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# EVALUATION OF POTENTIALLY TOXIC METALS (PTMS) ACCUMULATION AND TRANSLOCATION BY *ALBIZIA LEBBECK* FROM INDUSTRIAL SOIL

*Abdullahi Zakari and Abdulrahman A. Audu

Department of Pure and Industrial Chemistry, Bayero University, Kano, Nigeria.

*Corresponding Author Email Address: azakari.chm@buk.edu.ng

**ABSTRACT**
Field samples of *Albizia lebbeck*, deciduous tree with drought tolerant properties, growing on industrial soil (Challawa Industrial Estate) were collected and separated into leaves, stems, roots and associated ground soil to assess the accumulation and translocation of Six Potentially Toxic Metals (PTMs) (Zn, Cu, Cd, Cr, Pb and Ni ) from the soil. Atomic Absorption Spectroscopy (AAS) was used to assess their levels. The bioaccumulation/ transfer of metals from roots to shoots and from soil to roots were evaluated in terms of translocation and bioconcentration factor. TF values of 1.22 , 1.41, 3.57 and 1.86 for Cu **,** Cd , Pb and Ni respectively indicate that *A. lebbeck* was efficient in translocation of PTMs from roots to shoots and follows the trend Cu **>** Zn > Ni > Cr respectively. This depicts the plant as a likely candidate for phytoextraction of Zn**,** Cu, Cr and Ni. BCF values of Zn (0.94), Cu (0.85), Cd (1.37), Cr (1.25), Pb (2.3) and Ni (1.66) were noted for the PTMs. This reveals that *A. lebbeck* may be suitable for phytostabilization of Zn and Cr in the contaminated soils as it retains high concentration of these PTMs in its roots in the study area.

**Keywords:** PTMs, Albizia lebbeck, translocation, phytoextraction, bioaccumulation and phytostabilization.

**INTRODUCTION**
Growing industrial activity triggers environmental degradation as a result of the excessive accumulation of toxic substances like potentially toxic metals (PTMs) in soil ecosystems (Steliga & Kluk, 2020; Yang *et al*., 2020). Potentially toxic metals (PTMs) in most cases enter agro-ecosystems through anthropogenic activities (Opoku *et al*., 2020). Anthropogenic activities may be contribution of PTMs through application of fertilizers and organic manures, irrigation farming, deposition from atmospheric sources , waste generation and disposal, sewage application, and a host of human activities (Hu *et al*., 2018). Once PTMs find their way to the soil, they are difficult to be extracted or taken out of the system becoming hazardous to organisms and soil ecosystem (Lü *et al.*, 2018) Several methods and strategies have been proposed to solve this problem of soil contamination.. Remediation by physical, chemical, and biological methods are techniques usually employed (Li *et al*., 2019). However, these techniques are economically and environmentally expensive, and additionally can have harmful effects on soil structure (physical, chemical, and biological) (Salmani-ghabeshi *et al*., 2021). Phytoremediation is widely acknowledged as a prospective, preferential, inexpensive and environmentally friendly in-situ clean-up strategy for remediation of metal-contaminated soil (Zhu *et al*., 2020). It is a low technology high impact treatment method and has been advocated as an alternative to expensive remediation and cleaning up technologies (Madanan *et al*., 2021; Yasseen, 2021). It is environmentally friendly, cost effective and affordable compared to other methods (Yang *et al*., 2020;Antoniadis *et al*., 2021).
A tropical tree specie *A. lebbeck* (Family: Fabaceae, Subfamily*: Mimosaceae*) (Elshiekh *et al*., 2020), a fast-growing, medium-sized deciduous tree (Jo & David, 2020) with drought tolerant properties, that grows up to 30 meter high was selected as a good candidate for phytoremediation in this study. It has been identified as a prospective Cr hyperaccumulator and thus prospective agents in phytoremediation of chromium (VI) contaminated environments (Manikandan *et al.*, 2016). This tree can thrive on a wide range of soil types like alkaline and saline soils but avoiding water logging (Farooqi *et al*., 2011). Planting of *A. lebbeck* has been proposed for reducing PTMs concentrations in the redeveloping soil of mine spoil (Lam & Ng, 2011).There are available studies showing the uptake of PTEs from metal contaminated soils by this plant (Abdulrahman, 2019) and its quantification of some phytochemicals and minerals found in its aqueous stem bark extract (Avoseh *et al*., 2021). The aim of the study is two pronged: 1) to assess and compare the accumulation and translocation of six heavy metals in different tissues of this plant growing naturally at Challawa Industrial estate. (2) To look at the suitability of using these plant species for phytoremediation and as potential bio-indicators for metal contamination of soils.

**MATERIALS AND METHODS**;
In the preparation of reagents, chemicals of analytical grade purity and deionized water were used throughout the analysis. All the laboratory apparatus (glass wares and the plastic containers) were first soaked in nitric-acid and thoroughly washed with detergent solution, followed by several rinses with tap water, deionized water and finally with the analyte samples.

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**Study Area**
The field study was carried out in the vicinity of Challawa Industrial area. The area is located in Kumbotso local government of Kano state. Sampling was done at Yandanko village in Challawa Industrial area, located between latitudes 11°52´48.81” and along longitudes 8°28´17.25”. The Global Positioning System (GPS) was

used in recording the coordinates and Geographical Information System (GIS) was used to locate the map of the study area as shown below (Figure 1).This map was drawn by M.A Zikrullahi of geography department Bayero University, Kano (Zikrullahi, 2020).

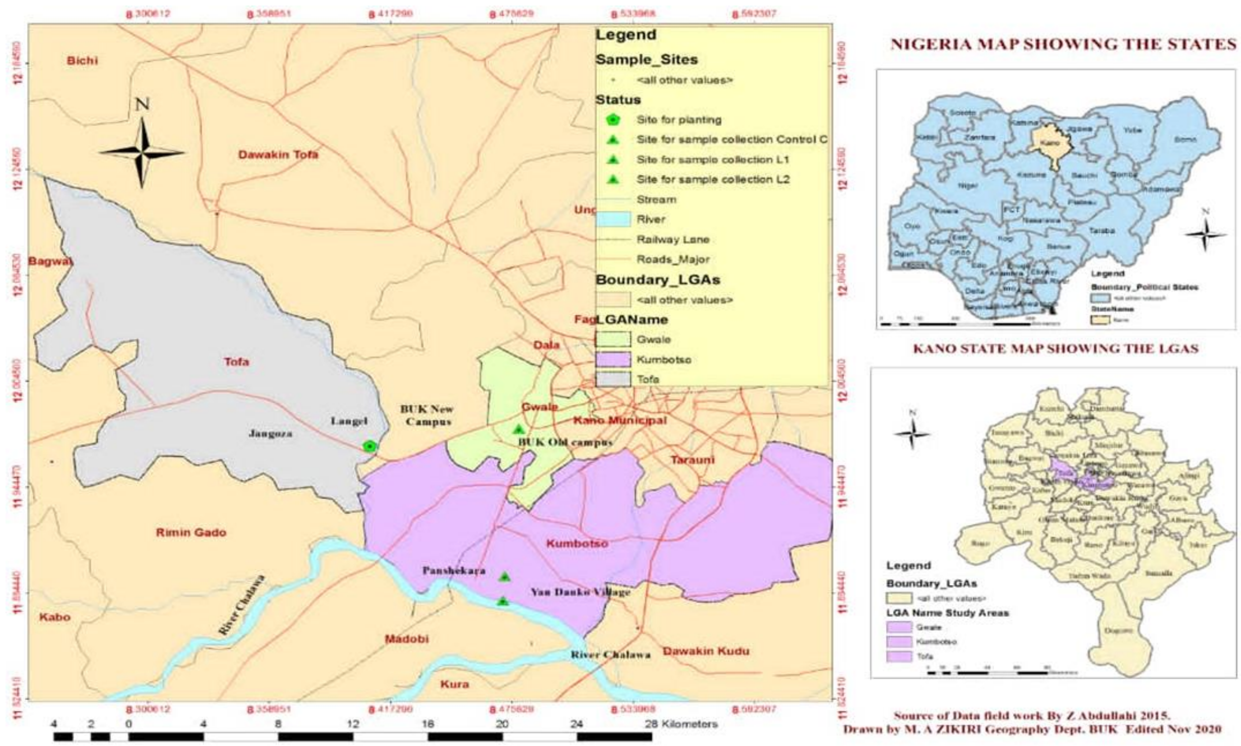


**Figure 1:** Map of Kumbotso and Tofa LGA Showing Sampling location (Zikrullah, 2020).

**Field Sampling of Soil and Plant Species (Yan danko Challawa and Langel Village, Tofa LGA).**

Nine sampling points from three locations were systematically established after every 100m. *Albizia lebbeck* was collected for analysis with at least three species per sampling point including the control site (Langel village), which was far away from Challawa Industrial area. The plant specie was collected from this sites at almost similar stage of growth as that from the Challawa sample and were used as the control.

Identification of the collected plant specie was done at the Plant Biology Department of Bayero University Kano and a herbarium number *Albizia lebbeck (bukhan 0187)* was assigned to the plant. The sample was labeled, placed in polythene bags and transported to the University and air-dried. Three soil samples were also collected at each sampling point for the plant and composites obtained. The composite soil samples was air dried and ground into fine powder using pestle and mortar and sieved through 2mm plastic mesh and stored in labeled polythene bags.

**Digestion of Soil Samples**

From the soil sample from Yandanko, at Challawa 1 g was mixed with 20cm$^3$ of nitric acid ($HNO_3$) (70% w/v, S.G 1.42g/cm$^3$) and allowed to stand for 1 hour. 15cm$^3$ of perchloric acid ($H_3ClO_4$) (70% w/v, S.G 1.67g/cm$^3$) was then added and the mixture was placed in a sand bath and heated at 55◦C until dense white fumes were observed. It was allowed to cool and filtered into the 100cm$^3$ volumetric flask and made to the mark. The resulting solution was analyzed for metal concentrations using Atomic Absorption Spectrophotometer Buck scientific, Model-210VGP (Tanee aand Amadi, 2016).

**Plant Tissue Analysis**

Before the analyses root and shoot samples were thoroughly washed using distilled water to remove all adhering soil particles. Samples were then oven dried to constant weights at 105°C. Each dried sample was ground to powder and 0.5 gram of each sample was used for analysis. These samples were placed in a crucible and transferred to the muffle furnace and ashed at 550◦C.The ash is then dissolved in 10ml 0.1M nitric acid, filtered and made up to the 100cm$^3$ mark and analyzed for metal content using Atomic Absorption spectrophotometer (Inuwa and Mohammed, 2018).

**Statistical analysis**

All data gathered were analyzed statistically using analysis of variance (ANOVA). When significant differences were detected between treatments, Tukey test (at $P < 0.05$) was calculated for each parameter and all graphs were plotted by employing Microsoft Excel.

**RESULTS AND DISCUSSION**

**Soil properties**

The soil physico-chemical characteristics from the study area have been reported in our earlier works. Results revealed that the area is characterized by sandy texture (66.8%).As indicated from earlier report, the pH of soil was slightly acidic with a value of 6.0 while that of the control is 6.8 (Zakari and Audu, 2021).

**Potentially Toxic Metals (PTMs) in *Albizia lebbeck***

Field studies data show that the PTMs contents in the plant tissues varied among plant species, which reflected the edaphic metal conditions in the area under study. Metal levels in plant tissues differed among species at the same location indicating their different capacities for metal uptake. Normal and phytotoxic concentrations of Pb, Cu, Zn and Cd were reported which were 0.6–28 mg $kg^{-1}$ for Pb, 20–30 mg $kg^{-1}$ for Cu, and 100–300 mg $kg^{-1}$ for Zn and 0.1– 3 mg $kg^{-1}$ for Cd (Midhat *et al*., 2017).

Fig 2-7 are charts showing the distribution of levels of Zn, Cu, Cd, Cr, Pb and Ni respectively in the plant *A. lebbeck*. In fig 2, Zn concentration in the tissues follows the decreasing order pattern as root > stem > leaf. One way Anova shows that there is significant difference between the Zn levels in the leaf, stem, root and soil at P < 0.05.

The Post Hoc Tukey test however, revealed that the Zn levels in the root of *A. lebbeck* is significantly higher than those obtained in the stem, soil and leaf. However, results showed that roots of *A. lebbeck* were found to accumulate considerable amounts of zinc than leaf and stem as depicted by fig 2. This results agrees with the findings of (Ishaq et al., 2013)Ishaq *et al*., 2013 who reported high Zn accumulation for the roots of the same plant in non-residential and industrial areas.

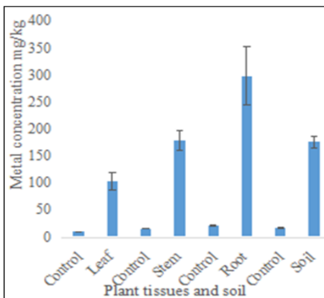


**Fig 2**: Distribution of Levels of Zinc in Tissues and Soil Samples of *A. lebbeck*

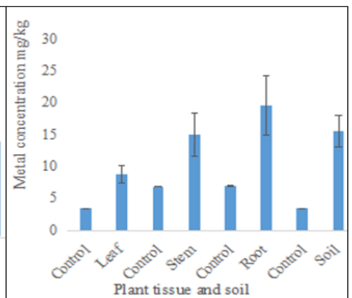


**Fig 3**: Distribution of Levels of Copper in Tissues and Soil Samples of *A. lebbeck*

The Cu concentration in the *A. lebbeck* tissues follows the decreasing order pattern as root > stem > leaf. One way Anova shows that there is significant difference between the Cu levels in the leaf, stem, root and soil at P < 0.05. The Tukey test also, revealed that there is no significant difference at P < 0.05 between the levels of Cu in leaf, stem and soil. Results showed that roots of *A. lebbeck* were found to accumulate high amounts of Cu than leaf and stem as depicted by fig 3. This results similar to the findings of Novo *et al*. (2013) and Kang *et al*. (2018) who reported high Cu accumulation for the roots of *Brassica juncea* and *M. azedarach* respectively.

The Cd concentration in the tissues follows the decreasing order pattern as root > stem > leaf. One way Anova shows that there is no significant difference between the Cd levels in the leaf, stem, root and soil. Furthermore, results showed that all three tissue parts of *A. lebbeck* are able to accumulate Cd in their system as depicted by fig 4. This results is consistent with the findings of Ishaq *et al*. (2013) and Kang *et al*. (2018) who reported high Cd accumulation for the shoots of the same plant and *V. awabuki* respectively.

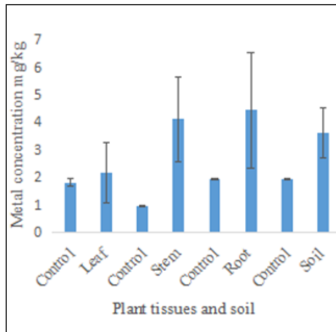


**Fig 4**: Distribution of Levels of Cadmium in Tissues and Soil Samples of *A. lebbeck*

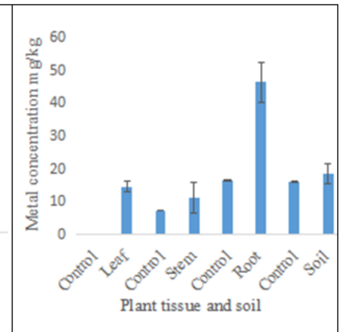


**Fig 5**: Distribution of Levels of Chromium in Tissues and Soil Samples of *A. lebbeck*

The Cr concentration in tissues of *A. lebbeck* follows the decreasing order pattern as root >leaf > stem. One way Anova shows that there is significant difference between the Cr levels in the leaf, stem, root and soil at P < 0.05. The Post Hoc Tukey test however, revealed that at P < 0.05, the Cr levels in the root of *A. lebbeck* is significantly higher than those obtained in the stem, soil and leaf. Results here showed that roots of *Albizia lebbeck* were found to accumulate considerable amounts of Cr in the roots than leaf and stem of as depicted by fig 5. Our results agree with the findings of (Manikandan *et al*. 2016) for the same plant. This gives credence to *A. lebbeck* as Cr hyperaccumulators and therefore potential agents in phytoremediation of chromium (VI) contaminated environments (Manikandan *et al*. 2016). This results also agrees with the findings of Patra *et al*. (2020)who observed that the maximum bioaccumulation of chromium occurs in roots of a similar leguminous plant *Sesbania sesban L*. as compared to shoots

The Pb concentration in the *A. lebbeck* tissues follows the decreasing order pattern as root > stem > leaf. One way Anova shows that there is significant difference between the Pb levels in the leaf, stem, root and soil at P < 0.05. The Post Hoc Tukey test however, revealed that the Pb levels in the stem of the plant is significantly higher than those obtained in the leaf, root and soil. However, results showed that the stem tissue of *A. lebbeck* were found to accumulate considerable amounts of Pb than leaf and root of as depicted by fig 6.This result agrees with the findings of Ishaq *et al*., 2013 in Pb accumulation for the stem of the same plant. Kang *et al*. (2018) also reported high accumulation of Pb in the shoots of another woody plant, *B. papyrifera*.

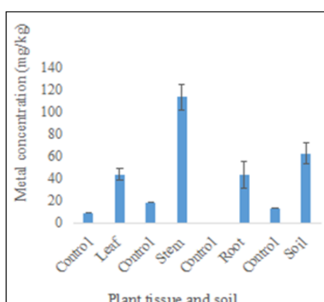


**Fig 6**: Distribution of Levels of Lead in Tissues and Soil Samples of *A. lebbeck*

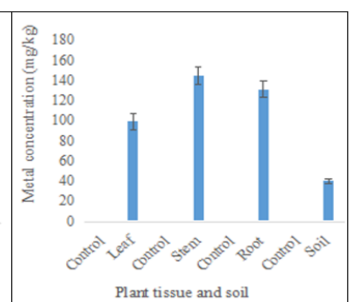


**Fig 7**: Distribution of Levels of Nickel in Tissues and Soil Samples of *A. lebbeck*

The Ni concentration in the *A. lebbeck* tissues follows the decreasing order pattern as stem > root > leaf. One way Anova shows that there is significant difference between the Ni levels in the leaf, stem, root and soil at P < 0.05. The Post Hoc Tukey test however, revealed that the Ni levels in the leaf of *A. lebbeck* is significantly higher than those obtained in the root and the stem. However, results showed that both the root and stem of *A. lebbeck* were found to possess the ability to accumulate fairly high amounts of Ni than the leaf as depicted by fig 7. This result agrees with the findings of Ishaq *et al*. 2013 in Pb accumulation for the root of the same plant.

**Bioaccumulation and Translocation of PTMs in *Albizia lebbeck***

The Translocation and Bioaccumulation in *Albizia lebbeck* is as shown in Figs 8a and 8b respectively. The translocation factors (TF) generally determines a plant capacity in heavy metals translocation from the root to shoot, demonstrating the efficiency to uptake the bio-available PTMs from the system. TF gives an idea whether the native plant is an accumulator, excluder or indicator. A plant is considered efficient in metal translocation from root to shoot when TF > 1; the reason being an efficient metal transport system.TF < 1, suggest an ineffective metal transfer indicating that such plant species accumulate metals mostly or substantially in the roots and rhizomes than in the shoot portions or the leaves of plants. Bioconcentration factor (BCF) on the other hand, can be used to evaluate a plant's phytoremediation potential. A BCF value > 1 indicate that a plant is a hyperaccumulator whereas, a value less than one is indicative of an excluder. *A. lebbeck* was screened for Zn, Cu, Cd, Cr, Pb, and Ni. Results show that it has the ability to take up and translocate more than one heavy metal from roots to shoots as shown in figs 8a and 8b with noticeable variations between TF and BCF. It is easy for plants species with TF > 1 to translocate metals from roots to shoots than those which restrict PTMs in their roots.

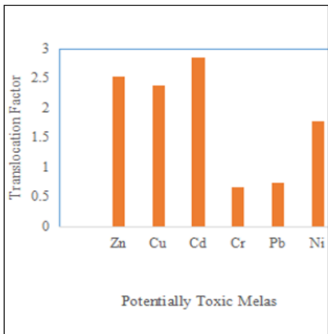


**Fig 8a**: Translocation Factor of the Six Potentially Toxic metals in *A. lebbeck*

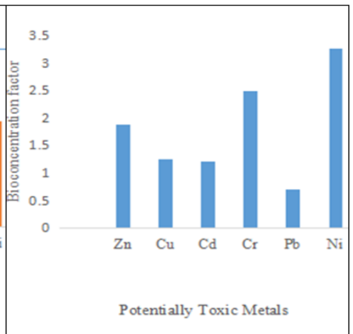


**Fig 8b**: Bioconcentration Factor of the Six Potentially Toxic Metals in *A. lebbeck*

Fig 8a show that *Albizia lebbeck* was efficient in translocation of PTEs from roots to shoots with TF values of 1.22, 1.41, 3.57 and 1.86 for Cu, Cd, Pb and Ni respectively. This is an indication that the plant is therefore suitable for phytoextraction of Cu, Cd, Pb and Ni. The exception being Zn and Cr with a TF value of 0.95 and 0.60. In Fig 8b, which illustrates the BCF values for *Albizia lebbeck*, BCF > 1 were observed for the metals Zn (1.69), Cu (1.26), Cd (1.22), Cr (2.50) and Ni (3.26) with the exception of Pb (0.70) which had a BCF < 1. Therefore, Zn and Cr with a TF value of 0.95 and 0.60 respectively on the one hand and BCF value of 1.69 and 2.50 on the other hand shows that *A. lebbeck* accumulates these two metals (Zn and Cr) more in the roots than in the shoots indicating ineffective transfer.

**Conclusion**

The potential for phytoremediation through bioaccumulation of *Albizia lebbeck*, against six PTEs (Zn, Cr, Cd, Cu, Ni and Pb) was studied. In the course of this study, we can reasonably conclude that the plant contains in its tissues amounts of PTEs that were much higher than those considered toxic for normal plants. Based on the translocation factor (TF) and the bio concentration factor (BCF) values, the study show the suitability of this plant for both phytoextraction of Zn**,** Cu, Cd and Ni and phytostabilization of Cr and Pb in the study area and where desired.

**Fig 9**: An image of *Albizia lebbeck* plant and its seeds

**Disclosure statement:** *Conflict of Interest:* The authors declare that there are no conflicts of interest.
*Compliance with Ethical Standards:* This article does not contain any studies involving human or animal subjects.

**Author's contributions:** Zakari Abdullahi conducted the research while Prof A.A Audu supervised the research.

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