Pollution Indices in Cement Waste Contaminated Soil and Efficacies of Selected *Jatropha* Species in Phytoremediation

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Abstract

This study evaluated soil toxicity and *Jatropha* potential indices for Phytoremediation of Heavy metal in Cement Waste uptake of heavy metals in selected *Jatropha* grown in cement waste contaminated soil. A 3 x 4 factorial in a complete randomized design replicated 8 times. The soil pots were labeled according to their compositions. The soil treatments composition consist: T_0 (30kg undisturbed soil and 0kg cement waste), T_1 (30kg undisturbed soil and 1kg cement waste), T_2 (30kg undisturbed soil and 2kg cement waste), T_3 (30kg undisturbed soil and 3kg cement waste). Ninety six (96) seed pots of *Jatropha* were labelled according to their compositions and growth parameters recorded for 4 months before harvest. Heavy metals were re-analyzed in soil and plant tissues (shoot and root). Data obtained in duplicates were subjected to two-way statistical analysis of variance. Mean were separated using the LSD method at 95% confidence limit. Result of Preliminary chemical analysis of soil composition showed highly significant amount of Cu (88.760 mg/L), Mn (49.623 mg/L), and Ni (20.180 mg/L). Hg (0.0002 mg/L) and Co (0.024 mg/L) were less significantly present. However, Pb (2.144 mg/L) Cr (0.179 mg/L) Fe (0.046 mg/L) amount level were found significant using atomic absorption spectrophotometer (AAS). Post investigation of roots and shoots were characterized by significant level hyperaccumulation, *Jatropha curcas* showed the highest for Co 0.4364 mg/L, Mn 0.3537 mg/L, and Fe 0.2985 mg/L, *J. podagrica* showed highest uptake of Ni 0.3912 mg/L while *J. gossipifolia* showed highest uptake of Cr 0.2987 mg/L. Significant amount of Cr (2.35 mg/L) and Fe (1.80 mg/L) was found in shoots of *J. gossipifolia and J. podagrica* respectively. The bio concentration and translocation factors of less than 1.0 and greater than 0.5 for Fe, Cr, Cu, and Ni in *Jatropha* shoots indicate its suitability for soil heavy metals remediation process by phytostabilization and phytoextraction.

Keywords: Soil Pollution, Phytoremediation Indices, Soil Heavy Metal

Introduction

Soil pollution is caused by chemicals released from human activities or other negative changes in the normal soil environment [1]. However, timely mitigation of industrial waste pollution from factory can avoid the spread of heavy metals through the food chain, thus reducing associated environmental risks [2]. Cement waste can be spread through different channels such as surface runoff, atmospheric deposition and adopt diverse chemical forms as exchangeable, carbonate-bound, iron manganese oxide-bound, residual, and organic-bound form [26]. The remediation of soil contaminated with heavy metal using plants with inherent potentials is largely called phytoremediation. It is an in situ environmentally friendly and long-lasting approach that required no particular tools [5]. Several plants species have been reported for their ability to absorb and store pollutants into their tissues metabolism, one of such plants belong to the genus "*Jatropha*" [4]. *Jatropha* belongs to the Euphorbiaceae family, it has wide topographical spread and is made up of over 170 species of herbaceous perennials, shrub, and ornamental woody trees. It is broadly dispersed within the tropic and subtropical locals, particularly in Africa and South America [3]. A few known *Jatropha* species have been detailed for their phytoremediation abilities namely, *J. curcas*, *J. podagrica*, *J. gossypifolia*, and *J. multifida*, among others [7]. Some studies have investigated toxic uptake from contaminated growth media in *Jatropha* species; most of these studies largely focused on the use of *J. curcas*. The ability of *J. curcas* to phytoremediate Cd and Pb from polluted soil was reported by [20]. The plant was also reported to uptake metals from sewage sludge contaminated soil demonstrating its potential to absorb Cd, Cu and Cr [19] while its heavy metals absorption in soil contaminated with sawdust sludge was previously examined, showing it can accumulate a significant amount of Cr, Fe, Al, Pb and Co in the roots and shoots. Studies by [23] showed the ability of *J. curcas* in the phytostabilization of toxic metals present in polymetallic acid mine tailing [19] assessed the tolerance to toxic metals and the potential of *J. curcas* for phytoremediation in refinery sludge thereby, reporting a significant absorption of Cu and Cr into the root of the plant. Some of these studies clearly demonstrated the potential of *J. curcas* phytoremediate heavy metals contaminated media. For the other species, the effect of Ethyl diamyl tetra acid (EDTA) on the phytoextraction of heavy metals by *J. gossypifolia* from industrial area was reported by [6]; [14]. The success of *J. curcas* is attributed to its highly effective and dedicated mechanism against abiotic pressures making it possible to endure severe climatic condition including excessive dryness, arid and seriously polluted soils [8]. However, little studies are available investigating the potential of other species such as *J. gossypifolia* and *J. podagrica* in the uptake of toxic metals from contaminated soil. Hence, the study was conducted to evaluate Soil toxicity and *Jatropha* potential indices for Phytoremediation of Heavy metal in Cement Waste.

Materials and Methods

Study Area

The study area as shown in Figure 2 is located at Mbayion, Mbatiav, and Ipav Communities, Gboko Benue State with latitude 14.82 (14^0 55'0N) and Longitude 9.45 (9^0 18' 60E) in North Central Nigeria [1] .

Experimental Design

Pot experiment was used for this study in Biological garden (Botany Department of Joseph Sarwuan Tarkaa University Makurdi (JOSTUM). The seeds of *Jatropha. curcas, Jatropha. gossypifolia* and *Jatropha. podagrica* were sourced locally in Benue State. The *Jatropha* seeds and plants were validated at Botany and Agronomy screening house respectively. Soil samples within the depth of 0 – 15cm was collected randomly around the location with a soil auger at the dump site sited around the Cement Plant Gboko Benue state, Nigeria ($7^0$18'N and $3^0$50'E). This cement waste had been deposited since 1992 [1]. Coarse and other unwanted materials were removed from the soil samples before potting. Control (undisturbed soil) was sourced from around the experimental site. Samples from the waste site soil and control (undisturbed soil) were mixed, air dried, sieved with 2 mm

mesh, followed by routine soil physico-chemical analysis of soil PH, texture, Electric conductivity (Ec), Cation Exchange Capacity (CEC) and soil heavy metals of Chromium (Cr) Lead (Pb) Mecury (Hg) Colbalt (Co) Iron (Fe) Manganese (Mn) Copper (Cu) and Nickel (Ni) using standard procedures. Seeds of *Jatropha curcas*, *Jatropha gossypifolia* and *Jatropha podagrica* were planted into a germination tray, seedlings of about 5cm, in length were transplanted into polythene pots containing 30kg contaminated soil. Seeds germination, number of leaves, Plant height, Stem girth, and Leaf area were recorded weekly. The experiment was set up in a 3×4 factorial, laid out in complete randomized design (CRD) replicated 8 times. The soil treatments composition (T_0, T_1, T_2, T_3) consist: T_0 (30kg undisturbed soil and 0kg cement waste), T_1 (30kg undisturbed soil and 1kg cement waste), T_2 (30kg undisturbed soil and 2kg cement waste), T_3 (30kg undisturbed soil and 3kg cement waste). A total of 96 pots used for the experiment. Preliminary investigation of the soil experimental pots for Physico- chemical and heavy metals was conducted and results shown in pre-soil planting analysis. Consequently post-planting investigation. Samples of the plants part (root and shoot) were harvested and soil samples taken from the pots after 12- 15weeks of growth for heavy metal analysis using Atomic Absorption Spectrophotometer (AAS) after acid digestion with diacid mixture of HCl and at 100°C for 3h [22].

Laboratory Techniques and Procedures

The following laboratory techniques and procedures were used to determined soil physico chemical properties. Particle distribution (soil texture) determined using bouyoucous hydrometer and laser diffractometry, Conductivity, Exchangeable Cation Exchange Capacity, Organic Matter, Plant Biomass, Heavy Metals elements include Nickel, Copper, Chromium, Lead, Mercury and Cobalt using an LF 92 WTW Multiparameter probe.

Soil texture 50g of the sampled soil was suspended in 500ml calibrated glass cylinder, distilled water, 1g of Sodium hydroxide (Na OH) was added and mixed thoroughly. Layers of clay, silt and sand was measured and calculated in soil percentages. Soil pH Soil pH was determined with Suntex TS-2, $_p$H Meter at 25° C after calibration with standard buffer solutions of $_p$H for 7 and 9. Electrodes will be inserted into the settled suspension and the soil pH was measured in triplicates (P_H Mclean, 1982). Cation exchange capacity was determined by the 0.05N cobalthexamine method performed at the soil pH since actual soil pH were lower than 6. Soil organic matter 5g soil sample was oven dried, weighed into a dry crucible and placed in a muffle furnace at 450c. The content was cooled at room temperature and re-weighed. The percentage (%) organic matter is calculated as the percentage (%) loss in weight on ignition during combustion. Soil electric conductivity: EC was determined with HACH conductivity meter CO-150 in mili-Siemens (mS).

Soil Digestion

After the digestion vessel cools down, the digest solution volume is adjusted to 100 ml. First, 0.5-1.0 g of sample is weighed out into a digestion vessel. After adding HNO_3 and $HClO_4$ (3:1, v/v), Soil pots samples were collected prior to seed planting and after using corer/auger. Sieved using a 0.5mm sieve size to remove debris. The sample was packed into sealable nylons bags, labelled and transferred to the Laboratory. One gram (1g) of soil was weighted into a beaker which was then digested with 10ml of concentrated hydrochloric acid and 5.0 ml of hydrogen peroxide in a ratio 2:1 (HCl 70 % H_2O_2, 30 % 5 ml). The beaker was covered with a watch glass and set aside during which the reaction would have subsided. The beaker and content were heated to not above 110 ^{o}C on a hotplate at 95 ^{o}C for 30sec interval until the volume in the beaker was about 2.5ml, soil dissolved and become colorless. The digest was allowed to cool and then transferred into a volumetric flask and subsequently diluted to a volume of 25 ml using distilled Water hydrogen peroxide (H_2O_2, 30% 25 ml) in a volumetric flask. Blank samples were included to verify the accuracy and precision of the digestion procedure and subsequent analyses. Atomic Absorption Spectrometer (AAS) instrument according to the method of APHA (1992).Calibration standards were prepared from the multi- element calibrated standard before analyzing each batch of the samples in triplicates.

Plant Digestion (shoots/roots)

At fourth month, the harvested plant total fresh weight (FW) biomass, root length (RL) and shoot length (SL) was measured and recorded. Dried weight biomass was also measured after oven dried at 80 ^{o}C for 4hours in the laboratory. The plants were cut with Clippers at 1cm above soil into two parts Root (R) and Shoot (S) and were separated and labelled accordingly for proper identification. The plant roots and shoots were oven dried at 40°C for 6 hours until a constant dry weight was obtained and stored for chemical digestion. 5g roots and shoots dry samples was ground into powder with a cutting mill (Gm200 knife blender), while shoots with centrifuge mill. 2.0 g of roots and shoots dry mass was weighed into a digestion tube, concentrated nitric acid (HN0$_3$, 70%, 5ml) was added. Afterwards, heated at 95% for 75 min using a digestion vessel. After cooling, hydrogen peroxide (H$_2$0$_2$, 30% 5ml) was added and the mixture was heated again at 95 ^{oC} for 30 sec. The sample when cooled was diluted to 25 mL using distilled water and analyzed for heavy metals by atomic absorption spectrometry (AAS).

Atomic Absorption Spectrometer (AAS) Analysis

The digested samples was taken for Atomic Absorption Spectrometer (AAS) analysis. The analysis begin with selection and adjustments of various units of the machines, begin with selection and adjustments of various units of the machines (lamp selection, wavelength selection, slit adjustment and flame adjustment) and the machine was standardized by aspirating 1000 mg/L for all the metals were prepared and from their working solutions with concentrations within the range of 0.5 mg/L were prepared by Seria dilutions [12] .The standard solutions were taken through the same digestion techniques as mentioned. After digestion, the solutions were taken as AAS and the absorbance value read and recorded. Graphs of absorbence vs concentration the caliberation curves) were plotted. The sample was then aspirated into the machine and the absorbance value read and recorded. The concentration (in mg/L) was obtained by interpolating and extrapolating the values of absorbance from the caliberation curve. The procedure was repeated for all the 36 samples. The wavelengths set for each metal were Pb-217.0nm, Cr-357nm, Cu-324nm, Mg-279.5nm, Fe-248.3nm, and Zn -213.9nm [12].The procedure was repeated for all the samples.

Statistical Analysis

The data generated from the laboratory were subjected to descriptive/inferential Statistics using GENSTAT 17 model and two way analysis of variance (ANOVA) at 95 % confidence limit. Differences between values of the mean and comparison of the mean was done using the New Duncan Multiple Range Test [9].

Phytoremediation Indices such as Soil Pollution Index (PI), Bioconcentration Factor (BCF) and Translocation Factor (TF) was calculated using equation as proposed by: [7]; [13].To calculate contamination level of soil metal, (PI) of each metal was attributed to concentration of each metal (post and pre soil) interaction using equation below: PI = C_n/B_n where C_n (Mg/kg) is the measured concentration of each heavy metal and B_n is background value for each metal. The PI of each metal was classified as either low (P <1), moderate (13). The Bio-concentration Factor (BAF) described below was calculated according to the equation of [13];

$$BCF = \frac{P\ harvested\ tissue}{P soil}$$

Where P$_{harvested}$ tissue is concentration of the target ions in the plant harvested tissue (roots and shoots) and P soil is concentration of the same ions in soil.

The Translocation Factor (TF) was calculated using equation below proposed by [13];

$TF = \frac{Pshoots}{Proots}$ Where TF = Translocation factor, P$_{shoots}$ concentration of ion in shoots and Proots.is concentration of same ion in roots [12]

Results

Table 1: Effect of *Jatropha* Spp on Residual Heavy Metals in Post Soil Investigation (mg/L)

Jatropha	Pb Soil	Cr Soil	Ni Soil	Co Soil	Fe Soil	Mn Soil	Cu Soil	Hg Soil
J.gossipifolia	0.278[b]	0.393[c]	6.798[a]	0.262[c]	0.426[c]	15.255[a]	28.757[b]	0.00000[c]
J. curcas	0.451[a]	0.451[b]	6.579[b]	0.281[b]	0.449[b]	13.330[c]	25.295[c]	0.00063[a]
J. podagrica	0.273[c]	0.533[a]	4.306[c]	0.409a	0.575a	14.666[b]	32.541[a]	0.00051[b]
LSD	0.001	0.001	0.001	0.001	0.001	0.013	0.009	0.00009
Mean	0.334	0.459	5.895	0.317	0.483	14.417	28.864	0.00038
SE	0.000	0.001	0.001	0.001	0.001	0.006	0.004	0.00004

Results with the different superscript in the same row are significantly different using LSD at 95% confidence limit

Differences in sand composition from post soil investigation however showed that the control treatment with higher percentage sand of 75.366 % varied significantly from all soils treated with various amounts of cement kiln waste (T_1, T_2 and T_3) with relatively lower percentage sands of 74.667 %. 73.433 % and 71.599 % respectively. Variations in organic matter in post soil analysis showed that the control soil treatment T_0 was lower in organic matter content (9.667 %), significantly different from organic matter contents of 10.000 %, 11.333 % and 12.999 % recorded for T_1, T_2 and T_3 respectively.

Figure 2 Gboko Local Government Area showing Study Areas
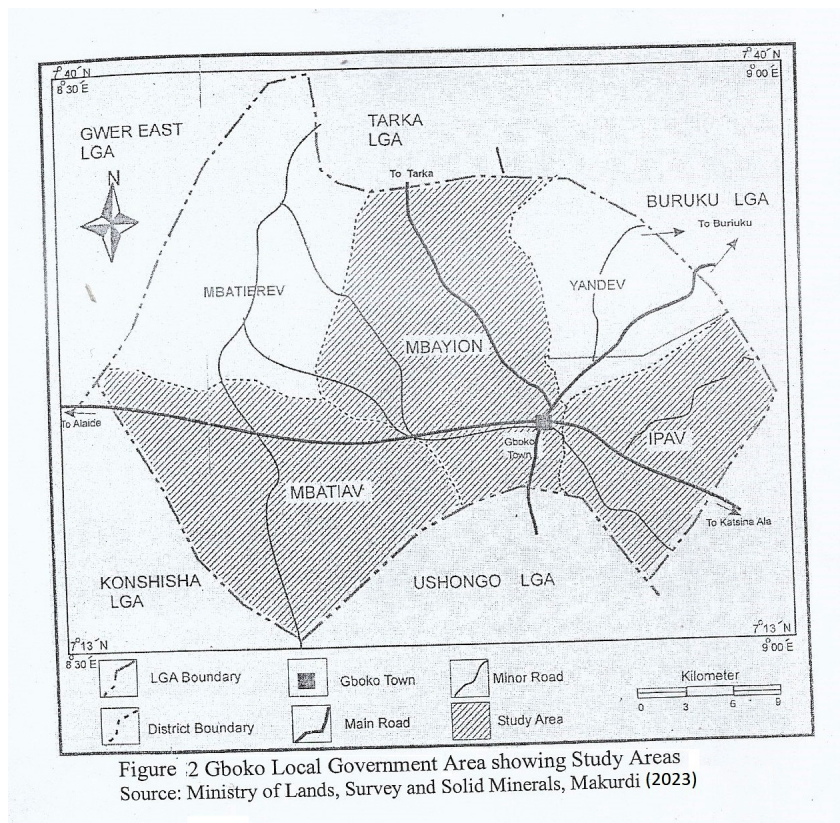Source: Ministry of Lands, Survey and Solid Minerals, Makurdi (2023)

Figure 1: Pollution Index Concentration of Heavy Metals of Cement Waste Soil

The pollution indices of soil contaminated with cement waste presented in figure 1 below revealed that Co pollution index was highest (T_1 1.02) above other cement kiln waste treatments followed by Cr in (T_0 0.894) and Fe in (T_1 0.868). Mercury (Hg) had the least pollution index in (T_2 0.2).
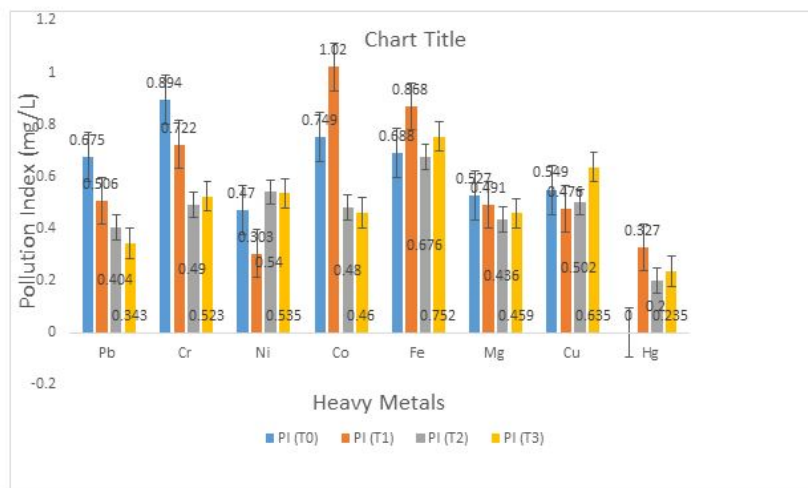
Figure 2: Bio-Concentration Factor of *Jatropha spp* from Cement Kiln Waste Soil

Figure 2 showed bio-concentration index of *Jatropha Spp* from cement waste contaminated soil. Result showed significant amount in *J. curcas* (Cu 0.4367) compared to amount concentration found in *J. gossipifolia* and *J. podagrica* were same (Cu 0.3060). *J. podagrica* bio-concentration index of Ni showed highest (0.3912) above *J. gossipifolia* (Ni 0.3069) and *J. curcas* (Ni 0.2371). *J. gossipifolia* (0.2987) bio-concentration index of Cr recorded significant amount compared to *J. curcas (*Cr 0.1305) and (Cr 0.0930). *J. podagrica* amount of Co was significantly lesser compared to bio-concentration index of both *J. gossipifolia* (Co 0.2431) and *J curcas* (Co 0. 2256). *J. podagrica* bio-concentration index in (Pb 0.1617) slightly above (Pb 0. 313) in *J. curcas* and (0.066).
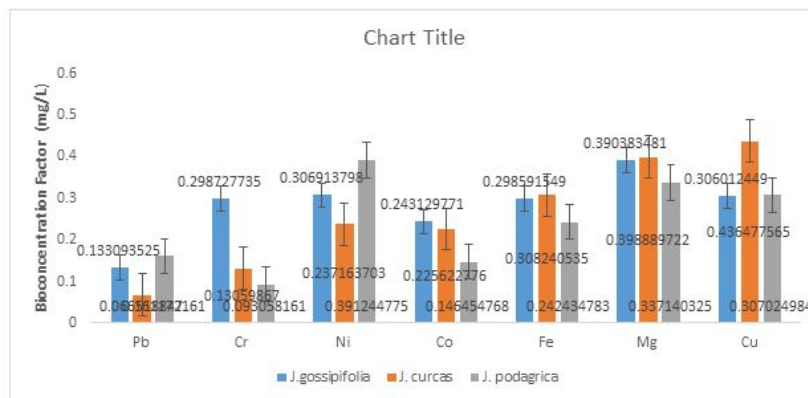

Figure 3: Translocation Factor of *Jatropha* spp from Cement Waste Soil

Figure 3, Translocation index of *Jatropha Spp* from cement kiln waste contaminated soil showed that Cr in *J. gossipifolia* was (2.4), *J. curcas* (0.57), and *J. podagrica* (0.54). However, *J. podagrica* showed significant translocation index of (Fe 1.82), while *J. curcas* and *J. gossipifolia* are (Fe 0.5) respectively. Cu, Mn translocation index in the *Jatropha spp* however recorded significant amount in *J. curcas* and *J. gossipifolia J. podagrica* within range (0.4 - 0.52).

Discussion

According to the findings on preliminary soil investigation, average mean of Cu was 53.560 mg/L, followed by Mn 30.270 mg/L, and Ni 12.270 mg/L, classified as (highly pollutants), another category is the (moderate pollutants) average mean of Cr 0.728 mg/L, Pb 0.651 mg/L, and Fe 0.649 mg/L. (Less pollutants) are Co 0.482 mg/L and Hg 0.0016 mg/L respectively. The con-

tamination factor (CF) was calculated to determine the degree of soil contamination and heavy metals accumulation in soil and in plants growing in cement kiln waste soil [1]. The bioaccumulation factor (BF) was calculated to determine the efficiency of the plant for accumulating a heavy metal from soil concentration of an element in below-ground tissues in (mg/L). The translocation factor (TF) was calculated to depict the ability of plant to translocate a heavy metal from below to above ground tissues in (mg/L) [13].In addition, the low pH in the cement kiln waste contaminated soil often leads to some solubilized soil heavy metals and increases their availability and supply to the plant uptake.

Concentrations of most heavy metals in tissues of *Jatropha* Spp in the present study were higher in the cement kiln waste contaminated compared with the uncontaminated control soil. This could be due to the low pH and EC values in the cement kiln waste contaminated soil and its higher content of these elements. The results of some research indicated that the land application of cement waste contaminated soil increased heavy metals accumulation in plants [4]. Indicating the presence of a physiological barrier in the transfer of these metals from roots or shoot tissues to fruits. Compared to other elements, Hg, Co, had the lowest concentration in the soil and all tissues of *Jatropha spp*. This is normal as these metals are usually very low [24]. Cu is a highly toxic element and enters the environment as a waste product, especially from mine tailings, metal refining and electroplating works [26]. It affects growth, metabolism and the water status of plants. The general effect of the cement kiln waste contaminated soil on the *Jatropha plant* growth are germination inhibition, chlorosis of leaves, and the reduction of plant biomass [7]. *Jatropha* Spp accumulate different elements simultaneously, so the element accumulation index was used to assess the overall performance of heavy metals accumulation in the three Jatropha species [6]. In the present study, *Jatropha curcas* grown in treatment 2 (T_2) had the highest concentration values, While *Jatropha podagrica* grown in treatment 3 (T_3) had the highest earn accumulation index values. T_0 is control, free from cement waste contaminant. The higher earn accumulation index values indicates that these species are better able to accumulate heavy metals, and are therefore more suitable for phytoremediation purposes. In general, the accumulation of heavy metals by plants is affected by *Jatropha species* diversity, growing stage of plant, physiological adaptation and sequestration of metals in plant cells, and heavy metal characteristics control absorption, uptake and translocation of elements [3]. Furthermore, accumulation of heavy metals is also affected by the environmental conditions such as organic matter, pH and heavy metal concentrations. The evaluation of the bioaccumulation factor (BF) represents a simple method to characterize quantitatively the transfer of available heavy metals from soil to plant while its ability to translocate them from roots to shoots is measured using the translocation factor (TF). Both BF and TF can be used to estimate a plant's potential for phytoremediation purposes [3]. According to [24], BF > 1.0 was found in heavy metal-accumulating plants, whereas they were typically < 1.0 in heavy metal-excluding plants. TF > 1.0 indicate that the plant is effective in the translocation of heavy metals from the root to the shoot tissue [17]. In the present study, all studied species were characterized by BF values > 1.0 for some of the studied elements, showing that they are able to accumulate elements and are therefore more suitable for phytoremediation purposes. BF was generally higher for Fe, followed by Fe, Ni, Pb, Co, Cr, Cu, Mn, and Hg (in a decreasing order). This agrees with the data reported by [25]; [24] which stated that generally Cu had the highest bioaccumulation factor, while Cu, Zn and Fe had the lowest. In the present study, TF varied among plant species and among heavy metals and it was < 1.0 for most studied heavy metals. The differences in values of TF could be related to heavy metals interactions [6]. These interactions in soil treatments can be engendered by conflicting and synergetic processes. Therefore, these interactions could affect the efficiency of heavy metals uptake and alter their distribution. The differences in the solubility and availability of each metal ion, plant physiological factors, and the plant regulation mechanisms to control shoot concentrations could be other reasons for the different translocation of heavy metals [23]. Phytoextraction usually includes the uptake of heavy metals from polluted soils and their accumulation in harvestable parts of plant species [6]; [15]. Hyperaccumulators are defined as those plants containing >1000 mg kg^{-1} metal (100 mg kg^{-1} for Cd) in above-ground plant biomass. Plants being considered as hyperaccumulators must have the potential to tolerate the heavy metals and transfer them from root system to shoots system. In our study, all plant species grown in cement waste showed Fe concentrations >1000 Mg kg^{-1} in the leaf and/or stem. Moreover, *Jatropha podagrica* and *Jatropha* curcas species showed Pb concentrations > 1000 mg kg^{-1} in the leaf and/or stem, while *Jatropha poda-*

grica showed Mn concentrations > 1000 mg kg^{-1} in the shoot. According to the definition of [11] and based on TF values, *Jatropha podagrica* and *Jatropha curcas* species are considered hyperaccumulators for Fe, *Jatropha gossipifolia* and *Jatropha curcas* are considered hyperaccumulators for Pb, and *Jatropha curcas* is a hyperaccumulator for Mn. Moreover, phytostabilization reduces metal mobility and leaching into the ground water, and also reduces metal bioavailability for entry into the food chain.

Such correlations indicate that these species reflect the cumulative effects of environmental pollution from the soil, and thereby suggesting their potential use in bio monitoring of most heavy metals examined. This indication is supported by several studies according to which the total quantity of some heavy metals in a soil is correlated with the quantity of heavy metals absorbed by the *Jatropha* plants [25];[24] Moreover, *Jatropha* plants with heavy metal concentrations strongly correlated with those in the soil have been considered potential indicators of heavy metal availability [6]; [15].

Conclusion and Recommendations

In this study, it has been found that *Jatropha* Spp were more effective in accumulating certain metals compared to other species grown at the same soil. The results indicated that the most species grown in cement kiln waste are enriched with heavy metals relative to those at the reference site, which suggests that the cement waste could not be used as an organic fertilizer particularly for food crops. In the present study, establishing a pattern of translocation of heavy metals from the root to the shoot of plants can be very useful in biological monitoring of heavy metals contamination as well as selection of heavy metals accumulator species. The highest element accumulation index values of *Jatropha curcas, Jatropha gossipifolia and Jatropha podagrica* growing under cement waste contaminated soil, and of *Jatropha curcas, Jatropha gossipifolia and Jatropha podagrica* growing at the control, indicate that they are better able to accumulate heavy metals and are therefore more suitable for phytoremediation purposes. Therefore, based on TF values, *Jatropha curcas, Jatropha gossipifolia and Jatropha podagricq* are considered hyperaccumulators for Fe, *Jatropha curcas* and *Jatropha podagrica* are considered hyperaccumulators for Pb, and *Jatropha curcas* is established as hyperaccumulator for Ni.

References

1. Abatyough M, Uyeh, D, Jibrin U, Abatyough B (2015) Distribution and Variation of Heavy Metals and Soil Properties around a Mega Cement Factory in Gboko, Benue State, Nigeria. MATTER: International Journal of Science and Technology, 4: 385-394.

2. Abdullahi UA, Shuaibu, KL (2016) Phytoremediation of Contaminated Soils from Challawa Industrial Estate, Kano-Nigeria. Science Journal of Analytical Chemistry, 4: 59-65.

3. Addo MA (2012) Evaluation of Heavy Metals Contamination of Soil and Vegetable in the Vicinity of a Cement Factory in the Volta Region, Ghana. International Journal of Science and Technology, 2: 40-50.

4. Ahiamadjie H, Adukpo, O.K., Tandoh JB, Gyampo O, Nyarku M (2011) Determination of the Elemental Contents in Soil around Diamond Cement Factory, Aflao. Research Journal of Environmental and Earth Sciences, 3:46-50.

5. Amanullah M, Ping W, Amjad A, Mukesh KA, Altaf, HL, Quan W et al. (2016) Challenges and Opportunities in the Phytoremediation of Heavy Metals Contaminated Soils: A Review. Journal of Ecotoxicology and Environmental Safety, 126: 111-21.

6. Awokunmi EE, Asaolu SS, Ajayi OO, Adebayo OA (2012) The Role of EDTA on Heavy Metals Phytoextraction by Jatropha gossypifolia Grown on Soil Collected from Dumpsites in Ekiti State Nigeria. British Journal of Environment & Climate Change, 2: 153-62.

7. Awotedu OL, Ogunbamowo PO, Awotedu BF, Emmanuel IB (2018) Comparative growth response of three Jatropha species on heavy metal contaminated soil. International Annals of Science, 5: 26-32.

8. Chang FC, Ko, CH, Tsai MJ, Wang YN, Chung CY (2014) Phytoremediation of Heavy Metal Contaminated Soil by Jatropha curcas. Journal of Ecotoxicology, 23:1969-78.

9. Diwan H, Ahmed A, Iqbal M (2010) Uptake Related Parameters as Indices of Phytoremediation Potential. Biologia, 65: 1004-11.

10. EL- Sherbiny M, Ismail M, Al- Hefnawy ME (2019) A Preliminary Assessment of Potential Ecological Risk and Soil Contamination by Heavy Metals around a Cement Factory, Western Saudi Arabia. Open Chemistry, 17: 671-84.

11. Galel and Shahata (2015) Bioaccumulation and translocation of heavy metals by Plantago major L. grown in contaminated soils under the effect of traffic pollution. Journal of Ecological Indices, 48: 44-51.

12. Laffout I, Schnob P, Dumas A, Rabier J, Miche L, Massotti V, Prudent T, Tatonic P (2011) Insight on metal tolerance and symbionts of the rare species Astagulas traqacantha aiming at phytostabilization of polluted soils and plant conservation Ecology, Mediteur, 37: 57-62.

13. Gupta N, Yadav KK, Kumar V (2015) A Review on Current status of Municipal Solid Waste Management in India. Journal of Environmental Science, 37: 206-17.

14. Hussain MU, Hassan M, Suthar V, Ahmad R, Yousra M (2017) Heavy metal phytoextraction natural and EDTA-assisted remediation of contaminated calcareous soils by sorghum and oat. Journal of Environment and Monitoring Assessment, 189-591.

15. Kamusoko R, Jingura RM (2017) Utility of Jatropha for Phytoremediation of Heavy Metals and Emerging Contaminants of Water Resources: A Review. Clean Soil Air Water, 45: 10-17.

16. Kapusta P, Sobczyk L (2015) Effects of Heavy Metal Poll from Mining and Smelting on Enchytraeid Communities under Different Land Manage. And Soil Conditions. Science of the Total Environment Journal, 536: 517-26.

17. Laffout I, Schnob P, Dumas A, Rabier J, Miche L, Massotti V et al. (2011) Insight on metal tolerance and symbionts of the rare species Astagulas traqacantha aiming at phytostabilization of polluted soils and plant conservation Ecology, Mediteur, 37: 57-62.

18. Luhach J, Chaudhry S (2012) Phytoremediation potential of J.curcasfor removal of heavy metals from refinery sludge. International Journal of Scientific and Engineering Research, 3: 1-5.

19. Mani D, Sharma B, Kumar NP, Balak S (2012) Phytoremediation potential of Helianthus annus L. In Sewage Irrigated Indo-Gangetic Alluvial Soil. International Journal Phytoremediate, 14235-246.

20. Soda S (2012) Constructed wetlands for advanced treatment of waste water with a complex matrix from a metal-processing plant: Bioconcentration and Translocation factors of various metals in Acorus gramineus and Cyperus alternifolius. Journal of Ecology and Engineering, 39: 60–70.

21. Waterlot C, Douay F (2012) Minimizing Chloride Interferences Produced by Calcium Chloride In: The Determination of Cd by Graphite Furnace Atomic Absorption Spectrometry. ISRN Spectroscopy, 2012: 1–10.

22. Wu Q, Wang S, Thangavel P, Li Q, Zheng H, Bai, J, Qiu R (2011) Phytostabilization potential of J. curcas L. in polymetallic acid mine tailings. International Journal of Phytoremediation, 13: 788-804.

23. Yadav SK, Juwarkar AA, Kumar GP, Thawale PR, Singh SK et al. (2019) Bioaccumulation and Phyto-Translocation of Arsenic, Chromium and Zinc by J. curcas L.: Impact of Dairy Sludge and Biofertilizer. Journal of Bioresource and Technology, 100: 4616-22.

24. Zerrouqi Z, Shaa M, Oujidi M, Elkharmouz M, Bengamra S, Zerrouqi A (2018) Assessment of Cement's Dust Impact on the Soil Using Principal Component Analysis and GIS". International Journal of Environmental Science and Technology, 591: 125-34.

25. Zhou H, Guo X (2015) Soil heavy metal pollution evaluation around mine area with traditional and ecological assessment methods Journal of Geoscience and Environmental Protection, 3: 28-33.

26. Zhuang P, Yang QW, Wang HB, Shu WS (2007) Phytoextraction of Heavy Metals by Eight Plant Species in the Field. Water, Air and Soil Pollution, 184: 235-42.