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ASSESSMENT OF *AZADIRACHTA INDICA* (L.) IN THE REMOVAL OF HEAVY METAL FROM SOIL CONTAMINATED WITH LEAD POISONING IN ANKA, ZAMFARA STATE

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ABSTRACT

This study was conducted to assess the potentials of *Azadirachta indica* (L.) in the removal of heavy metal from soil contaminated with lead poisoning in Anka, Zamfara State. Soil and *Azadirachta indica* samples were collected and analyzed for physico-chemical and heavy metals. Contamination and transfer factors were also calculated. The results of physico-chemical parameters revealed that Anka (control) has highest pH H_20 (1:2.50); 7.63, Organic Carbon (OC); 1.54%, Total Nitrogen (TN); 1.91%; Cationic Exchange Capacity (CEC); and 5.52cmol kg^{-1}. Abare has the highest values of Available Phosphorus (AP); 32.55 mg/kg, Electrical Conductivity (CEe); 1.33d/sm. The textural classes were Loamy Sand (LS). The highest concentrations of heavy metals were in Abare; Zn (54.68mg/kg), Mn (51.19mg/kg), Pb (493.85mg/kg) and Cd (3.78mg/kg). The highest CF of all the heavy metals was found in Abare with Zn (0.18), Mn (0.03), Pb (4.94) and Cd (1.26). Bagega has the highest concentrations of transfer factor (TF) of Mn (2.10), Pb (1.48) and Cd (0.75) while Anka town has the highest TF of Zn (2.53). The results obtained showed that soil physico-chemical properties enhance mobility and availability of heavy metals. *Azadirachta indica* can accumulate heavy metals from contaminated soils as the concentrations of the heavy metals were reduced in the polluted soils. The contamination factors revealed that most values fall within none to medium contamination due to the phytoremediation potential of the plant. Thus *Azadirachta indica* posses high phytoremediation potentials as it helps in reducing the high amount of heavy metals in the soil.

Keywords: Anka Assessment Concentration Lead Soil

INTRODUCTION

Phytoremediators are living plants that are used to clean up soil, air, and water contaminated with hazardous contaminants. These plants take up and accumulate elements in their tissue but can also be released back into the surrounding medium. The accumulation of an element by the plant therefore is referred to as net uptake and is based on both influx and efflux. Part of the element taken up is translocated further to other plant parts which continue to build in the body (Gul *et al*., 2021). The net uptake may be of different magnitude depending on the plant genotype which helps to reduce the concentrations of the heavy metals and other pollutants in the environment. Excluders plants are those that have low uptake of the element at quite high external concentrations of the element (Van der Ent *et al*., 2013). These plants have some kind of barrier to avoid uptake, but when the external concentrations become too high, this barrier loses its function, probably due to toxic action by the element, and uptake increases massively. Accumulators or includes are plants that have high accumulation of elements at very low external element concentrations (Lange *et al*., 2017). These plants have certain detoxification mechanisms within the tissue, which allows the plant to accumulate such high amounts of metals. At high external concentrations, however, these plants do not increase their uptake, probably due to competition between elements at the uptake site. A special case of accumulator is the hyperaccumulator, which shows extreme accumulation of the element in leaves. These plants have high phytoremediation potential and thus reducers the level of pollutants in the environment (Rocha *et al*., 2021).

A heavy metal is any one of a number of elements that exhibit metallic properties, which includes transition metals, lanthanides, actinides as well as the metalloids, Arsenic and Antimony (Rudakiya and Patel, 2021). While many heavy metals have considerable toxicity such as lead, cadmium, manganese, chromium among others, while there are those that are considered not deemed to possess significant toxic properties, and, in fact, several of these elements including zinc, iron, copper, chromium and cobalt are necessary for metabolic function for a large class of organisms. Although some heavy metals are essential micronutrients for animals, plants and many micro-organisms, depending on the route and dose, all heavy metals demonstrate toxic effects on living organisms via metabolic interference and mutagenesis (Rehman *et al*., 2021). The rate at which heavy metals accumulated in the soil depends on the physico-chemical properties of the soil and the relative efficiency of plants to remove the metals from the soil, therefore soil physico-chemical parameters plays a vital role in determining the level of contamination of the heavy metals in the soil and the rate of transfer of the heavy metals from the soil to the plant parts. For examples pH affects the mobility of heavy metals in soil. It has been found that soil pH is correlated with the availability of nutrients to the plant (Lwin *et al*., 2018). Texture is related to certain physical properties of soil such as plasticity, permeability, ease of tillage, fertility, water holding capacity and overall soil productivity (Kome *et al*., 2019).

The aim of this research is to assess the potentials of *Azadirachta indica* (L.) in the removal of heavy metal from soil contaminated with lead poisoning in Anka, Zamfara State. The objectives are to determine the soil physico-chemical properties before and after phytoremediation, to determine the heavy metal concentrations of soil before and after phytoremediation and *Azadirachta indica* as well as to determine the factors responsible for phytoremediation ability of *Azadirachta indica*.

MATERIALS AND METHODS

Study Area

The study was carried out at some selected areas (Abare, Bagega and Anka town) in Anka Local Government Area of Zamfara State (latitude 12°06'30"N and longitude 5°56'00"E).

Abare and Bagega have been recorded to have high levels of some heavy metals especially lead while Anka town serves as a control.

Soil Sample Collection and Preparation

Soil samples were collected at a depth of 0-10 cm using a soil auger. The samples were packaged in clean polythene bags and labeled accordingly. The samples were taken in two replicates as described by Bako *et al*. (2014). The samples were crushed and sieved through a 2.0mm mesh in the laboratory as described by Iyaka (2007).

***Azadirachta indica* Collection and Preparation**

Azadirachta indica samples were collected directly where the soil samples were obtained. The samples were taken in two replicates to the laboratory for preparation. The samples were washed with tap water followed by rinsing with distill water in order to remove all the debris present, the samples were air dried for 2 – 3 hours followed by oven dried for 24 hours at 105°c. They were crushed with the aid of porcelain mortar and pestle and then sieved through a 2.0mm mesh to obtain powdered form as described by Iyaka (2007).

Determination of Physico-chemical Parameters of Soil

The pH of the soil was measured in a 1:2.50 soil - water suspension ratio and also in 0.01M$CaCl_2$ using a glass electrode pH meter (Jaiswal, 2003). The electrical conductivity of the soil samples was measured alongside pH with an EC meter using the same soil - water suspension 1:2.50 used for measuring the soil pH in water (Jaiswal, 2003). The Organic carbon was oxidized by potassium dichromate ($K_2Cr_2O_7$) in the presence of sulphuric acid (H_2SO_4) and the carbon was titrated with 0.5N ferrous sulphate using diphenylamine indicator (Jaiswal, 2003). The total nitrogen content of the samples was determined by the Kjeldahl wet oxidation method (Bremner, 2007). The cation exchange capacity (CEC) of the soil samples was determined by neutral normal ammonium acetate displacement method. The available phosphorus content of the samples was determined by bicarbonate extraction method for near neutral and slightly alkaline soils (Parker *et al*., 2002). The particle size of the sample size was determined using the Buoyocuos hydrometer method as used by Gerenfes *et al*. (2022) and Jiswal (2003). The texture of the soil was obtained by applying the result of the particle size distribution to the Marshall's textural triangle.

Soil and *Azadirachta indica* Samples Digestion

About 5.0 g of dried soil and 100ml of soil and *Azadirachta indica* samples were **transferred separately to a 25ml conical flask**; 10 ml of concentrated HNO_3acid and 5 ml of concentrated HCl in ratio 2:1 were added and heated on a hot plate making sure the sample did not boil, until the volumes were reduced to about 15ml. The samples were then allowed to cool, filtered and quantitatively transferred into a 100ml standard volumetric flask and made up to mark with distilled water and further analyzed using A.A.S. as described by APHA (2000).

Determination of Heavy Metal Concentrations in Soil and Plant

Concentrations of Cd, Zn, Pb and Mn in the filtrate of digested soil and *Azadirachta indica*samples were analyzed by using Atomic Absorption Spectrophotometer (A. A. S.). The Instrument conditions and specifications are: Lead – wavelength 283.3 nm, slit 0.7 nm, atomization 2000ºC, read time 3 s, sample volume 10 µl, modifiers volume 20 µl. Cadmium - wavelength 228.8 nm, slit 0.7 nm, atomization 1 550ºC, read time 3 s, sample volume 10 µl, modifiers volume 20 µl.

The Contamination Factor of the Heavy Metals

The Contamination Factor was calculated as the ratio between metals effectively measured by chemical analysis to the reference value as described by Obasi *et al*. (2012). The reference standards used in the calculation was the Federal Environmental Protection Agency (FEPA, 1997) target value. Contamination factors of each heavy metal were calculated as given below:

Contamination Factor = Concentration of metal in soil (Liu *et al*., 2005)

Standard recommended maximum value in soil

Contamination Factor is used to determine the contamination status of the soil. The intensity of contamination is reflected on a scale with zero indicating no contamination, 1 none to medium, 2 moderate, 3 moderate to strong, 4 strong, 5 strong to very strong, and 6 high contamination (Nafiu, 2010).

Transfer Factors (TF) of the Heavy Metals from Soils to the Plant

Transfer factor (TF) is the ratio of the concentration of heavy metal in a plant to the concentration of heavy metal in soil. It signifies the amount of heavy metals in the soil that ended up in the *Azadirachta indica* (Kumar *et al*., 2021). One approach to assess the mobility of metal from soil to plants is to calculate transfer factor (TF) (Nahar and Shahadat Hossen, 2021). The higher the value of the TF, the more mobile/available the metal is for plant absorption. The transfer factors for each heavy metal were computed based on the method described by Uwah *et al*. (2009). The heavy metals transfers from soil to the *Azadirachta indica* were calculated as follows:

$$\text{Transfer Factor} = \frac{\text{Metal content in plant (mg/kg)}}{\text{Metal content in soil (mg/kg)}}$$

Data Analysis

Data collected were subjected to Analysis of Variance (ANOVA) at 5% level of significance ($p<0.05$). Where significant differences were observed among treatments, the means were separated using Duncan's Multiple Range Test (DMRT). The analysis was performed using SAS V. 9.4 (2020).

RESULTS AND DISCUSSION

Physico-chemical Parameters of Soils Before and After the Phytoremediation Process with *Azadirachta indica*

There were significant differences in the soil physico-chemical properties before and after phytoremediation processes with *Azadirachta indica* ($p< 0.05$) (Table 1). Anka Town (control) has the highest values of the following in both before and after phytoremediation respectively: pH H_20 (1:2.50); 7.30 and 7.63 before and after phytoremediation respectively, Organic Carbon (OC); 0.21% and 1.54%, Total Nitrogen (TN); 0.83% and 1.91%; Cationic Exchange Capacity (CEC); 3.82cmol kg^{-1} and 5.52cmol kg^{-1}. Abare has the highest values of the following in both before and after phytoremediation respectively: Available Phosphorus (AP); 12.81mg/kg and 32.55 mg/kg, Electrical Conductivity (CEe); 0.93ds/m and 1.33ds/m. However, all the textural classes were Loamy Sand (LS).

Anka town (control) has the highest values of pH H_20 (1:2.50) which is an indication that the soil is slightly alkaline. According to Zitta *et al*. (2022), soil that is alkaline in nature provides best growing condition and influences the uptake of nutrients by plants. Soil pH strongly influences soil processes such as nitrogen cycling by affecting the soil chemical, physical and biological processes (Abujabhah *et al*., 2018). Similarly, the highest of values of organic carbon was found in Anka, these highest values indicated that the soil is moderately evaluated. Study by Hayashi *et al*. (2022) revealed that soil high in organic carbon content is rich in mineral constituents which improve plant growth. It plays a huge role in the soil texture and water retention. Highest values of total nitrogen present in Anka soil is an indication of high nitrogen contents in the soil. This could be associated with the high organic carbon present in the soil. The highest amount of cationic exchange in Anka soil is an indication of high amount of hydrogen concentration. Previous study by Zitta *et al*. (2022) revealed that cationic exchange and nitrogen correlates with organic carbon thus improving soil nutrients. The highest available phosphorus is found in Abare, this is an indication that the soil is very low in the content. The highest range of electrical conductivity values obtained in Abare indicates that the soil is saline in nature. The result obtained is an indication of salinity from the sampled area. This is an indication of poor yield from the soil. Increased salinity level in the root medium reduces the uptake of K, Ca, and Mg which disrupts stomatal conductance and transpiration rate (Sharmin *et al*., 2021). Similarly, the high salinity values in Abare soil are an indication of high amount and availability of heavy metals in the soil. However, after phytoremediation with *Azadirachta indica* revealed increased amounts of all the physico-chemical parameters. This could be due to reduction in contamination load of the heavy metals present in the soil by the plant and the rate of metal transfer from the soil to the plant. The textural class of soil of the studied areas is loamy sand. According to Zitta *et al*. (2022) soil texture is the relative proportion of the different particle size fractions, specifically referred to as sand, silt and clay. As seen in this study, the sampled soil had a relative proportion of sandy, clay and silt. Furthermore, it is also an indicator of some other related soil features such as type of parent material, homogeneity and heterogeneity within the profile, migration of clay and intensity of weathering of soil material or age of the soil (Zitta *et al*., 2022).

Table 1: Physico-chemical Parameters of Soils Before and After the Phytoremediation Process with *Azadirachta indica*

		Soil Properties						Texture (%)			
Conditions	**Sites**	**pH H_20 (1:2.50)**	**ECe (ds/m)**	**OC (%)**	**TN (%)**	**CEC (cmol kg^{-1})**	**AP (mg/kg)**	**Sand**	**Clay**	**Silt**	**Class**
	Abare	3.52 ± 0.02^c	0.93 ± 0.02^a	0.11 ± 0.01^b	0.45 ± 0.05^b	1.23 ± 0.03^c	12.81 ± 0.01^a	85.1	7.5	25.3	LS
Before Rem.	Bagega	6.51 ± 0.01^b	0.81 ± 0.01^b	0.15 ± 0.02^b	0.51 ± 0.01^b	2.91 ± 0.01^b	9.51 ± 0.01^b	82.4	7.2	22.2	LS
	Anka Town	7.30 ± 0.01^a	0.52 ± 0.02^c	0.21 ± 0.01^a	0.83 ± 0.07^a	3.82 ± 0.02^a	5.62 ± 0.02^c	80.6	8.1	12.4	LS
	P – Value	**0.000****	**0.001****	**0.019***	**0.021***	**0.000****	**0.000****				
	Abare	3.84 ± 0.03^c	1.33 ± 0.03^a	1.02 ± 0.02^c	1.12 ± 0.01^c	2.93 ± 0.03^c	32.55 ± 0.05^a	85.1	7.5	25.3	LS
After Rem.	Bagega	6.84 ± 0.04^b	1.21 ± 0.01^b	1.22 ± 0.02^b	1.72 ± 0.02^b	4.61 ± 0.01^b	29.24 ± 0.04^b	82.4	7.2	22.2	LS
	Anka Town	7.63 ± 0.03^a	0.92 ± 0.02^c	1.54 ± 0.04^a	1.91 ± 0.01^a	5.52 ± 0.02^a	25.34 ± 0.04^c	80.6	8.1	12.4	LS
	P – Value	**0.000****	**0.001****	**0.002****	**0.000****	**0.000****	**0.000****				

Conditions: Before and after the phytoremediation process with *Azadirachta indica*. Means with the same superscripts along the same column are not statistically different ($p< 0.05$) using Duncan's Multiple Range Test (DMRT).

Keys: LS: Loamy Sand, Anka Town – Control, ECe – Electrical Conductivity, OC – Organic Carbon, TN – Total Nitrogen, CEC – Cationic Exchange Capacity, AP–Available Phosphorus, ****** – Highly Significant, ***** – Significant

Heavy Metal Concentrations (mg/kg) of Soils Before and After the Phytoremediation Process with *Azadirachta indica*

There were significant differences in the soil heavy metal concentration before and after phytoremediation processes with *Azadirachta indica* ($p < 0.05$). Abare was found to have the highest concentrations of all the heavy metals in both before and after phytoremediations with *A. indica*. Before phytoremediations, the concentrations were; Zn (54.68mg/kg), Mn (51.19mg/kg), Pb (493.85mg/kg) and Cd (3.78mg/kg) while after phytoremediations, the concentrations were Zn (16.13mg/kg), Mn (16.84mg/kg), Pb (292.63mg/kg) and Cd (2.25mg/kg). Anka town (control) was found to have the lowest concentrations of all the heavy metals in both before and after phytoremediations with *A. indica*. Before phytoremediations, the concentrations were; Zn (12.05mg/kg), Mn (20.18mg/kg), Pb (11.72mg/kg) and Cd (1.91mg/kg) while after phytoremediations, the concentrations were Zn (3.36mg/kg), Mn (9.03mg/kg), Pb (7.38mg/kg) and Cd (1.01mg/kg). However, the highest concentrations of Zn and Mn in both before and after phytoremediation as well as Cd after phytoremediation were below the WHO (1996) permissible limit of heavy metals for soil while Pb before and after phytoremediation as well as Cd before were above the permissible limit. However, all the heavy metal concentrations present in this study were lower after phytoremediation with *Azadirachta indica*. The concentrations of the heavy metals before phytoremediation were presented in the following order Pb > Zn > Mn > Cd, while after phytoremedaition were in the order of Pb > Mn > Zn > Cd (Table 2).

The highest concentrations of all the heavy metals in Abare could be due to the fact that pH was slightly acidic. Lower pH values in soil lead to higher heavy metal solubility **(**Singh *et al*., 2010**)**. Acidic soil results in the availability of heavy metals. The lower concentrations of the heavy metals in the control (Anka) could be as a result of alkaline pH in the soil which tends to reduce the availability and mobility of the heavy metals. Similar finding was obtained by **Zakari and Audu (2021)** who studied Phytoremediation of contaminated soils. Those heavy metals found to be above WHO (1996) could pose health risk to the community.

Table 2: Heavy Metal Concentrations (mg/kg) of Soils Before and After the Phytoremediation Process with *Azadirachta indica*

Conditions	Sites	Zn	Mn	Pb	Cd
Before Rem.	Abare	54.68 ± 1.58[a]	51.19 ± 0.18[a]	493.85 ± 2.74[a]	3.78 ± 0.02[a]
	Bagega	14.38 ± 0.23[b]	35.09 ± 0.09[b]	282.48 ± 0.72[b]	2.75 ± 0.16[b]
	Anka Town	12.05 ± 0.05[b]	20.18 ± 0.07[c]	11.72 ± 0.18[c]	1.91 ± 0.04[c]
	P - Value	***0.000****	***0.000****	***0.000****	***0.002****
After Rem.	Abare	16.13 ± 0.02[a]	16.84 ± 0.04[a]	292.63 ±3.46[a]	2.25 ± 0.10[a]
	Bagega	6.65 ± 0.05[b]	13.78 ± 0.08[b]	114.34 ± 0.26[b]	1.62 ± 0.02[b]
	Anka Town	3.36 ± 0.25[c]	9.03 ± 0.06[c]	7.38 ± 0.23[c]	1.01 ± 0.01[c]
	P – Value	***0.000****	***0.000****	***0.000****	***0.002****
	WHO (1996)	**300**	**2000**	**100**	**3.0**

Conditions: Before and after the phytoremediation process with *Azadirachta indica*. Means with the same superscripts along the same column are not statistically different ($p < 0.05$) using Duncan's Multiple Range Test (DMRT).
Keys: Rem. – Remediation, Anka Town – Control, Zn – Zinc, Mn – Manganese, Pb – Lead,
Cd – Cadmium, ****** – Highly Significant. WHO (1996) – World Health Organization Permissible Limit of Heavy Metals for Soil

Heavy Metal Concentrations (mg/kg) in *Azadirachta indica*

The highest concentrations of all the heavy metals in *Azadirachta indica* were found in Abare with Zn (40.05mg/kg), Mn (34.10mg/kg), Pb (200.37mg/kg) and Cd (1.54mg/kg). While the lowest concentrations were found in Anka town with Zn (8.49mg/kg), Mn (11.08mg/kg), Pb (2.38mg/kg) and Cd (0.61mg/kg). However, all the concentrations of Zn and Mn were found to be below the WHO (1996) permissible limit of heavy metals for plants while concentrations of Pb and Cd were above. The concentrations of the heavy metals in *Amaranthus indica* were presented in the following order Pb > Zn > Mn > Cd (Table 3).

The high concentrations of these heavy metals were present in Abare and these concentrations were found to accumulate high in the plant tissues, the uptake of metals in the plant tissues indicates that the soluble metals can enter into the root cytoplasm by crossing the plasma membrane of the root of the endodermal cells (**Lv*et al*., 2019**). The roots of **Azadirachta indica** accumulated high levels of all the heavy metals indicating that it has great potentials for phytoextraction of these metals from contaminated soil.

Table 3: Heavy Metal Concentrations (mg/kg) in *Azadirachta indica*

Sites	Zn	Mn	Pb	Cd
Abare	40.05 ± 0.05[a]	34.10 ± 0.40[a]	200.37 ± 0.14[a]	1.54 ± 0.01[a]
Bagega	8.86 ± 0.04[b]	28.91 ± 0.41[b]	169.06 ± 0.06[b]	1.21 ± 0.06[b]
Anka Town	8.49 ± 0.01[c]	11.08 ± 0.08[c]	2.38 ± 0.02[c]	0.61 ± 0.02[c]

P – Value	***0.000*****	***0.000*****	***0.000*****	***0.001*****
WHO (1996)	**100**	**500**	**0.30**	**0.10**

Means with the same superscripts along the same column are not statistically different (p< 0.05) using Duncan's Multiple Range Test (DMRT).
Anka Town – Control, Zn – Zinc, Mn – Manganese, Pb – Lead, Cd – Cadmium,
****** – Highly Significant. WHO (1996) – World Health Organization Permissible Limit of Heavy Metals for Plants.

Contamination Factor (CF) of the Heavy Metals
Table 4 revealed the contamination factors of the heavy metals studied. The highest CF of all the heavy metals were found in Abare with Zn (0.18), Mn (0.03), Pb (4.94) and Cd (1.26) before phytoremediation; Zn (0.05), Pb (2.93) and Cd (0.75) after phytoremediation. The lowest were found in Anka town (control) with Zn (0.04), Mn (0.01), Pb (0.12) and Cd (0.48) before phytoremediation; Zn (0.01), Pb (0.07) and Cd (0.34) after phytoremediation.

The result indicated that the highest contamination factor was found in Pb in Abare before phytoremediation, the highest value obtained revealed strong to very strong contamination while the least CF values were obtained in Mn in the three locations after phytoremediation indicating no contamination, however, majority of the values falls within none to medium contamination, this could be as a results of phytoremediation by *Azadirachta indica*. *Azadirachta indica* was found to be effective in reducing pollution load of heavy metal concentrations in the soil (Patel, 2020).

Table 4: Contamination Factor (CF) of the Heavy Metals

Conditions	Sites	Zn	Mn	Pb	Cd
	Abare	0.18	0.03	4.94	1.26
Before Remediation	Bagega	0.05	0.02	2.82	0.92
	Anka Town	0.04	0.01	0.12	0.48
	Abare	0.05	0.00	2.93	0.75
After Remediation	Bagega	0.02	0.00	1.14	0.54
	Anka Town	0.01	0.00	0.07	0.34

Anka Town – Control, Zn – Zinc, Mn – Manganese, Pb – Lead, Cd – Cadmium

Transfer Factors (TF) of the Heavy Metals from Soils to *Azadirachta indica*
The transfer factors of the heavy metals from soils to *Azadirachta indica* were presented in Table 4. Bagega has the highest concentrations of TF of Mn (2.10), Pb (1.48) and Cd (0.75) with lowest concentration of Zn (1.33) while Anka town has the highest TF of Zn (2.53) with lowest concentrations of Mn (1.23), Pb (0.32) and Cd (0.60).

The highest concentrations of TF of Mn, Pb, and Cd in Bagega as well as Zn in Anka town might be due to higher mobility of these heavy metals with a natural occurrence in soil (Alam *et al.*, 2003). The high TF values obtained in these soils might be attributed to the physico-chemical properties of the soils which might have enhanced soil-plant transfer of the metals (Chaoua *et al*., 2019).

Table 5: Transfer Factors (TF) of the Heavy Metals from Soils to *Azadirachta indica*

Sites	Zinc (Zn)	Manganese (Mn)	Lead (Pb)	Cadmium (Cd)
Abare	2.48	2.02	0.68	0.68
Bagega	1.33	2.10	1.48	0.75
Anka Town	2.53	1.23	0.32	0.60

Anka Town – Control

CONCLUSIONS
The results obtained showed that soil physico-chemical properties enhance mobility and availability of heavy metals. *Azadirachta indica* can accumulate heavy metals from contaminated soils as the concentrations of the heavy metals were reduced in the polluted soils. The contamination factors revealed that most values fall within none to medium contamination due to the phytoremediation potential of the plant. The high TF values obtained in these soils might be attributed to the physico-chemical properties of the soils which might have enhanced soil - plant transfer of the metals. Thus *Azadirachta indica* posses high phytoremediation potentials as it helps in reducing the high amount of heavy metals in the

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CONFLICT OF INTEREST
There is no conflict of interest.

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REFERENCES
Abujabhah, I. S., Doyle, R. B., Bound, S. A. and Bowman, J. P. (2018). Assessment of bacterial community composition, methanotrophic and nitrogen-cycling bacteria in three soils with different biochar application rates. *Journal of Soils and Sediments*, **18**(1): 148 - 158.

American Public Health Association. (A.P.H.A.). (2000). Standard methods for the examination of water and wastewater, 22nd edition. Washington, D.C. pp. 1291.

Bako, S. P., Ezealor, A. U. and Tanimu, Y. (2014). Heavy Metal Deposition in Soils and Plants Impacted by Anthropogenic Modification of Two Sites in the Sudan Savanna of North Western Nigeria. pp. 57.

Bremner, J. M. (2007). Nitrogen-Total in Method of Soils Analysis, Part 3: Chemical Methods. Sparks, D. L. (Ed). Soil ScienceSociety of America, Madison, W. I., USA., pp: 1085 - 1121.

Chaoua, S., Boussaa, S., El Gharmali, A. and Boumezzough, A. (2019). Impact of irrigation with wastewater on accumulation of heavy metals in soil and crops in the region of Marrakech in Morocco. *Journal of the Saudi Society of Agricultural Sciences*, **18**(4): 429 - 436.

Gerenfes, D. Giorgis, G. A. and Negasa, A. (2022). Comparison of Organic Matter Determination Methods in Soil by Loss on Ignition and Potassium Dichromate Method. International Journal of Horticulture and Food Science, 4(1), 49 - 53.

Gul, I., Manzoor, M., Hashim, N., Shah, G. M., Waani, S. P. T., Shahid, M., ... and Arshad, M. (2021). Challenges in microbially and chelate-assisted phytoextraction of cadmium and lead–A review. *Environmental Pollution*, **287**: 117667.

Hayashi, R., Maie, N., Wagai, R., Hirano, Y., Matsuda, Y., Makita, N., ... and Tanikawa, T. (2022). An increase of fine-root biomass in nutrient-poor soils increases soil organic matter but not soil cation exchange capacity. *Plant and Soil*, 1 - 22.

Iyaka, Y. A. (2007). Concentration of Cu and Zn in some fruits and vegetables commonly available in North Central Zone of Nigeria. *Electron. Journal of Environment, Agriculture and Food Chemistry,* **6**: 2150 - 2154.

Jaiswal, P. C. (2003). Soil, Plant and Water Analysis. Kalyami Publisher Ludhiana – New Delhi- Noid (UP), Indian, PP.98 - 103.

Kome, G. K., Enang, R. K., Tabi, F. O. and Yerima, B. P. K. (2019). Influence of clay minerals on some soil fertility attributes: a review. *Open Journal of Soil Science*, **9**(9): 155 - 188.

Kumar, H., Sahoo, P. K. and Mittal, S. (2021). Sustainable remediation of heavy metals: A review of current status and its future prospects. *New Trends in Removal of Heavy Metals from Industrial Wastewater*, 571 - 610.

Lange, B., van der Ent, A., Baker, A. J. M., Echevarria, G., Mahy, G., Malaisse, F., ... and Faucon, M. P. (2017). Copper and cobalt accumulation in plants: a critical assessment of the current state of knowledge. *New Phytologist*, **213**(2): 537 - 551.

Liu, W. H., Zhao, J. Z., Ouyang, Z. Y., Söderlund, L. and Liu, G. H. (2005). Impacts of Sewage irrigation on Heavy Metal distribution and contamination in Beijing, China. *Environment International*, **31**(6): 805 – 812.

Lv, J., Christie, P. and Zhang, S. (2019). Uptake, translocation, and transformation of metal-based nanoparticles in plants: recent advances and methodological challenges. *Environmental Science: Nano*, **6**(1): 41 - 59.

Lwin, C. S., Seo, B. H., Kim, H. U., Owens, G. and Kim, K. R. (2018). Application of soil amendments to contaminated soils for heavy metal immobilization and improved soil quality—A critical review. *Soil science and plant nutrition*, **64**(2): 156 - 167.

Nafiu, A. (2010). Geochemical assessment, distribution and dynamics of Trace Elements in contaminated Urban Soil under long term Wastewater irrigation in Kano, Northern Nigeria. *African Journal of Earth Science*, **5**: 4.

Nahar, N. and Shahadat Hossen, M. (2021). Influence of sewage sludge application on soil properties, carrot growth and heavy metal uptake. *Communications in Soil Science and Plant Analysis*, **52**(1): 1 - 10.

Obasi, N. A., Akubugwo, E. I., Ugbogu, O. C. and Otuchristian, G. (2012). Assessment of Physico-chemical Properties and Heavy Metals bioavailability in Dumpsites along Enugu/Port-Harcourt Expressways, South-east, Nigeria. *Asian Journal of Applied Sciences*, **5**(6): 342 – 356.

Parker, J. L., Fernandez. I. V., Rustad, E. L. and Norton, A. S. (2002). Soil Organic Matter Fractions in Experimental ForestedWatersheds. Water, Air, and Soil Pollut. **138**: 101 – 121.

Patel, H. (2020). Batch and continuous fixed bed adsorption of heavy metals removal using activated charcoal from neem (*Azadirachtaindica*) leaf powder. *Scientific Reports*, **10**(1): 1 - 12.

Rehman, A. U., Nazir, S., Irshad, R., Tahir, K., ur Rehman, K., Islam, R. U. and Wahab, Z. (2021). Toxicity of heavy metals in plants and animals and their uptake by magnetic iron oxide nanoparticles. *Journal of Molecular Liquids*, **321**: 114455.

Rocha, C. S., Rocha, D. C., Kochi, L. Y., Carneiro, D. N. M., Dos Reis, M. V. and Gomes, M. P. (2021). Phytoremediation by ornamental plants: a beautiful and ecological alternative. *Environmental Science and Pollution Research*, 1 - 19.

Rudakiya, D. M. and Patel, Y. (2021). Bioremediation of metals, metalloids, and nonmetals. In *Microbial Rejuvenation of Polluted Environment* (pp. 33 - 49). Springer, Singapore.

Sharmin, S., Lipka, U., Polle, A. and Eckert, C. (2021). The influence of transpiration on foliar accumulation of salt and nutrients under salinity in poplar (Populus× canescens). *PloS one*, **16**(6): e0253228.

Singh, A., Agrawal, M. and Marshall, F. M. (2010). The role of organic vs. inorganic fertilizers in reducing phytoavailability of heavy metals in a wastewater-irrigated area. *Ecological Engineering*, **36**(12): 1733 - 1740.

Uwah, E. I., Ndahi, N. P. and Ogugbuaja, V. O. (2009). Study of the Levels of some Agricultural Pollutants in Soils, and Water Leaf (*Talinum triangulare*) obtained in Maiduguri, Nigeria. *Journal of Applied Science and Environment, Sanita*, **4**(2): 71 – 78.

Van der Ent, A., Baker, A. J., Reeves, R. D., Pollard, A. J. and Schat, H. (2013). Hyperaccumulators of metal and metalloid trace elements: facts and fiction. *Plant and soil*, **362**(1): 319 - 334.

Zakari, A. and Audu, A. A. (2021). Bioaccumulation and Translocation of Potentially Toxic Elements (PTEs) by Khaya Senegalensis at Challawa Industrial Estate, Kano, Nigeria. *Journal of Material and Environmental Science*, **12**(5): 684 - 692.

Zitta, W. S., Sarah, J. and Jack, K. K. (2022). Physio-Chemical Properties of Soil in Ganawuri, Plateau State, Nigeria.

Infrastructure Project in Indian Construction Industry. *The International Journal of Business & Management*, 171-175.

Vivian W. Y. Tam and Liyin Y. Shen (2012). Risk Management for Contractors in Marine Projects, 'An International *Journal in Engineering and Technology*, pp. 403-410, DOI: 10.5592/OTMCJ.2012.1.5.

Yang Zou, Arto Kiviniemi and Stephen W. Jones (2015). A Review of Risk management through BIMand BIM-related Technologies, *Journal of Safety Science*, accepted by Elsvier

Zou, P. X., Wang, G. Z., & Jia-Yuan, P. (2005). Identifying Key Risks in Construction Projects: Life Cycle and Stakeholder Perspectives. 1-14