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Effect of Biochar Amendment on Heavy Metals Concentration in Dumpsite Soil and their Uptake by Amaranthus (*Amaranthus cruentus*)

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Authors' contributions

This work was carried out in collaboration between all authors. Author EN designed the study, wrote the protocol and wrote the first draft of the manuscript. Author OJJ managed the literature searches, analyses of the study performed the spectroscopy analysis and author EN managed the experimental process and author JIO identified the species of plant. All authors read and approved the final manuscript.

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ABSTRACT

A pot experiment was conducted in screen house of Faculty of Agriculture, Nasarawa State University Lafia, Nigeria during the dry season of 2014 to assess the presence of heavy metals and the effect of biochar on the concentration of these heavy metals in dumpsite soil and their uptake by Amaranthus *(Amaranthus cruentus*). Five kilogram of dumpsite soil was filled into 27 plastic buckets. The experimental design used was completely randomized design (CRD) and the treatments consisted of three levels of both sawdust and rice husk biochars: 0, 60, 120 g, factorially combined to form 9 treatments and laid out in the screen house. The result revealed that the dumpsite soil was contaminated with heavy metals and their concentration in ascending order in the soil is as follows: Pb< Cd< Ni < Zn< Mn. Only Cadmium (3.7 $mgkg^{-1}$) was above FEPA allowable limit of 3 $mgkg^{-1}$. There was a significant ($p< 0.05$) decreased in soil cadmium, nickel and manganese when both biochars were incorporated into the dumpsite soil. Application of 120 g of

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rice husk biochars reduced the concentration of cadmium (0.27 $mgkg^{-1}$), nickel (0.53 $mgkg^{-1}$) and manganese (0.66 $mgkg^{-1}$); but increased the concentration of lead (1.79 $mgkg^{-1}$) and zinc (6.82 $mgkg^{-1}$) in the soil. Also, 120 g of saw dust biochar reduced the concentration of cadmium (0.27 $mgkg^{-1}$), nickel (0.55 $mgkg^{-1}$) and manganese (0.71 $mgkg^{-1}$). Both rice husk and sawdust biochars rates applied in dumpsite soil significantly ($p< 0.05$) reduced the quantities of manganese uptake by amaranthus plant. However, the uptakes of cadmium, zinc, lead and nickel by amaranthus were not significantly ($p< 0.05$) affected by the application of different rates of both rice husk and sawdust biochars; but an increased in both biochars applied on dumpsite soil resulted to a gradual decrease in the entire heavy metals uptake by amaranthus plant. The combined effect of rice husk and sawdust biochar did not showed any significant effect on the concentration of heavy metals in dumpsite soil and subsequent uptake by Amaranthus.

Keywords: Biochar; amendment; metal; dumpsite; soil.

1. INTRODUCTION

Heavy metals are naturally present in the soil, but geological and anthropogenic activities increase the concentration of these elements to amounts that are harmful to both plants and animals [1]. Some of these anthropogenic activities include mining and smelting of metals, burning of fossil fuels, use of fertilizers and pesticides in agriculture, production of batteries and other metal products in industries, sewage sludge, and municipal waste disposal [2]. Heavy metals like iron, tin, copper, manganese and vanadium occur naturally in the environment and could serve as plant micro-nutrients depending on their concentrations. However, mercury, lead, cadmium, silver, chromium and many others that are indirectly distributed as a result of human activities could be very toxic even at low concentrations [3]. Some heavy metals like As, Cd, Hg and Pb are particularly hazardous to plants, animals and humans [4]. Municipal waste contains such heavy metals as As, Cd, Cu, Fe, Hg, Mn, Pb, Ni and Zn which end up in the soil when they are leached out from the dumpsites [5]. The incorporation of dumpsite soils on farm land to improve the quality of the soil for vegetable production is a common practice in urban and sub-urban centers in Nigeria because of the fact that decayed and composted wastes enhance soil fertility [5]. Small holder farmers in Nigeria cultivate a variety of crops in some temporarily abandoned sections of the dumpsite and some times, they collect these “soils” from the dumpsite and incorporate them as compost on the farms. This is because of the general belief that the native fertility of soil from a waste dumpsite is high [6]. However, many fall victim of heavy metal contamination on their farm land due to lack of adequate information on the status of heavy metals in dumpsites soils. Plants grown on a soil polluted with heavy metals may absorb these heavy metals inform of mobile ions present in the soil through their roots. These absorbed metals get bioacumulated in the roots, stems, fruits, grains and leaves of plants [7].

Remediation of these hazardous soils by conventional practices, which include excavation and land filling is not feasible on large scale because these techniques are cost-prohibitive and environmentally disruptive [8]. Therefore, biochar is one organic material that is currently being exploited for its potential in the management of heavy metals polluted soils [9]. Reduction in the availability of heavy metals when polluted soil was amended with biochar which brought about reduction in absorption of these metals by plants was reported by [10]. The ability of biochar to increase soil pH unlike most other organic amendments may have increased sorption of these metals by biochar, thus reducing their bioavailability in the soil for plant uptake. Also, [11] reported that, the large surface area of biochar and their high cation exchange capacities enhanced the sorption of both organic and inorganic contaminants to their surfaces, reducing pollutant mobility in contaminated soils. Several results of the works of [12-14] showed that the addition of biochar in the soil help to reduce the availability of heavy metals. For these reasons, the application of biochar has recently been advocated as a sustainable means to promote the restoration of contaminated soils [15].

Therefore, this research is aimed at assessing the presence of heavy metals and the suitability of using biochars locally produced from rice husk and sawdust in reducing heavy metal concentration in dumpsite soil and also determines the amount of heavy metal uptake by *Amaranthus crentus* growing in contaminated soil.

2. MATERIALS AND METHODS

The experiment was conducted during the dry season of 2015 at the screen house of Nasarawa State University Keffi, Faculty of Agriculture Shabu Lafia. The study area falls within southern guinea savanna agroecological zone of Nigeria. Rainfall period is usually from March – October and the average monthly rainfall figures range from 40 mm-350 mm. The months of July and August usually record heavy rainfall. The daily maximum temperature ranges from 20.0℃–38.5℃ and daily minimum ranges between 18.7℃–28.2℃. The months of February to early April are the months that have the highest maximum temperature while the lowest maximum temperature are recorded in December and January because of the prevailing cold harmattan wind from the northern part of the country at this period. The relative humidity rises from April to a maximum of about 75- 90 percent in July [16].

2.1 Plant and Soil Sample Collection and Pot Experiment

Dumpsite soil sample was collected from one of the biggest dumpsites at Doma for pot experiment. The dumpsite soil was prepared for analysis of heavy metals before planting. Then 5kg of the soil were filled into 9 plastic buckets which is equal to the number of treatment and replicated three times to produced 27 plastic buckets. The experimental design used was completely randomized design (CRD) and the treatments consisted of three levels of sawdust and rice husk biochar: 0, 60, 120 g per pot; factorially combined to form 9 treatments and laid out in the screen house. After filling the pots with soil, water was also applied in the pots and allowed to stay for one week, two amaranthus seedlings were transplanted into each pot as the test crop. 35 g of NPK 15:15:15 fertilizer was applied in each pot and other agronomic practices were carried out. The following parameters were taken after five weeks of transplanting: plant height, number of leaves, fresh and dry biomass weight, amaranthus from each plastic bucket were harvested and oven dried at 45^{o}c for tissues analysis. Finally, soil samples were taken for post-harvest laboratory soil analysis of heavy metals.

2.2 Laboratory Analyses

The dump site soil sample was air-dried, mechanically ground using a stainless steel roller and sieved to obtain < 2 mm fraction. A 30 g samples was taken from the original bulk dumpsite soil for analysis of heavy metals. The < 2 mm fraction sieved soil sample was used to determine pH (1: 5) soil/water extract. Soil and oven dry plant tissues were digested in a mixture of concentrated nitric acid (HNO_3), concentrated hydrochloric acid (HCl) and 27.5% hydrogen peroxide (H_2O_2) according to the USEPA method 3050B for the analysis of heavy metals [17]. The extracts were analyzed by atomic absorption spectrophotometer (Perkin Elmer, Model No. 2380).

2.3 Heavy Metal Uptake

The heavy metal uptake was determined by metal concentration in the plant tissue multiply by total plant dry matter [7].

2.4 Data Analysis

The data collected were subjected to analysis of variance using GENSTAT, and where there is a significant difference; the means were separated using F-LSD at 5% probability level.

3. RESULTS

The study revealed that the dumpsite soil was contaminated with heavy metals (Table 1). These metal increases in ascending order in the soil as follows: Pb< Cd< Ni < Zn< Mn. All these heavy metals were present in lower quantities in dumpsite soil except Cadmium (3.7mg/kg) which was high and above the European Union, United State of America and Federal Environmental Protection Agency (FEPA) of Nigeria allowable limit of 3 $mgkg^{-1}$ Cadmium in the soil.

The chemical properties of sawdust and rice husk biochars used for soil amendment are presented in (Table 2). The pH of rice husk biochars used was almost neutral (7.14) and sawdust biochar was strongly alkaline (9.33). Rice husk biochar had higher quantities of total nitrogen of 4.25 gkg^{-1}, organic carbon 6.87 gkg^{-1} compared with the sawdust biochar. However, the saw dust biochar had higher quantities of ashes (15.78 gkg^{-1}) compared to the rice husk biochar. The C/N ratio of rice husk biochar was 1.44 gkg^{-1}; while the C/N ratio of sawdust biochar was 1.76 gkg^{-1}. The cation exchange capacities of both saw dust and rice husk biochar were very low; but the percentage base saturation of both biochars were very high (88% saw dust biochar and 96% rice husk biochar).

Table 1. Heavy metal concentration in dumpsite soil before incorporating biochar

Heavy metal	Values before incorporation ($mgkg^{-1}$)	Allowable limit in European soils ($mgkg^{-1}$)	Allowable limit in USA soils ($mgkg^{-1}$)	Allowable limit by FEPA ($mgkg^{-1}$)
Zn	6.4	200	200-300	300
Pb	1.6	70	100	230
Mn	16.6	-	-	-
Ni	6.0	50	50	-
Cd	3.7	3	3	3

Sources: Ndors' field work (2015) and W.H.O (1996)

There was a significant ($p< 0.05$) decreased in soil Cadmium, Nickel and Manganese when both rice husk and sawdust biochars were incorporated into the dumpsite soil (Table 3). However, the concentration of Lead and Zinc in the soil significantly ($p< 0.05$) increased when rice husk and saw dust biochar were applied on the dumpsite soil. Application of 120 g of rice husk biochars reduced the concentration of cadmium (0.27 $mgkg^{-1}$), nickel (0.53 $mgkg^{-1}$) and manganese (0.66 $mgkg^{-1}$); but increased the concentration of lead (1.79 $mgkg^{-1}$) and zinc (6.82 $mgkg^{-1}$) in the soil. Also, 120 g of saw dust biochar reduced the concentration of cadmium (0.27 $mgkg^{-1}$), nickel (0.55 $mgkg^{-1}$) and manganese (0.71 $mgkg^{-1}$); but the concentration of lead and zinc increase to 1.80 $mgkg^{-1}$ and 6.81 $mgkg^{-1}$ respectively. Interaction between rice husk and saw dust biochar did not showed any significant effect on the heavy metals concentration in dumpsite soil.

Application of both sawdust and rice husk biochar rates did not showed any significant ($p< 0.05$) increase on the growth parameters (no. leaves, plant height and biomass weight) of *Amaranthus crentus* (Table 4). Also, the interaction between sawdust and rice husk biochar did not produce any significant effect on the number of leaves, plant height and biomass weight of Amaranthus.

Table 2. Chemical properties of biochar used for the trials

Chemical composition	Saw dust	Rice husk
pH(H_2O)	9.33	7.14
pH(KCl)	9.07	7.03
Ashes(gkg^{-1})	15.78	13.56
T N(gkg^{-1})	3.85	4.25
OC(gkg^{-1})	6.13	6.78
C/N(gkg^{-1})	1.76	1.44
Av. P($mgkg^{-1}$)	8.01	6.01
K($cmolkg^{-1}$)	0.32	0.31
Mg($cmolkg^{-1}$)	1.28	1.34
Ca($cmolkg^{-1}$)	3.68	3.01
Na($cmolkg^{-1}$)	0.69	0.52
Exch. A($cmolkg^{-1}$)	0.70	0.20
CEC($cmolkg^{-1}$)	5.97	5.18
%Base Saturation	88	96

Rice husk and sawdust biochar rates applied on contaminated dumpsite soil significantly ($p< 0.05$) reduced the quantities of Manganese uptake by amaranthus plant (Table 5). However, the uptake of Cadmium, Zinc, Lead and Nickel by amaranthus were not significantly ($p< 0.05$) affected by the application of different rates of

Table 3. Effect of biochar on heavy metal concentration in dumpsite soil

Treatments	Cd (mg/kg)	Ni (mg/kg)	Mn (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
Rice Husk (g)					
0	0.28	0.60	0.79	1.68	6.74
60	0.28	0.58	0.75	1.74	6.80
120	0.27	0.53	0.66	1.79	6.82
LSD (0.05)	0.003	0.003	0.005	0.001	0.003
Sawdust (g)					
0	0.28	0.60	0.77	1.71	6.77
60	0.28	0.56	0.72	1.71	6.78
120	0.27	0.55	0.71	1.80	6.81
LSD(0.05)	0.003	0.003	0.005	0.001	0.003
Interaction					
RH & SD	NS	NS	NS	NS	NS

RH= Rice husk biochar; SD= Sawdust biochar; NS= No significant both rice husk and sawdust biochar. Although, an increase in both rice husk and sawdust biochar applied on contaminated soil resulted to a gradual decrease in the entire heavy metals uptake by amaranthus plant. Therefore, amaranthus that were planted in control pots of both rice husk and sawdust biochar, absorbed the highest quantities of cadmium (0.31 mgkg^{-1} and 0.32 mgkg^{-1}) zinc (6.83 mgkg^{-1} and 6.82 mgkg^{-1}) lead (1.83 mgkg^{-1} and 1.81 mgkg^{-1}) nickel (0.57 mgkg^{-1} and 0.56 mgkg^{-1}) and manganese (0.63 mgkg^{-1} and 0.62 mgkg^{-1}).

Table 4. Effect of biochar Soil amendment on growth parameters of Amaranthus at 4 weeks after transplanting

Biochar	No. of leaves	Plant height (cm)	Biomass weight (g/plant)
Rice Husk (g)			
0	17.00	37.56	27.22
60	17.67	38.11	27.78
120	17.78	39.00	27.78
LSD (0.05)	1.683	3.980	3.725
Sawdust (g)			
0	17.78	38.44	27.56
60	17.00	38.67	27.67
120	17.67	37.56	27.56
LSD(0.05)	1.683	3.980	3.725
Interaction			
RH & SD	NS	NS	NS

RH= Rice husk biochar; SD= Sawdust biochar; NS= No significant

4. DISCUSSION

The study revealed that the dumpsite soil contain heavy metals in increasing order of Pb< Cd< Ni < Zn< Mn. This finding is in consonance with the result obtained by [18]. The saw dust biochar contained higher quantities of carbon and carbon /nitrogen ratio than rice husk biochar (Table 5). This signified that the decomposition of the saw dust biochar materials may continue at higher rates than that of rice husk and higher nitrogen amount may be released for use by crops and other micro-organism in the soil [19]. This corroborates the finding of [20], who worked with biochar of poultry materials for soil amendment. Also, amendment of dumpsite soil with biochars resulted to gradual reduction in heavy metals concentration in the soil. This may be attributed to the ability of biochar to increase soil pH which may have increase sorption of these heavy metals by biochar surfaces, thus reducing their bioavailability in the soil for plant uptake. This assertion is in tandem with the findings of [11] who reported that, the large surface area of biochar and their high cation exchange capacities enhanced the sorption of both organic and inorganic contaminants to their surfaces; thereby reducing pollutant mobility in contaminated soils. [21] reported retention of heavy metals on biochar surfaces and also proved that sorption of these metals were produced at the biochar surface and that this process was not immediately reversible. Biochar might also immobilize heavy metals by transforming the readily available fractions to geochemically more stable residual fractions, resulting in reducing the mobility and bioavailability of heavy metals [22]. Also, due to biochars' unique characteristics, it has been suggested by [10], that biochar is more suitable than other materials to remediate different organic and inorganic contaminants in the soil. The non significant effect of biochar on the growth parameters of *Amaranthus crentus* in this

Table 5. Effect of biochar on heavy metal uptake of *Amaranthus crentus*

Biochar (g/pot)	Cd mgkg^{-1}	Zn mgkg^{-1}	Pb mgkg^{-1}	Ni mgkg^{-1}	Mn mgkg^{-1}
Rice husk					
0	0.31	6.83	1.83	0.57	0.63
60	0.29	6.78	1.76	0.56	0.59
120	0.28	6.74	1.70	0.55	0.51
LSD(0.05)	0.12	0.22	0.18	0.18	0.11
Sawdust					
0	0.32	6.82	1.81	0.56	0.62
60	0.27	6.79	1.74	0.56	0.57
120	0.27	6.67	1.72	0.56	0.50
LSD(0.05)	0.12	0.22	0.18	0.18	0.11
Interaction					
RH X SD	NS	NS	NS	NS	NS

RH= Rice husk biochar; SD= Sawdust biochar; NS= No significant study may be attributed to the high native fertility status of the dumpsite soil and when amaranthus was transplanted the growth was also spontaneous. This agrees with the findings of [6] who worked on the characteristics of dumpsites soils and their uptake by plants. The uptake of these heavy metals especially Mn by amaranthus was significantly reduced when different rates of both rice husk and sawdust biochar were applied compare to control treatment. Increased in both rice husk and sawdust biochar incorporated in the contaminated soil resulted to a gradual decrease in the entire heavy metals uptake by amaranthus plant. The reductions in the concentration of heavy metals in amaranthus in biochar-amended contaminated soil can be attributed to the immobilization of available metals [11].

5. CONCLUSION

In conclusions, this study revealed that the dumpsite soil contained heavy metals (Pb, Cd, Zn, Ni and Mn) and soil amendment with rice husk and sawdust biochar at the rate of 120 g/pot (equivalent of 53.81t ha^{-1}) reduced the concentration of these heavy metals in both the dumpsite soil and *Amaranthus crentus* tissues.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ajayi OO. Heavy metal contents of soil in auto mechanic workshop in Lagos—Research Note. Nigerian Journal of Soil Science. 2005;15(2):163–165.
2. Haliru M, Ajibola VO, Agbaji EB. Evaluation of the uptake and accumulation of metals by some commonly irrigated vegetables in soils treated with different concentration of these metals. J. of App. Sci. 2009;9(8):1573–1577.
3. Anikwe MAN, Nwobodo KCA. Long term effect of municipal wastes disposal on soil properties and productivity of sites used for urban Agriculture in Abakaliki, Nigeria. Bioresources Technology. 2001;83:241–251.
4. Wang X, Shan X, Zhang S, Wen BA. Model for evaluation of the phytoavailability of trace elements to vegetables under the field conditions. Chemosphere. 2004;(6): 81122.
5. Opaluwa OD, Aremu MO, Ogbo LO, Abiola KA, Odiba IE, Abubakar MM, Nweze NO. Heavy metal concentrations in soils, plant leaves and crops grown around dump sites in Lafia Metropolis, Nasarawa State, Nigeria. Advances in Applied Science Research. 2012;3(2):780-784.
6. Amusan AA, Ige DV, Olawale R. Characteristics of soils and crop uptake of metals in municipal waste dumpsite in Nigeria. Journal of Human Ecology 2005;17(3):167–171.
7. Abul K. Md, Singh B. Heavy metal contamination of soil and vegetation in the vicinity of industries in Bangladesh. Technical Report. 1999;115:347-361.
8. Arthur EL, Rice PJ, Anderson TA, Baladi SM, Henderson KLD. Phytoremediationdan overview. Crit Rev Plant Sci. 2005;24(2):109-122.
9. Namgay T, Singh B, Singh BP. Influence of biochar application to soil on the availability of As, Cd, Cu, Pb, and Zn to maize (*Zea mays* L.). J. Aust. Soil Res. 2010;48:638–647.
10. Paz-Ferreiro J, Lu H, Fu S, Méndez A, Gascó G. Use of phytoremediation and biochar to remediate heavy metal polluted soils: A review. Solid Earth. 2014;5:65–75.
11. Park JH, Park GH, Choppala NS, Bolan JW, Chung T. Chuasavathi Biochar reduces the bioavailability and phytotoxicity of heavy metals. Plant Soil. 2011;348:439–451.
12. Karami N, Clemente R, Moreno-Jime´nez E, Lepp NW, Beesley L. Efficiency of green waste compost and biochar soil amendments for reducing lead and copper mobile uptake to ryegrass. J Hazard Mater. 2011;191(13):418.
13. Fellet G, Marchiol L, Delle Vedove G, Peressotti A. Application of biochar on mine tailings: Effects and perspectives for land reclamation. Chemosphere. 2011; 83(9):12627.
14. Houben D, Evrard L, Sonnet P. Mobility, bioavailability and pH-dependent leaching of admium, zinc and lead in a contaminated soil amended with biochar. Chemosphere. 2013;92(11):14507.
15. Beesley L, Moreno-Jime´nez E, Gomez-Eyles JL, Harris E, Robinson B, Sizmur T. A review of biochars' potential role in the

remediation, revegetation and restoration ofcontaminated soils. Environ Pollut. 2011;159(12):326982.
16. NIMET. Nigerian Meteorological Agency. Lafia field station report; 2014.
17. USEPA. Test methods for evaluating solid waste. Physical/Chemical Methods (3rd ed.). Method 3050B, Acid Digestion of Sediment, Sludges and soils, USEPA, Washington, DC, SW-846; 1996.
18. Ebong GA, Etuk HS, Johnson AS. Heavy metals accumulations on waste dumpsites in Uyo Metropolis, AkwaIbom State, Nigeria'. Journal of Applied Science. 2007;7(10):1404-1409.
19. Glaser B, Lehmann J, Zech W. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal-a review. Biol. Fertil. Soils. 2002;33:219–230.
20. Chan KY, Zwieten LV, Meszaros I, Downie A, Joseph S. Using poultry litter biochars as soil amendments. Aust. J. Soil Res. 2008;46:437–444.
21. Beesley L, Marmiroli M. The immobilisation and retention of soluble arsenic, cadmium and zinc by biochar. Environ Pollut. 2011;159(2):474.
22. Ahmad M, Lee SS, Lim JE, Lee SE, Cho JS, Moon DH, Hashimoto Y, Ok YS. Speciation and phytoavailability of lead and antimony in a small arms range soil amended with mussel shell, cow bone and biochar: EXAFS spectroscopy and chemical extractions. Chemosphere. 2014; 95:433–441.

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