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PHYTOREMEDIATION OF HEAVY METALS BY SOME NATURALLY GROWN AND CULTIVATED PLANTS ON AND AROUND ABANDONED MINE AREAS OF BARKIN LADI LGA OF PLATEAU STATE, NIGERIA

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ABSTRACT

The ability of *Helianthus annuus, Spinacia oleracea, Eucalyptus camaldulensis* and *Tithonia diversifolia* to accumulate heavy metals from abandoned Tin mine areas of Barkin Ladi was examined by XRF and the available forms by MP-AES. The soil and sediment were found to be acidic, non-saline and infertile. The concentrations of As, Cd, Fe and Cu fractions were above the WHO (2001) and NAFDAC (2001) limits for irrigation water. The concentrations of the metals in the soil were Cr: 670.5, Cu: 678.93, Ni: 267.47, Mn: 2415, Zn: 304.94 and Fe: 128,956 mg/kg and the plants accumulated the metals in the following ranges; Cr (608.95 - 1984.21), Cu (1996.87 - 9295.78), Ni (385.47 - 1966.67), Mn (2633.8 – 100704), Zn (481.48 - 3611.11) and Fe (14700 – 222442) mg/kg. The bioaccumulation (BCF) and translocation (TF) factorsnof the metals were in the orders Cu>Mn>Zn>Ni>Cr>Fe and Mn>Zn>Cu>Ni>Cr>Fe respectively and for the plants were *E. camaldulensis>H. annuus>T. diversifolia>S. oleracea* and *H. annuus>spinach>E. camaldulensis>T. diversifolia* respectively. BCF and TF were mostly greater than 1 indicating that the plants would be good for phytoremediation. The results further revealed that, *H. annuus L. and S. oleracea* (spinach) are plants that would be good for the phytoremediation for low soil levels; *T. diversifolia* is for moderate soil levels and *E. camaldulensis* for very deeper soil levels contaminations.

Key Words: Abandoned Mine, Barkin Ladi, Heavy Metals, Phytoremediation

INTRODUCTION

After the tin mining activities on Jos Plateau, altered landscape, unused pits and shafts, land no longer usable due to loss of soil, waste rocks, contaminated soils and aquatic sediments remained without remediation [1, 2]. As a result, large quantities of polluted materials are left abandoned and exposed to weathering [3]. The abandoned tin mines when untreated contain high concentration of toxic metals and become a source of metal pollution. Metal contaminated soil and water pose serious environmental and health problems worldwide because of biomagnifications of toxic heavy metal in food chain [4]. High concentrations of heavy metals in soil can also negatively affect plant growth as these metals interfere with physiological and biochemical processes including photosynthesis and respiration, contributing to the degeneration of organelles and cells and even plants' death [5].

The laws governing mining operations on Jos Plateau were less stringent concerning their environmental impacts. It has been a common practice to simply abandon mining operations following the exhaustion of the tin reserve, and then declare bankruptcy [2]. The mining operators walked away from liabilities, including environmental devastation. Mining no doubt has impact negatively on agriculture because of the complex catena of various interactions that occur as waste containing heavy metals become part of the ecosystem into which it was deposited. Mining in the State also had no any remediating strategy that removed chemicals from the contaminated soils. Eucalyptuses were planted on very few reclaimed lands to restore soil structures. In some areas, contaminated soils, where need be, were removed into landfills.

Most of conventional metal remedial technologies like leaching of pollutant, vitrification, electrokinetical treatment, excavation and off-site treatment are expensive and inhibit the soil fertility; which subsequently cause negative impacts on the ecosystem. Therefore, currently preference is being given to *in situ* methods (phytoremediation) that are less environmentally disruptive and more economical. Phytoremediation, an emerging cost effective, and environmental-friendly alternative technology, uses plants to reduce, remove, degrade, or immobilize environmental toxins, with the aim of restoring area sites to a condition useable for private or public applications [1, 6]. The selection of appropriate plant species is crucial for phytoremediation. The plants should be tolerant to the heavy metal conditions, dense rooting systems to immobilize heavy metals, stabilize soil structure, and prevent soil erosion. Plants should be able to produce a large amount of biomass and grow fast to timely establish a vegetation cover in a specific site. In addition, the plant cover should be easy to maintain under field conditions [7].

Phytoremediation efficiency is enhanced by adding organic or inorganic amendments to the contaminated soil. These soil amendments can alter metal speciation; reduce heavy metal solubility and bioavailability by changing pH value and redox status of the soil. Moreover, the application of amendments can increase the organic matter content and essential nutrients of the soil and improve physicochemical and biological properties [8].

The aim of this study is to assess the possibility of two naturally grown (*E. camaldulensis* and *T. diversifolia*) and two cultivated (*H. annuus and S. oleracea*) plant species in rehabilitating abandoned tin mine areas of Barkin Ladi LGA of Plateau State, Nigeria.

EXPERIMENTAL

Study Area: The samples were collected from the farmlands on/around abandoned tin mine areas of Barkin Ladi LGA of Plateau State, Nigeria. Barkin Ladi is a Local Government Area in Plateau State, Nigeria with its headquarter in the town at 9º32'32 and N8º54'E. It has an area of 1032km^2 and population of 175267 in 2006 census. The area played host to many foreign companies which rendered the area derelict with numerous waste dumps and ponds [9].

Collection of Samples

Collection of water, sediment, soil and plant samples

Water samples were obtained from ponds located on/around abandoned tin mine sites in Barkin Ladi Local Government Area. Surface soil and sediments samples were obtained with the aid of soil auger. Two cultivated plant (*Helianthus annuus* and *Spinacia oleracea*) and two naturally grown plants (*Eucalyptus camaldulensis* and *Tithonia diversifolia*) samples from the abandoned mine areas were collected [10].

Water sample preparation and analysis

The water was filtered and concentrated HNO_3 acid was added to the samples and analyzed with MP – AES for heavy metals concentrations.

Analysis of soil and sediment physico-chemical properties

The soil and sediment samples were air-dried, mechanically ground using a stainless steel roller and sieved to obtain <2 mm fraction at FECOLART Analytical Laboratories, Kuru, Jos. The distribution of particle sizes larger than 2.0 mm was determined by sieving, while the distribution of particle sizes smaller than 2.0 mm was determined by a sedimentation process using a hydrometer [11]. This fine material was used to determine organic carbon and total metal content in soil. The <2 mm fraction was used to determine pH of soil and sediment (1g sample:5mlwater), electrical conductivity (EC) (1:5) soil -water extract. Organic carbon was determined by the modified dichromate oxidation and titration and cation exchange capacity by the 0.01M silver-thiourea method [12].

Extraction of available fractions of heavy metals from soil

Soluble fractions (SS) of various heavy metals in the soil samples was extracted with water (1g of soil was extracted with 5 ml of the water) from the pond used for irrigation. The exchangeable and specifically adsorbed fraction of soil (E) was extracted with 0.11 M acetic acid.

Extraction of exchangeable and specifically fractions of heavy metals from sediment

The exchangeable and specifically adsorbed fraction of sediment (SE) was each extracted with 0.11 M acetic acid.

Analysis of soil and sediment samples by XRF

X-ray fluorescence was used to determine the total heavy metal concentrations in soil and sediment samples at Nigeria Metallurgical Development Centre, Jos and MP – AES was used to determine the available fraction soil and sediment at the Center for Dry Land Agriculture, Bayero University, Kano (BUK).

Plants sample preparation and analysis

Plant samples were partitioned into leaves, stems, and roots, air dried and pulverized prior to analysis. XRF was used to determine the total heavy metal concentrations in plants tissues,

Data Processing and Statistical Analysis

In this study, the translocation factor (TF) and the bioconcentration factor (BCF) were calculated using the ratio of the heavy metal concentrations in the roots and shoots [TF = Cshoot/Croot] and the ratio of the heavy metal concentrations in the shoots and soils [BCF = Cshoot/Csoil] respectively. The heavy metals data were subjected to a one-way analysis of variance (ANOVA) using the Statistical Package for Social Science (IBM SPSS Statistics 23) and the means were separated by using Turkey post hoc test (at $P< 0.05$). In addition, Pearson's correlation coefficient was used to determine the relationships between the heavy metal concentrations in the soils and plants at $P< 0.05$ [13].

RESULTS AND DISCUSSION

Table 1 presents the results of physico–chemical properties of the soil and sediment and Table 2 the concentrations of total, soluble, exchangeable and specifically adsorbed fractions of metals in the soil and sediment from abandoned mine of B/Ladi LGA,

Table 1: Results of the physico–chemical properties of the soil and sediment from abandoned mine of B/Ladi LGA

Sample Code	pH	EC dS/m	OC %	N %	OM %	P Ppm	K cMol/kg	Ca cMol/kg	Mg cMol/kg	Na Mol/kg	EA cMol/kg	CEC cMol/kg	PBS %	Clay %	Silt %	Sand %	Textural Class
BL1	5.92 ±0.2	0.13 ±0.02	1.32 ±0.09	0.066 ±0.00	2.28 ±0.50	26 ±5.00	0.19 ±0.07	2.0 ±0.30	0.56 ±0.10	0.030 ±0.00	1.63 ±0.60	4.41 ±1.40	63.04 ±8.00	36.44 ±3.00	25 ±6.00	38.56 ±7.20	C,L
BLS	5.70 ±0.00	0.06 ±0.00	1.32 ±0.06	0.07 0±0.00	2.40 ±0.80	13 ±2.10	0.17 ±0.04	2.03 ±0.90	0.56 ±0.10	0.026 ±0.00	1.62 ±0.30	4.38 ±2.00	63.01 ±6.00	37.44 ±3.00	24 ±0.90	38.56 ±6.00	C,L

Key: BL = Barkin Ladi, Subscript 1 = 0 -10 cm soils. S=sediment, C= clay, L = loam, S=sandy

Table 2: Concentrations of total, soluble, exchangeable and specifically adsorbed fractions of metals in the soil and sediment

Sample Area	Sample Code	As	Cd	Cr	Mn	Fe	Ni	Cu	Zn	Pb
B/Ladi	BLT	ND	ND	636.32	929.58	134555.59	251.73	694.91	256.79	ND
	BLS	0.65	ND	684.21	852.11	171500.05	228.13	678.9	240.74	900.40
	BLSS	0.42	0.19	0.01	0.11	5.13	ND	0,27	ND	ND
	BLSE	0.54	0.60	0.04	2.39	32.10	0.05	0.79	3.42	0.19
	BLE	0.44	0.46	0.02	1.18	14.27	0.02	0.67	0.34	0.17
	Intervention value	79	-	94.16	-	-	135.54	201	812.73	542.47
	*WHO (Irr. water)	0.1	0.01	0.55	0.2	0.5	1.4	0.017	0.2	0.065
	*WHO (Soil)	20	3	100	2000	50000	50	100	300	100

Key: BL =Barkin Ladi, T=Total, S =Sediment SS = Soluble fraction, SE = Sediment Exchangeable and specifically adsorbed fraction. E = Soil Exchangeable and specifically adsorbed fraction

*source: Chiroma et al., 2014

Physico–chemical properties of the soil and sediment of B/Ladi and Foron

Table 1 shows mean values of the characteristics of top soil and sediment samples of Barkin Ladi abandoned mine farm areas. pH values ranged from 5.70 – 5.92indicating soil and sediment are acidic in nature. The pH of aqueous solution is an important operational parameter in the absorption process and the form which a particular metal exists. The low pH obtained could be responsible for the high available fractions of the metallic ions obtained in this study [14]. The EC values ranged from 0.06 in BLS to 0.13 in BLFS showing the soil and sediment of the areas were non-saline. The carbon and the organic matter percentages were in a narrow range and less than 3% indicating that the fertility of the tin tailings was extremely deficient. The tailing in Barkin Ladi had high %clay.

Heavy metals concentration in the soil and sediment

The soil and sediment accumulated elevated levels of heavy metals (Cr: 636.32 and 684.21, Mn: 929.58 and 852.11, Fe: 134555.59 and 171500.05, Ni: 251.73 and 228.13, Cu: 694.91and 678.9, Zn:256.79 and 240.74 and Pb: ND and 900.40 respectively) from the abandoned mine areas (Table 2). As and Cd were below the XRF detection limit (in %). Cr and Ni and Cu concentrations were all above the WHO (2001) maximum permissive levels of agricultural soils and their intervention values [15] but were within the US EPA (2001) limit [16]. According to Marjanović et al., if the concentration of a metal in the analyzed soil sample exceeded the intervention value it means that the location requires remediation [17]. Mn concentrations were all within the values as stated in Chiroma *et al*. [16]. Zn concentrations were within the allowable concentration of WHO (2001)and US EPA (2001). The distributions of heavy metals in the soil and their availability to plants were due to the low pH and high %clay and could have accumulated more if the percentage of carbon and organic matter were higher [2, 18],

Available fractions

The results of the concentrations of the available forms of the nine heavy metals in soil and sediment are given in Table 2. The metals exhibited different fractions' distribution patterns. The concentrations of As, Cd, Fe and Cu soluble fractions were above the WHO (2001) and NAFDAC (2001) limits for irrigation water. The concentrations of heavy metals in the SE and E were above the WHO (2001) and NAFDAC (2001) limits (except for Cu and Ni) for irrigation water. The high concentrations of metals in the available fractions showed that, the metals have great probability of being leached to the underground water [11]. Plants may absorb these fractions of metals and transfer them to the food chain. Various soil physicochemical factors, such as the presence of chelating agents, the soil pH, and microbial activity are said to have impact on bioavailability and solubility of heavy metals in the soil [19].

The potentials of *Spinacia oleracea* (spinach) in phytoremediation

Spinacia oleracea is a member of the Caryophyllales order, comprising broad, green and leafy vegetables possessing large surface areas, relatively high growth rates and rather elevated heavy metal absorption rates [20]. The distribution of six heavy metals (Cr, Cu, Ni, Mn, Zn and Fe) in leaves, stem and roots of spinach plants and soil is shown in Figure 1.

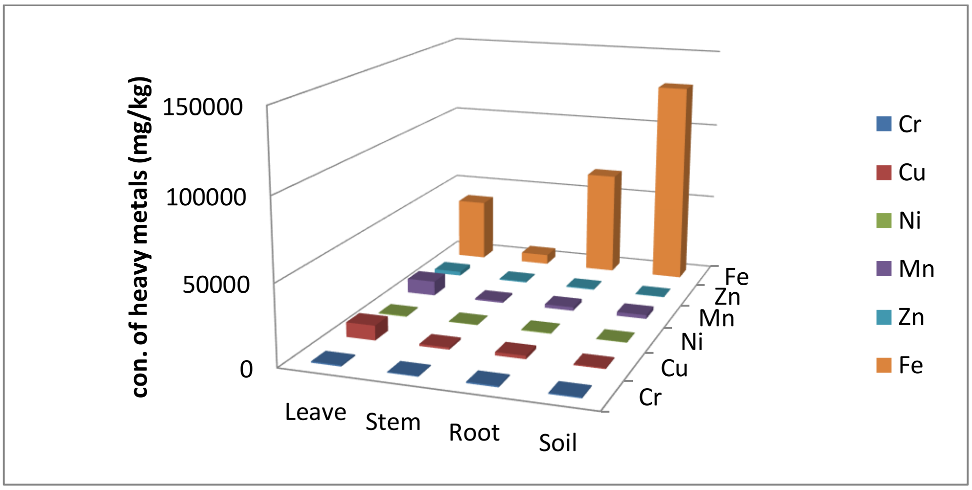

Figure1: Heavy metal accumulation heavy metals in spinach (*Spinacia oleracea*) tissues

Cr has its highest concentration in both root and leaves which made the plant good for both phytostabilization and phytoextraction of Cr. Cu, Ni, Zn and Mn were accumulated highest in the leaves and the lowest in the stem (except for Zn) making *Spinacia oleracea* most suitable for phytoextraction of the metals. The concentration Fe in the root was almost twice the concentration in the leaves and therefore, *Spinacia oleracea*is suitable for the phytostabilization of Fe.

The variations in heavy metal concentrations in various parts of plants have been ascribed to compartmentalization and translocation through the vascular system [21]. With the high bioavailability of metals in the soil, plants have accumulated metals into different plant parts and this may subsequently pose risks to human health especially as the plants are cultivated on or near metal contaminated areas [22]. The locals mostly cultivate the plants on abandoned tin mine soils and dump sites. The leaves of the plant in combination with other leaves are used as 'tere', a pottage enjoyed by the Biroms and other ethnic groups in the State. Sharma *et al.* reported that plants grown on waste water-irrigated soils are contaminated with heavy metals and pose health concern [23]. Abhilash *et al.* also reported that *Spiracia oleracea* L and *Zeamays L* plant species were more effective in accumulating certain metals compared to other species grown at the control soil [21]. This however was contrary to the work of Ali *et al*. [24] who found that spinach absorbs cadmium and lead within the permissible limit with an exception . Zinc was found to be within the acceptable limit for all spinach samples.

Spinach was found in this work to be very suitable for phytoremediation as it grows fast on the contaminated areas and had accumulated much of the metals in the parts above the ground. Majida *et al.* [25] found that the concentrations of Zn, Pb and Ni in spinach leaves in both summer and fall cropping seasons exceeded the maximum admissible limit 5, 0.5 and 0.5 mg. l^{-1} in water fresh and treated water. According to Majida *et al.* [25] and Sardar*et al* [26], increasing concentrations of Cd, Pb and Zn in both single and mixture forms significantly ($p<0.05$) reduced growth parameters of *S. oleracea* seedlings.

The bioconcentration factor (BCF)and the translocation factor were determined and the result is shown on Table 4. The order of the BCF and TF in spinach was Cu>Zn> Ni>Mn >Cr>>Fe and Zn>Cu>Mn>Ni>Cr>Fe respectively. Accumulation of the metals in spinach recorded high TF and BAF values (Table 4). This showed that the plants are good for the phytoextraction and phytostabilization of most of the metals studied except Fe. Fe is the most abundant metal in the soil of all the metals studied and therefore showed low BCF but its low TF was due to its inability to be translocated Fe to the aerial parts. The phytoremediation efficiency of field crops is rarely high, but their greater growth potential compared with hyperaccumulators should be considered positively. They also establish a dense green canopy on polluted soil, improving the landscape and reducing the mobility of pollutants through water, wind erosion and water percolation [27].

The potentials of sunflower *(H. annuus L)* in phytoremediation

The distribution of six heavy metals in the organs of sun flower and soil is presented in Figure 2

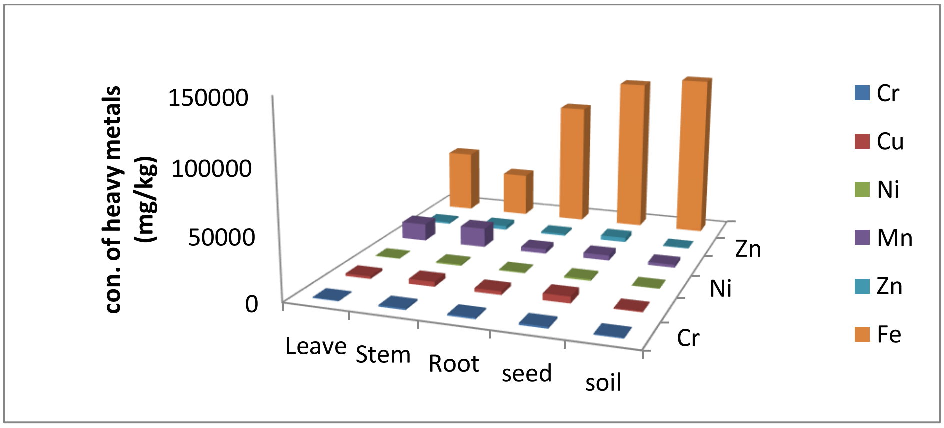

Figure 2: Metal accumulation heavy metals in sunflower (*H. annuus* L) tissues

The concentrations of the metals were: Cr: 605.78in the leaves to 1368.42mg/kg in the seed, Cu :1996.89 in leaves to 5271.6mg/kg in the seed, Ni: 385.47 in the leaves to 1258.67mg/kg in the seed, Mn: 3563.35 in roots to 15492.96mg/kg in the stem, Zn: 1283.95 in the leaves to 3611.11mg/kg in the seed, Fe: 50400.1 in the leaves to 122888.92mg/kg in the seed. The seed accumulated the highest concentrations of Cr, Cu. Ni, Zn and Fe. The concentrations of the metals were higher than the allowable concentrations in plants.

To minimize the detrimental effects of heavy metal accumulation, plants evolved detoxification mechanisms, mainly based on chelation and subcellular compartmentalization. The efficiency of these processes might result in the natural heavy metals tolerance and their basic understanding might be crucial for improving plant performances in phytoextraction of heavy metals from polluted soils [28].

The average heavy metal content in the seeds of the sunflower was the highest in comparison to that in the roots, stem and leaves. This was in line with the work of Angelova *et al.* [29] that found significant amount of Cu, Zn and Cd were stored in the regenerative organ when cultivated on the contaminated soil and reported that there was highest accumulation of Cu and Zn when irrigated with waste water. The heavy metal accumulation in sunflower seeds was likely caused by the conductive system [29]. The content of the heavy metals in the seeds of sunflower from the abandoned mine sites exceeded the critical levels recommended for livestock (300 mg/kg for Zn). This was far above the concentrations of heavy metals in the seed in the work of Виолина *et al.* [30] that found the distribution of the heavy metals in the organs of the sunflower has a selective character and decreases in the following order: leaves > roots> stems > seeds. The highest Cu^{2+} content was in the stem followed by leaves and roots of H. annuus. This was contrary to the previous studies by Mahardika *et al*. [31] where they found that the metal content was accumulated more in the root than the shoots and leaves because, according to them, the roots were the first to utilize nutrient and uptake metal and act as a barrier against heavy metal translocation which causes the concentration in the roots to be higher than other parts of the plants.

The order of the heavy metal bioconcentration and translocation factors (Table 4) were Zn>Cu>Mn>Ni>Cr>Fe and Mn>Zn>Ni>Cu>Cr>Fe respectively. Translocation factors obtained were greater than 1 indicating that the plant could be included with the hyperacumulator plants and is able to be used in phytoextraction [31].

The potentials of *Tithonia diversifolia* in phytoremediation

Tithonia diversifolia is another species of sunflower, was investigated for its potential to remove Cr, Cu, Ni, Mn. Zn and Fe from contaminated soils of abandoned mine areas and the results are displayed on Figure 3 below. The ability of the plant to colonize and thrive in heavily contaminated soil and semi-arid areas and deep-reaching root systems were some of criteria used for choosing *Tithonia diversifolia*. The concentrations of Cr, Cu and Ni in the tissues of *Tithonia diversifolia* ranged from 1026.32 mg/kg in the leave to 1847.37 mg/kg in stem, 1757.23 mg/kg in the leave to 5750.94 mg/kg in stem, 676.53 mg/kg in the leaves to 1730.67 mg/kg in stem respectively.

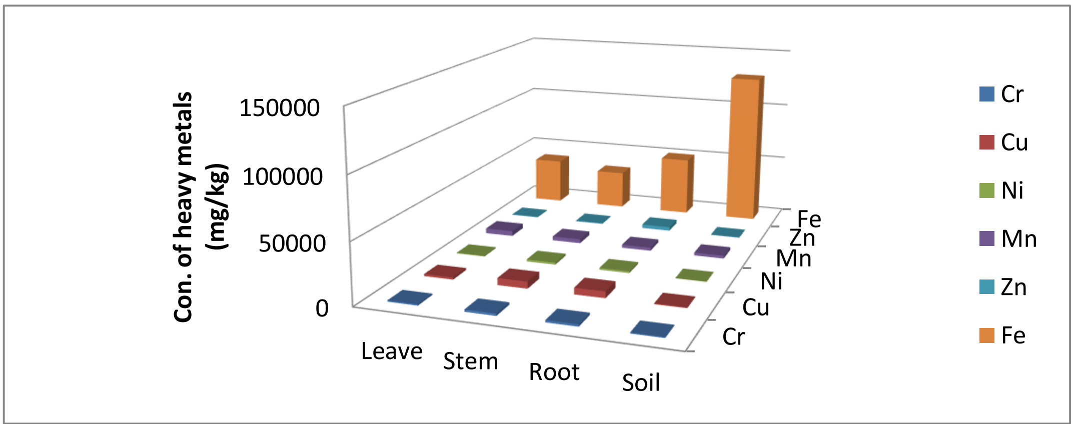

Figure 3: Heavy metal accumulation heavy metals in *T. diversifolia* tissues

The concentrations of the metals in plant's parts were higher than in the soil in the work. The order of the accumulation of Cr, Cu and Ni in the tissues of *Tithonia diversifolia* was stem>roots>leaves which indicates that the plant is good for the phytoextraction and phytostabilization of Cr, Cu, and Ni with translocation factor of 1.68, 1.40 and 1.61 respectively. There is no significant difference ($p<0.05$) in the contents of the metals in the different tissues.

The concentrations of Mn in the tissues of *Tithonia diversifolia* ranged from 2633.80mg/kg in the roots to 4260.56mg/kg in leaves. The order of the accumulation of Mn in the tissues of *Tithonia diversifolia* was leaves>stem> roots indicating that the plant is good for the phytoextraction.

The concentrations of Zn in the tissues of *Tithonia diversifolia* ranged from 481.48mg/kg in the leaves to 3209.88mg/kg in root. The order of the accumulation of Zn in the tissues of *Tithonia diversifolia* was root>stem> leave which indicated that the plant is good for the phytostabilization of Zn.

The concentrations of Fe in the tissues of *Tithonia diversifolia* ranged from 32511.12 mg/kg in leaves to 50088.90 mg/kg in the roots. The order of the accumulation of Fe the tissues of *Tithonia* *diversifolia* was roots>stem>leaves which indicates that the plant is good for the phytostabilization of Fe. The concentrations of Mn, Zn and Fe in plant's tissues were higher than in the soil.

The order of the accumulation of the six metals *Tithonia diversifolia* was Fe>Cu>Mn>Cr>Zn>Ni. Dada *et al.*, [32] reported lower accumulation of some metals in other tissues of *Tithonia diversifolia* but most of metals were accumulated in the roots. Though the metals contents in the plant were low, the plant is of high biomass. Biomass plays more important role in the risk element removal than element concentration [33]. The plant seems to employ phytoaccumulation principles in accumulation metallic pollutants. Dada [34] described phytoaccumulation as process where fast growing species and pollutant-accumulating plants are used to remove metals or organics from soils by concentrating them in the harvestable parts. Once established, *T. diversifolia* quickly forms dense stands with the potential to outcompete native vegetation and thus prevent the recruitment and growth of native plant species) [30]. *Tithonia diversifolia* is an herbaceous flowering plant that has been widely introduced as an ornamental and has escaped from cultivation to become invasive, mostly in disturbed sites, along roadsides and in ruderal areas near cultivation. Due to the invasiveness of this plant in Nigeria, farmers have abandoned their lands owing to the difficulty of curbing the Mexican sunflower from taking over their farms. *T. diversifolia* is a successful invader of new habitats through its tolerance to heat and drought, its rapid growth rates and its large production of lightweight seeds which are easily dispersed by wind, water and animals plant [34]. Ayesa *et al.* also found *Tithonia diversifolia* and *C. odorata* were capable of reducing heavy metals in polluted soils, thus, the plants are good candidates for the phytoextraction of heavy metals from polluted soils [35].

The potentials of *E. camaldulensis* in phytoremediation

The concentrations of Cr in the tissues of *E. camaldulensis* ranged from ND in the stem to 1984.21mg/kg in roots (Figure 4). The concentrations of Cr in leaves and roots were higher than in the soil in the work. The order of the accumulation of Cr in the tissues of *E. camaldulensis* was roots>leaves>stem which indicates that the plant is good for the phytostabilization of Cr. The concentrations of Cu in the tissues of *E. camaldulensis* ranged from 2555.97 in the stem to 6949.06mg/kg in roots. The concentrations of Cu in plant's tissues were higher than in the soil. The order of the accumulation of Cu in the tissues *of E. camaldulensis* was roots>leaves>stem which indicates than the plant is good for the phytostabilization and phytoextraction of the metal with translocation factor of 1.08.

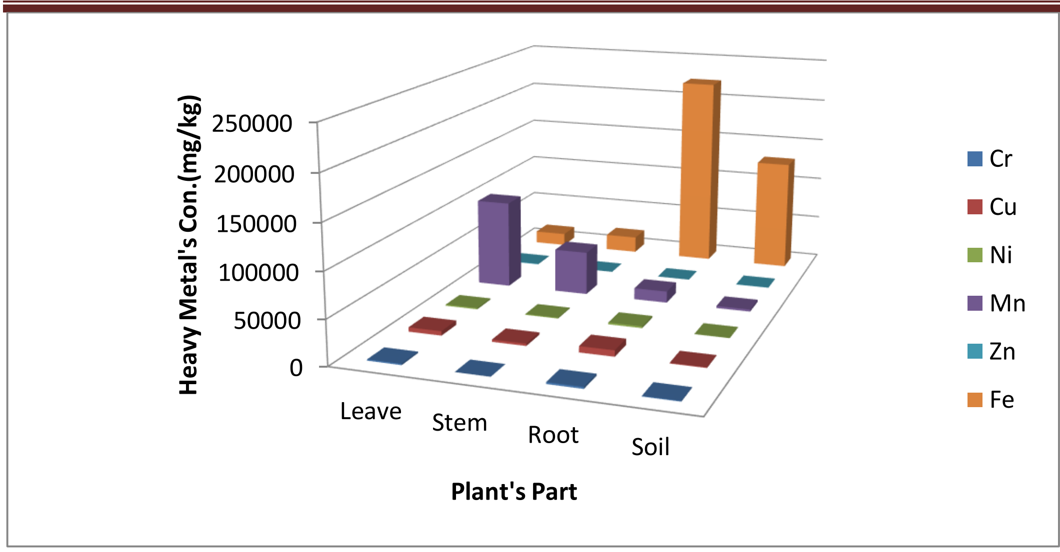

Figure4: Heavy metal accumulation heavy metals in *E. camaldulensis* tissues

The concentrations of Ni in the tissues of *E. camaldulensis* ranged from 944.mg/kg in the stem to 1966.67.06mg/kg in roots. The concentrations of Ni in plant's tissues were higher than in the soil. The order of the accumulation of Ni in the tissues of *E. camaldulensis* was roots>leaves>stem which indicates than the plant is good for the phytostabilization of Ni.

The concentration of Mn in the tissues of *E. camaldulensis is* ranged from 13169.02 mg/kg in the roots to 100704.24 mg/kg in leaves. The concentrations of Mn in plant tissues were higher than in the soil. The order of the accumulation of Mn in the tissues of *E. camaldulensis* was leaves>stem> roots which indicates than the plant is good for the phytoextraction. Zn was only detected in the leaves with the concentration of 641.98mg/kg. The concentrations of Zn in leaves were over twice the concentration in the soil. The accumulation of Zn in the leaves of *E. camaldulensis* indicates that the plant is good for the phytoextraction of Zn. The concentration of Fe in the tissues of *E. Camaldulensis* ranged from 14700 mg/kg in leaves to 222,442.22 mg/kg in the roots. The concentrations of Fe in plants tissues were higher than in the soil. The order of the accumulation of Fe the tissues of *E. camaldulensis* was roots >stem>leaves which indicates than the plant is good for the phytostabilization of Fe. The order of the accumulation of the six metals in *E. camaldulensis* was Fe>Mn>Cu>Ni>Cr>Zn. The concentrations of these metals were higher than in the works of Daniel et al. [36].

The combination of high biomass of the plant, the high accumulation of the metal and its tolerance to hash growing conditions on the mine soil should make this plant suitable agent of phytoremediation of the metals. Herbaceous or woody biomass species may be promising in view of their high-yielding ability, which can compensate for low concentrations of contaminants in their tissues [37], thus resulting in similar or even higher uptake of pollutants than hyperaccumulators [27].

Eucalyptus trees produce extensive canopy cover, they are fast to achieve high annual biomass production, and generally possess a high tolerance against metal pollution [33]. In addition, it provides high nutrient to the grass while lowering water stress and improve soil physical properties. *Eucalyptus* trees can grow on land of marginal quality, have massive root systems, and their above-ground biomass can be harvested with subsequent resprouting without disturbance of the site. However, the cost for planting trees is high and the growth rate is low [38]. Tree species have a range of characteristics that make them possible candidates for application in phytoremediation approaches.

Table 3: Average heavy metals concentration (mg/kg) in six potential plants for phytoremediation at $p < 0.05$

Plants	Cr	Cu	Ni	Mn	Zn	Fe	p-value
H. annuus L	10.93±1.67	34.75±70	8.06±2.02	92.96±31.49	23.67±5.88	768.44±204[a]	0.001
S. oleracea	7.12±1.09	42.43±25.35	4.77±0.87	42.09±25.65	12.87±6.41	373.98±173.54[a]	0.023
E. camaldulensis	11.40±5.92	48.19±12.70	14.42±2.96	546.39±253.74	6.42±0.00	853.73±685.46[a]	0.012
T. diversifolia	15.28±2.54	42.87±12.70	13.01±3	34.34±4.70	14.44±8.84	404.70±51.42[a]	0.001

Table 4: Bioconcentrationfactorand translocation factor of the plants

Plant Type	Bioconcentration Factor						Translocation Factor					
	Cr	Cu	Ni	Mn	Zn	Fe	Cr	Cu	Ni	Mn	Zn	Fe
H. annuus L,	6.5	20.5	12.1	15.4	31.1	2.4	2.8	4.0	4.8	9.4	5.6	2.1
S. aleracea	3.18	18.75	5.35	5.23	12.66	0.87	1.60	5.13	1.84	4.62	5.25	0.70
E. camaldulensis	5.10	21.29	16.18	67.85	2.11	1.99	0.72	1.08	1.20	11.45	0.00	0.15
T. diversifolia	6.84	18.94	14.59	4.26	14.21	0.94	1.68	1.40	1.61	2.91	0.35	1.42

Table 5: Correlation between heavy metals in abandoned mine soil and potential plants for phytoremediation

Heavy metals	Cr	Cu	Ni	Mn	Zn	Fe
Cr	1					
Cu	0.85*	1				
Ni	0.92*	0.84*	1			
Mn	0.02	0.03	0.21	1		
Zn	0.75*	0.61*	0.43	-0.16	1	
Fe	0.02	0.01	0.07	-0.27	-0.05	1

E. camaldulensis accumulated the highest average Cu, Ni, Mn and Fe making it the best among the four in phytoremediation (Table 3). *H. annuus L* a better accumulator of Zn metals whereas *T. diversifolia* was the better accumulator of Cr.

The phytoremediation efficiency obtained for the plants were mostly greater than 1 indicating that the plant could be used for phytoremediation (Table 4). The work showed that the four plants have potentials to phytoremediate the contaminated soil depending on the levels to be cleansed. The trend of the BCF with the metals was; Cu>Mn>ZN>Ni>Cr>Fe and the order of BCF with the plants was;*E. camaldulensis*> sunflower>*T.diversifolia*>spinach. The order of translocation among the metals was Mn>Zn>Cu>Ni>Cr>Fe and according to plants was sunflower>spinach>>*T. diversifolia*.

Plant species for phytoremediation are selected based on their root depth, the nature of the contaminants and the soil, and regional climate. The root depth directly impacts the depth of soil that can be remediated. It varies greatly among different types of plants and can also vary significantly for one species depending on local conditions such soil structure, depth of a hard pan, soil fertility, cropping pressure, contaminant concentration, or other conditions. The cleaning depths are approximately <3 feet for spinach and sun flower, <10 feet for *T. diversifolia* and <20 feet for, deep rooting trees ([35, 39]. Sunflower and spinach are plants that are good for the phytoremediation for low levels, *Tithonia diversifolia* is for moderate levels and *E. camaldulensis* for very deep levels contaminations.

The average concentrations of Fe in all the plant samples were significantly different ($p<0.05$) from other metals. The correlation coefficient between the heavy metals in soil and those in the plants (Table 5) indicated strong relationship between Cr and Cu (0.85), Cr and Ni (0.92) and Cr and Zn (0.75), Cu and Ni (0.84) and Cu and Zn (0.61).This showed that increased concentration of heavy metals in the mining-impacted sites of the mine soils was positively correlated with the bioaccumulation of such elements in plant tissues [40].

CONCLUSION

The mine tailings soil and stream sediments were found to be acidic, non-saline, infertile and also contained elevated concentrations of Cu, Co, Cd, As, Zn, Ni and Mn. Soil analysis of the studied area showed that mine tailing has the greatest probability of metals being leached because of the high available forms of the heavy metal concentrations. *Eucalyptus camaldulensis*, *Tithonia. diversifolia, Helianthus annuus L* and *Spinacia oleracea* could extract Cr, Cu, Zn, Mn, and Ni from metal contaminated soil with high efficiency. *E. camaldulensis* accumulated the highest average Cu, Ni, Mn and Fe making it the best among the four in phytoremediation, H. *annuus L* was a better accumulator of Zn metals whereas *T. diversifolia* was the better accumulator of Cr, The trend of the BCF with the metals was; Cu>Mn>ZN>Ni>Cr>Fe and the order of bioaccumulation of BCF with the plants was;*E. camaldulensis*>sunflower>*T. diversifolia*>spinach. The order of translocation among the metals was Mn>Zn>Cu>Ni>Cr>Fe and according to plants was sunflower>spinach>>*T. diversifolia*. Sunflower and spinach are plants that are good for the phytoremediation for low levels, *Tithonia diversifolia* is for moderate levels and *E. camaldulensis* for very deep levels contaminations.

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