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ASSESSING THE POTENTIAL of *Khayasenegalensis* IN PHYTOREMEDIATION OF HEAVY METALS UNDER BOREHOLE WATER AND TANNERY EFFLUENT IRRIGATION

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ABSTRACT

Khayasenegalensis was planted on soil irrigated with tannery effluent and borehole water for duration of three months. Plant samples were collected after harvest and soil samples were collected before planting and after harvesting. Atomic Absorption Spectroscopy (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 Khayasenegalensis under these conditions. After harvesting, a noticeable 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 Cd (5.53±0.56mg/kg), Cr (*13.99± 0.82*mg/kg), Pb(*10.61±0.57*mg/kg), Ni (*8.33±2.78*mg/kg)and Zn(25.72±0.00 mg/kg) accumulation were found in the roots, whereas the highest Cu ((*7.29±1.80mg/kg*) concentrations was observed in the shoot.. The roots of Khayasenegalensis were found to be suitable for the phytostabilization heavy metals in both the tannery effluent and borehole water irrigated media..In addition, Cd, Cr, Cu, Ni and Pb mainly accumulated in the Khayasenegalensisroots. The results of translocation factors (TF) and bioconcentration factors (BCF) of Khayasenegalensis for heavy metals revealed that Khayasenegalensis is an excluder plant for Cd, Cr, Pb, Ni and Zn and a potential accumulator plant for Cu serving as an ideal remediation plant for this metal. Furthermore, the increasing heavy metal contents in soil that have been irrigated with tannery effluent resulted in the accumulation of these metals in Khayasenegalensis.

Key words: Heavy metals, *Khayasenegalensis*, phytoremediation, AAS, Tannery effluent.

INTRODUCTION

The widespread accumulation of heavy metals in the environment is becoming an increasingly main concern worldwide as a result of the pollution of the ecosystem that comes with it (Si *et al*., 2021);Li *et al*., 2021;Zhang *et al*., 2020; He *et al*., 2020;Steliga & Kluk, 2020).One of this environmental pollution is soil contamination by heavy metals due to land degradation caused by synthetic substances or Anthropogenic activities (Ibrahim and El, 2020). These heavy metals are those element that have relatively high atomic and mass number greater than 20 and 5 g/cm^3 respectively (Godwin and Oluwagbemiga, 2020).They are present in industrial effluents and municipal waste both in liquid and solid state in excessive concentrations posing very damaging effects to both fauna and flora(Amir *et al*., 2020). Irrigation by sewage water and industrial effluents has been cited as a major reason for accumulation of heavy metals in the plants (Gupta *et al*., 2008;Ullah *et al*., 2021). The conventional methods of tackling heavy metal contamination from polluted soil, includes chemical oxidation, soil vapor extraction, solidification, soil flushing, and electrokinetics separation most times do not yield expected results or are not encouraging due to the fact that it is an expensive process (Elshamy *et al*., 2019; Eid *et al*., 2020). Phytoremediation, a promising and cost effective approach is a widely accepted approach of confronting this age old problem due to its economic feasibility and eco-friendliness(Ravi *et al*., 2020). Phytoremediation of contaminated soils is defined as “use of plants or their rhizosphere to remove contaminants through harvestable sections including stems and leaves (phytoextraction) or the control and immobilization of contaminants in roots (phytostabilization)”(Yang *et al*., 2020). In Phytoremediation, plants are used to remove pollutants from environmental media. Plants act as bioreactors, as their roots show unique and selective pollutant uptake capabilities, and the shoot is a site for translocation, bioaccumulation, and contaminant degradation (Madanan *et al*., 2021).

In spite of the fact that traditional phytoremediation by using native plants to alleviate soil contamination seems a viable approach to tackle pollution of soil by heavy metals, it has not been applied successfully as a result of a number of limitations. The use of native plants having the ability to accumulate trace metals for phytoremediation has an important ecological aspect since these plants are more efficient in terms of survival under environmental stress conditions than introduced plants(Eid *et al*., 2020). *Khayasenegalensis* (Family: Meliaceae) was selected for this study. It is a Juss (called madaciin Hausa speaking communities of Nigeria and mahogany in English) (Tauheed *et al*., 2020). Studies are available that show absorption of heavy metals from metal contaminated soils by this plant (Olajuyigbe and Aruwajoye, 2014) and its quantification of some phytochemicals and minerals found in its aqueous stem bark extract. Other studies have been conducted on the accumulation of heavy metals in plant tissues irrigated with wastewater (Wise and Mokokwe, 2020).

Current knowledge regarding the potential phytoremediation of soils treated with tannery waste water (effluent) by *Khayasenegalensis*is limited. Therefore, this study was designed to elucidate the potential of *Khayasenegalensis* to clean toxic heavy metals in soils treated with effluent waste water from the tannery industry in Challawa Industrial Estate, Kano, Nigeria. A Picture of *Khayasenegalensis* under experimental set up (Plate 2.

MATERIALS AND METHODS

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 (Plate 1).

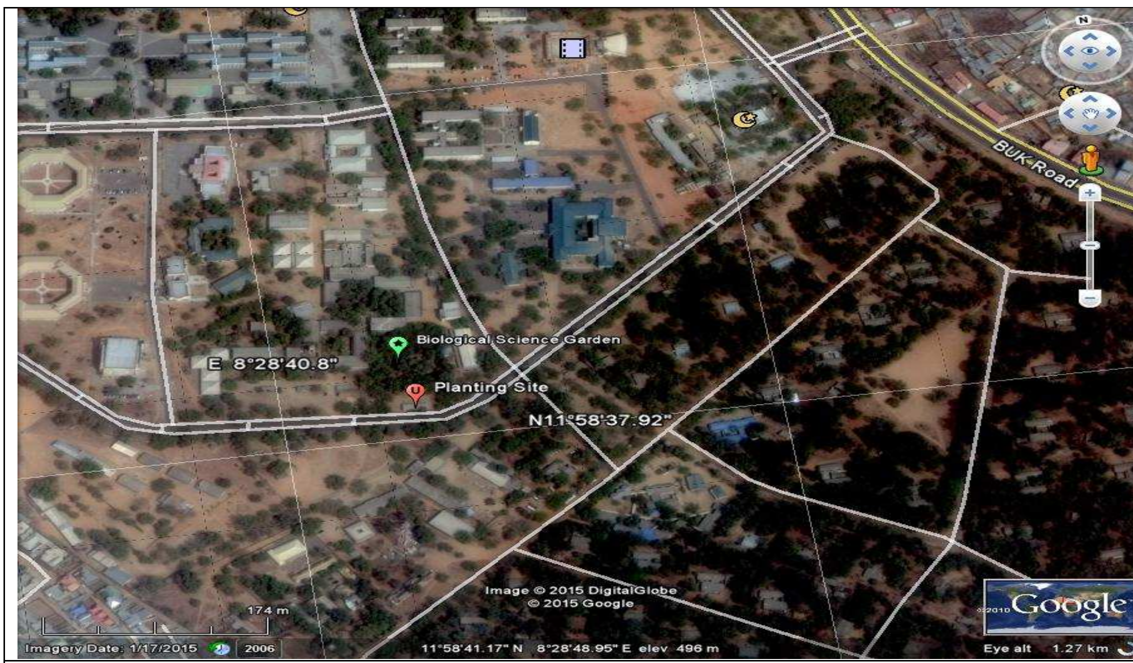


Plate 1: Google Map showing Planting Location in the Screen House of thePlant Biology Department, Bayero University, Kano, Nigeria.

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 (Cuske *et al*., 2016).

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. Plate 2 shows a picture of *Khayasenegalensis* in the screen house.

Plate 2: A picture of *Khayasenegalensis* in the screen house

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.

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 (Tanee and 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 analysed 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 (Mohanty & Patra, 2020).

3.0 RESULTS AND DISCUSSION

3.1 Heavy Metal Concentrations in Plant Tissues and Soil Media before Planting and after Harvesting

The concentrations of Cd, Cr, Cu,Ni, Pb and Zn in plant tissues (shoots and roots) and soil media before planting and after harvesting for *K. senegalensis* are as shown in fig 2-6. The following description were adopted in labelling the tissues of *K. senegalensis* and the growth medium where they were planted viz; the heavy metal concentration in the plant tissues are represented as effluent irrigated plant tissue are labeled EFKHST (shoot) and EFKHRT (root) and EFKHS (for effluent irrigated soil medium) The borehole water irrigated plant tissue and soil are labeled; WKHST (for shoot), WKHRT (for root), WKHS (for borehole water irrigated soil medium) and control.

Fig. 1 shows the uptake of Cadmiumby the tissues of *K. senegalensis* in the respective growth media. The concentrations of Cd after 3months in the tissues were 3.58±0.56 mg/kg, 5.53±0.56 mg/kg, 2.93±0.98 mg/kg, 3.90±0.00 mg/kg, in EFKHST (shoot), EFKHRT (root), WKHST (shoot), WKHRT (root) respectively and the control plant values gives the lowest concentration of 1.30±0.56mg/kg (shoot) and 1.63±0.56 mg/kg (root).

The initial Cd level of the growth media was 12.85mg/kgin both EFKHS and WKHS and 9.43 mg/kg in control before planting. However, after harvesting, the Cd level decreases in the residual soil sample after remediation with the plant to 4.07, 2.93, and 6.02mg/kg in EFKHS, WKHS and control respectively as illustrated by Fig. 1.This shows an appreciable proportion of cadmium was removed from the soil which could be traced to uptake of this metal by the tissues of *K. senegalensis.*

As for the tissues, *K. senegalensis* took up more concentration of Cd in the roots compared to concentrations in the shoots. The total uptake of Cd by the plant with respect to the initial metal in the soil media is 8.13mg/kg 6.83mg/kg, and 2.93mg/kg as represented by the soil media of EFKHS, WKHS and the control respectively (Fig 1).The highest Cd accumulation (5.53±0.56mg/kg) was observed in the root of the *K. senegalensis* planted in the EFKHS growth media while the lowest shoot accumulation of 1.95±0.56mg/kg was observed in the control (Fig 1). As for the root, the highest Cd concentration of 4.23±0.33 mg/kg was observed in growth medium EFKHS represented by EFKHRT. The lowest root accumulation of Cd (1.63±0.56 mg/kg) was detected in the control. One way Anova shows that there is significant difference between the Cd levels in the shoots of the *Khayasenegalensis* obtained from irrigation with tannery effluent, borehole water and control at P < 0.05. The Post Hoc Tukey test however, revealed that the Cd levels in the root of *Khayasenegalensis* from the tannery effluent irrigated medium is not significantly higher than those obtained from the borehole water irrigated soil but significantly higher than control. Also, the root levels of Cd obtained from irrigation with borehole water is significantly higher than control. This results however differs with the findings of Ali *et al*., 2013 for the same plant which had higher Cd levels in the leaf tissues than the root(Ali *et al*., 2013).The deposition of Cd in plants in Cd polluted soil poses serious problems to the health of animals and humans due to its high mobility in contaminated soils(Ullah *et al*., 2021).

Fig. 2 illustrates the uptake of Chromium (Cr) by the tissues of *K. senegalensis* in the respective growth media. The concentrations of Cr after 3months in the tissues were 11.65±1.65 mg/kg, 13.99± 0.82mg/kg, 7.41±2.47 mg/kg, 10.50±1.65 mg/kg, and in EFKHST (shoot), EFKHRT (root), WKHST (shoot), WKHRT (root), respectively and the control plant values gives the lowest concentration of 2.47±0.00mg/kg (shoot) and 2.47±0.00 mg/kg (root). The initial Cr content of the soil media were 52.77mg/kg in both EFKHS and WKHS and 8.33mg/kg in control before planting. However, after harvesting, the Cr level decreases in the residual soil sample after remediation with the plant to 24.69, 32.51and 3.70mg/kg in EFKHS, WKHS and control respectively. The results indicate that in the effluent irrigated media, *K. senegalensis* 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 PTE accumulation in the roots were observed. The results indicate that *K. senegalensis* mopped up more amounts of Cr in the roots compared to concentrations in the shoots (Fig 2). This is in agreement with the findings of Muhammad *et al.,* (2013) in a related research for the same plant. After 3months period, the total uptake of Cr by the plant with respect to the initial metal in the soil media is 25.51mg/kg, 18.93mg/kg and 4.94mg/kg as represented by the soil media of EFKHS, WKHS and the control respectively (Fig 2). The highest Cr accumulation (13.99± 0.82mg/kg) was observed in the root of the *K. senegalensis* planted in the EFKHS growth media while the lowest root accumulation of 2.47±0.00mg/kg was observed in the control (Fig 2).**)** Previous research reports on heavy metal accumulation by several terrestrial plants have also shown that roots have higher metal deposition than other parts of plant (Mohanty & Patra, 2020). Also, in another study, *Hyptissuaveolens* L. roots showed high accumulation of Cr (Sivakumar, 2016). This is consistent with the findings of our study.

One way Anova shows that there is significant difference between the Cr levels in the roots of the *Khayasenegalensis* obtained from irrigation with tannery effluent, borehole water and control at P < 0.05.The Post Hoc Tukey test however, revealed that the Cr levels in the root of *Khayasenegalensis* from the tannery effluent irrigated medium is not significantly higher than those obtained from the borehole water irrigated soil but significantly higher than control. Also, the root levels of Cr obtained from irrigation with borehole water is significantly higher than control.

Fig. 3 illustrates the uptake of Copper (Cu)by the tissues of *K. senegalensis* in the respective growth media. The concentrations of Cu after 3months in the tissues were 7.29±1.80 mg/kg, 6.25±0.00 mg/kg, 6.25±0.00 mg/kg, 4.17±1.80 mg/kg, in EFKHST (shoot), EFKHRT (root), WKHST (shoot), WKHRT (root) respectively and the control plant values gives the lowest concentration of 5.21±1.80mg/kg (shoot) and 3.13±0.00mg/kg (root). The initial Cu content of the growth media were 20.08mg/kg in both EFKHS and WKHS and 15.71 mg /kg in control before planting. However, after harvesting, the Cu level decreases after remediation to 7.29, 8.85, and6.25mg/kg in EFKHS, WKHS and control respectively as illustrated by Fig. 3.The results indicate that in the effluent irrigated media, uptake of Cu in the shoots of *K. senegalensis* was more pronounced compared to concentrations in the roots. A similar trend was observed in the borehole irrigated media. The total uptake of Cu by the plant with respect to the initial metal in the growth media is 13.54mg/kg, 10.42mg/kg and 8.33mg/kg as represented by the growth media ofEFKHS, WKHS and the control respectively (Fig 3). The highest Cu accumulation (7.29±1.80mg/kg) was observed in the shoot of the *K. senegalensis* planted in the EFKHS growth media while the lowest shoot accumulation of 5.21±1.80mg/kg was observed in the control (Fig 3). One way Anova shows that there is significant difference between the Cu levels in the shoots of the *Khayasenegalensis* obtained from irrigation with tannery effluent, borehole water and control at $P < 0.05$.The Post Hoc Tukey test however, revealed that the Cu levels in the shoot of *Khayasenegalensis* obtained from the tannery effluent, borehole water irrigated media and control are not significantly different from each other. 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 result agrees with the findings of (Yang *et al.*, 2020) with another woody specie willow, *Salix spp* which accumulated high quantities of Cu in the shoots. A similar result observation was made with the findings of (Purakayastha *et al.*, 2008) with another plant *Brassica juncea* which accumulated in high quantities of Cu in the shoots.

Fig. 4illustrates the uptake of Nickel (Ni)by the tissues of *K. senegalensis* in the respective growth media. The concentrations of Ni after 3months in the tissues were 3.70±1.60 mg/kg, 4.71±1.60mg/kg, 7.41±4.24mg/kg, 8.33±2.78mg/kg in EFKHST (shoot), EFKHRT (root), WKHST (shoot) and WKHRT (root) respectively and the control plant values gives the lowest concentration of 3.70±1.60mg/kg (shoot) and 6.48±1.60mg/kg (root). The observed initial value of Nickel in EFKHS, WKHS and control were 39.69, 39.69,17.46mg/kg and only a residual amount of 28.70, 23.61, 7.41 mg/kg was detected in the soil media after remediation respectively as depicted by Fig. 4.The results indicate that in the effluent irrigated media, *K. senegalensis* took up more amounts of Ni in the roots compared to concentrations in the shoots. Similar observations were made 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 are 11.11mg/kg, 15.74 mg/kg, and 10.19mg/kg as represented by the growth media of EFKHS, WKHS and the control respectively (Fig 5). The highest Ni accumulation (8.33±0.00mg/kg) was observed in the root of the *K. senegalensis* planted in the WKHS soil media while the lowest root accumulation of 4.71±1.60mg/kg was observed in EFKHS (Fig 4).One way Anova shows that there is significant difference between the Ni levels in the roots of the *Khayasenegalensis* obtained from irrigation with tannery effluent, borehole water and control at $P< 0.05$. The Post Hoc Tukey test however, revealed that the Ni levels in the root of *Khayasenegalensis* obtained from the tannery effluent, borehole water irrigated media and control are not significantly different from each other. 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 results agrees with the findings of (Olajuyigbe and Aruwajoye, 2014)who reported high accumulation for the roots of the same plant.

Fig. 5 illustrates the uptake of Lead (Pb)by the tissues of *K. senegalensis* in the respective growth media. The concentrations of Pb after 3months in the tissues were 7.30±0.29 mg/kg, 10.61±0.57 mg/kg, 2.32±0.29 mg/kg and 3.15±0.29mg/kg in EFKHST (shoot), EFKHRT (root), WKHST (shoot), and WKHRT (root) respectively and the control plant values gives the lowest concentration of 0.50±0.00mg/kg (shoot) and 1.33±0.29mg/kg (root). Fig. 5 also shows the uptake of Lead where the initial value was 31.74 mg/kg in both EFKHS and WKHS and 7.93mg/kg and control. However, decreases in the final level after harvest in mg/kg were 12.02,17.16 and 4.81 respectively. In Effluent irrigated media, *K. senegalensis* mopped up more amounts of Pb in the roots compared to concentrations in the shoots. A similar trend was observed in the borehole irrigated media. After harvesting, the total uptake of Pb by the plant with respect to the initial metal levels in the soil media are 17.91mg/kg, 5.47mg/kg and 1.82mg/kg as represented by the growth media of EFKHS, WKHS and the control respectively (Fig 5). The highest Pb accumulation (10.61±0.57mg/kg) was observed in the root of the *K. senegalensis* planted in the EFKHS growth medium while the lowest root accumulation of 1.33±0.29mg/kg was observed in the control (Fig 5). One Way ANOVA shows that there is significant difference between the Pb levels in the shoots of the *Khayasenegalensis* obtained from irrigation with tannery effluent, borehole water and control at $P < 0.05$. The Post Hoc Tukey test however, revealed that the Pb levels in the root of

Khayasenegalensis from the tannery effluent irrigated medium is significantly higher than those obtained from the borehole water irrigated soil and control. Also, the root levels of Pb obtained from irrigation with borehole water is significantly higher than control. Overall, results show that Pb mostly accumulates in the roots. Our results agree with the findings of (Olajuyigbe and Aruwajoye, 2014 ; Ali *et al*., 2013 for the same plant and (Sharma *et al*., 2021) who reported high Pb concentrations in the roots of *Eclipta alba (L).*

Fig. 6 illustrates the uptake of Zinc (Zn)by the tissues of *K. senegalensis* in the respective growth media. The concentrations of Zn after 3months in the tissues were 9.89±0.00 mg/kg, 18.46±1.14mg/kg, 1.98±0.00mg/kg, and 11.87±0.00mg/kg, in EFKHST (shoot), EFKHRT (root), WKHST (shoot) and WKHRT (root) respectively and the control plant values gives the lowest concentration of 2.64±1.14mg/kg (shoot) and 3.30±1.14mg/kg (root).In the effluent irrigated media, *K. senegalensis* mopped up more amounts of Zn in the roots compared to concentrations in the shoots. Fig 6 also shows Zinc levels in the soil media where the observed initial value of Zincin both EFKHS and WKHS was 87.04mg/kg where the control has a value of35.09mg/kg. A residual amount of 57.70, 71.22, 28.68 mg/kg were detected in the growth media after harvest in EFKHS, WKHS and control respectively. After harvest, the total uptake of Zn by the plant with respect to the initial metal in the growth media is 28.35mg/kg, 13.85mg/kg, 5.93mg/kg as represented by the growth media of EFKHS, WKHS and the control respectively (Fig 6). The highest Zn accumulation (18.46±1.14mg/kg) was observed in the root of the *K. senegalensis* planted in the EFKHS growth medium while the lowest root accumulation of 3.30±1.04mg/kg was observed in the control (Fig 6).One-way ANOVA shows that there is significant difference between the Zn levels in the roots of the *Khayasenegalensis* obtained from irrigation with tannery effluent, borehole water and control at $P < 0.05$. The Post Hoc Tukey test however, revealed that the Zn levels in the root of *Khayasenegalensis* from the tannery effluent irrigated medium is significantly higher than those obtained from the borehole water irrigated soil and control. Also, the root levels of Zn obtained from irrigation with borehole water is significantly higher than control. This results is consistent with the findings of (He *et al*., 2020) and (Steliga and Kluk, 2020)who noted that Zn mainly accumulated in the roots of *Ricinuscommunis* and *Festucaarundinacea* respectively(Yang *et al*., 2020) noted a high concentration of zinc in the roots of salix clones under flooded conditions.

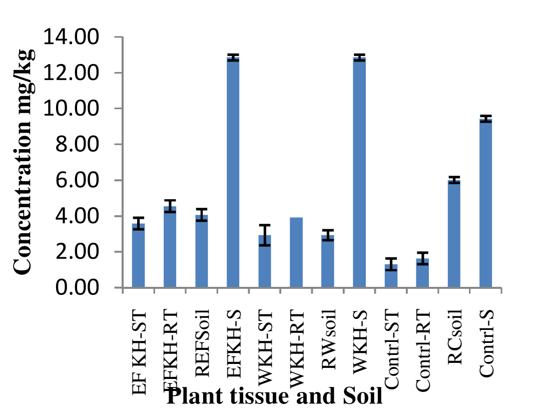


Fig 1 : Concentration of Cadmium in tissues and Soil of *Khayasenegalensis*

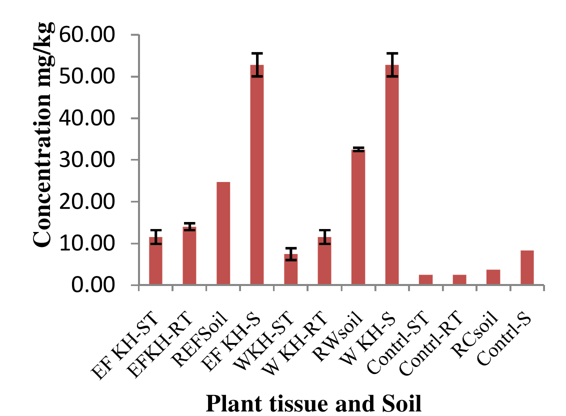
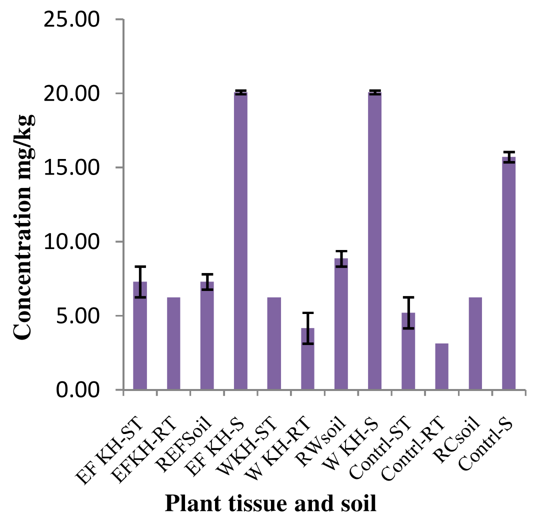


Fig 2. : Concentration of Chromium in tissues and Soil of *Khayasenegalensis*



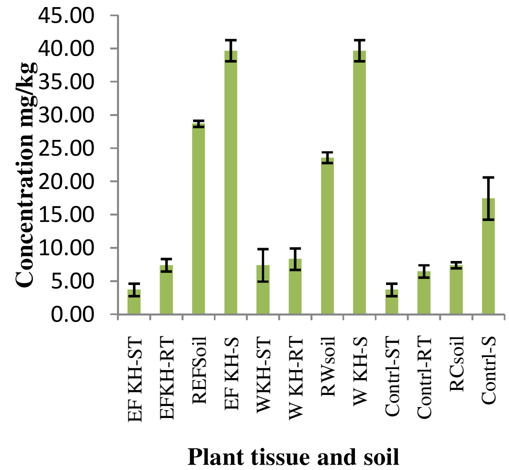
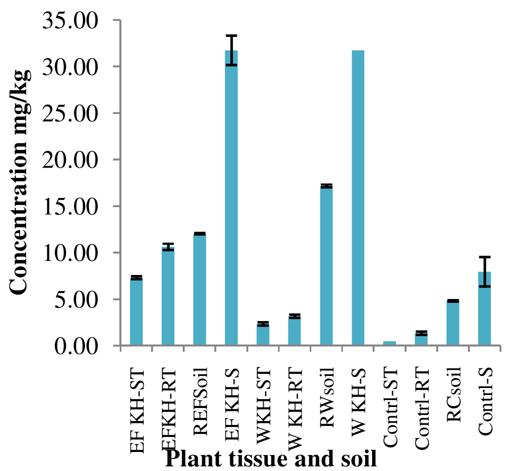


Fig 3 : Concentration of Copper in tissues and Soil of *Khayasenegalensis*

Fig 4: Concentration of Nickel in tissues and soil of *Khayasenegalensis*



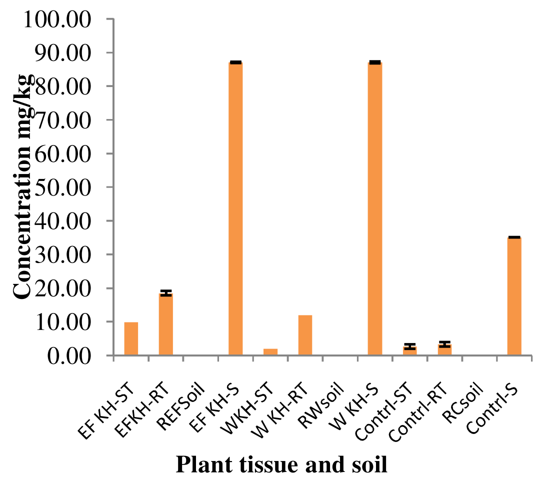


Fig 5: Concentration of Lead in tissues and soil of *Khayasenegalensis*

Fig 6 : Concentration of Zinc in tissues and soil of *Khayasenegalensis*

Translocation 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(Sharma *et al.*, 2021;Madanan *et al.*, 2021)

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

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 *Khayasenegalensis* had concentrations of metals showing TF values of (1.17, 1.50 and 1.67) 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, for Cd (0.79, 0.75 and 0.80),Cr (0.82, 0.64 and 1.00), Ni (0.50, 0.89 and 0.57), Pb (0.69, 0.74 and 0.38) and Zn (0.54, 0.17 and 0.80) concentrations in the tissues of the same plant show values of TF < 1 in growth media irrigated with tannery waste water, borehole water and control respectively (Table 1). This is an indication that this plant could be regarded as an efficient plant for translocation of Cu from the roots to the shoots.

Table 1:Translocation and Bioconcentration for *Khayasenegalensis*

TF				BCF		
	EFKHS	WKHS	CONTROL	EFKHS	WKHS	CONTROL
Cd	0.79	0.75	0.8	0.71	0.51	0.52
Cr	0.82	0.64	1	0.62	0.48	0.49
Cu	1.17	1.5	1.67	0.78	0.67	0.6
Ni	0.5	0.89	0.57	0.42	0.47	0.37
Pb	0.56	0.17	0.23	0.27	0.18	0.21
Zn	0.33	0.16	0.17	0.41	0.2	0.11

Ability of a plant to accumulate metals from contaminated soils was evaluated by the Bioconcentration factor (BCF) using the formula (Madanan *et al*., 2021).

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

This study assumed that plants with BCF values > 1 are accumulators, while plants with BCF values less than 1 are excluders. The results in this study showed that *Khayasenegalensis* irrigated with tannery effluent, borehole water and control had BCF values <1 for the elements, Cd, Cr, Ni, Pb and Zn indicating that the plant has the potential to be used as excluders (Phytostabilization). This property may be employed in phytostabilization where it is necessary to maintain the metals below the ground.

CONCLUSION

The study was able to reveal *Khayasenegalensis* as anaccumulator of Cu and is recommended for phytoextraction of this metal. Furthermore, the study revealed the potentials of this plant to be used as excluders of Cd, Cr, Ni, Pb and Zn. The elevated concentration of these metals in its roots and low translocation to above ground parts show suitability for phytostabilization of these metals. Therefore, planting *Khayasenegalensis* in soils polluted with these metals as a result of contamination from tannery waste water can be an ideal option for phytostabilization. This will checkmate soil polluted with toxic elements as a result of pollution from tannery waste water.

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

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.

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