FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 7 No. 2, April, 2023, pp 313 - 320
DOI: https://doi.org/10.33003/fjs-2023-0702-2043

METAL ACCUMULATION ASSESSMENT IN PLANTS AND SOIL AT KUDUKU MINING SITE, NASARAWA, NIGERIA

[1]Ilyas, S., [2]Sabo, A., *[1]Akomolafe, G. F., [1]Mustafa Y. S.

[1]Department of Plant Science and Biotechnology, Federal University of Lafia, PMB 146, Lafia, Nasarawa State, Nigeria
[2]Department of Environmental Management Technology, Abubakar Tafawa Balewa University, PMB 0248, Bauchi State, Nigeria.

*Corresponding authors' email: gbenga.akomolafe@science.fulafia.edu.ng Phone: +2348068997606

ABSTRACT
Mining activities usually alter ecosystems through the disruption of the vegetations and the deposition of potentially toxic elements. This study investigated the soil pollution level and evaluated the phytoremediation potential of some native plant species on a mining site at Kuduku, which is located in Keana local government area of Nasarawa State. Plant samples and associated soils were collected from the mining site and analyzed for the presence of metals such as Pb, Cd, Cr and Mn. The Bioconcentration factor (BCF), Translocation Factor (TF) and Enrichment Factor (EF) were also analyzed. They were generally higher concentration of the heavy metal in most of the plants than in soils which indicates the ability of the plant to tolerate and accumulate these metals. Most of the investigated plants have potentials of been phytostabilizers or phytoextractors. Lead recorded the following plants as phytostabilizers; *Acalypha indica*. Copper had the following plants as good phytoextractors; *Sida acuta, Fumaria parviflora, Triumfetta rhomboidea, Acalypha indica* and *Ageratum conyzoides.* For Manganese, the phytoextractors includes: *Calopogonium mucunoides, Fumaria parviflora, Ageratum conyzoides* while phytostablizers includes: *Triumfetta rhomboidea and Sida acuta.* Most of the investigated plants had an enrichment factor (EF) greater than one which also emphasizes on the extent of metal uptake by the plants. For the majority of the plants investigated, their EF was greater than one except in few cases.

Keywords: Enrichment factor, Heavy metals, Kuduku, Mining, Phytoremediation

INTRODUCTION
Mining operations completely alter a site's ecosystems by disrupting the ecological balance, natural landscapes, agricultural lands, forests, plantations and vegetation as well as economic food and tree crop. A major factor regarding mining operations is the deposition of potentially toxic elements (PTEs), during the exploitation process or after the closure of the activity without any form of remediation. The PTEs include metals such as (Zn, Pb, Cd, Cu etc.). The presence of these metals especially in high amount have seriously affected the physiological and biochemical processes in plants ,animals as well as soil microorganisms(Ramirez *et al.,* 2019; Pagano *et al.,* 2015; Tchounwou *et al.,* 2012; Zhang *et al.,* 2022).

Heavy metals are non-degradable by any biological or physical processes and tend to exist in the soil for a long period of time which in turn becomes a threat to the Environment (Suman et al 2018).They are a group of metallic chemical elements that have relatively high densities, atomic weights and atomic numbers. The common ones include: Cadmium (Cd), Mercury (Hg), Lead (Pb),Arsenic(As),Zinc(Zn), Chromium(Cr) etc which can originate either from natural or anthropogenic sources such as product water generated in oil and gas industries (Neff *et al.,* 2011; Pichtel, 2016), the use of phosphate fertilizers in Agriculture (Hazah *et al.,* 2016; Rafique and Tariq, 2016), sewage sludge (Farahat and Linderholm, 2015), metal mining and smelting (chen et al., 2016),pesticide application(Iqbal et al.,2016) electroplating and fossil fuel burning (Muradoglu et al.,2015).The non-essential heavy metals such as Pb Cd, As, Hg can enter into the food chain and accumulate in the human body through biomagnification, posing a serious threat to overall human health (Sarwar *et al.,* 2010; Rechman *et al.,* 2017).

The increasing discharge of this heavy metals to the environment due to the mining activity is posing serious threats to the soils, water and health of people in this area. Long-term application of heavy metals such as Cd, Cr, Pb and Zn in soil causes a decline in soil microbial activity, ground water, contamination of the human food chain. Heavy metal accumulation can enter the food chain through agricultural products or leach into drinking water. Many species of plants have been successful in absorbing contaminants such as Lead, Cadmium, Chromium arsenic and various radionuclides from soils. Metals accumulate in plant parts (Kamal *et al.,* 2004), In this case, the degree of plant adoption by tolerance to metals is very variable from species to species (Nestic, 2011). Plants have the abilities to absorb ionic compounds in the soil even at low concentration through their root system. They extend their root system into the soil matrix and form a rhizosphere ecosystem where heavy metals are accumulated and their bioavailability is also regulated and hence reclaiming the polluted soil and also stabilizing the fertility of the soil (Ali *et al.,* 2013; Jacob *et al.,* 2018; DalCorso *et al.,* 2019). This work tends to address the problems of heavy metal contamination in Kuduku mining site and comparing the level of contamination with the allowable limit as well as identifying the herbaceous plants with Phytoremediation capacity.

MATERIALS AND METHODS
Study area
Kuduku is located Along Giza Road in Keana Local Government Area of Nasarawa State. The LG is one of the 13 Local Government Areas found in the state. It has abundance of minerals such as Baryte, Galena, Salt, Lead, Zinc and Gemstone. The state has a climate typically of the tropical zone because of its location with minimum and maximum temperature of 18.7^{0}F and 16.7^{0}F respectively.

Rainfall varies from 131.73cm in some places to 145cm in others. The month of December, January and February are cold due to harmattan wind blowing across the state from the North East. It is characterized by two seasons; Dry and Rainy. The Dry Season spans from November to February while the Rainy Season from March to October. Benue Valley are composed of sandstone. However, the sandstone zone lying district of Awe, Keana and Akili are detached Synclinal area formed by localized flooding.

The Mineral that is mined in this site is Baryte. Baryte is a mineral composed of Barium Sulphate ($BaSO_4$). It has a transparent crystalline appearance. Its colours ranges from colourless to white, shades of yellow, blue, brown. It has a high specific gravity of 4.5 which is exceptional for a non-metallic mineral. Its high specific gravity makes it suitable for a wide range of industrial media and manufacturing usage. Most Baryte produced is used as a weighing agent in drilling muds. It is also used as a pigment in paints and as a weighted filter for paper, cloth and rubber. Baryte is the primary ore of Barium which is used to make a wide variety of barium compounds. Some of them are used for X-ray shielding. It also has the ability to block X-ray and gamma ray emissions. The area has a coordinate of Latitude 08^o 33` 822``N and Longitude 08$^o$ 32`833``E.

Plate 1: Collected Sample of Baryte from Kuduku Mining Site
Photo credit: Saudat, 2019

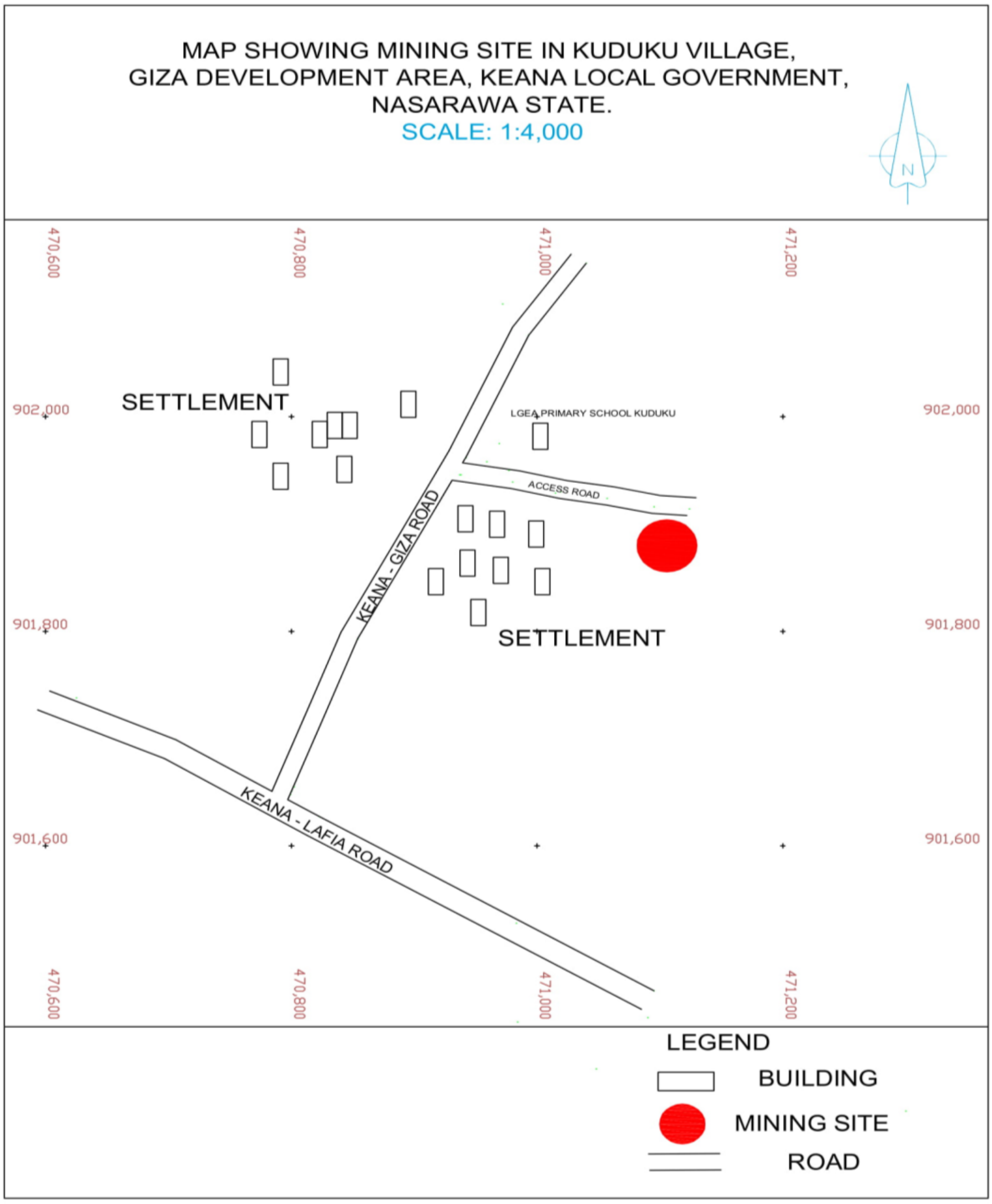

Figure 1: Map showing Kuduku Mining Site

Sample collection

Fresh plant samples were carefully uprooted from the sampling areas to avoid any damage to the plant parts. The sampling areas were marked using a measuring tape starting from 0cm, 50cm and 100cm away from the mining location. Three representatives' plant samples were uprooted from each of the marked point and stored in a well labeled polythene bag to be transported to the laboratory. The soil sample around the rhizosphere of each sampled plant was carefully collected using a hand trowel and stored also in a polythene bag for analysis.

Determination of Metal Content

Plant samples were carefully separated into portions of leaves, stems, and root. They were washed, placed into an oven for 48 hours until they are dried, and grinded using ceramic mortar and pestle. The respective soil samples were also dried, ground and sieved using a 2mm mesh sieve size. The plant samples were ashed using crucibles and the extraction process was done using Aqua regia solution. The filtrates were stored in glass vials for extraction. The soil samples were extracted using Mehlich -3 extracting solution. Soil pH was determined in water and also in 1N potassium chloride solution. Organic carbon was determined using Black (1965) potassium dichromate wet oxidation method. Organic matter in the soil was determined according to Black (1965) as;

%.Organic matter = % Organic Carbon x 1.729

Phosphorus concentrations in both the soil and plants filtrates were determined using the conventional method (Bray and Kurtz, 1984).

The concentration of metals in the filtrates was determined using atomic absorption spectrophotometer, equipped with a digital read out system. Working standards were prepared prepared for the elements individually. A blank reading was also taken and necessary corrections were made during the calculation of concentration of various elements. The parameters that were investigated include Cd, Cr, Cu, Pb, Mn, Ca, Mg and P.

Determination of Bioconcentration, Translocation and Enrichment factors

Bioconcentration factor (BCF), is defined as the metal concentration in plant root to extractable concentration of the metal in the soil. It refers to the ability of the plant body to accumulate the heavy metals from the soil to the roots of the plant. It is expressed mathematically as;

BCF = C_{root}/C_{soil}

Where Croot = concentration of metal in root, Csoil = concentration of metal in soil

Translocation Factor (TF) refers to as plant's ability to translocate heavy metal from root to harvestable aerial part (Khan, 2013). When TF > 1 is obtained, it indicates a preferential partitioning of metals from soil to the root and from the root to shoot respectively (Baker and Whiting, 2002). Mathematically, it is expressed as:

TF = C_{shoot}/C_{root}

Where Cshoot = Concentration of metal in shoot, Croot = concentration of metal in root

Enrichment factor (EF) is defined as the metal content ratio in shoot to soil. Mathematically, it is expressed as:

EF = Cshoot/ Csoil

Where Cshoot = concentration of metal in shoot, Csoil = concentration of metal in soil

A plant species that has both BCF and TF > 1 has the potential of being used in phytoextraction.

If, however only the BCF > 1 and the FT < 1, the species is said to have potential for phytostabilization (Sabo and Ladan, 2014).

Plants capable of accumulating excessive high amount of metal in its above ground part are called hyperaccumulators. Hyperaccumulator are defined as plants that can accumulate > 1000 mg/kg of Fe, Mn, or Zn (Baker and Brooks, 1989).

In addition to this criterion, other authors have included two important attributes associated with hyperaccumulation of heavy metals. According to Baker and Brooks (1989); Market (2003), hyperaccumulator should have metal TF > 1, an important attribute which depicts 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 plants (Mc Grath and Zhao, 2003).

Data Analysis

The differences in soil metal concentrations were determined by one-way ANOVA using the general linear models' procedure (SAS 2004). The comparisons of means were performed using least significant difference. The differences in the metal concentrations between the shoots and roots were determined using the Kruskal-wallis non parametric test.

RESULTS AND DISCUSSIONS

The herbaceous plant species recorded at Kuduku Mining Site are shown in (Table 1).Identical plants were collected at two different locations. In total, seven different herbaceous plants found growing in the site were collected. The exact distance from the starting point of collection was also recorded.

Table 1*:* Identified Plants at Kuduku Mining Site

S/N	Plant Name	Common Name	Location(s)
1	*Tridax procumbens*	Coat Button	KS_1 (0cm)
2	*Sida acuta*	Wire Weed	KS_2 (0cm)
3	*Calopogonium mucunoides*	Fact Sheet	KS_3 (0cm)
4	*Ageratum conyzoides*	White Weed	KS_4 (50cm)KS_7 (100cm)
5	*Fumaria parviflora*	Fine Leaf Fumitory	KS_5 (50cm)
6	*Triumfetta rhomboidea*	Diamond Burbark Chines	KS_6 (50cm)KS_8(100cm)
7	*Acalypha indica*	Indian Acalypha three-seeded Mercury	KS_9 (100cm)

KS = Kuduku Mining Site

Table 2: WHO permission level for heavy metals in plants and soils

Element	Target Value of Soil (Mg/Kg)	Permission Value of Plant (Mg/Kg)
Cd	0.8	0.02
Zn	50	0.6
Cr	36	10
Cu	100	1.3
Pb	85	2
Ni	35	10

Target values are specified to indicate a desirable maximum level of elements in the unpolluted soils.
Source: Denman Robbers 1990; Ministry of Housing, Netherlands (1994) Xxx source: WHO 1996

Investigation of the different parameters present in the root and shoot were carried out using Kruskal wallis non-parametric test (Table 3). The parameters include cadmium, chromium, calcium, manganese, copper, lead, magnesium and phosphorus. The mining site recorded high amount of nutrients such as calcium, magnesium and phosphorus both in the plant parts and in the soil. The presence of calcium and magnesium in the soil has led to a decrease in the uptake and accumulation of the metal manganese in both the soil and plants at the site. Calcium is known to ameliorate the toxicity of heavy metals. Cd and Cr were not recorded in any of the plant parts. The absence of Cd in the site could be attributed to the fact that calcium was recorded in high concentration and it is likely to suppress the concentrations of cadmium. This is in line with the report of Naoko *et al.* (2011), where they reported that the transport of Cd from the roots through stems and leaves are suppressed by calcium treatment, indicating that the presence of Ca regulates Cd transport from the roots. Chromium on the other hand, was also not recorded in any of the plant parts. Cr is a toxic non-essential element to plants; hence they do not possess specific mechanism for its uptake. Therefore, the uptake of this heavy metal is through carriers used for the uptake of essential metals for plant metabolism. Iron, Sulphur and Phosphorus are known also to compete with Cr for carriers building (Wallace *et al.,* 1976). This could explain the reason why lead concentration wasn't that severe on the mining sites. For phosphorus, both the water-soluble and the insoluble ones have been proven to be effective in ameliorating lead in contaminated soils and plants. Phosphorus might have gotten its way into the mining sites due to fertilizer application in nearby farms as some of the collected plants were found growing close to farmlands. The analysis also revealed that Lead concentrations recorded the highest concentration in the shoot of *Tridax procumbens* (12.28ppm) while its root recorded a concentration of (0.694ppm). These values recorded, exceed the permissible value of lead in the plant in mg/kg which is 2mg/kg. However, the recorded values are less compared to that reported by Sabo and Ladan (2014) where they recorded a concentration of 42.40ppm in the root of *Tridax procumbens* and 22.40ppm in its shoot. Ambo *et al.* (2012) recorded a lesser concentration of lead in the plant *Frosobis africana* where they recorded lead concentration to be within the range of 3.21 - 10.51mg/kg in the plant. Ogundele *et al.* (2015) also reported lead concentration in plants and soils along heavy traffic in North Central Nigeria to be within the range of 24 - 142mg/kg which is a higher content compared to the previous authors. The reason for high absorption in the shoot could be as a result of its creeping stem reaching 20 - 75cm in length and also it has been categorized as a noxious weed invading virtually all forms of lands and it's preferability to cease textured soils located in tropical locations which fits the description of the sampling area. The plant is a native species to that locality.

Copper accumulation by plants in this study was recorded to be highest in the root of *Triumfetta rhomboidea* with a concentration of (3.313ppm) while its shoot recorded a concentration of (0.338ppm). The recorded level of Cu in the roots exceeds its permissible value (1.30mg/kg). Sabo and Ladan, 2014 recorded copper concentrations in plants to be within the range of 17.86 to 32.21mg/kg in roots and 12.37 to 25.61mg/kg in the shoot. Both recorded concentrations were higher than the present study. Ogundele *et al*.,(2015), reported copper concentration in plants raised on soil along heavy traffic road in North Central Nigeria to be 88.55mg/kg. This recorded concentration exceeds the previously reported cases of copper concentration in plants. The high tolerance of copper in the plant *Triumfetta rhomboidea* might be due to its adaptation to waste site habitat where it has developed a mechanism to accumulate heavy metals in it. The concentration of manganese recorded in this site was highest in root of *Triumfetta rhomboidea* having a concentration of (3.164ppm) while it's shoot recorded a concentration of (0.305ppm). For manganese, the amount that is considered adequate for plant growth is 50mg/kg, so any value higher than this might be considered to be manganese toxicity (Epstein, 1965). Following this, the level of manganese recorded in this site is below the toxicity level. Idzeital, (2012) recorded Mn level in the plant *Frosobis africana* to be in the range of 0.64 - 0.22mg/kg. This recorded value is less compared to the present study. Manganese uptake by roots is characterized as a biphasic process. The initial and rapid uptake phases are reversible and non-metabolic with Mn2+ and Ca2+ or other cations being freely exchanged in the rhizophere. This phenomenon might explain the low uptake of Mn by the plants at this site.

Table 3: Analysis of Plants Parts at Kuduku Mining Site

PLANT NAME	PLANT PART	LOCATION	Ca (PPM)	Mg (PPM)	Mn (PPM)	Cu (PPM)	Pb (PPM)	P (PPM)
Tridax procumbens	ROOT	KS1 (0cm)	0.597	2.124	0.152	0.134	0.694	5.60
	SHOOT	KS1 (0cm)	8.141	8.256	0.900	0.538	12.288*	5.80
Sida acuta	ROOT	KS2 (0cm)	3.902	7.741	1.043	0.341	0.064	5.40
	SHOOT	KS2 (0cm)	29.004	7.932	0.539	0.454	0.105	4.60
Calopogonium mucunoides	ROOT	KS3 (0cm)	0.569	2.706	2.537	0.137	0.312	5.06
an	SHOOT	KS3 (0cm)	17.091	7.718	1.043	0.341	0.064	4.40
Ageratum conyzoides	ROOT	KS4 (50cm)	9.486	6.231	0.157	0.159	0.027	5.60
	SHOOT	KS4 (50cm)	8.499	7.306	0.323	0.228	1.056	2.25
Fumaria parviflora	ROOT	KS5 (50cm)	9.697	7.698	2.444	0.323	0.314	5.70
	SHOOT	KS5 (50cm)	23.62	8.456	2.974	0.372	0.696	5.40
Triumfetta rhomboidea	ROOT	KS6 (50cm)	4.912	7.603	3.164	3.313*	0.030	5.85
	SHOOT	KS6 (50cm)	8.182	8.230	0.350	0.338	0.263	5.8
Ageratum conyzoides	ROOT	KS7 (100cm)	6.699	6.042	1.025	0.178	0.880	5.31
	SHOOT	KS7 (100cm)	14.71	7.216	1.269	0.183	0.531	5.20
Triumfetta rhomboidea	ROOT	KS8 (100cm)	12.644	7.268	0.456	0.196	0.433	5.31
	SHOOT	KS8 (100cm)	25.133	8.351	0.759	0.332	1.059	5.20

Acalypha indica	ROOT	KS9 (100cm)	3.271	7.070	0.941	0.523	1.232	5.40
	SHOOT	KS9 (100cm)	61.511	10.031	1.715	0.407	0.671	5.67

Key: values with asterisk indicates plants exceeding permissible WHO values

The result of soil analysis (Table 4) for the eight (8) different parameters at the Kuduku Mining Site revealed that for the heavy metal Lead (Pb) there is a significant difference between the 0cm with the 50cm and 100cm distance. The 0cm distance had a Mean and Standard error of (62.81 ± 0.54) while the 50cm and 100cm had Means and Standard errors of (0.97 ± 0.30 and 1.10 ± 0.08) respectively.

All the other heavy metals in the soil found at the Mining Site did not show a significant difference. The soils collected under the investigated plant species recorded various concentrations of metals in them. The permissible concentration of Lead in the soil is 85mg\kg. At the mining site, the highest concentration of lead was recorded in soils of *Tridax procumbens* (3.785ppm) while its plant recorded a much higher concentration of 12.288ppm and 0.694 in its root. This recorded value of Pb is lower than that reported by (Sabo and Ladan, 2014). Udiba *et al*., 2019 reported mean soil Lead concentration for residential areas in Dareta Village, Zamfara, Nigeria to each concentration value of 1029.42 ± 98.50mg/kg, 1523.99 ± 201.00mg/kg, 1404.57 ± 141.00mg/kg. These concentrations exceed the World Health Organization (WHO), US Environmental Protection Agency (USEPA) limit for soil Lead levels in residential areas. Copper concentrations recorded in this Mining site was highest in soil of *Ageratum conyzoides* (0.294ppm), its shoot contained 0.341ppm while the root had 0.137ppm in it. The recorded value of Copper is lesser than the maximum allowable limit of Copper in soils which is 100mg/kg according to (WHO, 1996). Idzeital, (2012) reported Copper concentrations in soil of a Lead - Zinc mines to be within the range of 0.03 - 0.06mg/kg which fall below the allowable limit also. According to Sabo and Ladan, 2014 they recorded concentrations of Copper at a metalliferous Mining site at Nahuta, Bauchi state to be within the range of 11.62 - 21.18mg/kg in soils at Gold Mining site in South Western Nigeria.

Manganese concentration in soils at this Mining site revealed that soils of the plant *Ageratum conyzoides* (2.209ppm) had the highest level of Mn content in them, while the shoot of the plant recorded a concentration of 0.323ppm and the root recorded a concentration of 0.157ppm. The recommended levels of Mn in soils is within the range of 20 - 3000ppm according to (Kraus KP of K.B, 1972). Therefore, the recorded Mn level is below the maximum level in soils. Idzietals, 2012 also reported Mn content in soils to be within the range of 0.05 - 0.38mg/kg.

For most of the heavy metals recorded in soils at this Mining site there is generally higher concentration of metals in plants compared to their associated soils (except for soils where Manganese was recorded highest and its associated plant). This corroborates the findings of Kim et al., 2003 where he reported that plant species under normal growing conditions can accumulate metal ions, in order of magnitude greater than their surrounding medium.

Table 4: Soil Analysis Result for Kuduku Mining site

Parameter	Location(cm)	KS
Ca	0	4.08 ± 0.75^{a}
	50	4.69 ± 1.66^{a}
	100	3.23 ± 0.86^{a}
Mg	0	3.62 ± 0.42^{a}
	50	3.67 ± 0.79^{a}
	100	2.97 ± 0.42^{a}
Mn	0	0.91 ± 0.21^{a}
	50	1.43 ± 0.43^{a}
	100	$0.95 \quad 0.15^{a}$
Cu	0	0.24 ± 0.009^{a}
	50	0.23 ± 0.04^{a}
	100	0.17 ± 0.01^{a}
Pb	0	2.81 ± 0.54^{h}
		0.97 ± 0.30^{i}
	50	1.10 ± 0.05^{j}
	100	
P	0	3.43 ± 0.17^{a}
	50	2.98 ± 0.04^{a}
	100	3.14 ± 0.11^{a}

BCF, TF and EF of the heavy metals at the Mining Site

The BCF, TF and EF of the herbaceous plants at this Mining Site (Table 5) revealed that for the heavy metal Pb, its highest BCF was recorded in the plant *Acalypha indica* (1.040ppm) and lowest recorded in *Ageratum conyzoides* (0.017ppm). The heavy metal Copper recorded its highest BCF content in the plant *Triumfetta rhomboidea* reaching up to (23.67ppm) while its lowest concentration was in the plant *Ageratum conyzoides* (0.2376ppm). In Manganese, the highest BCF was recorded in the plant *Triumfetta rhomboidea* (4.513ppm) and lowest BCF in *Ageratum conyzoides* (0.2376ppm).

However, the TF of these metals Pb, Cu and Mn revealed that for the heavy metal Pb its highest TF was recorded in the plant. *Triumfetta rhomboidea* with a concentration of (17.782ppm) very close to that concentration is *Sida acuta* with a concentration of (17.706ppm). Copper recorded its highest TF in the plant *Triumfetta rhomboidea* reaching up to (23.67ppm) and the lowest TF recorded in *Ageratum conyzoides*) (1.028ppm). For Manganese, the highest TF was recorded in the plant *Tridax procumbens* (5.921) and the lowest TF in the plant *Triumfetta rhomboidea* (0.102ppm). For the Enrichment Factor (EF) at this Site, the heavy metal Pb recorded its highest EF in the plant *Triumfetta rhomboidea*) (16.832ppm), the lowest EF was then recorded in the herbaceous plant *Ageratum conyzoides* (-0.461ppm).
For Copper, it was revealed that the highest EF was recorded in the herbaceous plant *Triumfetta rhomboidea* (2.4144ppm) and its lowest EF recorded in *Acalypha indica* (1.25ppm). Manganese recorded its highest EF in the plant *Ageratum conyzoides* (1.610ppm) and the least EF was recorded in the *Ageratum conyzoides* (0.0132ppm). At the mining site the following plants are phytostabilizers of Lead: Sida *acuta, Ageratum conyzoides, Fumaria parviflora, Triumfetta rhomboidea.* Copper had the following plants as good phytoextractors; *Sida acuta, Fumaria parviflora, Triumfetta rhomboidea, Acalypha indica* whereas the following plants acted as good phytostablizers of the metal they are *Ageratum conyzoides* and *Triumfetta rhomboidea* .Manganese recorded these plants as phytostablizers and phytoextractors. Those plants that acted as phytoextractors includes: *Calopogonium mucunoides, Fumaria parviflora, Ageratum conyzoides.* The phytostablizers includes: *Triumfetta rhomboida, Ageratum conyzoides* and *Acalypha indica.*
As earlier stated, plants that are able to extract metals from soil and store them in their above ground parts have Enrichment Factor (EF) greater than one which also emphasizes on the extent of metal uptake by the plants. For the majority of the plants investigated, their Enrichment Factor was greater than one except in *Sida* acuta, *Calopogonium mucunoides Ageratum conyzoides, Fumaria parviflora and Acalypha indica* for pb remediation. With respect to Manganese, the following plants had an Ef of less than one; *Tridax procumbens, Sida acuta, Ageratum conyzoides, Fumaria parviflora and Triumfetta rhomboidea and lastly Triumfetta rhomboidei.*

Table 5: BCF, TF and EF of the heavy metals at Kuduku Mining Site

Plant Species	Bio concentration Factor (BCF)			Translocation Factor (TF)			Enrichment Factor (EF)		
	Pb	Cu	Mn	Pb	Cu	Mn	Pb	Cu	Mn
Tridax procumbens	0.1833	0.587	0.114	17.706	4.014	5.921	3.246	2.359	0.677
Sida acuta	0.0378	1.808	1.502	1.64	1.331	0.516	0.0231	1.321	0.776
Calopogonium mucunoides	0.165	0.531	3.558	0.205	2.489	1.462	0.165	1.358	1.462
Ageratum conyzoides	0.017	0.43	0.2376	39.1	1.433	2.057	0.609	1.433	0.1032
Fumaria parviflora	0.43	1.218	2.188	2.216	1.151	1.216	0.953	1.403	0.273
Triumfetta rhomboidea	0.0478	23.67	4.513	8.767	23.67	0.102	2.735	2.414	0.46
Ageratum conyzoides	0.887	1.112	1.3	0.603	1.028	1.238	-0.461	1.173	1.61
Triumfetta rhomboidea	0.95	0.739	0.335	17.782	1.693	1.664	16.832	1.252	0.558
Acalypha indica	1.04	0.746		0.554	1.867	1.822	0.3437	1.25	1.361

CONCLUSION

Conclusively, this study has revealed that most of the herbaceous plants growing in the mining vicinity have remediation capacity in them. Even though none can be categorized as a hyper-accumulator, majority have potentials of been phytoextractors or phytostabilizers depending on the amount of metal they are able to contain in them. The level of metals in most of the plants are within the permissible level which may be exceeded as mining activities continues. Further degradation of the vicinity where this mining activity is taking place is likely to occur paving way for other environmental degradation such as erosion. These plants could also act as bioindicators of the presence of some heavy metals even though more studies should be carried out to investigate such mechanism.

REFERENCES

Ali H., Khan, E., and Sajad, M.A (2013).Phytoremediation of polychlorinated biphenyls: new trends and promises.*Environ.Sci.Techno*, 44:2767-2776

Awotoye, O.O., Dada, A.C. and Arawomo, G.A.O. (2011). Impact of Palm Oil Processing Effluent Discharge on the Quality of Receiving Soil and River in South Western Nigeria, *Journal of Applied Sciences Research*, 7(2): 111-118, ISSN 1995-0748

Baker, A.J.M. and Brooks, R.R. (1989) Terrestrial Higher Plants which Hyperaccumulate Metallic Elements—A Review of Their Distribution, Ecology and Phytochemistry. *Bio recovery*, 1, 81-126.

Chen, B., Stein, A.F., Castell .N., Gonzalez-Castenedo, Y.,De Lampa, A.S.,and De La Rosa.j.(2016).Modelling and evaluation of urban pollution events of atmospheric heavy metals from a large Cu smelter.Sci. *Total Environ*.539, 17-25

Dal Corso,G.,Fasani,E.,Manara,A.,Visovili G.,and Kramer,U.(2019).Heavy metals pollutions: state of the art and innovation in phytoremediation.*Int.J.Mol.Sci*,20:3412

Farahat, E., and Linderholm,H.W, H. W.(2015).The effect of long term waste water irrigation on accumulation and transfer of heavy metals in *Cupressus sampe, rvirens* leaves and adjacent soils.Sci.Total.Environ,51:1-7

Hamzah, A., Hapsari, R, I., and Wisnubroto, E.I.(2016).Phytoremediation of Cadmium contaminated agricultural land using indigenous plants, *Int.J.Environ Agric.Res*, 2:8-14

Iqbal, M., and Idqbal, N., Bhatti, I.A., Ahmad, N. and Zahid, M.(2016).Response surface methodology application in optimization of cadmium absorption by shoe waste :a good option of waste mitigation by waste. *Ecol.Eng*.88,265-275

Jacob,J.M.,Karthik,C.,Saratale,R.G.,Kumar,S.S.,Prabakar,D. ,Kadrirvelu,K.,et al.(2018).Biological approaches to tackle heavy metal pollution:a survey of literature.*J.Environ.Manage*,217:56-70

Kamal, M., Ghalya, A.E., Mahmouda,N., Cote,R.(2004). Phyto-accumulation of heavy metals by aquatic plants. *Environment International*,**29**: 1029-1039

Khan, Z.I., Bibi, K., Ahmad, M., Ashraf, N.,Akram,F.,Arshad.(2013).Asessment of metals and metalloids accumulation in waste water irrigated soil and uptake by pumpkin(*Cucurbita maxima*) at Sargodha, Pakistan .*Asian journal of chemistry*,25,9712-9716.

Kim, S.J., Kang, K.H., Johnson, P., Green, R.J., Lee (2003).Investigation of heavy metals accumulation in *Polygonium thumbergii* for Phytoextraction. *Environ pollut* .126:253-43

Mc Grath, S.P and Zhao, F.G. (2003) phytoextraction of metalloids from contaminated soils, *Current opinion Biotechnol J.,* 14(3):277-282

Muradoglu, F, Neff, J., Lee, K., and Deblois, E.M.(2011).”Produced water: overview of composition, fates and effects, in produced water; Environmental Risks and Advances in Mitigation technologies, eds K, Lee and J.Neff (*New York, NY: and springer*),3-54

Muradoglu,F.,Gundogdu,M.,Ercisli,S.,Encu,T.,Balta,F.,Jaafar,H.Z.,et al(2015).Cadmium toxicity affects the chlorophyll a and b content,antioxidant enzyme activities and mineral nutrient accumulation in strawberry.*Biol.Res.*48:11

Naoko H., Rie, T and Chisato, T.(2011).Effects of calcium uptake and transport in tree species *Gamblea innovans.Soil science and plant nutrition,57(5);691-695*

Nestic, N.(2011).Fitoremedijacija i biljik pogodne za fitoremedijaciju voda zagadenih teskim metalima.Univerzitet u Beogradu. Institute za multidisciplinarna istrazivanja

Ogundele, D.T., Adio, A.A., and Oludele, O.E.(2015).Heavy metals concentrations in plants and soil along heavy traffic roads in North Central, Nigeria. *J.Environ and Toxicol,* 5(6):334.

Pagano G., Aliberti F., Guida M., Oral R.,Siciliano A.,Trifuoggi M.,Tommasi F.(2015).Rare earth elements in human and animal health: State of Earth and research priorities ,*Environ.Res,*142:215-220

Pitchtel, J.(2016).Oil and Gas production wastewater: soil contamination and pollution prevention. Appl.Environ.*Soil.sci*, 2016:2707989

Rafique. N., and Tariq, S.R.(2016).Distribution and source apportionment studies of heavy metals in soil of cotton/wheat fields.*Environ.Monit.Assess*,188:309

Ramirez O., Sanchez de la Campa A.M. Sanchezez-Rodas D.,de la Rosa J.D.(2020). Hazardous trace elements in thoracic fraction of airborne particulate matter: Assessment of temporal variations, sources and health risks in a megacity. *Sci Total Environ,* 710:136344

Rechman, M.Z.U.,Rizwan,M.,Ali,S.,Ok,Y.S., Ishaque, W., Saifullah, et al(2017).Remediation of heavy metal contaminated soils by using *Solanum nigrum:* a review.*Ecotox.Environ.safe,*143:236-248

Sabo, A. and Ladan, M.(2014).Phytoremediation potential of some indigenous herbaceous plant species growing on metalliferous mining site at Nahuta, Bauchi State, Nigeria. Journal of selcuk, University of Natural and Applied Sciences, 747-754.

Sarwar, N., Malhi, S.S., Zia, M.H., Naeem, A., Bibi, S., and Fadrid, G. (2010).Role of mineral nutrition in minimizing cadmium accumulation by plants. *J.Sci.Food.Agric*, 90:925-937

Sebastien Roy, Suzanne Labelle,…Charles W.Greer.(2005).Phytoremediation of heavy metal and PAH-Contaminated brownfield sites.*Plants and soil,* **272**:277-290.

Steve, P. Mc Grath and Fang-Jie, Zhao (2003).Phytoextraction of metals and metalloids from contaminated soils. *Current Opinion in Biotechnology, 14(3); 277-82*

Suman, J., Uhlik, O., Viktorova, J., and Macek, T. 2018). Phytoextraction of heavy metals: a promising tool for cleanup of polluted Environment? *Front plat sci,* 9:1476

Tchounwou P.B.,Yedjou C.G.,Patlolla A.K.,Sutton D.J.(2012).Heavy metals toxicity and the Environment.*Exp.Suppl*,101:133-164

Wallace, A., Soufi, S.M., Cha, J.W., Romney, E.M.(1976). Some effects of Chromium toxicity on bush bean plants growth in Soil. *Plant Soil,* 44:471 – 3.

Udiba, U. Udiba, Ekom .R. Akpan, Ekpo, E. Antai.(2019). Soil Lead Concentrations in Dareta Village, Zamfara, Nigeria. *Journal of Health and Pollution,* (9 (23): 190910.https://doi.org/10.5696/2156-9614-9.23.190910

Xiao, X., J. Ellis, N.,Zhaoping, Z.(2011).Structure properties of pyrolyctic lignin extracted from aged bio oil.*Chinese Science Bulletin*,56:1417-1421

Zhang M., Zhang T.,Zhoub L., Lou W.,Zeng W., Liu T.,Yin H., Liu X., Mathivanan K.,et al.(2022).soil microbial community assembly model in response to heavy metal pollution. *Environ Res*, 213:113576