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Phytoremediation Potential of *Jatropha Curcas* and *Cassia Occidentalis* on Selected Heavy Metals in the Soil

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ABSTRACT

The potential of *Cassia occidentalis* and *Jatropha curcas* to remediate the heavy metals: Pb, Mn, Zn, Cr and Cu in polluted soil was studied. The seedlings of the plants, *Cassia occidentalis* and *Jatropha curcas* were obtained and planted in six pots which were spiked with aqueous solution of each metal. The matured plants were harvested and separated into roots, stem and leaves. Standard operating procedures was used to extract the metals from the plant parts. Results revealed uptake of the metals through the roots, stem and leaves of the plants. *Cassia occidentalis* and *Jatropha curcas* grown in the spiked soil showed relatively higher values for the uptake of the analysed metals as compared to those grown on the control soil. The order of metal accumulation in the parts of the plant are: Pb, leaves > root > stem; Mn, roots > leaves > stem; Zn, roots > leaves > stem; Cr, roots > leaves > stem and Cu, leaves > roots > stem, for *C. occidentalis*, while for *J. cucas* metals accumulation was found to be in the order: Pb, stem > roots > leaves; Mn, stem > roots > leaves; Zn, roots > stem > leaves; Cr, stem > roots > leaves and Cu, stem > roots > leaves. The Translocation Factor (TF) revealed that Pb (1.52) and Cu (1.41) are highly accumulated in the leaves of *C. occidentalis* plant, while a TF of Pb (1.53), Mn (1.31), Cr (1.27) and Cu (1.19) was observed in the stem of *J. curcas*. The high remediation potential observed in this study as occasioned by the Bioconcentration Factor (BCF) value recorded indicates that *C. occidentalis* and *J. curcas* have vital characteristics that can be used for phytoextaction of the analysed metals.

Keywords: *Heavy Metals, Translocation, Bioaccumulation, Seedling, Chromium*.

INTRODUCTION

The term phytoremediation consists of the Greek prefix “*phyto”* which means ‘plant’ and in Latin “*remedium”*, meaning 'restoring balance. It involves the technologies that use living plants to clean up soil, air, and water contaminated with hazardous contaminants and to improve the environment quality (Reichenauer and Germida, 2008). The term phytoremediationc can also be defined as the use of green plants and the associated microorganisms, along with proper soil amendments and agronomic techniques to contain, remove or render toxic environmental contaminants harmless. The phytoremediation of metals is a cost-effective, efficient, environment and eco-friendly ‘green’ technology based on the use of metal-accumulating plants to remove toxic metals, including radionuclides as well as organic pollutants from contaminated soils and water (Ali *et al*., 2013).

Phytoremediation can be applied in terrestrial and aquatic environments. It can be used as a preparative or finishing step for other clean-up technologies (Nahal and Ramachandra, 2016**)**. Plants evolved a great diversity of genetic adaptations to handle the accumulated pollutants that occur in the environment. Growing, and in some cases harvesting the plants on a contaminated site as a remediation method is a passive technique that can be used to clean up sites with shallow, low to moderate levels of contamination. Phytoremediation can be used to clean up metals, pesticides, solvents, explosives, crude oil, poly aromatic hydrocarbons and landfill leachates. It can also be used in river basin management through the hydraulic control of contaminants (Nahal and Ramachandra, 2016**)**.

There are several ways by which plants clean up or remediate contaminated sites. The uptake of contaminants in plants occurs primarily through the root system, in which the principal mechanisms for preventing toxicity are found. The root system provides an enormous surface area that absorbs and accumulates the water and nutrients essential for growth along with other non-essential contaminants (Yin, 2012).

Plant roots cause changes at the soil-root interface as they release organic and inorganic exudates in the rhizosphere. These root exudates affect the number and activity of microorganisms, the aggregation and stability of the soil particles around the root, and the availability of the contaminants. Root exudates by themselves can increase or decrease (immobilize) the availability of the contaminants in the root zone of the plants through changes in soil characteristics, release of organic substances, changes in chemical composition and/or increase in plant assisted microbial activity (Nahal and Ramachandra, 2016**).**

The term heavy metal refers to those metals whose specific weight are greater than $5 g/cm^3$ or has an atomic number above 20, generally excluding alkali and alkaline earth elements. The term is somewhat imprecise when taking into account the particular properties ionic physicochemical elements, properties that define the composite ability and biological properties. The most commonly found heavy metals at contaminated sites are lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), and nickel (Ni) (EPA 2010).

Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition (Khan *et al*., 2018). Therefore the aim of this research is to investigate the phytoremediation potential of *Jatropha curcas* and *Cassia occidentalis* on selected heavy metals in the soil.

MATERIALS AND METHODS

Study Area

This research work was conducted at the Botanical garden and the Botany laboratory of the Department of Plant Science and Biotechnology Kebbi State University of Science and Technology Aliero. The town lies at latitudes 11°03'S, 12°47'N and longitudes 3°6'W and 4°27'E of Kebbi State, Nigeria. It has a total area of 412 square kilometer and is bordered in the east by Tambuwal Local government area of Sokoto state in the North West by Birnin Kebbi local government area in the South West by Jega local government area. The average temperature of the experimental area is 30^0C. The people living in this area area predominately farmers.

Soil Sample Collection

The method developed by Ogbodo *et al*. (2019) was employed in the collection of soil samples. About 10Kg samples of sandy loamy soil was randomly collected from 0-15cm depth using soil auger in the FADAMA Area in Aliero. Before sampling the waste materials on the top soil were cleared and the soil was collected into zipper locked polythene bags and taken to the laboratory. The soil was then air dried for 7 days and pulverized, passed through a 2-mm sieve, thoroughly mixed and stored in a dry place.

Poultry Manure

Poultry droppings was collected from Labana Farms Aliero into a zipper locked polythene bag and transported to the laboratory. The poultry droppings collected were separated from the litter or rice husk manually, air-dried and ground into powder (Ogbodo *et al*., 2019).

Plants Seeds

The seeds of the plant species were collected from matured plants (*Jatropha curcas* and *Cassia occidentalis*) and taken to the herbarium unit of the Department of Plants Science and Biotechnology, Kebbi State University of Science and Technology, (KSUSTA) for further identification. The identified seeds were then planted, kept in an open space (botanical garden) and watered (about four weeks) until they grow visibly above the soil surface.

METHODS

Preparation of Soil/ Manure Samples

Ten kilogram (10kg) of the dried garden soil was carefully weighed into seven perforated pots. Then 100g of poultry manure was added to the soil and mixed thoroughly, watered adequately and was allowed to compose for two weeks. Upon composition of the soils, each of the pots was spiked with 100ppm of the prepared solution of soluble metals salts (Pb, Zn, Mn, Cr and Cu) to generate the contaminant test soil. The contaminated soils in the pots was allowed to stay for one month before transplanting the seedlings in order to achieve equilibrium between the solid phase and liquid phase of the soil and to allow for stabilization of these reactions (Ndubueze, 2018).

The seedlings of the plants, *Jatropha curcas* and *Cassia occidentalis* were then transplanted into the pre-treated pots. The experiment was conducted in six pots. Five seedlings each of *Jatropha curcas* and *Cassia occidentalis* were grown in each pot. In the same pots, the seedlings were allowed to grow until maturity. The mature plants were depoted and separated into leaves, stem and roots. Background concentrations of heavy metals in the soil and water were analyzed.

Determination of Physicochemical Properties of the Soil and Manure

pH: 20g of each air-dried soil sample was weighed into 50 cm^3 beaker and 20 cm^3 of distilled water was added. It was stirred with a glass rod and allowed to stand for 30 minutes. Calibrated HANNA PH meter (Model H1991000) was inserted into the solution and pH recorded (Black, 2015).

Electrical conductivity: 25 g of air dried soil sample was placed into a 250 cm^3 beaker. Distilled water was added slowly drop by drop uniformly over the entire soil surface until the soil appears to have been wetted. A stainless steel spatula was used to form a homogeneous soil saturated paste. The beaker was then covered with a petri-dish. 50cm^3 distilled water was added and shaken for 1hour. 40cm^3 of the diluted extract was placed into 100cm^3 beaker and the conductivity meter was inserted and the electrical conductivity of the soil recorded in $uScm^{-1}$ (Walkley and Black 2014).

Colour: Garden soil samples were compared to colour standards and suitably graded (Hendershot *et a*l. 2013).

Organic Carbon: The organic carbon content of the soil was determined by wet oxidation as reported by Walkley and Black in which organic carbon is oxidized by KO_7 in the presence of sulphuric acid (H) according to the following reaction (Todoroui *et al.*, 2001):

$$2K_2Cr_2O_7 + 8H_2SO_4 \longrightarrow 2Cr_2(SO_4)_3 + 8H_2O + 3O_2$$

$$3C + 3O_2 \longrightarrow 3CO_2$$

The soil samples were sieved using 0.5mm sieve often which, they were weighed in duplicate and transferred to a 250 cm^3 Erlenmeyer Flash. Exactly $10cm^3$ of 1M potassium heptaoxodichromate (VI) $(K_2Cr_2O_7)_2$ was pipetted into each flash and swirled gently to dispose the soil followed by adding 20 cm^3 concentrated tetraoxosulphate (vi) acid. The flask was swirled gently until soil and reagents were thoroughly mixed. The mixture was thus allowed to stand for 30 minutes on a glass plate. $100cm^3$ of distilled water was added followed by addition of 3-4 drops of ferrois indicator,

after which it was titrated with 0.5M, ferrous sulphate solution. A blank titration was similarly carried out. The percentage organic caution is given by the equation (Todoroui *et al*., 2001):

$$\%\text{organic carbon} = \frac{(\text{MeK2Cr2O7} - \text{Me Fe SO}) \times 1.331 \times 100 \times F}{\text{Mass (s) of soil level}}$$

Where

F = Correction factor

Meq = Molarity of solution transferred multiplied by volume in cm^3 of solution used.

% organic matter in the soil = % organic carbon X1.729.

Moisture content: 1g of sieved soil sample was weight into dry crucible. The crucible was then placed in an air circulated oven at 105^0C and dried to constant weight (for 6 hours). The sample was cooled in a desicator and re-weighed. The percentage air dried moisture from the loss weight was then determined as fellows **(**Nounamo *et al*., 2010):

$$\%\text{ moisture content} = \frac{\text{Loss in weight} \times 100}{\text{Initial weight}}$$

Extraction of Metals from Soil Samples

The method developed by Shriadah (1999) and modified by Udiba *et al*., (2012) was used to extract metals from the soil samples. Soil samples from each plot were thoroughly mixed to obtain a representative sample, air dried, crushed and sieved with 2 mm mesh before wet digestion. One (1.0) g of a well-mixed sample from each sampling point was taken into a 250 cm^3 glass beaker and digested with 10 cm^3 of concentrated nitric acid, perchloric acid and hydrofluoric acid in the ratio 3:1:1 on a hot plate. After evaporating to near dryness, 10 cm^3 of 2% nitric acid was added, filtered through Whatman filter paper into a 50 mL-volumetric flask and then made up to mark with distilled deionized water.

Extraction of Metals from the Plant Parts

Each plant part was washed carefully with running tap water in order to remove soil particles. Clean parts were dried and then placed in an oven for 24 hrs at 105°C. The method developed by Awofolu (2015) was used in digesting the plant samples. A 0.5 g sample of plant part was taken in a beaker. 2mL of $HClO_4$ and 4 mL concentrated (65%) HNO_3 were added and heated on a hot plate until plant parts were digested. It was then allowed to cool and thereafter filtered through the Whatman filter paper into a 50 cm^3 volumetric flask of 50 cm^3. The filtrate was collected and diluted to 50 cm^3 with distilled water. All the filtrate both soil and plant parts were analysed for heavy metals using AAS (AAS-700, Perkin-Elmer, USA) using acetylene/air as a gas mixture. Each experiment was repeated in triplicate. The mean results were calculated.

Uptake efficiency and accumulation of heavy metals in different parts indicated the Bioconcentration Factor (BCF). It is the percentage calculation of heavy metal accumulation in different parts as compared to that in the soil. It was calculated following Zhuang *et al.*, (2014).

$$\text{Bioconcentraion Factor (BCF)} = \frac{\text{Metal concentration in parts of a whole plant}}{\text{initial concentration of metal in soil.}}$$

The efficiency of plants to accumulate and translocate heavy metals from root to shoots indicated the translocation factor (TF). The accumulation of heavy metals in stem and leaves to that of roots were calculated in TF. It is calculated as according to the method of Padmavathiamma and Li, (2014).

$$\text{Translocation Factor (TF)} = \frac{\text{Metal concentration in aerial parts}}{\text{Metal concentration in roots.}}$$

Statistical Analysis

All results were shown in mean ± SD. ANOVA test was used to assess significant variation in metal concentrations in the soil, roots, stem and leaves of *Cassia occidentalis* and *Jatropha curcas* using SPSS version 20. Probabilities less than 5% ($p < 0.05$) were considered to be statistically significant.

RESULTS AND DISCUSSION

Physico-chemical Parameters

The physico-chemical parameters of soil are known to have influence on the availability of heavy metals in plants. The results of the physico-chemicals analysis obtained are shown in Table 1.

Table 1: Physico-chemical values of soil and manure

	Soil	Manure	Control
pH	6.9	7.5	7.1
Electrical Conductivity (μScm^{-1})	$4.0x10^{-2}$	$4.25x10^{-2}$	$2.0x10^{-2}$
Colour	dark brown	black grey	dark ash
Organic Carbon (%)	2.5	12.9	1.3
Moisture Content (%)	7,8	5.3	3.2

The physical chemical properties of soil and manure samples studied are shown in Table 1, The pH of soil is one of the most important physicochemical parameter. It affects mineral and nutrient contents of the soil, the quality as well as microorganisms' activities. The pH of 6.9 and 7.5 were recorded for soil and manure respectively. The pH range of 6.8 to 8.0 has been recommended optimum for plants growth, and pH value of above 7.5 shows basic nature (Kiran, 2013). The findings of this study were found to agree with the results obtained by Bamgbose *et al*., (2015), who reported that the pH of the agricultural soils at Ita-Osun and Ibereuodo dumpsites in Imo State (Nigeria) ranged from 6.44 to 10.10. They have also reported that the organic matter content of the contaminated site ranged from 5.79 to 7.59% (Bamgbose *et al*., 2015). Metal mobility has been shown to decrease with increasing soil pH due to precipitation of hydroxides, carbonates or formation of insoluble organic complexes (Smith *et al*., 2016). Hence, high pH values observed in the present study could lead to decreased mobility of metals in the soil. The higher Electrical Conductivity (EC) observed for the manure could be attributed to the decomposition of the wastes which yield more of the exchangeable bases thereby raising its fertility status (Udo and Ogunwale, 2018). Normal EC ranges from 0.02 to 2.0 mS/cm and such soil is said to be non-saline. The low EC values of the soil samples could be due to high rainfall in this area (as samples were taken during wet season) which washes out soluble cations from the soils. The analysed soil samples are dark brown in colour while the manure was black grey in color and have unpleasant smell. High moisture content signifies that the water available to the plants in the soils is also high. High organic matter content indicates humans-rich soil. This implies that all the soils studied were highly fertile. Moisture content, according to Veihmeyer and Hendrickson, signifies the upper level of water available to plants in the soil (Veinhmeyer and Hendrickson, 2011). The results obtained in this study are in agreement with that reported by Rhoades and his coworkers in their study of physico-chemical properties of agricultural soil (Rhoades *et al*.,2019). Researches have shown that among other factors such as presence of dolomite and phosphates, organic matter in soils reduce the concentration of metals by precipitation, adsorption and complexation (Mench *et al*., 2014, Chen and Lee, 2017) and thus making them unavailable to the plants. In the present study, the soils were observed to have higher levels of organic matter (2.5%) which could reduce the concentrations of the metals absorbed by plant in the soils than the control areas.

Table 2: Concentration of heavy metals in different parts of the plants (ppm).

	Cassia occidentalis			*Jatropha curcas*		
Metals	Roots	Stem	Leaves	Roots	Stem	Leaves
Pb	36.92±1.20	10.51±2.09	56.09±12.22	41.12±2.08	62.71±8.11	17.73±2.34
Mn	58.77±22.10	19.95±7.90	31.55±11.20	51.99±7.52	68.08±5.81	29.54±4.21
Zn	80.36±20.11	20.69±5.97	57.61±9.31	82.42±6.12	57.99±7.33	69.55±7.34
Cr	49.71±13.90	16.60±6.07	28.96±8.11	42.66±5.09	54.33±11.02	31.79±5.71
Cu	57.03±8.22	13.61±3.87	80.22±6.92	66.42±12.14	79.14±9.77	59.64±8.09

Note: concentrations are values of triplicate results.

Table 2 showed the concentration of heavy metals in different parts of *Cassia occidentalis* and *Jatropha curcas*. In *C.occidentalis*, the concentration of Pb in roots, stems and leaves is 36.92 ppm, 10.51 ppm and 56.09 ppm respectively, while the concentration of Pb in roots, stem and leaves in *J. curcas* is 41.12 ppm, 62.71 ppm and 17.73 ppm respectively. The highest Pb concentration was found in the leaves and the least in the stem of *Cassia occidentalis*, while the highest Pb concentration was found in the stem of *J. curcas*. The concentration of Pb in the samples were in the order, *C. occidentalis*: leaves > roots > stems, *J. curcas*: stem > roots > leaves. This result is in agreement with that reported by Udiba *et al*., (2020) in their work on Pb remediation potential of *Senna obtusifolia*. The concentration of Mn in different parts of *cassia occidentalis* was in the order: root (58.77 ppm) > leaves (31.55 ppm) > stem (19.95 ppm), while *J. curcas* was found to be in the order: stem (68.08 ppm) > roots (51.99 ppm) > leaves (29.54 ppm). The highest concentration of manganese was found accumulated in the roots of *C. occidentalis* and the stem of *J. curcas*. This revealed that roots of *C. occidentalis* were more favourable for the absorption of manganese, while *J. curcas* accumulated most of the metal in the stem. In addition, this observation is in line with the finding of Zhang *et al*. (2009). Again Smical *et al*. (2008), in their study reported that the roots and stems are the most important parts which absorbs and eliminates heavy metals in an excess amount. The concentration of zinc in different parts of *Cassia occidentalis* was found to be in the order: root (80.36 ppm) > leaves (57.61 ppm) > stem (20.69 ppm), while in *J. curcas* it was found to be in the order: roots (82.42 ppm) > leaves (69.55 ppm) > stem (57.99 ppm). The highest concentration of Zn was found to accumulate in roots of both plants indicating that zinc has greater propensity to accumulated in the roots of remediating plants. Peralta *et al*. (2011) in their study of alfalfa plants reported that zinc was accumulated more in their roots than other metals. This could be attributed to the fact that zinc can act as a supplement for nutrient, which explains the higher mass accumulation when grown in soil treated with Zn.

The concentration of chromium in the different parts of the samples analysed was found to be in the order: root (49.71 ppm) > leaves (28.96 ppm) > stem (16.60 ppm) for *C. occidentalis* and stem (54.33 ppm) > roots (42.66 ppm) > leaves (31.79 ppm) for *J. curcas*. The root of *Cassia occidentalis* was found to accumulate more chromium than other parts. This result is in agreement with the result reported by Roy *et al*., (2015) in their study of uptake and effect of heavy metals. However, the highest concentration of Cr was found accumulated in the stem of *J. curcas*. The result obtain in this study is in agreement with the findings of many scientists (Wang and Chen 2009; Rahman and Hasegawa 2011; Huang *et al*. 2013) who recorded the highest concentration of Cr in the stems of *Amaranthus hybridus* followed by roots and leaves.

The concentration of Cu in the different parts of *C. occidentalis* plant was in the order: leaves > roots > stem, while Cu accumulation in parts of *J. curcas* was found to be in the order: stem > roots > leaves. The leaves of *Cassia occidentalis* were found to accumulate most of the metals while the stem least. Sahibin *et al*. (2012) had earlier reported that most of the copper contents in plants are usually concentrated in the leaves. The large difference in Cu concentrations between the roots and the leaves indicate relatively low restriction, hence the efficiency of the internal transport of the toxic metal from the roots towards the aerial parts (EPA, 2019: Dahman-Muller *et al*., 2019). Copper highest concentration was found in the stem of *J. curcas*. This revealed that the stems have greatest potential to accumulate copper. Bhattacharya *et al*., (2016) reported high copper concentration in stems in their study of metals uptake by *Scirpus littoralis schrad* in spiked soil.

Table 3: Translocation Factor (TF) of *C. occidentalis* and *J. curcas* for the analysed metals

Metal	Conc. in Soil (ppm)			TF of Shoots *C. occidentalis*.		TF of Shoots *J.curcas*	
Metals	Background conc.	Conc. added to soil	Total conc.	TF Stem	TF Leaves	TF Stem	TF Leaves
Pb	27.31±3.17	100	127.31±3.17	0.28	1.52	1.53	0.43
Mn	32.17±5.33	100	132.17±5.33	0.34	0.54	1.31	0.57
Zn	67.91±9.52	100	167.91±9.52	0.26	0.72	0.70	0.84
Cr	13.20±2.11	100	113.20±2.11	0.33	0.58	1.27	0.75
Cu	59.23±6.41	100	159.23±6.41	0.24	1.41	1.19	0.90

Table 4: Bioconcentration Factor (BCF) of *C. occidentalis* and *J. curcas* for the analysed metals

	Metal Conc. in Soil (ppm)			BCF of Harvested tissues in *C. occidentalis*			BCF of Harvested tissues in *J.curcas*		
Metals	Background conc.	Conc. added to soil	Total conc.	BCF root	BCF stem	BCF leaves	BCF root	BCF stem	BCF leaves
Pb	27.31±3.17	100	127.31	0.29	0.08	0.44	0.32	0.49	0.14
Mn	32.17±5.33	100	132.17	0.44	0.15	0.24	0.39	0.52	0.22
Zn	67.91±9.52	100	167.91	0.48	0.12	0.34	0.49	0.35	0.41
Cr	13.20±2.11	100	113.20	0.44	0.15	0.26	0.38	0.48	0.28
Cu	59.23±6.41	100	159.23	0.36	0.09	0.50	0.42	0.50	0.37

Table 3 shows that a TF of 0.28, 0.34, 0.26, 0.33 and 0.24 was obtained for Pb, Mn, Zn, Cr and Cu in *Cassia occidentalis* stem respectively, and the TF of 1.52, 0.54, 0.72, 0.58 and 1.41 was obtained for Pb, Mn, Zn, Cr and Cu in *C occidentalis* leaves respectively. The TF for all the metals in the stem and leaves were less than one with the exception of Pb and Cu in the leaves of *Cassia occidentalis*. While the TF of 1.53, 1.31, 0.70, 1.27 and 1.19 was obtained for Pb, Mn, Zn, Cr and Cu in *Jatropha curcas* stem respectively, and the TF of 0.43, 0.57, 0.84, 0.75 and 0.90 was obtained for for Pb, MN, Zn, Cr and Cu in *Jatropha curcas* leaves respectively. The TF for all the metals with the exception of zinc were found to be greater than one in *Jatropha curcas* stem. The less than unity values obtained for some of these metals is generally a limitation encountered in phytoremediation of heavy metals as opined by Ali *et al*., (2013). Turan and Esringu (2017), also stated that the less than unity values are due to the restriction of internal transport of these metals from the roots to the shoots resulting in accumulation in roots. TF values of 1.52 for Pb and 1.41

for Cu means that these metals have high potential to accumulate in the leaves of *Cassia occidentalis*. The TF of 1.53, 1.31, 1.27 and 1.19 for Pb, Mn, Cr and Cu respectively, means that *Jatropha curcas* can hyper accumulate these metals in the stem. The BCF obtained for the harvestable tissues were all less than one and found to be in the order: leaves > roots > stem for *C. occidentalis* and stem > roots > leaves for *J. curcas* (Table 4).

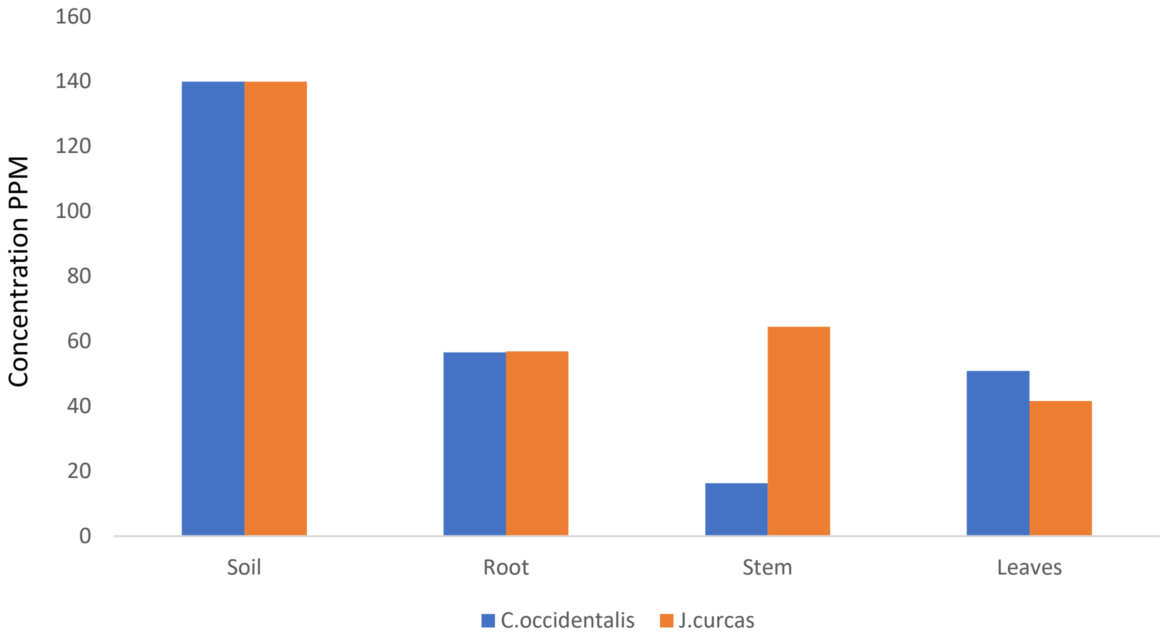

Figure 1: Mean Concentration of Metals in the Root and Other Plant Parts

The concentration of metals in parts of *Cassia occidentalis* and *Jatropha curcas* did not follow the trend of soil metals level (Fig.1). This observation could be attributed to differences in the chemical form of the metals present in soil in relation to the differences in soil chemistry. It also suggests that the bioavailable percentage of total metals have a significant effect on metals, and the internal transport mechanism of the various plant parts (Annan *et al*., 2013). The stem of *J. curcas* was shown to accumulate more metals while most of the extractable metals were found in the leaves of *C. occidentalis*. This result is similar to that reported by Juan *et al*., (2020), in their study of metal accumulation by *J. curcas* L. adult plants grown in heavy metals contaminated soil.

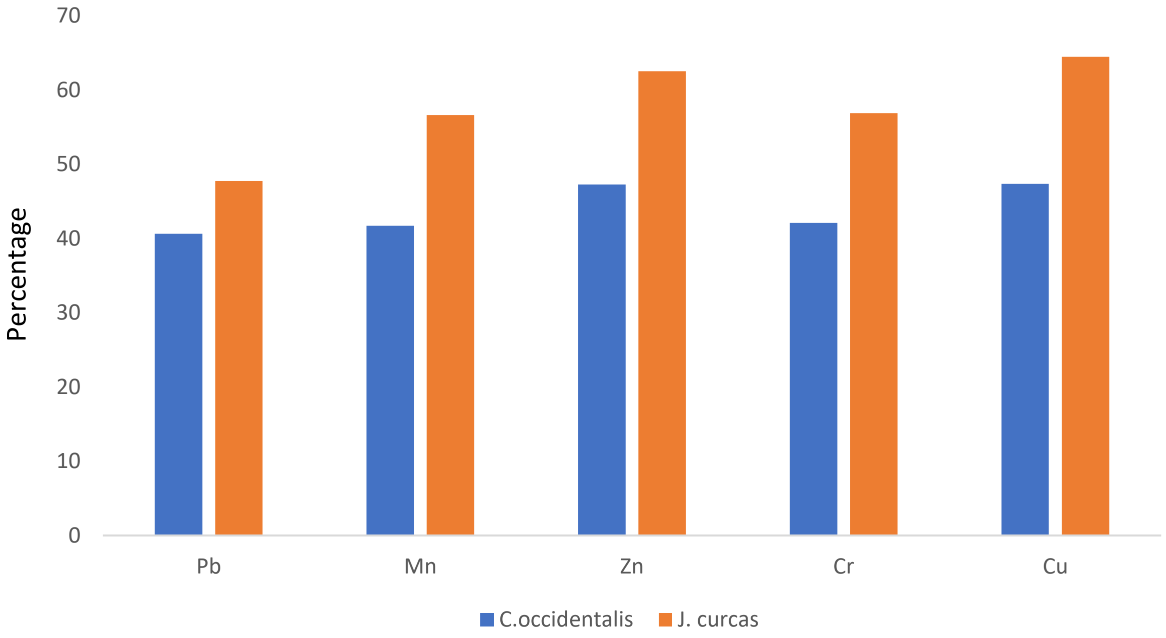

Figure 2: Percentage Remediation Potentials of metals by *C. occidentalis* and *J. curcas*.

Figure 2; shows the percentage remediation potentials of metals are in the following order: 40.65%, 41.72%, 47.25%, 42.08% and 47.37% remediation for Pb, Mn, Zn, Cr and Cu respectively for *C. occidentalis*, while 47.74%, 56.60%, 62.52%, 56.88% and 64.44% remediation was recorded for Pb, Mn, Zn, Cr and Cu respectively in *J. curcas*. The observed high metal remediation potential observed in this study may suggest that a good proportion of the analysed metals in the soils is present in the mobile phase, thus readily available for uptake by plants. Plants growing in a metal-enriched environment are able to accumulate large quantities of the metal in their tissues depending on the percentage bioavailabilty/mobility of the toxic metal. This is in agreement with the report of Alvarez-Mateos *et al*., (2019) who stated that *J. curcas* L. can remove extremely high metal amounts from mining soils at any stage of its lifetime. Considering the TF and BAF achieved, *J. curcas* L. can be labelled as a hyperaccumulator plant. Hyperaccumulators absorb large amounts of heavy metals from the soil, which are not retained in the roots but are translocated to the shoots and accumulated in the aboveground organs at concentrations between 100 and 1000 folds higher than in non-hyperaccumulator plants (Singh *et al*., 2016). However, as observed in this study, high metal concentrations, to certain extend, could pose toxic effects on plants, as has been reported by other researchers' findings (Singh *et al*., 2016; Rascio, 2017). However, this metal accumulation in plant aerial parts makes *J. curcas* L. unsuitable for phytostabilization. *J. curcas* L. could be used for phytoextraction in mining areas, thus removing high amounts of heavy metals from these soils.

Statistical analysis revealed a significant (ANOVA, $p < 0.05$) difference in overall metals concentration between the soil, plants parts, roots, stem and leaves, and metals concentrations in soil were significantly higher than the metals concentration in roots and stem. The metals concentration in *Cassia occidentalis* leaves and *Jatropher curcas* stem were also found to be significantly ($p < 0.05$) different amongst other parts. The metals concentration in *Cassia occidentalis* stems was found to be significantly ($p < 0.05$) higher than in the root. The difference in overall metals concentration between the soil and leaves was not statistically significant ($p > 0.05$).

Cassia occidentalis is a green leafy vegetable and an important medicinal plant, known for its efficacy in treating various degree of fever. It is commonly called ‘sanga-sanga’ among the Hausa of northern Nigeria. The lead and copper contents of the leaves recorded in this study (*Table 1*) were found to be generally higher than the permissible levels by the Food and Agriculture Organization of the United Nations and World Health Organization (FAO/ WHO) and the European Union (EU) maximum levels of 0.30 mg/ kg for Pb and 0.50mg/Kg in leafy vegetables. (EC. 2011: Codex, 2011). Lead concentrations of *cassia occidentalis* leaves were also higher than the reported human toxicity levels of 1.00 mg Pb/day (Abah *et al*., 2013). Consumption of these leaves thus poses significant risk of Pb toxicity. *J. curcas* has also shown hyper-accumulation of Pb, Cr and Cu in the aerial parts of the plants and can also predispose people consuming this plant in any form to high risk of metal toxicity especially if they are grown in polluted soil.

Conclusion

The ability of plants to clean up metals contaminated sites depend on the amount of the metal that can be accumulated by the plants, soil metals concentration, rate of uptake, and translocation and accumulation potential in the harvestable tissues. This study showed that heavy metals accumulated in the roots, stem and leaves of *Cassia occidentalis* and *Jatropha curvas*. Metals such as Mn, Zn and Cr have their highest concentration in the roots, while Pb and Cu are concentrated more in the leaves of *Cassia occidentalis*. This is evident from the TF which is 1.52 and 1.41 respectively, indicating significant accumulation of the toxic metals in the leaves. *Cassia occidentalis* leaves were therefore noted as the major storage organ for Pb and Cu in the plant. While the stem of *Jatropha curcas* was shown to be the site for the storage of metals such as Pb, Mn, Cr and Cu with the exception of Zn which was found concentrated in the roots of the plant. The high translocation factor and bioaccumulation factor observed in this study indicates that both *Cassia occidentalis* and *Jatropha curcas* have vital characteristics which can be used for phytoextraction of the metals. Since *Cassia occidentalis* is known for its’ used as medicinal plant it is therefore imperative to note that *Cassia occidentalis* grown in a Pb polluted areas will have significant levels of Pd in the leaves.

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