±0.06	3.62±0.03	4.00±0.04	4.01±0.05
Ni	51.30±0.04	84.93±0.07	76.90±0.05	5.95±0.08	25.72±0.04	38.10±0.06
Pb	69.30±0.04	75.90±0.04	25.58±0.06	60.27±0.02	59.80±0.01	63.53±0.06
Zn	55.93±0.11	28.90±0.12	5.60±0.05	40.30±0.04	23.95±0.02	21.17±0.03

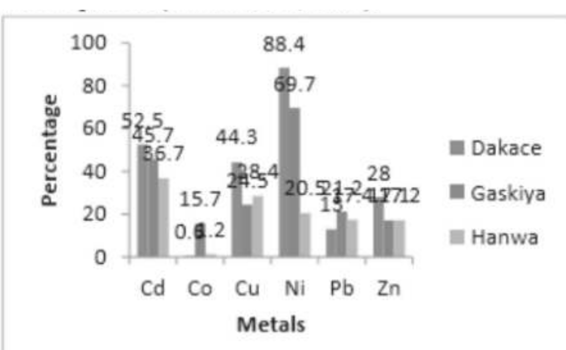

Figure 6: Percentage Removal of Heavy Metals by Plant from soil at Dakace, Gaskiya and Hanwa Dumpsites

4.0 CONCLUSION

The phytoextraction potential of each plant species is determined by its bioaccumulation factor. The metals were extracted by each of the plant species and then translocated from the roots to the shoot, hence the bioaccumulation factors for all the metals were found to be greater than 1. This factor illustrated 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. The percentage removal of the heavy metals from the soil at the study sites by the five plant species ranged from 0.6% to 88.4%. The five studied plant species were very efficient in removing heavy metals from soil, thus can be used in the remediation process. It is recommended that other local plants or genetically developed new plants and the used ofchelating agents could be investigated for better phytoremediation of these metals and other metals not studied in this research.

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