Arabian Journal of Chemical and Environmental Research

Vol. 08 Issue 2 (2021) 259–274

Assessing the potential of *Albizia lebbeck* in phytoremediation of heavy metals under borehole water and tannery effluent Irrigation.

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Received 18 July 2020, Revised 26 June 2020, Accepted 27 June 2020

Abstract

Albizia lebbeck seedlings were planted on soil irrigated with tannery effluent and borehole water for duration three months. Plant samples were collected after harvest and soil samples were collected before and after planting. Atomic Absorption Spectrophotometry (AAS) was used to determine the concentration of heavy metals in the planting media and plant tissues. The aim was to establish the phytoremediation potential of *Albizia lebbeck.* After harvesting, a decrease in the concentrations of Cd, Cr, Cu Ni, Pb and Zn in the media was observed from the initial values. The highest levels of Cr (10.70±0.82 mg/ kg), Ni (5.56±0.00 mg/kg), Pb (3.15±0.17 mg/kg) and Zn (13.85±1.14) were found in the roots, whereas the highest Cd (5.85±0.56 mg/ kg) and Cu (10.42±1.04 mg/ kg) were observed in the shoot respectively. The roots of *Albizia lebbeck* were found to stabilize Cr, Ni, Pb and Zn in both the tannery effluent and borehole water irrigated media. In addition, Cd and Cu mainly accumulated in the shoots. The translocation factors (TF) and bioconcentration factors (BCF) revealed *Albizia lebbeck* as an excluder for Cr, Ni, Pb, and Zn and a potential accumulator plant for Cd and Cu serving as an ideal remediation plant for these metals.

Keywords: Albizia lebbeck, heavy Metals**,** Phytoremediation, Effluent; AAS.

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1. Introduction

The rapid development of industrial and agricultural production has resulted in a sharp increase in soil heavy metal pollution [1]. The major sink for pollutants is soil and subsequently these pollutants are released into the atmosphere by organic contaminants and anthropogenic activities [2]. Whatever is added to the air, water or land which makes these areas unsafe for life is called a pollutant. Industrial effluent is another form of pollutant constituting a threat to human, plant and aquatic lives [3].

The most harmful pollutants of industries come from its effluents. Although tannery industries have a positive role in the country's economy, the industry also imposes environmental concerns owing to usage of the toxic heavy metals during the tanning process [4]. The accumulation of toxic elements in soil can reduce crop yield, cause diseases, affect food security and endanger sustainable development [5].Heavy metals cannot be degraded and thus concentrate throughout the food chain in environments, eventually entering the human body [6]. Metal contaminated soil and water can be remediated by chemical, physical and biological methods [7]. All remediation processes have unique benefits and consequences leaving secondary contamination traces after the process undergo completion [8]. However, phytoremediation a plant based technique that uses plant species for the removal of toxic metals from contaminated soils has been advocated as the best eco-friendly method for cleaning up the environment [9], [10], [11], [4]. In this study, *Albizia lebbeck (A. lebbeck),* a fast-growing, medium-sized deciduous tree was chosen for our investigation having in mind its drought tolerant properties to assess its heavy metal remediation ability from soil irrigated with tannery waste water.

A. lebbeck is a large erect deciduous plant [12], that grows up to 30 meter high belonging to the family Fabaceae (subfamily- Mimosaceae) [13], It is a multipurpose tree for semiarid regions and has been widely distributed around the tropics and mainly planted as a shade tree. This tree is found on a multiple range of soil types like those that are alkaline or saline. The seed is round and colourful and usually grown as a wild plant [14]. Studies are available that show absorption of heavy metals from metal contaminated soils by this plant and its quantification of some phytochemicals and minerals found in its aqueous stem bark extract [15]. *Albizia lebbeck* seeds has been used as low cost adsorbents in treatment of aqueous solution that contains heavy metals (Cd) with other pollutants by adsorption technique which shows that the seed adsorbents had significant heavy metal removal efficiency [16].

Current knowledge regarding the potential phytoremediation of soils treated with tannery waste water (effluent) by *A. lebbeck* is limited. Therefore, this study was designed to elucidate the potential of *A. lebbeck* to clean toxic heavy metals in soils treated with effluent waste water from the tannery industry in Challawa Industrial Estate, Kano, Nigeria. *A. lebbeck* under experimental set up is shown in **Fig 1**.

Fig 1. *Albizia lebbeck* in the screen house

2. Materials and methods

2.1. The study area

The current study was carried out in the in a screen house in botanical garden of Plant Biology department of Bayero University Kano. The area is located between latitudes 11°58´3.79" and 8°24´27.08" in Gwale local government of Kano state. The global positioning system (GPS) was used in recording the coordinates Geographical Information System (GIS) was used to locate the map of the study area as shown below (**Fig 2**).

Fig 2: Google map showing planting location in the screen house of the plant biology department, Bayero university, Kano, Nigeria.

2.2. Soil sampling

Soil sample for this research was collected from Challawa Industrial area of Kano, Kano state, Nigeria at a depth of 20cm. The surface soil layer to a depth of 0-20 cm (ploughing layer) was sampled with a stainless steel auger and the soil sample was transferred to a labelled bag. Soil from the control site (Langel village), which was far away from Challawa industrial area were sampled in a similar manner and used as the control [17].

2.3. Soil preparation for pot experiment

Seeds of the six plant species were planted in pots filled with 5kg of soil type intended for planting (i.e. Soil from locations at Challawa Industrial Estate) and control soil from Langel village which is a non-industrial farm settlement and irrigated for up to 90 days in a screen house in botanical garden of Plant Biology Department of Bayero University, Kano. Seeds were irrigated with water up to field capacity of the soil daily or every third day with effluent to maintain optimum water conditions. The plants were grown for a period of three months (90days). After 90 days the plant samples from each pot was collected and washed thoroughly with distilled water so that no soil particles remained.

2.4. Collection and preparation of Industrial effluent

Tannery industrial effluents were collected from discharge points of the various tannery industries in Challawa area. The collected samples of tannery waste water effluents were mixed together and then used as irrigation water.

2.5. Digestion of soil samples

1g of the soil sample from Yandanko, at Challawa was mixed with 20cm^3 of nitric acid (HNO_3) (70% w/v, S.G 1.42g/cm^3) and allowed to stand for 1hour. 15cm^3 of perchloric acid ($HClO_4$) (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 analysed for metal concentrations using Atomic Absorption Spectrophotometer Buck scientific, Model-210VGP [18].

2.6. 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 analysed for metal content using Atomic

Absorption spectrophotometer [19].

2.7. 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 [20].

3. Results and discussion

3.1. Heavy metal concentrations in growth media before planting and after harvesting

The concentrations of heavy metals before planting and after harvesting are as shown in **Fig 3-8**. Uptake of Heavy metals such as Cd, Cr, Cu, Pb, Ni and Zn were recorded in varying proportions in the different growth media. The growth media are effluent irrigated soil labelled EL1ABS, borehole water irrigated soil labelled L1ABS and control soil.

The initial Cd content of the growth media was 12.85mg/kg for both EL1ABS, L1ABS and 9.43mg/kg for the control respectively before planting. However, after harvesting, the Cd level decreases in the residual soil sample after remediation with to 2.28, 1.63 and 4.55mg/kg in EL1ABS, L1ABS and control respectively as represented by **Fig 3**. This indicated that large proportion of cadmium was removed from the soil which could be traced to phytoextraction potential of *A. lebbeck.* Cadmium (Cd) is a toxic element and exists along with Zinc in nature in soils. Cadmium is one of the increasingly frequent contaminants of agricultural soils. Cadmium contamination in agricultural soils is due to either excessive phosphate fertilization, use of sewage sludge as a fertilizer in agriculture [21].

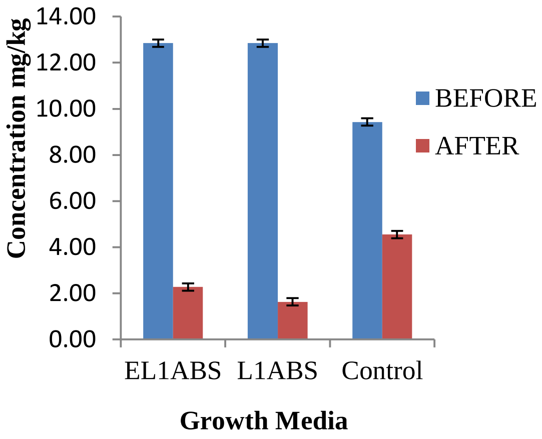

Fig 3: Concentration of cadmium in growth medium before planting and after harvesting in *A. lebbeck*

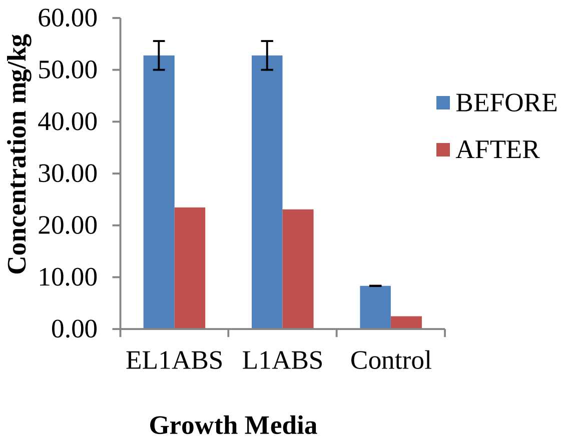

Fig 4: Concentration of chromium in growth medium before planting and after harvesting in *A. lebbeck*

The initial Cr content of the growth media was 52.77mg/kg for both EL1ABS, L1ABS and 8.33 mg/kg in the control respectively before planting. However, after harvesting, the Cr level decreases in the residual soil sample after remediation with the plant to 23.46mg/kg, 23.05mg/kg and 2.47mg/kg in EL1ABS, L1ABS and control respectively as shown in Fig 4. Chromium (Cr) is one of the toxic metals widely distributed in nature. The high soil chromium may be due to the fact that chromium and its compounds are largely used in industrial production as raw materials in metal processing, electroplating, and tanning industries [22].

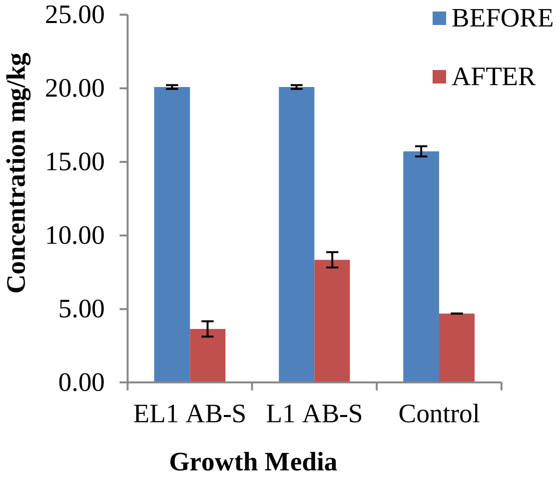

Fig 5: Concentration of copper in growth medium before planting and after harvesting in *A. lebbeck*

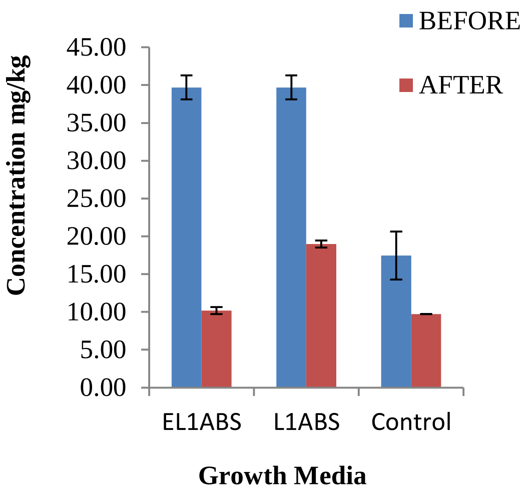

Fig 6: Concentration of nickel in growth medium before planting and after harvesting in *A. lebbeck*

Cu levels also decrease in the *A. lebbeck* growth media. The initial Cu content of the growth media was 20.08mg/kg in both EL1ABS and L1ABS and 15.71mg/kg in control respectively before planting. However, after harvesting, the Cu level decreases after remediation to 3.65 mg/kg, 8.33 mg/kg *and* 4.69mg/kg in EL1ABS, L1ABS and control respectively as illustrated by **Fig 5**. Essential heavy metals like Cu is required for physiological and biochemical processes during plant life cycle but can be toxic when present in excess [23].

The observed initial value of Nickel in both EL1ABS, L1ABS was 39.69 mg/kg and 17.46mg/kg in the control. Only a residual amount of 10.19 mg/kg, 18.98 mg/kg, and 9.72 mg/ kg were detected in the growth media after remediation respectively as depicted by **Fig 6**. It takes the same trend which was observed with the other elements earlier investigated above. Nickel (Ni) is one of the heavy metals that its levels in most soils ranges from 10 to 40 ppm, but in serpentine soils or soils enriched with Ni-bearing ores even surpassing 1,000 ppm [24].

Fig 7 shows the uptake of Lead where the initial value at the start was 31.74 mg/kg in both EL1ABS and L1ABS *and 7.93 mg/ kg* in the control. However, decreases in the final level after harvest were 19.98

mg/kg, 17.99 mg/kg and 5.06 mg/kg respectively. Lead (Pb) is one of the most widespread heavy metal prevalent in several countries, since the abundance of this metal is due to natural climatic processes and uncontrolled anthropogenic activity [25]. According to the Agency for Toxic Substances and Disease Registry, Pb is the second element in the priority list of hazardous substances due to its low solubility, high diffusion, persistence, and toxicity and is classified as carcinogenic and mutagenic [26]. Being a persistent pollutant, Pb is absorbed by root cells via the apoplastic pathway or through calcium channels Lead is not an essential element and potentially is toxic to plant, animal and human [25]. *A. lebbeck* was found to remove lead (Pb) efficiently. Lead (Pb) concentration was significantly decreased in the growth media as the highest reduction recorded.

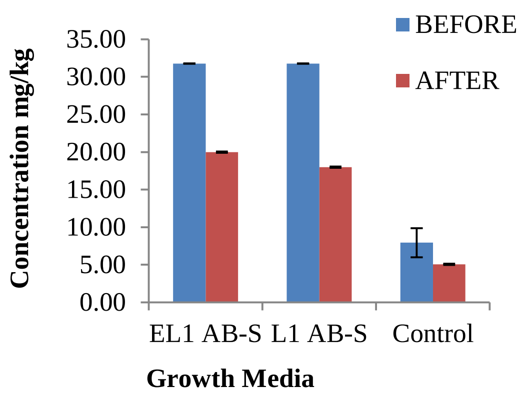

Fig 7: Concentration of Lead in growth medium before planting and after harvesting in *A. lebbeck*

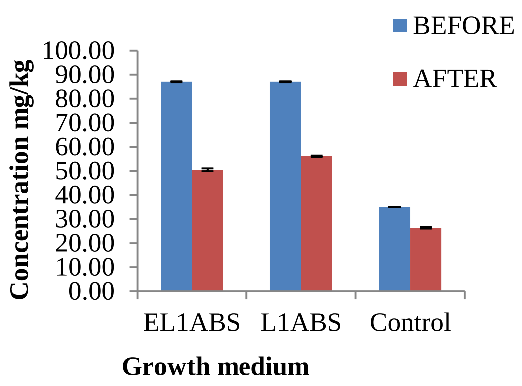

Fig 8: Concentration of Zinc in growth medium before planting and after harvesting in *A. lebbeck*

Fig 8 illustrates the uptake of Zinc from the growth media where the observed initial value of Zinc in both EL1ABS and L1ABS was 87.04 mg/kg and control was 35.09mg/kg and only a residual amount of 50.45mg/kg, 56.05mg/kg and 26.38mg/kg were detected in the growth media after harvest respectively. Zinc concentration decreased in the growth media, which may be as a result of its higher uptake by the plant. Zn pollution results from human activities, such as leather tanning, textile and microelectronics, chemical fertilizers, manures, and pesticides [27].

3.2. Heavy metal concentrations in plant parts

The concentrations of Cd, Cr, Cu Ni, Pb and Zn in plant tissues (shoots and roots) at three months after planting are as shown in **Fig 9-14**. The heavy metal concentration in the plant tissues are represented as effluent irrigated labelled EL1ABST (shoot) and EL1ABRT (root) in the growth medium of EL1ABS together with the borehole water irrigated labelled L1ABST (shoot) and L1ABRT (root) in the growth medium of L1ABS and control.

Fig 9 shows the uptake of Cadmium by the tissues of *Albizia lebbeck* in the respective growth media. The concentrations of Cd after 3months in the tissues were 5.85±0.56mg/kg, 4.23±0.33mg/kg, 5.53±0.33 mg/kg, 3.25±0.33 mg/kg and 1.95±0.56mg/kg (shoot) and 1.30±0.33 mg/kg (root) in EL1ABST (shoot), EL1ABRT (root), L1ABST (shoot), L1ABRT (root), and the control respectively. The results indicate that *Albizia lebbeck* mopped up more concentration of Cd in the shoots compared to concentrations in the roots. The results also showed that, at the end of 3months period, the total uptake of Cd by the plant with respect to the initial metal in the growth media is 10.08mg/kg (75.80%), 8.78mg/kg (68.33%), and 3.25mg/kg (34.49%) as represented by the growth media of EL1ABS, L1ABS and the control respectively. The highest Cd accumulation (5.85±0.56mg/kg) was observed in the shoot of the *Albizia lebbeck* planted in the EL1ABS growth media while the lowest shoot accumulation of 1.95±0.56mg/kg was observed in the control. As for the root, the highest Cd concentration of 4.23±0.33 mg/kg was observed in growth medium EL1ABS represented by EL1ABRT. The lowest root accumulation of Cd (1.3±0.33 mg/kg) was detected in the control. There was no significant difference observed in the concentrations of the Cd in the plant tissue samples ($P < 0.05$). Results indicated that Cd could be accumulated in all plant organs (shoots and roots). This result is similar to the findings of [27] who reported a high concentration of Cd in the shoots of *Chenopodium album L* and high concentration in the roots of *Ranunculus sceleratus.*

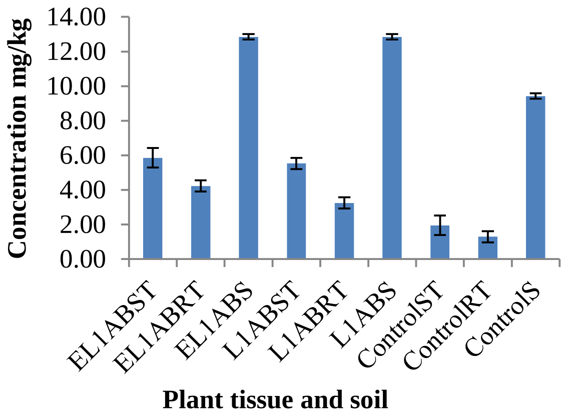

Fig 8: Concentration of Cadmium in tissues and soil of *Albizia lebbeck*

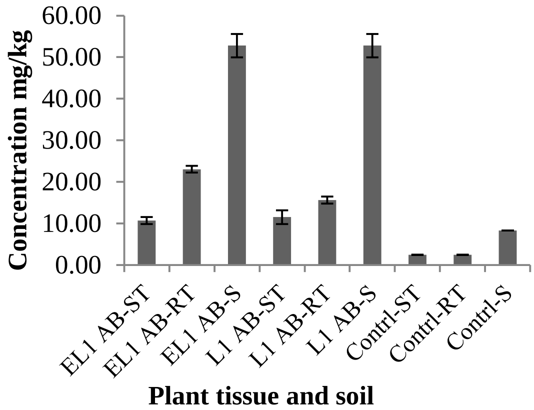

Fig 9: Concentration of Chromium in tissues and soil of *Albizia lebbeck*

Fig 9 illustrates the uptake of Chromium (Cr) by the tissues of *Albizia lebbeck* in the respective growth media. The concentrations of Cr after 3months in the tissues were 10.70±0.82 mg/kg, 23.05±0.82 mg/kg, 11.52±1.65 mg/kg, 15.64±0.82 mg/kg and 2.47±0.00mg/kg (shoot) and 2.47±0.00 mg/kg (root) in EL1ABST (shoot), EL1ABRT (root), L1ABST (shoot), L1ABRT (root) and the control. The results indicate that in the effluent irrigated media, *Albizia lebbeck* mopped up more amounts of Cr in the roots compared to concentrations in the shoots. With respect to the borehole irrigated media a similar trend of more metal accumulation in the roots were observed. The results indicate that *Albizia lebbeck* mopped up more amounts of Cr in the roots compared to concentrations in the shoots. Previous research reports on heavy metal accumulation by several terrestrial plants has shown that roots have higher metal deposition than other parts of plant [20]. The results also showed that, at the end of 3months period, the total uptake of Cr by the plant with respect to the initial metal in the growth media is 34.57mg/kg (55.32%), 27.16mg/kg (46.26%) and 4.94mg/kg (38.49%) as represented by the growth media of EL1ABS, L1ABS and the control respectively. The highest Cr accumulation (23.05±0.82mg/kg) was observed in the root of the *Albizia lebbeck* planted in the EL1ABS growth media while the lowest root accumulation of 2.47±0.00mg/kg was observed in the control This results agrees with the findings of [29] who observed that the maximum bioaccumulation of chromium occurs in roots of a similar leguminous plant *Sesbania sesban L*. as compared to shoots. As for the shoot, the highest Cr concentration of 11.52±1.65 mg/kg was observed in growth media, L1ABS represented by L1ABST. The lowest shoot accumulation of Cr (2.47±0.00 mg/kg) was detected in the control. There was no significant difference observed in the heavy metal concentrations of the Cr in the plant tissue samples ($P < 0.05$). Results indicated that all parts of *Albizia lebbeck* were able to absorb and store Cr however the uptake by the roots is more.

Fig 10 illustrates the uptake of Copper (Cu) by the tissues of *Albizia lebbeck* in the respective growth media. The concentrations of Cu after 3months in the tissues were 10.42±1.04 mg/kg, 6.25±0.00 mg/kg, 5.21±1.04 mg/kg, 5.21±1.04 mg/kg and 5.21±1.04mg/kg (shoot) and 5.21±1.04mg/kg (root) in EL1ABST (shoot), EL1ABRT (root), L1ABST (shoot), L1ABRT (root), and the control respectively. The results indicate that in the effluent irrigated media, *Albizia lebbeck* mopped up more amounts of Cu in the shoots compared to concentrations in the roots. However, in the borehole irrigated media and control roughly equal amounts of the metal concentrations were observed in both tissues. The results also showed that, at the end of 3months period, the total uptake of Cu by the plant with respect to the initial metal in the growth media is 16.67mg/kg (61.75%), 10.42mg/kg (47.09%), and 10.42mg/kg (58.69%) as represented by the growth media of EL1ABS, L1ABS, and the control respectively (Fig.9). The highest Cu accumulation (10.42±1.04mg/kg) was observed in the shoot of the *Albizia lebbeck* planted in the EL1ABS growth media while the lowest shoot accumulation of 5.21±1.04mg/kg was observed in the borehole irrigated tissue and the control. As for the root, the highest Cu concentration of 6.25±0.00 mg/kg was observed in growth media, EL1ABS, represented by EL1ABRT. There was no significant difference observed in the heavy metal concentrations of the Cu in the plant tissue samples ($P < 0.05$). The present findings showed total Cu concentration in the shoots more than root Cu concentration in effluent treated medium than the water irrigated medium. This agrees with the findings of [29] where a high shoot Cu concentration was observed in another study with the plant *Eclipta alba* (L).

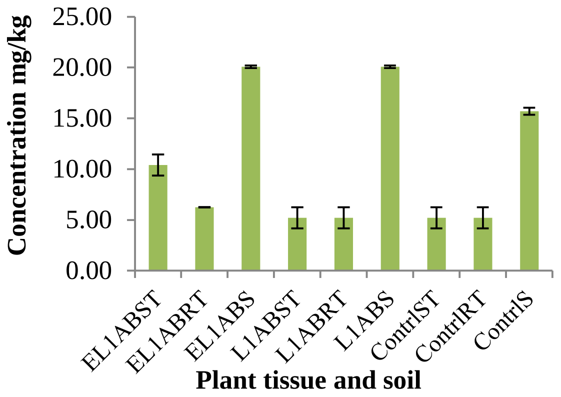

Fig 10: Concentration of copper in tissues and soil of *Albizia lebbeck*

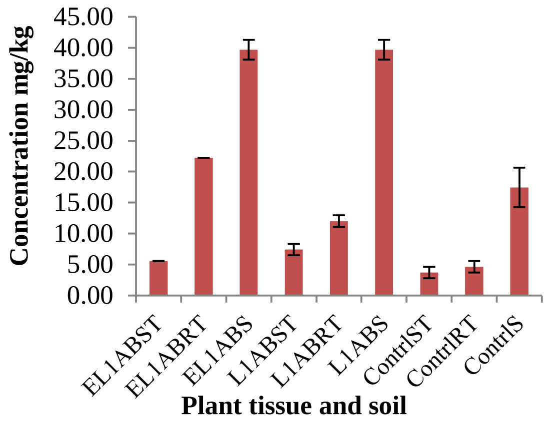

Fig 11: Concentration of nickel in tissues and soil of *Albizia lebbeck*

Fig 11 illustrates the uptake of Nickel (Ni) by the tissues of *Albizia lebbeck* in the respective growth media. The concentrations of Ni after 3months in the tissues were 5.56±0.00 mg/kg, 22.22±0.00mg/kg, 7.41±0.93mg/kg, 12.04±0.93 mg/kg and 3.70±0.93mg/kg (shoot) and 4.63±0.93mg/kg (root) in EL1ABST (shoot), EL1ABRT (root), L1ABST (shoot), L1ABRT (root) and the control respectively. The results indicate that in the effluent irrigated media, *Albizia lebbeck* mopped up more amounts of Ni in the roots compared to concentrations in the shoots. A similar trend was also observed in the borehole irrigated media. The results also showed that, at the end of 3months period, the total uptake of Ni by the plant with respect to the initial metal in the growth media is 27.78mg/kg (63.30%), 19.44mg/kg (45.68%) and 8.33mg/kg (40.97%) as represented by the growth media of *EL1ABS*, L1ABS and the control respectively. The highest Ni accumulation (22.22±0.00mg/kg) was observed in the root of the *Albizia lebbeck* planted in the EL1ABS growth media while the lowest root accumulation of 4.63±0.93mg/kg was observed in the control. As for the shoot, the highest Ni concentration of 7.41±0.93 mg/kg was observed in growth media L1ABS represented by L1ABRT. The lowest shoot accumulation of Ni (3.70±0.93 mg/kg) was detected in the control. There was no significant difference observed in the heavy metal concentrations of the Ni in the plant tissue samples ($P < 0.05$). The present findings showed total Ni concentration in the roots more than shoot Ni concentration in effluent treated medium than the water irrigated medium. This is consistent with the findings of [8] who reported elevated levels for Cu in the roots of *P. angustifolia*.

Fig 12 illustrates the uptake of Lead (Pb) by the tissues of *Albizia lebbeck* in the respective growth media. The concentrations of Pb after 3months in the tissues were 3.15±0.17 mg/kg, 4.15±0.33mg/kg, 2.32±0.17mg/kg, 3.98±0.00 mg/kg, in EL1ABST (shoot), EL1ABRT (root), L1ABST (shoot), L1ABRT (root) respectively and the control plant values gives the lowest concentration of 0.83±0.17mg/kg (shoot) and 1.16±0.17mg/kg (root). The results indicate that in the effluent irrigated media, *Albizia lebbeck* mopped up more amounts of Pb in the roots compared to concentrations in the shoots. A similar trend of the metal concentrations in the roots and shoot were observed in the borehole irrigated media. The results also showed that, at the end of 3months period, the total uptake of Pb by the plant with respect to the initial metal in the growth media are 7.30mg/kg (22.16%), 6.30mg/kg (19.85%) and 1.99mg/kg (25.10%) as represented by the growth media of EL1ABS, L1ABS and the control respectively. The highest Pb accumulation (4.15±0.33mg/kg) was observed in the root of the *Albizia lebbeck* planted in the EL1ABS growth medium while the lowest root accumulation of 1.16±0.17mg/kg was observed in the growth medium of control (Fig 41).. There was no significant difference observed in the heavy metal concentrations of the Pb in the plant tissue samples ($P < 0.05$). This is similar to the findings of who [8] and [29] who reported a high concentration of Pb in the roots of *Artemisia vulgaris* and *Alternanthera philoxeroide* (L) respectively.

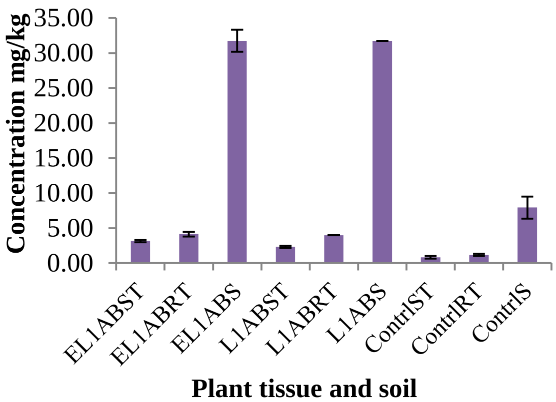

Fig 12: Concentration of lead in tissues and soil of *Albizia lebbeck*

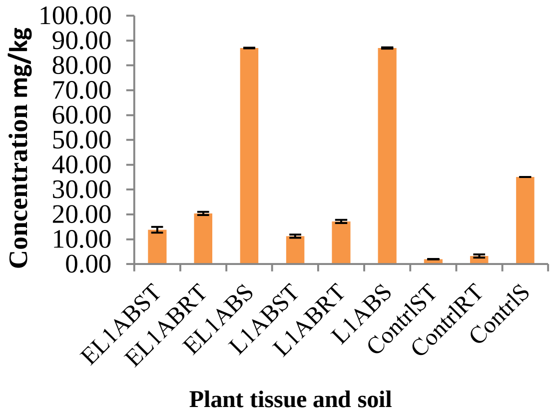

Fig 13: Concentration of zinc in tissues and soil of *Albizia lebbeck*

Fig 13 illustrates the uptake of Zinc (Zn) by the tissues of *Albizia lebbeck* in the respective growth media. The concentrations of Zn after 3months in the tissues were 13.85±1.14 mg/kg, 20.44±0.66mg/kg, 11.21±0.66mg/kg, 17.14±0.66mg/kg and 1.98±0.00mg/kg (shoot) and 3.30±0.66mg/kg (root) in EL1ABST (shoot), EL1ABRT (root), L1ABST (shoot), L1ABRT (root) and the control plant respectively. The results indicate that in the effluent irrigated media, *Albizia lebbeck* mopped up more amounts of Zn in the roots compared to concentrations in the shoots. The results also showed that, at the end of 3months period, the total uptake of Zn by the plant with respect to the initial metal in the growth media is 34.29mg/kg (34.72%), 28.35mg/kg (30.50%), and 5.28mg/kg (11.82%) as represented by the growth media of EL1ABS, L1ABS, and the control respectively. The highest Zn accumulation

(20.44±0.66mg/kg) was observed in the root of the *Albizia lebbeck* planted in the EL1ABS growth media while the lowest root accumulation of 3.30±0.66mg/kg was observed in the control in Fig 13. As for the shoot, the highest Zn concentration of 13.85±1.14mg/kg was observed in growth media, EL1ABS, represented by EL1ABST. The lowest shoot accumulation of Zn (1.98±0.00mg/kg) was detected in the control. There was no significant difference observed in the heavy metal concentrations of the Zn in the plant tissue samples ($P < 0.05$). Our results agree with the findings of [5] who reported an elevated concentration of Zn in the roots of Aztec Marigold (*Tagetes erecta L.*)

3.3. Translocation Factor and Bioconcentration Factor

The ability of phytoremediation has commonly been characterized by a Translocation Factor, TF which is defined as the ratio of the metal concentration in the shoots to that in the roots. Translocation factor (TF) was calculated using the formula [5], [29].

$$\text{Translocation Factor (TF)} = \frac{\text{Metal concentration in shoot of plant(mg/kg)}}{\text{Metal concentration in root of plant(mg/kg)}}$$

Phytoextraction as a process depends on successful heavy metal removal by the shoots. Plants with TF values > 1 are classified as high-efficiency plants for metal translocation from the roots to shoots. The results in this study showed that *Albizia lebbeck* had concentrations of metals showing TF values of (1.38, 1.70 and 1.50) for Cd and (1.60, 1.00 and 1.00) for Cu which are all greater than one in growth media irrigated with tannery waste water, borehole water (ground water) and control respectively. However, Cr, Ni, Pb and Zn concentrations in the tissues of the same plant show values of TF < 1(Table 1). This is an indication that the plant could be regarded as an efficient plant for metal translocation from the roots to the shoots. Ability of a plant to accumulate metals from contaminated soils was evaluated by the Bioconcentration factor (BCF) using the formula [5].

$$\text{Bioconcentration factor (BCF)} = \frac{\text{Average metal conc.in the whole plant (mg/kg)}}{\text{Metal conc.in soil (mg/kg)}}$$

This study assumed that plants with BCF values > 1 are accumulators, while plants with BCF values less than 1 are excluders. Additionally, plants were classified as potential hyper accumulators if the BCF values were > 10. The results in this study showed that *Albizia lebbeck* irrigated with tannery waste water, borehole water (ground water) and control had BCF values <1 for the elements, Cr, Ni, Pb and Zn indicating that the plant has the potential to be used as excluders. This property may be employed in phytostabilization where it is necessary to maintain the metals below the ground (**Table 1**). Generally, natural metal hyper accumulators can accumulate large amounts of heavy metals in their aboveground tissues and should be tolerant of metal contaminants and other site conditions that may limit plant growth.

Table 1: Translocation and bioconcentration factor for *Albizia lebbeck*

TF				BCF		
	EL1 ABS	L1 ABS	CONTROL	EL1 ABS	L1 ABS	CONTROL
Cd	1.38	1.70	1.50	0.78	0.68	0.34
Cr	0.50	0.74	1.00	0.66	0.51	0.59
Cu	1.67	1.00	1.00	0.83	0.52	0.66
Ni	0.25	0.62	0.80	0.70	0.49	0.48
Pb	0.76	0.58	0.71	0.23	0.20	0.25
Zn	0.68	0.65	0.60	0.39	0.33	0.15

Conclusion

This study demonstrated the potential of the plant to remediate heavy metal contaminated soil revealing *Albizia lebbeck* as an accumulator of Cd and Cu. It is recommended for phytoextraction of these metals. Furthermore, the study was able to reveal *Albizia lebbeck* as an excluder of Chromium, Nickel, Lead and Zinc. The elevated concentration of these metals in its roots and low translocation in above ground parts show its suitability for phytostabilization of the metals. Therefore, planting of *Albizia lebbeck* in soils polluted with heavy metals as a result of contamination from tannery waste water can be an ideal option to be grown for phytoremediation in multi-metal contaminated sites and to checkmate soil pollution arising as a result of pollution from tannery waste water and other associated contaminants. Being a non-food plant, *Albizia lebbeck* can be an ideal option to be grown for phytoremediation in multi-metal contaminated sites and to mitigate soil pollution.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgement

The authors wish to acknowledge the financial support from Bayero University, Kano, Nigeria through the Directorate of research, innovation and partnerships research grant (BUK/DRIP/RG/2017/0063).

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(2021); www.mocedes.org/ajcer