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Phytoremediation Potential of Some Indigenous Herbaceous Plant Species Growing on Metalliferous Mining Sites At Nahuta, Bauchi State, Nigeria

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Abstract: *Heavy metals constitutes a serious threats because unlike most organic pollutants they are not easily degraded through natural process and therefore remain in the environment for a very long time. Soil contamination resulting from mining activities affects surrounding flora and fauna and presents a large clean-up challenge to the mining industry. One alternative biological approach to deal with this problem is phytoremediation – which involves the extraction or inactivation of these metals in soils by plants. Compared to other technologies, phytoremediation is less expensive and is particularly suitable for treatment of large volumes of soil in abandoned mining site. The extent of soil contamination by heavy metals (Zn, Cu, Pb and Cd) and potentials of herbaceous plant species to remediate the soil at Nahuta spoiled mining site in Bauchi State, Nigeria was assessed. Herbaceous plants and their associated soils were collected from three sites namely Jijigari, Jijidaba and Gamagari. There were generally higher concentrations of the heavy metals in plants than in soils which indicate the ability of the plants to tolerate and accumulate these metals. Considering the definition of a hyperaccumulator – plants that accumulate >1000mg kg−1 of Cu, Co, Cr, Ni or Pb, or >10,000mg kg−1 of Mn or Zn, none of the plants investigated attained the status of hyperaccumulator. However considering their high metals Bioconcentration Factor (BCF) and Enrichment Factor (EF), Cenchrus biflorus, Cyperus rotundus and Cynodon dactylon, are potential phytostabilizers. It may be concluded that the indigenous herbaceous plant species growing on soils of the spoiled mining sites at Nahuta have phytoremediation potentials.*

Keywords: *Heavy Metals; Herbaceous Plants; Phytoremediation; Mining Sites; Nahuta*

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I. Introduction

The accumulation of heavy metals above the normal background concentration could pose a serious health risks and hazards to humans and the ecosystem. Soil and other environmental media may be contaminated with heavy metals through various human activities such as mining, smelting of metal ores and application of chemical pesticides and fertilizers to agricultural land [1, 2]. Tailings from metalliferous mining sites are among the major sources of heavy metal pollution that affects almost all the environmental media. Heavy metals constitutes a serious threats because unlike most organic pollutants, they are not easily degraded through natural process and therefore remain in the environment for a very long time. Soil contamination resulting from mining activities affects surrounding flora and fauna and presents a large clean-up challenge to the mining industry. One alternative biological approach to deal with this problem is phytoremediation – which involves the extraction or inactivation of these metals in soils by plants. Compared to other technologies, phytoremediation is cost effective, environmentally friendly [3] and is particularly suitable for treatment of large volume of soil in abandoned mining site. There are three major categories of phytoremediation as far as metal contaminated site is concern. The first category is called phytoextraction in which the plant species accumulate metal and store it in its harvestable part [4]. The second is called rhizofiltration whereby the metal accumulating plants grow and absorb the metal in contaminated water or effluent [5]. The third is known as phytostabilization in which the plant species stabilizes the metal in contaminated soil thereby reducing its mobility [6, 7].

The terms commonly used in identifying a plant species' potentials for use in phytoremediation include metal Bioconcentration Factor (BCF), Translocation Factor (TF) and Enrichment Factor (EF). The BCF is defined as the metal concentration ratio in root to soil. The TF is referred to as the ratio of metal concentration in shoot to root [8, 9, 10]. The EF is the metal content ratio in shoot to soil [11].

A plant spp that has both BCF and TF > 1 has the potential of being use in phytoextration. If however only the BCF > 1 and the TF < 1 the spp is said to have the potentials for phytostabilization [8].

Plant capable of accumulating excessively high amount of metals in its above ground parts is called hyperaccumulator. Hyperaccumulators are defined as plants that accumulate > 1000 mg/kg of Cu, Co, Cr, Ni or Pb, or > 10000 mg/kg of Fe, Mn or Zn [12]. In addition to this criterion, other authors have included two important attributes associated with hyperaccumulation of heavy metals. According to [12] and [13] hyperaccumulator should have metal TF >1, an important attribute which depict the ability of the plant to transfer the metal from root to shoot and a mechanism to tolerate excess concentration of the metal in soil. The Enrichment Factor should also be greater than one (EF >1) which indicates higher concentration of the metal in plant than that in the soil and placing emphasis on the extent of metal uptake by the plant [14].

The identification of metal hyperaccumulator plants capable of accumulating extra- ordinarily high metal levels demonstrates that plants have the genetic potential to clean up contaminated soil [15]. Native plants should be used for phytoremediation because they are often better in terms of survival, growth and reproduction under environmental stress than plants introduced from the other places [8].

The aim of this investigation was to determine the concentrations of Cu, Cd, Pb and Zn in native herbaceous plants and their associated soils from Nahuta metalliferous mining sites and assess the potentials of these plants for use in phytoremediation.

II. Materials And Methods

2.1 Study Area

The area is located within the guinea savanna belt of Nigeria which consist of shrubs, stunted grasses and few scattered trees mostly of the same strata. There are two major seasons, the wet season that spans between May and October and dry season occur between November and late April.

According to [16], the study area is a sedimentary environment characterized by two outcrops, which are the Cenomanian Yolde formation that overlies the Albian Bima sandstone. The drainage in the area is the River Payi with several tributaries that drain water from the elevated Bima sandstone outcrops to the Yolde formation which bears the river. The geological formation of the mining site is on Benue Trough which originated from Early Cretaceous rifling of the central West African basement uplift. It forms a regional structure which is exposed from the northern frame of the Niger Delta and runs north-eastwards for about 1000km to underneath Lake Chad, where it terminates. Regionally, the Benue Trough is part of an Early Cretaceous rift complex known as the West and Central African Rift System. The study area is endowed with abundant of wildlife, Hydrocarbon deposit and other mineral resources. The major mineral ores that are mined include Lead and Zinc deposited in trend of narrow vein. The Nahuta mining site lies between Latitude N9^0 35'-N9^0 40' and Longitude E10^o 44' and E10^0 55'.

2.2 Sampling and sampling strategy

Plants and soil samples used for this study were collected from metalliferous mining sites at Nahuta in Gwana District of Alkaleri Local Government Area of Bauchi State, Nigeria. Three major sites (Jijigari, Jijidaba, Gamagari) where extensive mining activities have taken place were selected for this study. In each of the sites, a 50m by 50m plot was demarcated and all the herbaceous plant species contained in the plots were collected. Each of the plant samples was separated into its shoot and root. Soil samples were also collected around the rhizosphere of each plant collected using clean stainless steel shovel and taken to laboratory well secured in a polythene bag for analysis.

2.3 Laboratory Analysis

2.3.1 Digestion of Soil Samples

The soil samples were oven dried at 70^{0}C. The dried soil samples were crushed in a porcelain mortar with a pestle. The crushed soil samples were sieved through a 2mm sieve made of stainless steel, and the sieved soil samples were further pulverized to a fine powder and passed through a 0.5mm sieved for analysing total metal content. The soil sample (1.0g) was weighed into a 50ml beaker for acid digestion. Thereafter, a 10ml of HNO_3 and HCL_4 acid mixture (2:1 by volume) was used for the digestion. The tubes were placed in the digester and were set to about 150^{0}C, it was digested for 2 hours. The mixture was allowed to cool and filtered through Whitman filter paper. Each filtrate was collected into 100ml volumetric flask. The filtrate was diluted to mark with distilled water and the resultant solution was analysed for Cadmium (Cd), Lead Pb, Zinc Zn, and Copper Cu, using Atomic Adsorption Spectrophotometer (AAS) Buck Scientific VGP210 Model.

2.3.2 Digestion of Plant Sample

The plant species were oven dried at 70^{0}C until stable weight were obtained. Samples of roots and shoots were then grinded in a mortar, passed through a 2mm sieved and stored at room temperature before the analysis. Each of the prepared sample (1.0g) was weighed into 100cm^3 conical flasks and 3:1 ratio of HNO_3 and HCl acid was added and the mixture was heated for 30 minutes on a water bath at 100^{0}C. The digest was allowed to cool and another 5cm^3 of HNO_3 was added and heating continued for 1 hour at 100^{0}C. The volume of the digest was reduced by boiling on the water bath and this allowed cooling. Distilled water was added heating continued for another 30 minutes. The final digest was allowed to cool and filtered. The final volume of digest was made up to 100cm^3 with the distilled water and was analysed for the required heavy metal by Atomic Adsorption Spectrophotometer (AAS) Buck Scientific VGP210 Model.

2.4 Data Analysis

Simple descriptive statistics was used to interpret the raw data generated in the course of this investigation. Analysis on the phytoremediation potentials of the various plant species was based on the determination of Bioconcentration Factor (BCF) = metal concentration in soil/metal concentration in root; Translocation Factor (TF) = metal concentration in root/metal concentration in shoot; Enrichment Factor (EF) = metal concentration in soil/metal concentration in shoot [17].

III. Results And Discussion

3.1 Zn content in soil and plants

The mean Zn concentrations in plant spp and their associated soils obtained from the mining sites at Nahuta are as shown in Table 1. The result indicates that the soil collected under *Eleusine indica* has the highest Zn content of 226.84mg/kg. The least Zn content (116.80mg/kg) was however recorded in soil collected under *Cynodon dactylon*. In terms of metal uptake, the root of *Cyperus rotundus* has the highest metal content of 321.50mg/kg while *Eleusine indica* has the least (19.25mg/kg). The highest Zn content of 41.86mg/kg was recorded in the shoot of *Eleusine indica* while the least shoot Zn level was recorded in *Cynodon dactylon.*

Table 1 The mean Zn concentrations (mg/kg) in soil and herbaceous plant species obtained from Nahuta mining site

S/N	Plant species	Soil	Root	Shoot
1	*Eleusine indica*	226.84	19.25	41.86
2	*Cenchrus biflorus*	227.80	304.60	238.00
3	*Chloris pilosa*	258.20	361.80	284.80
4	*Cyperus rotundus*	293.60	384.90	306.20
5	*Pennisetum pedicellatum*	283.10	266.90	244.50
6	*Echinochloa stagnina*	168.50	321.50	175.70
7	*Sorghum lanceolatum*	258.40	330.10	290.40
8	*Cynodon dactylon*	115.80	203.60	136.60
9	*Setaria pumila*	166.80	325.20	302.00
10	*Ceptochloa filiforms*	170.30	243.10	204.40

3.2 Cu content in soil and plants

The soil samples collected under *Cyperus rotundus* has the highest Cu content of 21.18mg/kg while those collected under *Echinochloa stagnina* has the least (11.62mg/kg). The plant analysis revealed that *Eleusine indica* has the highest shoot (32.21mg/kg) and root (25.61mg/kg) mean Cu content. The least root and shoot Cu concentrations of only 17.86mg/kg and 12.37mg/kg were however recorded in *Cynodon dactylon* and *Echinochloa stagnina* respectively as indicated in Table 2.

Table 2. The mean Cu concentrations (mg/kg) in soil and herbaceous plant species obtained from Nahuta mining site

S/N	Plant species	Soil	Root	Shoot
1	*Eleusine indica*	18.14	32.21	25.61
2	*Cenchrus biflorus*	14.34	23.08	16.27
3	*Chloris pilosa*	16.63	21.79	22.85
4	*Cyperus rotundus*	21.18	26.62	22.72
5	*Pennisetum pedicellatum*	18.55	22.59	19.60
6	*Echinochloa stagnina*	11.62	22.83	12.37
7	*Sorghum lanceolatum*	17.35	19.54	18.16
8	*Cynodon dactylon*	13.60	17.86	15.97
9	*Setaria pumila*	16.68	27.17	25.20
10	*Ceptochloa filiforms*	17.03	28.54	23.01

3.3 Pb content in soil and plants

The soil samples collected under *Echinochloa stagnina* had the highest mean Pb concentration of 27.70mg/kg. The least mean Pb concentration (13.20mg/kg) was however recovered in soil samples collected under *Cynodon dactylon.* Plant species with the highest root mean Pb concentration was *Eleusine indica* with

85.40mg/kg of the metal. The root of *Cyperus rotundus* however contained the least Pb content with only 39.90mg/kg concentration of the metal. Among all the plant species under consideration, the shoot of *Setaria pumila* had the highest mean Pb content of 50.20mg/kg. The least mean Pb value was though recovered in the shoot of *Cenchrus biflorus* with a mean Pb concentration of 21.00mg/kg.

Table 3. The mean Pb concentrations (mg/kg) in soil and herbaceous plant species obtained from Nahuta mining site

S/N	**Plant species**	**Soil**	**Root**	**Shoot**
1	*Eleusine indica*	15.30	85.40	23.80
2	*Cenchrus biflorus*	15.80	63.30	21.00
3	*Chloris pilosa*	22.60	62.40	22.80
4	*Cyperus rotundus*	23.30	39.90	34.10
5	*Pennisetum pedicellatum*	16.60	55.80	27.60
6	*Echinochloa stagnina*	27.70	58.30	36.50
7	*Sorghum lanceolatum*	20.10	42.40	22.40
8	*Cynodon dactylon*	13.20	54.20	39.70
9	*Setaria pumila*	16.70	60.70	50.20
10	*Ceptochloa filiforms*	20.10	46.80	22.70

3.4 Cd content in soil and plants

The maximum Cd content in soil was obtained in samples collected under *Eleusine indica* with a mean metal concentration of 1.07mg/kg while the minimum content was determined in soil samples associated with *Cynodon dactylon* with mean Cd concentration of 0.31mg/kg. The root of *Setaria pumila* had the highest level of Cd with mean concentration of 1.17mg/kg while the least mean value of 0.94mg/kg was recovered in the root of *Cyperus rotundus.* The shoot system of *Cynodon dactylon* had the maximum Cd content with a mean concentration of up to 3.97mg/kg. The least mean value was however recovered in the shoot of *Cyperus rotundus* and *Echinochloa stagnina* with mean Cd value of 0.65mg/kg each.

Table 4. The mean Cd concentrations (mg/kg) in soil and herbaceous plant species obtained from Nahuta mining site

S/N	**Plant species**	**Soil**	**Root**	**Shoot**
1	*Eleusine indica*	1.07	1.62	0.73
2	*Cenchrus biflorus*	0.84	1.53	0.97
3	*Chloris pilosa*	0.76	0.97	0.78
4	*Cyperus rotundus*	0.40	0.94	0.65
5	*Pennisetum pedicellatum*	0.72	1.37	0.83
6	*Echinochloa stagnina*	0.66	1.06	0.65
7	*Sorghum lanceolatum*	0.57	1.17	0.71
8	*Cynodon dactylon*	0.31	0.85	3.97
9	*Setaria pumila*	0.85	1.79	1.62
10	*Ceptochloa filiforms*	1.02	1.30	1.11

3.5 Metals Accumulation by Plants

The ability of the plant species to accumulate metals and be used in Phytoremediation can be determined using BCF, TF and EF as shown in Table 5. The maximum BCF factor for Zn (2.34) and Cu (1.96) were recorded in *Echinochloa stagnina* while those of Pb (5.58) and Cd (2.74) were recorded in *Eleusine indica* and *Cynodon dactylon* respectively. The highest TF values for the metals Zn (2.17), Cu (1.04), Pb (0.85) and Cd (4.67) were determined for *Eleusine indica, Chloris pilosa, Cyperus rotundus* and *Cynodon dactylon* respectively. The EF values for the metals showed that *Setaria pumila* had the maximum Zn and Cu EF value of 1.81 and 1.51 respectively. The maximum EF for Pb (3.01) and Cd (12.81) were however recorded in *Cynodon dactylon.*

Table 5. The Bioconcentration Factor (BCF), Translocation Factor (TF) and Enrichment Factor (EF) of Zn, Cu, Pb and Cd in the different herbaceous plant species at Nahuta mining site

Plant species	Bioconcentration Factor (BCF)				Translocation Factor (TF)				Enrichment Factor (EF)			
	Zn	Cu	Pb	Cd	Zn	Cu	Pb	Cd	Zn	Cu	Pb	Cd
Eleusine indica	0.08	1.78	5.58	1.51	2.17	0.79	0.27	0.45	0.18	1.41	1.55	0.68
Cenchrus biflorus	1.34	1.61	4.00	1.82	0.78	0.70	0.33	0.63	1.04	1.13	1.33	1.15
Chloris pilosa	1.40	1.31	2.78	1.2	0.79	1.04	0.37	0.80	1.10	1.37	1.01	1.02

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Cyperus rotundus	1.31	1.25	1.71	2.35	0.80	0.85	0.85	0.69	1.04	1.07	1.46	1.62
Pennisetum pedicellatum	0.94	1.22	3.36	1.90	0.92	0.87	0.49	0.61	0.86	1.05	1.66	1.15
Echinochloa stagnina	2.32	1.96	2.10	1.60	0.55	0.54	0.63	0.61	1.04	1.06	1.32	0.98
Sorghum lanceolatum	1.28	1.13	2.11	2.05	0.88	0.93	0.53	0.61	1.12	1.04	1.11	1.24
Cynodon dactylon	1.78	1.31	4.11	2.74	0.67	0.89	0.73	4.67	1.18	1.17	3.01	12.81
Setaria pumila	1.94	1.63	3.63	2.11	0.92	0.93	0.83	0.91	1.81	1.51	3.00	1.91
Ceptochloa filiforms	1.42	1.68	2.33	1.27	0.84	0.49	0.49	0.85	1.20	1.35	1.13	1.09

There are generally higher concentrations of the metals in plants compared to their associated soils (except for Zn in soil collected under *Eleusine indica* and to some extent *Pennisetum pedicellatum*). This corroborates the findings of [18] who reported that plant species under normal growing condition can accumulate metal ions an order of magnitude greater than their surrounding medium. The study also indicates that the herbaceous plants thriving on the mining sites have the ability to remove the metals from the soil and store them in their roots and shoots. The plants species being native to the area must have developed some mechanisms that enable them to cope with the high levels of these metals in the environment.

Considering the hyperaccumulator definition given by Baker and Brooks (1989) none of the herbaceous plants considered in this study is a hyperaccumulator i.e. has accumulated Zn, Cu, Pb or Cd > 1000mg/kg. However, the ability of these plants to tolerate and accumulate relatively high amount of metals makes them potential candidates for use as phytostabilizers and/or phytoextractors. As earlier pointed out, a plant *spp* with BCF and TF >1 is a potential candidate for phytoextraction. It follows therefore that *Chloris pilosa* with BCF of 1.40 and TF of 1.04 is a potential phytoextractor of Cu. *Cynodon dactylon* with BCF of 2.74 and TF of 4.67 is also a good candidate for phytoextraction of Cd.

Also as earlier reported by [8], plant species with BCF > 1 and TF < I is a potential phytostabilizer. As such, all the herbaceous plants under consideration (except *Eleusine indica* and *Pennisetum pedicellatum* for Zn remediation) could be used as phytostabilizers of the various metals in the soil environment.

All the plant species (except Eleusine indica for Zn and Cd remediation, *Pennisetum pedicellatum* for Zn remediation and *Echinochloa stagnina* for Cd remediation) have EF > 1. This further revealed that although the spp do not attained the pull status of hyperaccumulators, they could still be useful candidates for phytoremediation as phytoextractors. This is especially so for *Cynodon dactylon* (with Pb EF of 3.01 and Cd EF of 12.81) and *Setaria pumila* (with Pb EF of 3.00 and Cd EF of 1.91).

IV. Conclusion

This investigation revealed that indigenous herbaceous plant species could be used to remediate heavy metals impacted soil due to mining activities at Nahuta in Bauchi State, Nigeria. The use of these species could help to restore the lost vegetation in the area through the mining activities. Although none of the spp can be classified as Hyperaccumulator some of them can be used as phytoextractors or phytostabizers. Be that as it may be, certain issues need to be addressed to successfully use these herbaceous plants in phytoremediation. There is the possibility of metal transfer from the plants to human through the grazing animals as the plant spp under consideration are all herbaceous and palatable to ruminants. An effective way of preventing grazing animals from accessed to the sites need to be workout. Another challenge is that of disposal of the heavy metals contaminated plants. The harvested plant biomass should be properly stored or disposed in such a way that it does not constitute any serious threat to the environment

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