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EFFECT OF COMPOSTED POULTRY MANURE AND BIOCHAR ON BIOACCUMULATION OF LEAD/ZINC IN OKRA (*ABELMOSCHUS ESCULENTUS*. L.) IN AMAGU MINING SOILS

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ABSTRACT

Remediation of contaminated soils with organic amendments to attenuate the side effect of Heavy metals has been scarcely investigated on okra pods. This study was conducted to evaluate the effect of composted poultry manure and biochar on heavy metals (lead and Zinc) bioaccumulation in Okra plant and the effect of artisanal mineral mining activities on the environment using ecological risk indices in Amagu, Abakaliki, Southeastern Nigeria. Soil samples for this study were collected at farmlands beside mining areas. The treatment consisted of four sources of biochar (control, empty oil palm bunch, maize cob, wood shavings) and two rates of poultry manure (0, 10 t/ha), replicated three times. The study was a 4 × 2 factorial experiment in a completely randomized design. Biochar from three feed stocks were pyrolysed at 320.0 ^{0}C, while poultry manure from battery cage system were composted for 90 days before application. Ecological risk assessment using indices were applied on data collected. After harvest, lead and zinc still exceeded the Food and Agricultural Organization (FAO) permissible limit of 100 mg/kg in Agricultural soils. Composted poultry manure (CPM) showed significant ($P \leq 0.05$) reduction by 14 % in the amount of Pb in the soil after harvesting of okra. Significant increases were recorded in the level of lead and zinc in the fruit by 50 and 28 % respectively. The ERF values for lead were rated as posing a very high ecological risk within the environment; while zinc was rated as having a low ecological risk. Also the geo accumulation index (I_{geo}) of the study showed that the soils are extremely contaminated. In conclusion, the application of EMCB and EOPBB in combination with CPM demonstrated the capacity to reduce bioaccumulation of lead and zinc in okra plant

Keywords: Okra, lead, zinc, biochar, bioaccumulation, poultry manure.

INTRODUCTION

Okra (*Abelmoschus esculentus L.*) belongs to the family Malvaceae and also known as lady's fingers. It is an annual herbaceous vegetable cultivated throughout the tropical, sub-tropical and warm temperate regions of the world (NRC, 2006). Extracts of young okra pods have also been reported to display moisturizing and diuretic properties, whereas the seeds of this plant have been reported to possess anticancer and fungicidal properties (Durazzo *et al* ., 2018). Okra seeds have been reported to have different protein compositions from cereals and pulses, as their protein ingredients are modified to bear a balance of characteristic amino acids, namely lysine and tryptophan. Thus, owing to their rich content of essential amino acids, okra seeds represent an important constituent of the human diet (Gemede *et al*., 2015). Due to its economic value, Okra is grown in home gardens and small holder plots in Nigeria and is commonly found in almost all Nigerian markets throughout the year (Schippers, 2000).

Composted organic manure especially from poultry wastes has been reported to improve the mineral composition in tissues of vegetables (Jonathan *et al*., 2012), and source of nutrients in the soil for plant uptake. Contaminated soils have been documented to suppress plant growth (Hossain and Komatsu, 2013) and yield. Various management strategies have been proposed and developed for improving problem soils (Lal, 2015), of which amendment using biochar shows great promise (Yuan *et al*., 2019). Owing to its liming effects, high cation-exchange capacity (CEC), porous structure, and the presence of abundant mineral elements, biochar is a promising material for the remediation of heavy metal-polluted soil (Roy *et al*., 2021). Biochar has been shown to exert passivation effects on Cd (Gu *et al*., 2020), Pb (Boostani *et al*., 2021), Zn (Sikdar *et al*., 2020), and Cu (Silva *et al*., 2019).

Numerous anthropogenic activities have not only changed and deteriorated soil properties, but also introduced pollutants, such as synthetic organic compounds and heavy metals into soils. The presence of heavy metals in soil, plants and their bioavailability are pertinent because of the multiple adverse effects on human health when consumed. These chemical elements have as well as carcinogenic (Alloway, 1990, 2013) and neurological effects (Garza-Lombo *et al.*,2018). In Amagu, Abakaliki South-eastern Nigeria, lead and zinc mining has been going on for over fifty years, and in recent times its exploration has been intensified. This has had many effects on various aspects of the environment including the soil fertility and productivity (Duruibe *et al.*, 2007). According to Onyedika and Nwosu (2008) illegal and uncontrolled mining in developing countries have left a lot of environmental hazards and enormous of wastes and different types of pollutants are generated. It is based on this consideration that this study was undertaken to assess the effects of composted poultry manure (CPM) and different sources of biochar on bioaccumulation of lead and zinc in okra planted in Pb/Zn mining soils. The objectives of the study is to assess the effect of different sources of biochar and composed poultry manure on uptake of Pb/Zn in okra plant and to evaluate the level of soil contamination using ecological risk indices.

MATERIALS AND METHOD

Description of soil sample location: The soils samples were collected from farmlands around the mining sites located in Amagu, Enyigba in Abakaliki local government area of Ebonyi State. The area (Amagu) is located between latitude 06^{0} 10’ - 06^{0} 13’ N and longitude 08^{0} 05’ - 08^{0} 10’ E in the derived savanna vegetation of the southeast ecological zone. The area experiences bimodal patterns of rainfall (April – July) and (September – November). The rainfall range is between 1700 – 2000mm. The minimum and maximum temperatures lie within 27 ^{0}C – 31 ^{0}C respectively. The soil belongs to the order Ultisol, with shale as the predominant parent material (Nwaogu and Ebeniro, 2009). Illegal mining of minerals, stone quarrying, palm wine tapping and farming constitutes the major economic activities of the people in study area.

Description of the location of screen house experiment:

The study was conducted in the screen house of Soil Science and Meteorology Department (M.O.U.A.U). Umudike is located between the latitude 05°2’ North and longitude 07°33’ East, with elevation of 112 m above sea level. The climate of the area is essentially humid; it has an average rainfall distribution of 2117 mm which is distributed over 10 months in a bimodal rainfall pattern. It has a relative humidity ranging from 75- 76% and temperature range of 19-35°C (NRCRI, 2020).

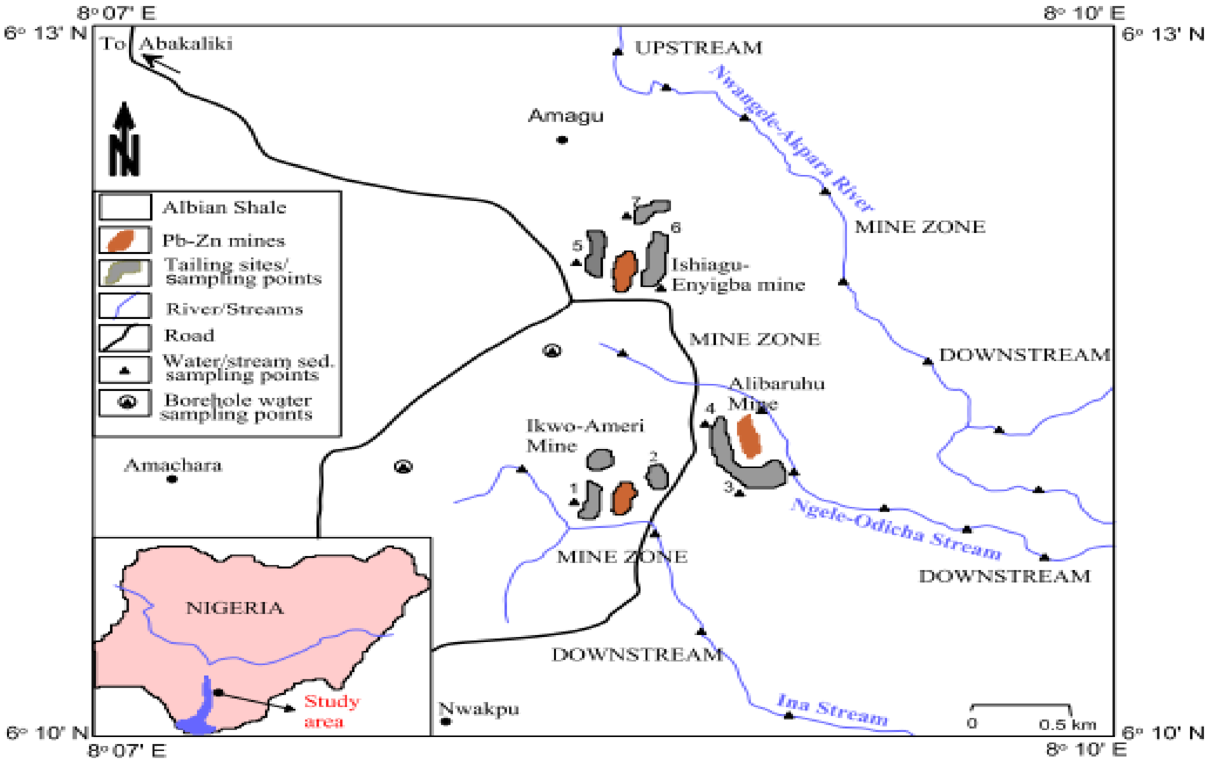

Fig. 1: Location and accessibility map of the area.

Soil sample collection:

The soil samples used for the analysis were randomly collected between a range of 0 – 20 cm depth using a soil auger and spade. Soil samples were collected from cultivated farmlands around the mining site. Random soil samples were collected at five different points which were bulked together, air-dried at room temperature (27.0 ^{0}C) and sieved with a 2 mm and 4 mm sieve for laboratory analysis, and greenhouse experiment respectively.

Biochar production and collection of research materials:

The different feed stocks for biochar production were pyrolysed at 320 ^{0}C in a double-barrel metallic drum (height 67 inches × diameter 22.5 inches). The process was carried out in 45 minutes, while the temperature was determined using an infra-red meter. The biochar produced was allowed to cool, finely ground using and automated grinding machine and passed through a 0.25 mm mesh sieve size. Poultry manure collected fresh from battery cage system was composted in a perforated plastic drum composter. The poultry manure collected was composted for 90 days with a regular stirring at two weeks interval to increase aeration and decomposition. The liquid waste dripping below he drum was poured back into the composter and stirred weekly. This set up was situated in a greenhouse to avoid direct contact with sunlight. At the expiration of 90 days the composted manure was air dried, grinded and sieved with a 1mm sieve and stored. Chemical compositions of the CPM were also analysed. Okra was sourced from the Research and Training Unit of Michael Okpara University of Agriculture, Umudike.

Experimental procedures and test crop:

Ten kilograms of collected soil sample was placed in a 12-liter container. Biochar was applied to the soil at the rates a uniform rate of 10 tons/ha (equivalent to 44.4 g/10 kg of soil), and allowed for two weeks before planting. The study was a 4 × 2 factorial experiment in completely randomized design. The treatments consisted of four sources of biochar (control, empty oil palm bunch, maize cob, wood shavings) and two rates of poultry manure (0, 10 t/ha), replicated three times**.** In each pot, three seeds were planted and then thinned down to two seedlings after 10 days of germination. Hand-picking of weeds was done as they emerged during the period of study.

Laboratory analysis:

Soil physico-chemical analysis conducted included: particle size analysis, using Bouyoucos hydrometer method as described by Kettler *et al.,* (2001). Soil pH was determined in a 1:2.5 ratio, soil to water suspension using an electrode pH meter (Mclean, 1965). Organic carbon was determined according to Wet dichromate oxidation method as described by Walkey and Black (1934) and modified by Nelson and Sommers, (1996). Available phosphorus was determined using Bray 2 method of Bray and Kurtz (1945) as described by Kuo, (1996). Total nitrogen was determined using the micro kjeldhal method as described by Bremner (1996). Exchangeable calcium, magnesium, sodium and potassium were extracted with NH_4OAc. Calcium and magnesium were determined using Ethylene-diamine Tetra Acetic (EDTA) titration method while potassium and sodium were read using a flame photometer (Rhoades, 1982). Total Heavy metals level in both soil and plant samples were determined using Aqua Regia method (3:1 ratio of HCl: HNO_3), a method described by Ehi-Eromosele *et al*., (2012). All plant samples were carefully harvested and separated into shoot and roots. They were oven dried at a temperature of 70 ^{0}C for 72 hours and constant weight was recorded.

Determination of bioaccumulation factor (BCF): This refers to the ratio of metals concentration in plant tissues to metals concentration in the soil.

Indices for assessment of soil contamination

Contamination factor (CF): The CF is the ratio obtained by dividing the concentration of each metal in the soil by the baseline or background value (Turekian and Wedepohl 1961):

$$\mathrm{CF}_{Metal} = \frac{C_{Metal}}{C_{Background}}$$

Geo-accumulation index (Igeo): This was calculated after Muller (1979) using the equation below:

$$I_{geo} = log2 \times \frac{C_n}{1.5B_n} \text{.............................(Eqn. 2)}$$

where C_n = concentration of metal determined in the soil sample, B_n = same metal's background concentration in the earth's crust adopted from Turekian and Wedepohl (1961), whereas 1.5 is a constant factor to neutralize variations due to lithogenic actions.

Ecological risk factor (Er): The degree of hazard contamination in sediments and soils is indicated by the ecological risk factor (Er), which is suggested by Hakanson (1980):

$$Er = Tr \times CF \qquad \text{…………………} \text{(Eqn. 3)}$$

This factor depends on contamination factor (CF) and the toxic-response factor (Tr) of elements with the value of 5, 5, and 1 for Pb, Cu, and Zn respectively as described by Hakanson (1980).

Table 1. Equation for Ecological risk indices assessment and their classification.

Index	Equation	Rating	Citations
CF	$CF= C_a / C_b$	$CF < 1$ (low CF) $1 \leq CF < 3$ (moderate CF) $3 \leq CF < 6$ (considerable CF) $CF \geq 6$ (very high CF	Hökanson, 1980.
Igeo	$I_{geo}=\log_2(Cn /1.5\ B_n)$	$I_{geo} < 0$ Class 0 (unpolluted) $0 < I_{geo} < 1$ Class 1 (unpolluted to moderately) $1 < I_{geo} < 2$ Class 2 (moderately polluted) $2 < I_{geo} < 3$ Class 3 (moderately to heavily polluted) $3 < I_{geo} < 4$ Class 4 (heavily polluted) $4 < I_{geo} < 5$ Class 5 (heavily to extremely polluted) $I_{geo} \geq 5$ Class 6 (extremely polluted)	Müller, 1979; Mohiuddin, 2010.
Er	$Er = T_r \times C_F$	$Er< 40$ low risk; $40 <Er< 80$ moderate risk $80 <Er< 160$ considerable risk $160 <Er< 320$ high risk $Er> 320$ very high risk	Hökanson, 1980

Statistical Analysis: The data collected were subjected to analysis of variance using Genstat statistical package. Treatment means for each parameter measured were compared using the Least Significant Difference at $P \leq 0.05$.

RESULTS AND DISCUSSION

The Physico-chemical properties of soil samples used during the study.

The physicochemical properties of the soil samples used for the experiment are presented in Table 2. Particle size distribution shows percentage sand of 670 in the farmland beside the mining area. The percentage silt also showed a value of 240 %, while clay distribution was 90. Based on the results shown, the soil was observed to belong to textural class of Sandy clay loam (SCL). Available phosphorus was observed with the value of 8.47 mg/kg. The strong acidic nature of the soils of the areas is indicated by low soil pH (4.83), low soil pH is one of the important factors that determine P availability. Strong acidic soils have been reported to have the tendency to immobilize the P and thereby reducing available P content in the soil. Beside the effect of low pH, the presence of these heavy metals in high concentrations could have directly influenced the availability of P in the soil. Example, the bioavailability of lead ions can be decreased by complexation with various materials in order to decrease their toxicity.

Total organic carbon content (0.98 %) was observed to be low. This result was compared with organic matter content for soil natural fertility rating of FDALR (2004), it was observed that Amagu soil belongs to low % OC content class. This was supported by similar findings of Ano *et al*., (2007), who also reported that mining activity reduced SOM content of soil of a mining area. The low organic matter content of these soils could also be attributed to sparse vegetation of the areas, which is an indication of highly mineralized soil and poor fertility status.

The mean values of total nitrogen content (0.04%) in the farmyards beside the mining soil of Amagu were compared with FDALR (2004) soil natural fertility rating for nitrogen content; it recorded a low N content class. This is similar to the findings reported by Ogbodo (2006). Soil total nitrogen is prone to leaching and volatilization and requires to be continuously replenished in the soil, this would have been achieved with adequate vegetation cover. But the mineral mining activities have created both physical and chemical impact on the soils of the locations which might have led to sparse vegetation of these areas. Volatilization of nitrogen due to exposure of surface soils of the mining areas may also be another factor responsible for the low nitrogen content in the soils of study. The concentration of exchangeable magnesium (Mg), Potassium (K) and Sodium (Na) in the soils of Amagu mining area were generally low, while exchangeable calcium (Ca) recorded 8.23 Cmol/kg. When the mean concentration of these exchangeable cations was compared with FDALR (2004) soil natural fertility rating, it was observed that Mg and K the mean values concentration in Enyigba soil was rated low. It could be that low pH which depicts strong acidity might have resulted in preponderance of exchangeable acidic cations that have displaced most of the basic cations in the soils of the mining area.

The amount of lead and zinc (7342 and 1709 mg/kg) in the soil were extremely high and exceeded the permissible limit of 100 mg/kg as recommended by FAO. The extremely high amount of these heavy metals observed in the farmlands around Amagu mining area were similar to that reported by Aremu *et al.* (2010); Ayodele and Modupe (2008). The artisanal mining activities expose the geological materials (the shale and the ores), which are the natural sources of these heavy metals to intensive surface weathering. When these geological materials are broken down either by chemical, biological or mechanical weathering, the composite metals are released into the soil either as aqueous species or in dispersed forms of the constituting mineral or as precipitates of new minerals. Once heavy metals especially lead has been deposited in the soil, it moves very slowly down the profile and can persist for a long time at the surface. The high heavy metals concentration (lead) in soils of the study sites portend a great risk to human health and environment, as soil is a veritable channel of heavy metals entrance into food chain. The hazardous effects of high concentration of these heavy metals due to artisanal mining activities on human population might be further aggravated by the fact that major staple food crops were planted as close as 50 meters from the mines.

Table 2: The physicochemical properties of soil samples used in the study.

Soil parameters	Mining site
% sand	67.0
% silt	24.0
% Clay	9.0
pH	4.83
Textural class	Sandy clay loam
Exchangeable calcium (cmol/kg)	8.23
Exchangeable magnesium (cmol/kg)	1.12
Exchangeable sodium (cmol/kg)	0.32
Exchangeable potassium (cmol/kg)	0.11
Available phosphorus (mg/kg)	8.47
Organic carbon (%)	0.98
Total nitrogen (%)	0.04
Lead (Mg/Kg)	7342
Zinc (Mg/Kg)	1709

Table 3: Analysis of organic amendments used for the studies.

Chemical properties	EMCB	EOPBB	WSB	CPM
pH (H_2O)	8.11	8.50	6.45	8.01
Total nitrogen (%)	2.72	1.85	0.92	1.92
Available phosphorus (ppm)	0.15	0.34	0.21	0.99
Total organic carbon	40.1	52.2	56.3	3.87
Lead (Pb) (mg/kg)	0.66	0.54	0.45	0.03
Zinc (Zn) (mg/kg)	0.92	1.23	0.10	0.13

Note: EMCB = Empty maize cob biochar, EOPBB= Empty oil palm bunch biochar, WSB= Wood shaving biochar, CPM= Composted poultry manure.

Physical and chemical composition of organic amendments used for study.

The chemical properties of the different sources of biochar used for the study are shown in Table 3. The pH value of the biochar showed variance across the different sources of biochar. EOPBB and EMCB had a pH of 8.5 and 8.11 respectively; which indicates they are alkaline in while wood shavings biochar (WSB) had the least pH value of 6.45. Total nitrogen across the different biochar sources ranged between 0.92 and 2.27 %. EMCB had the highest amount of total nitrogen (2.72 %); while available phosphorus was lowest at EMCB (0.15 ppm) and highest at EOPBB (0.34 ppm). The total organic carbon was also observed to be highest as WSB with the value of 56.3%, while EMCB and EOPBB had a total organic carbon content of 40.12 and 52.2 %, respectively. Two heavy metals were analyzed to ascertain their contribution to the experiment. The highest level of lead (Pb) was found in EMCB with the value of 0.66 mg/kg > EOPBB (0.54 mg/kg) > WSB (0.45 mg/kg) > CPM (0.03 mg/kg).

Effects of CPM and biochar on lead and zinc amount in Soil and plant.

The Effects of biochar and composted poultry manure on lead (Pb) and Zinc (Zn) level in the soil after planting of okra is shown in Table 4. After the application of the different sources of biochar, the heavy metals content still exceeded the Food and Agricultural Organization (FAO) permissible limit of 100 mg/kg. According to this table, CPM showed significant ($P \leq 0.05$) reduction by 14% in the amount of Pb in the soil after harvesting of okra. Similarly, the root region recorded significant ($P \leq 0.01$) reduction in Pb level across the different sources of biochar when compared with control. The soil samples amended with EOPBB recorded the highest reduction rate by 19.5 %, while WSB recorded the least reduction by 3.5 %. The amount of Pb in the root of okra followed the reduction sequence of CONTROL > WSB > EMCB > EOPBB. Based on the result shown in Table iv, there was significant accumulation of Pb in the okra fruit. The accumulation of Pb in the fruit also followed the similar trend as observed in the root region. There was also significant increase in the level of Pb in the fruit by 50 % after the application of CPM. In comparison with other similar studies, the mean concentration of Pb in soil of study area was significantly higher than the concentrations reported in Sudan, Ghana and South Africa, respectively by Mushtaha *et al.* (2017), Crentsil and Anthony (2016) and Caspah *et al.* (2016), in addition, this concentration was also higher than obtained in the studies carried out by Sijin *et al.* (2015), around a Zinc-Lead mining area in China.

After the application of the different sources of biochar, zinc all still exceeded the Food and Agricultural Organization (FAO) permissible limit of 300 mg/kg. According to this table, biochar showed significant ($P \leq 0.001$) reduction when compared with CONTROL by 50.6, 46.8 and 28.4 % in EMCB, EOPBB and WSB respectively in the amount of Zn in the soil after the harvest of okra. Also in the root region, there was significant ($P \leq 0.001$) reduction in Pb level across the different sources of biochar when compared with control. The result also recorded that EOPBB recorded the highest reduction rate by 30.8 %, while WSB recorded the least reduction by 12.5 %. The amount of Zn in the root region followed the reduction sequence of CONTROL > WSB > EMCB > EOPBB. Based on the result shown in Table 4, there was significant accumulation of Zn in the okra fruit. The accumulation of Zn in the fruit also followed the similar trend as observed in the root region. When compared with the control EOPBB, EMCB and WSB recorded significant ($P \leq 0.001$) reduction by 50.4, 33.1 and 23.2 % respectively. There was also significant increase in the level of Zinc in the fruit by 28 % after the application of CPM. The level of Zn in this study area was higher than the concentrations found in studies on soils around gold mine in China (Feifei *et al*. 2015) and Sudan (Mushtaha *et al*., 2017). Soil amendments are used to enhance and strengthen the lead and zinc immobilization effect in the soil. The presented results demonstrate that biochar application significantly affected the effectiveness of Pb and Zn immobilization in the soil. This may be due to the large specific surface area of these amendments and the occurrence of liming and adsorption effects. The latter phenomenon may include precipitation, co-precipitation, a reduction in metal species, complexation with functional groups, cation exchange and attractive electrostatic interactions (Jiang *et al*., 2012).

Table 4: Effect of amendments on bio-accumulation of Zn and Pb (mg/kg) in okra plant.

	Pb			Zn		
Treatment	**Soil**	**Root**	**Fruit**	**Soil**	**Root**	**Fruit**
Control	2768	256	9.5	783	543	125
EMCB	2912	210	1.7	374	408	84
EOPBB	3306	206	1.5	416	376	62
WSB	3088	247	5.9	561	475	96
CPM (0t/ha)	3246	224	3.1	518	441	77
CPM (10t/ha)	2792	235	6.2	549	460	107
Biochar $_{\mathrm{LSD0.05}}$	n.s	31.6**	2.14***	80.7***	65***	21.9***
CPM $_{\mathrm{LSD0.05}}$	385.7	n.s	1.85**	n.s	n.s	15.5***
Bio*CPM $_{\mathrm{LSD0.05}}$	n.s	n.s	n.s	n.s	n.s	n.s
FAO (Permissible Limit)	100	100	100	300	300	300
CV %	14.8	11.2	46.1	12.4	11.8	19.5

EMCB = empty maize cob biochar; WSB = wood shaving biochar; EOPBB = empty oil palm branch biochar; CPM = composted poultry manure; n.s = not significant; FAO = Food and Agricultural Organization

Ecological Risk Assessment of the soil of study Contamination factor (CF):

The values obtained for contamination factor (Cf) for Pb and Zn under the various treatments are as shown in Table 5. The result showed that the contamination factor rating standard (129.4 – 184.7) indicated very high for lead (Pb) due to its value greater than 6; however the contamination factor for zinc across the various treatments varied. According to the ratings of Hakanson, (1980), EMCB/CPM, EOPBB/CPM, EMCB, EOPBB were classified as considerable while others were rated as having very high contamination factor.

Bioaccumulation Factor (BCF).

The bioaccumulation of zinc and lead is as shown in Table 5. The bioaccumulation rates varied among the treatments. The highest bioaccumulation factor value of Lead (272 mg/kg) was recorded at Control/CPM treatment while the lowest bioaccumulation factor value was recorded in EOPBB/CPM treatment. The bioaccumulation values of Zinc ranged from 376 mg/kg in EOPBB treatment to 583 mg/kg in the control.

Geo-accumulation Index (I_{geo})

The geo accumulation index of the various treatments applied in the experiment is shown in Table 5. The index of geo-accumulation (I_{geo}) introduced by Muller (1969) is used to assess metal pollution in a soil sample. It enables us to assess the level of contamination by comparing the concentrations of the various treatments with the natural concentration at the reference point (control). The geo-accumulation index values for Pb in the study ranged from 15.1 in the control and EMCB to 15.6 in EOPBB/CPM; while that of zinc ranged from 14.2 in EMCB/CPM to 15.6 in Control/CPM. The geo-accumulation values were greater than five, therefore it was classified as extremely contaminated with Pb and Zn despite the treatments applied (Table 5). These shows that the soils were extremely contaminated and would need a long term soil reclamation processes.

Treatments (tons/ha)		CF		BAF		I_{geo}		ERF	
CPM	**Biochar**	**Lead**	**Zinc**	**Lead**	**Zinc**	**Lead**	**Zinc**	**Lead**	**Zinc**
0	CONTROL	129.4	8.5	227	376	15.1	15.6	647	8.5
	EMCB	132.8	4.7	185	377	15.1	14.8	664	4.7
	EOPBB	145.9	4.3	220	393	15.2	14.7	730	4.3
	WSB	150.2	5.6	201	425	15.3	15.0	751	5.6
10	CONTROL	147.4	8.0	240	459	15.2	15.6	737	8.0
	EMCB	154.4	3.2	254	490	15.4	14.2	792	3.2
	EOPBB	184.7	4.4	272	503	15.6	14.7	924	4.4
	WSB	158.6	6.7	240	583	15.4	15.2	793	6.7

Table 5: Ecological Risk Assessment Index of the soil of study

Ecological risk Factor (ERF)

The ecological risk factors of Pb and Zn for the various treatments are as showing in Table 5. This study applied the potential ecological risk index proposed by (Hakanson, 1980) to evaluate the potential ecological risk of heavy metals. This method comprehensively considers the synergy, toxic level, concentration of the heavy metals and ecological sensitivity of heavy metals. The Ecological Risk Factor (ERF) values for Pb in the study ranged from 647 in the control to 924 in EOPBB/CPM; while, the values for Zn in the study ranged from 3.2 in EMCB/CPM to 8.5 in control. The ERF values for lead were greater than 320, according to the rating in Table 1, the risk assessment can therefore be classified as having a very high ecological risk. The values of ecological risk factor (Er) obtained in the present study were higher than a similar work of Yahaya *et al.*,(2021) in contaminated soils of three mining villages in Zamfara State, Nigeria. However, the ecological risk values for Zinc fluctuated within 3.2 to 8.5; therefore the soils with regards to zinc level were rated as posing a low ecological risk.

CONCLUSION

Based on the findings of the study, the application of different sources of biochar to the soil increased the level of Pb in the soil, but reduced its accumulation in the root of Okra plant. The Okra pod had lesser accumulation of Pb in the soil at the application of biochar. In contrast, biochar reduced the accumulation of Zn in the soil but allowed a significant level into the root and fruit. However, the application of CPM further increased the accumulation of Zn and Pb in the soil of study. From the indices used in the ecological risk assessment, it can be concluded that the level of Zn and Pb in the soil is posing a serious threat to the growth and productivity of Okra plant. According to the study, EMCB and EOPBB in combination with CPM showed efficient potentials in reducing the bioaccumulation of Pb and Zn concentration in Okra pod, therefore the use of EMCB and EOPBB are recommended to farmers located within that vicinity. Moreover, further research on increasing the rates of biochar in the bid to record effective reduction of Pb and Zn in edible portions of crops should be encouraged.

REFERENCES

Alloway, B. J. (2013). Sources of Heavy Metals and Metalloids in Soils. In B. J. Alloway (Ed.), Heavy Metals in Soils (pp. 11-50). Dordrecht: Springer.

Alloway, B. J. (1990). Cadmium. In Heavy Metals in Soils, Blackie and Son Ltd., Glasgow, 100-124.

Ano, A. O., Odoemelam, S. A. and Ekwueme, P. O. (2007). Lead and Cadmium levels in soils and cassava (*Manihot esculantacrantz*) along Enugu-Port-Harcourt Express way in Nigeria. *Electronic journal of environmental, agricultural and food chemistry*, 6(5): 2024-2031.

Aremu, M. O., Atolaiye, B. O. and Labaran.L. (2010). Environmental implication of metal concentrations in soil, plant foods and pond in area around the derelict Udege mines of Nassarawa state, Nigeria. *Bulletin of the Chemical Society of Ethiopia*. 24(3): 351-360

Ayodele, R. I. and Modupe D. (2008).Heavy metals contamination of topsoil and dispersion in the vicinities of reclaimed auto-repair Workshops in Iwo, Nigeria. *Bulletin of the Chemical Society of Ethiopia* . 22(3):339-343.

Boostani, H. R., Hardie, A. G., Najafi-Ghiri, M., and Khalili, D. (2021). The effect of soil moisture regime and biochar application on lead (Pb) stabilization in a contaminated soil. *Ecotoxicol. Environ. Saf.* 208:111626.

Bray, R. H. and Kurtz, L. T. (1945). Determination of total organic carbon and available forms of phosphorus in soils. *Journal of soil Science.* 51, 22-25.

Bremner, J. M. (1996). Nitrogen-total. In: Sparks, D.L., Ed., *Methods of Soil Analysis*, Part 3, Soil Science Society of America, Madison, 1085-1121.

Caspah, K., Manny, M. and Morgan, M. (2016). Health risk assessment of heavy metals in soils from witwatersrand gold mining basin, South Africa. Int. J. Environ. Res. Public Health, 13: 663.

Crentsil, K. and Anthony, E. (2016). Heavy metals contamination and human health risk assessment around Obuasi gold mine in Ghana. *Environ. Monit. Assess*., 188: 261-261.

Durazzo, A., Lucarini, M., Novellino, E., Souto, E. B., Daliu, P., & Santini, A. (2018). Abelmoschus esculentus (L.): Bioactive components' beneficial properties—Focused on antidiabetic role—For sustainable health applications. *Molecules*, *24*(1), 38.

Duruibe J. O., Ogwuegbu, M. O. C. and Egwurugwu, J. N. (2007). Heavy Metal Pollution and Human Biotoxic Effects. *International Journal of Physical Science* 2, 112-118.

Ehi-Eromosele, C. O., Adaramodu, A. A., Anake, W. U., Ajanaku, C. and Edobor-Osoh, A (2012). Comparison of Three Methods of Digestion for Trace Metal Analysis in Surface Dust Collected From an E-waste Recycling Site. *Nature and Science* 10(10):42-47].

FDALR/FAO. (2004). Soil test-based Fertilizer Recommendations for extension workers National Special Programme for Food Security

Feifei, C., Linghao, K., Liyuan, Y. and Wei, Z. (2015). Geochemical fractions and risk assessment of trace elements in soils around Jiaojia gold mine in Shandong Province, China. *Environmental Science* and *Pollution Research.* 22: 13496-505.

Garza-Lombo, C., Posadas, Y., Quintanar, L., Gonsebatt, M. E. and Franco, R. (2018). Neurotoxicity linked to dysfunctional metal ion homeostasis and xenobiotic metal exposure: Redox Signaling and Oxidative Stress. *Antioxid. Redox Signal*., 28, 1669–1703.

Gemede, H. F., Haki, G. D., Beyene, F., Woldegiorgis, A. Z. and Rakshit, S. K.

(2015). Proximate, mineral, and antinutrient compositions of indigenous Okra (Abelmoschus esculentus) pod accessions: Implications for mineral bioavailability. Food Science and Nutrition., 4, 223–233.

Gu, P. X., Zhang, Y. M., Xie, H. H., Wei, J., Zhang, X. Y. and Huang, X. (2020). Effect of cornstalk biochar on phytoremediation of cd-contaminated soil by *Beta vulgaris* var. cicla L. *Ecotoxicology and Environment. Safety*. 205:111144.

Hakanson, L. (1980). The ecological risk index for aquatic pollution control sediment logical approaches. *Water Research*, 14: 975–1001.

Hossain, Z and Komatsu, S. (2013). Contribution of proteomic studies towards understanding plant heavy metal stress response. *Frontiers in Plant Science*. **3**:310.

Jiang, J., Xu, R. K., Jiang, T. Y. and Li, Z. (2012). Immobilization of Cu (II), Pb (II) and Cd (II) by the addition of rice straw derived biochar to a simulated polluted Ultisol. *Journal of Hazardous Materials*. 229, 145–150.

Jonathan, S. G., Oyetunji, O. J., Olawuyi, O. J. and Asemoloye, M. D. (2012). Growth responses of *Corchorus olitorius* Lin. (Jute) to the application of organic manure as an organic fertilizer. *Academia Arena* 4(9):48–56

Kettler, T. A., Doran, J. W., and Gilbert, T. L. (2001). Simplified method for soil particle-size determination to accompany soil-quality analyses. *Soil Science Society of America Journal.*, 65, 849–852.

Kuo, S. (1996). Phosphorus. In: Sparks, D.L., Ed., *Methods of Soil Analysis*: Part 3, SSSA Book Series No. 5, *Soil Science Society of America Journal* and ASA, Madison, 869-919.

Lal, R. (2015). On Sequestering Carbon and Increasing Productivity by Conservation Agriculture. *Journal of Soil Water Conservation.* , in press.

Mclean, E. O. (1965). Aluminium in Methods of Soil Analysis. America Science Agronomy, Madison, Wisconsin, 978-998.

Mohiuddin, K. M., Zakir, H. M., Otomo, K., Sharmin, S. and Shikazono, N. (2010). Geochemical distribution of trace metal pollutants in water and sediments of downstream of an urban river. I*nternational Journal of Environmental Science and Technology*., 7 (1): 17-28.

Muller, G. (1979). Heavy metals in the sediment of the Rhine-Changes seity 1971. Umsch. Wiss. Tech., 79: 778-783.

Mushtaha, A., Abdalla, E., Jamal, E. and Magboul, S. (2017). Influence of the artisanal gold mining on soil contamination with heavy metals: A case study from Dar-Mali locality, North of Atbara, River Nile State, Sudan. *Eurasian Journal of Soil Science*., 6: 28-36

National Root Crop Research Institute Umudike (2020). Agrometrological Unit, Umudike Abia State, Nigeria.

Nelson, D. W. and Sommers, L. E. (1996). Total carbon, organic carbon, and organic matter. In Sparks, D.L., et al., Eds., Methods of Soil Analysis. Part 3, *Soil Science Society of America Journal*, Book Series, Madison, 961-1010.

NRC (National Research Council). (2006). Okra: Lost crops of Africa: Vegetables. National Academies Press.;2.

Nwaogu, E. N. and Ebeuiro, C. N. (2009). Green house evaluation of the performance of turmeric grown on soils of different parent materials in Southeast Nigeria. ASN 43rd Annual Conference. Proceedings. Pp.864.

Ogbodo, E. A. (2006). Effect of Slope on Lead Contamination and it‘s effect on the Chemical properties of the soils of Enyigba mining site of Southeastern Nigeria. *Nigerian Journal of Tropical Agriculture*. Vol 8.58-66.

Onyedika, G. O. and Nwosu, G. U. (2008). Lead, Zinc and Cadmium in Root Crops from mineralized Galena-Sphalerite Mining Areas and Environment. *Pakistan Journal of Nutrition* 7 (3) 418-420.

Rhoades, J. D. (1982). Cation exchange capacity. In: Methods of soil analysis. Part 2. Chemical and Microbiological Properties (A.L. Page, R.H. Miller and D.R. Keeney), (Eds.) American Society of Agronomy, Inc. *Soil Science Society of America*. Inc. Madison, Wisconsin, pp: 149-157.

Roy, R., Núnez-Delgado, A., Sultana, S., Wang, J., Munir, A. and Battaglia, M. L. (2021). Additions of optimum water, spent mushroom compost and wood biochar to improve the growth performance of Althaea rosea in drought-prone coal-mined spoils. *Journal of Environmental. Management.* 295:113076.

Schippers, R. R. (2000). African indigenous vegetables: An overview of the cultivated species. Chathan, UK: National Resources Institute/ACPEU. CTA.

Sijin, L., Yeyao, W., Yanguo, T. and Xuan, Y. (2015). Heavy metal pollution and ecological risk assessment of the paddy soils near a zinc-lead mining area in Hunan. *Environmental Monitoring and Assessment.*, 187: 627-627.

Sikdar, A., Wang, J. X., Hasanuzzaman, M., Liu, X. Y., Feng, S. L., Roy, R., Sial, T. A., Lahori, A. H., Jeyasundar, P. G. S. A. and Wang, X. Q. (2020). Phytostabilization of Pb-Zn mine tailings with Amorpha fruticosa aided by organic amendments and triple superphosphate. *Molecules* 25, 1617.

Silva Gonzaga, M. I., Oliveira da Silva, P. S., de Jesus, C., Santos, J., de Oliveira, G. and Junior, L. F. (2019). Biochar increases plant water use efficiency and biomass production while reducing cu concentration in *Brassica juncea L.* in a cu-contaminated soil. *Ecotoxicology and Environmental Safety.* 183:109557. d

Turekian, K. K. and Wedepohl, K. H. (1961). Distribution of the elements in some major units of the Earth's crust. *Geological Society of America Bulletin*., 72(2): 175-192.

Walkley, A., and Black, I. A. (1934). An examination of the different methods of determining soil organic matter and proposed modification of the chromic acid titration method. Soil Science Society of Nigeria, 37:29-38.

Yahaya, S. M, Abubakar, F. Abdu, N. (2021).Ecological risk assessment of heavy metal contaminated soils of selected villages in Zamfara State, Nigeria.SN *Applied Sciences* 3:168 |

Yuan, P., Wang, J., Pan, Y., Shen, B., and Wu, C. (2019). Review of biochar for the management of contaminated soil: Preparation, application and prospect. *Science of the Total Environment*., 659, 473–490.