

## Bioaccumulation of Pb and Cd in tissues of *Amaranthus cruentus* (L) under the influence of biochar in contaminated soils of Sudan and Northern Guinea savanna agro-ecologies of Nigeria

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### ABSTRACT

Influence of biochar on bioaccumulation and translocation of Pb and Cd in plant tissues obtained from contaminated soils; Bagega in Sudan savanna agro-ecology of Zamfara state and Barrakallahu in the Northern Guinea savanna agro-ecology of Kaduna state, Nigeria, was assessed. This research was carried out to determine the effects of biochar (woodchar and bonechar) on the bioaccumulation and translocation of Pb and Cd by *Amaranthus cruentus* in contaminated soils. A screen house study was established with twenty-one biochar and fertilizer treatment combinations replicated three times in a completely randomized design. The study involved two trials to determine the initial and residual influence of biochar on metal transfer in tissues of *Amaranthus cruentus*. Plant roots and shoots were analyzed for total concentration of Pb and Cd. Translocation values of Pb in the first trial ranged from 0.50-1.19 and 0.53-4.61 for Bagega and Barrakallahu respectively while 0.38-0.83 and 0.38-1.35 were obtained for Cd. In the second trial, 0.25-1.06 and 0.76-2.13 were obtained for Pb from Bagega and Barrakallahu respectively while 0.30-2.02 and 0.48-1.68 were obtained for Cd under the residual influence of biochar. However bioaccumulation values of Pb and Cd were far below the threshold value of one (1) for both soils examined. Biochar (bonechar) effectively reduced bioaccumulation of Pb and Cd in plant tissues.

**Keywords:** Biochar, bioaccumulation, heavy metals, lead, cadmium, contaminated soils

### INTRODUCTION

In cases of agricultural-induced-heavy metal-contamination, a variety of materials are introduced into the root zone of crops to enhance agricultural productivity of our land. These additions that contain heavy metal elements include irrigation water, fertilizers, soil amendments, animal manures, sewage effluents and sludge and pesticides. Other inadvertent sources of these elemental inputs are acidic precipitation and atmospheric deposition. The portion of these additives not consumed by crops may be lost through

surface runoff, percolation beyond the root zone and volatilization. They may also be stored or immobilized in the root zone in the soil matrix, microbial biomass and in soil organic matter.

Elevated heavy metal concentrations in the soil can lead to enhanced crop uptake (Oyinlola and Onokebhagbe, 2008; Abdu and Yusuf, 2013). Excessive metals in human nutrition can be toxic and can cause acute and chronic diseases (Jarup, 2003; Jaishankar *et al.* 2014). A major incidence of the negative

impact of heavy metals on human health, was the death of hundreds of children and adults in gold mining towns of Zamfara State of the northern part of Nigeria, due to the negative effect of Pb poisoning with the continuous contact of humans with Pb contaminated water, soil and through ingestion of food that contain Pb (NNP 2011; Abdu and Yusuf, 2013).

The need to minimize these incidences has led to the adoption of various technologies such as soil swapping and excavation. Recently, biochar has been proved to be excellent in heavy metal remediation processes (Park *et al.* 2011 and Zhang *et al.* 2013). This is due to its ability to immobilize heavy metals such as Pb present in the contaminated soils. This it does by modifying the pH of the soil as well as the distribution of the heavy metal ion species in the contaminated soil (Onokebhagbe *et al.* 2018b). Heavy metals such as Pb and Cd are common heavy metals that coexist in contaminated soils. Plants especially vegetables have been known to accumulate heavy metals at elevated concentrations in the soil (Abba and Ibrahim, 2017). Therefore the objective of

this study was to determine the influence of biochar on the accumulation and translocation of Pb and Cd in *Amaranthus cruentus*.

## **MATERIALS AND METHODS**

As previously outlined by Onokebhagbe *et al.* (2018a), soil processing, biochar production (from wood and bones) and routine analysis were carried out at the Department of Soil Science, Ahmadu Bello University, Zaria. These results are shown in Tables 1 and 2. Screen house study was carried out at the Department of Soil Science, Ahmadu Bello University, Zaria. Experimental design employed in the screen house study was a completely randomized design consisting of twenty-one biochar and fertilizer treatment combinations. *Amaranthus cruentus* (L) was used as a test crop. Plant analysis was carried out in the laboratory using the wet digestion method as outlined by Lim and Jackson (1986). Concentrations of Pb and Cd in the digested plant tissues (shoots and roots) were determined in the plant tissues using the atomic absorption spectrophotometer (Buck 211VGP AAS).

**Table 1:** Physical and chemical properties of soils of Bagega and Barkalau

Soil Property	Bagega	Barrakallahu
Particle Size Distribution (g kg <sup>-1</sup> )		
Clay	100	120
Silt	200	220
Sand	700	660
Textural Class	Sandy loam	Sandy loam
pH in H <sub>2</sub> O	6.9	7.1
pH in CaCl <sub>2</sub>	6.6	6.4
EC (dSm <sup>-1</sup> )	0.45	0.9
Organic Carbon (g kg <sup>-1</sup> )	5.01	9.5
Organic Matter (g kg <sup>-1</sup> )	8.6	16.3
Total Nitrogen (g kg <sup>-1</sup> )	0.4	0.7
Available P (mg kg <sup>-1</sup> )	10.95	24.3
Exchangeable Bases (cmol (+) kg <sup>-1</sup> )		
Ca	1.22	6.32
Mg	0.48	1.43
K	0.16	0.39
Na	0.5	0.54
CEC (cmol (+) kg <sup>-1</sup> )	2.36	8.68
Extractable Heavy metals (mg kg <sup>-1</sup> )		
Extractable Pb	143.98	5.78
Extractable Cd	5.79	2.88

Source: Onokebhagbe et al. 2018a.

**Table 2:** Chemical properties of biochars

Chemical properties	Woodchar	Bonechar
pH in H <sub>2</sub> O	9.4	7.3
pH in CaCl <sub>2</sub>	7.9	7.3
Total Nitrogen (%)	0.7	2.98
Carbon (%)	68.03	8
Total P (g kg <sup>-1</sup> )	1.6	63.2
Exchangeable bases (cmol (+) kg <sup>-1</sup> )		
K	20.51	2.56
Ca	88	338.75
Na	5.22	19.67
Mg	3.08	40.83
Micronutrients (mg kg <sup>-1</sup> )		
Cu	27	27
Mn	57.03	34.28
Co	ND	ND

Source: Onokebhagbe et al. 2018a.

### Metal transfer and translocation factor

Translocation of metals from one part of a vegetable to another which is a function of root-shoot or shoot-shoot transport was expressed as the translocation factor (TF):

$$TF = C \text{ shoot} / C \text{ root} \text{ -----Eqn. 1}$$

The Metal Transfer Factor also referred to as 'bio-accumulation factor' – an index of the ability of a plant to accumulate a particular metal as a function of its concentration in the soil (C soil) was calculated from the following equation:

$$BAF = C \text{ (shoot and root)} / C \text{ soil} \text{ -----Eqn. 2}$$

Both equations were outlined by Ghosh and Singh (2005). Where C shoot was determined to be the concentration of Pb and Cd in the above-ground portion of the vegetable and C root is their concentration in the below-ground portion.

### Statistical analysis

Data obtained from the experimental studies were subjected to descriptive statistics and one-way analysis of variance (ANOVA). Mean differences were separated using Duncan's Multiple Range Test (DMRT) as outlined by Gomez and Gomez (1984). Statistical analysis were carried out using SAS version 9.1 (SAS, 1999) software package.

## RESULTS

### Effects of fertilizer and biochar on Translocation Factor of Pb

Translocation factors of Pb obtained from Bagega shows that there was no significant ( $p < 0.05$ ) difference among treatment means obtained from the first trial (Table 3). The values indicate that 4.76% of the TF obtained from Bagega were greater than one. The values obtained from Barrakallahu shows significant ( $p < 0.05$ ) differences among treatment means in the first trial (Table 3). The data showed that translocation factors obtained from plants grown on Barrakallahu soil ranged from 0.53 to 4.61. Percentage fraction of the data obtained from Table 3 shows that 14.29% of the translocation values obtained from Barrakallahu were greater than one. Data obtained from the second trial of both soils as presented in Table 3 show the residual influence of fertilizer and biochar amendments on translocation factor of Pb in the plant tissues. For Bagega, all values obtained from the treatments under the combined application of fertilizer and biochar were less than one.

### Effects of fertilizer and biochar on Translocation Factor of Cd

The data on the effects of combined fertilizer and biochar application on translocation of Cd from the roots to the shoots of *Amaranthus cruentus* are presented in Table 4. The results indicated that there was no significant ( $p < 0.05$ ) difference among treatment values obtained from Bagega in the first trial. Translocation values less than one ( $TF < 1$ ), were obtained for all treatments from Bagega in the first trial. The TF (Translocation Factor) data ranged from 0.38 to 0.83.

**Table 3:** Effects of combined fertilizer and biochar use on Translocation factor of Pb

Treatments	Translocation factor of Pb			
	Bagega		Barrakallahu	
	First trial	Second trial	First trial	Second trial
0 kg NPK ha <sup>-1</sup>	0.70	1.04 <sup>ab</sup>	0.92 <sup>b</sup>	2.13 <sup>a</sup>
40 kg NPK ha <sup>-1</sup>	0.53	1.06 <sup>a</sup>	4.61 <sup>a</sup>	1.93 <sup>ab</sup>
80 kg NPK ha <sup>-1</sup>	0.55	0.35 <sup>c</sup>	2.93 <sup>ab</sup>	1.65 <sup>a-c</sup>
10 t ha <sup>-1</sup> PC + 0-Fert ha <sup>-1</sup>	0.52	0.32 <sup>c</sup>	0.53 <sup>b</sup>	1.58 <sup>a-d</sup>
20 t ha <sup>-1</sup> PC + 0-Fert ha <sup>-1</sup>	0.65	0.37 <sup>c</sup>	0.63 <sup>b</sup>	1.07 <sup>b-d</sup>
30 t ha <sup>-1</sup> PC + 0-Fert ha <sup>-1</sup>	0.93	0.53 <sup>c</sup>	0.70 <sup>b</sup>	1.27 <sup>a-d</sup>
10 t ha <sup>-1</sup> BC + 0-Fert ha <sup>-1</sup>	0.69	0.62 <sup>bc</sup>	0.90 <sup>b</sup>	1.23 <sup>b-d</sup>
20 t ha <sup>-1</sup> BC + 0-Fert ha <sup>-1</sup>	0.56	0.38 <sup>c</sup>	0.76 <sup>b</sup>	0.81 <sup>cd</sup>
30 t ha <sup>-1</sup> BC + 0-Fert ha <sup>-1</sup>	0.64	0.63 <sup>bc</sup>	1.06 <sup>b</sup>	0.91 <sup>cd</sup>
10 t ha <sup>-1</sup> PC + 40 kg NPK ha <sup>-1</sup>	0.63	0.25 <sup>c</sup>	0.60 <sup>b</sup>	1.47 <sup>a-d</sup>
10 t ha <sup>-1</sup> PC + 80 kg NPK ha <sup>-1</sup>	0.84	0.35 <sup>c</sup>	0.86 <sup>b</sup>	1.04 <sup>cd</sup>
20 t ha <sup>-1</sup> PC + 40 kg NPK ha <sup>-1</sup>	0.82	0.63 <sup>bc</sup>	0.85 <sup>b</sup>	1.12 <sup>b-d</sup>
20 t ha <sup>-1</sup> PC + 80 kg NPK ha <sup>-1</sup>	0.82	0.63 <sup>bc</sup>	0.80 <sup>b</sup>	1.00 <sup>cd</sup>
30 t ha <sup>-1</sup> PC + 40 kg NPK ha <sup>-1</sup>	1.19	0.55 <sup>c</sup>	0.74 <sup>b</sup>	1.01 <sup>cd</sup>
30 t ha <sup>-1</sup> PC + 80 kg NPK ha <sup>-1</sup>	0.59	0.51 <sup>c</sup>	0.78 <sup>b</sup>	1.14 <sup>b-d</sup>
10 t ha <sup>-1</sup> BC + 40 kg NPK ha <sup>-1</sup>	0.78	0.32 <sup>c</sup>	0.95 <sup>b</sup>	0.83 <sup>cd</sup>
10 t ha <sup>-1</sup> BC + 80 kg NPK ha <sup>-1</sup>	0.62	0.31 <sup>c</sup>	0.70 <sup>b</sup>	0.76 <sup>d</sup>
20 t ha <sup>-1</sup> BC + 40 kg NPK ha <sup>-1</sup>	0.50	0.45 <sup>c</sup>	0.92 <sup>b</sup>	0.85 <sup>cd</sup>
20 t ha <sup>-1</sup> BC + 80 kg NPK ha <sup>-1</sup>	0.51	0.55 <sup>c</sup>	0.75 <sup>b</sup>	0.97 <sup>cd</sup>
30 t ha <sup>-1</sup> BC + 40 kg NPK ha <sup>-1</sup>	0.68	0.56 <sup>c</sup>	0.54 <sup>b</sup>	1.00 <sup>cd</sup>
30 t ha <sup>-1</sup> BC + 80 kg NPK ha <sup>-1</sup>	0.82	0.42 <sup>c</sup>	0.63 <sup>b</sup>	0.98 <sup>cd</sup>
SE (+)	NS	0.040	0.220	0.070
Interaction				
PC*BC*Fert	NS	NS	NS	NS

Means with the same letter(s) are not significantly different.

NS: Not significant

The results obtained from Barrakallahu in the first trial (Table 4), shows significant ( $p < 0.05$ ) differences among the treatment means. The values were low ( $< 1$ ) and ranged from 0.38 to 1.35. Higher mean translocation values of Cd were obtained from Barrakallahu under the residual effects of fertilizer and biochar in the second trial (Table 4). Significant ( $p < 0.05$ ) differences were not observed among treatment means. An observed percentage of 47.62 translocation values of treatment means found to be greater than one ( $TF > 1$ ) was obtained from Barrakallahu (second trial).

#### **Effects of fertilizer and biochar on Bioaccumulation Factor of Pb and Cd**

Data on the effects of combined fertilizer and biochar application on bioaccumulation factor of Pb are presented in Table 5. Bioaccumulation

factor (BAF) values obtained from all trials on both locations were extremely low. All treatment bioaccumulation values of Pb obtained were less than one i.e.  $BAF < 1$  and ranged from 0.006 to 0.008 as shown in Table 5.

The result on the effects of fertilizer and biochar on bioaccumulation factor of Cd is presented in Table 6. The result showed no significant ( $p < 0.05$ ) differences among treatment mean values obtained from Bagega in the first trial. The BAF values obtained were observed to be less than one. Bioaccumulation factor data obtained from Barrakallahu (first trial), as presented in Table 6, shows that significant ( $p < 0.05$ ) differences were observed among treatment means. The BAF values ranged from 0.010 to 0.023.

**Table 4:** Effects of combined fertilizer and biochar application on Translocation factor of Cd

Treatments	Translocation factor of Cd			
	Bagega		Barrakallahu	
	First trial	Second trial	First trial	Second trial
0 kg NPK ha <sup>-1</sup>	0.51	0.65 <sup>b</sup>	0.52 <sup>bc</sup>	1.24
40 kg NPK ha <sup>-1</sup>	0.63	0.76 <sup>b</sup>	0.67 <sup>bc</sup>	1.65
80 kg NPK ha <sup>-1</sup>	0.51	0.32 <sup>b</sup>	0.59 <sup>bc</sup>	1.43
10 t ha <sup>-1</sup> PC + 0-Fert ha <sup>-1</sup>	0.63	0.30 <sup>b</sup>	0.38 <sup>c</sup>	1.33
20 t ha <sup>-1</sup> PC + 0-Fert ha <sup>-1</sup>	0.81	0.51 <sup>b</sup>	0.60 <sup>bc</sup>	0.88
30 t ha <sup>-1</sup> PC + 0-Fert ha <sup>-1</sup>	0.66	0.58 <sup>b</sup>	0.73 <sup>a-c</sup>	1.65
10 t ha <sup>-1</sup> BC + 0-Fert ha <sup>-1</sup>	0.76	0.86 <sup>b</sup>	1.12 <sup>ab</sup>	0.90
20 t ha <sup>-1</sup> BC + 0-Fert ha <sup>-1</sup>	0.38	0.61 <sup>b</sup>	0.67 <sup>bc</sup>	0.48
30 t ha <sup>-1</sup> BC + 0-Fert ha <sup>-1</sup>	0.68	1.25 <sup>ab</sup>	0.74 <sup>a-c</sup>	0.66
10 t ha <sup>-1</sup> PC + 40 kg NPK ha <sup>-1</sup>	0.83	0.17 <sup>b</sup>	0.57 <sup>bc</sup>	1.15
10 t ha <sup>-1</sup> PC + 80 kg NPK ha <sup>-1</sup>	0.62	0.32 <sup>b</sup>	0.67 <sup>bc</sup>	0.88
20 t ha <sup>-1</sup> PC + 40 kg NPK ha <sup>-1</sup>	0.81	0.55 <sup>b</sup>	1.35 <sup>a</sup>	1.47
20 t ha <sup>-1</sup> PC + 80 kg NPK ha <sup>-1</sup>	0.62	0.75 <sup>b</sup>	0.85 <sup>a-c</sup>	1.35
30 t ha <sup>-1</sup> PC + 40 kg NPK ha <sup>-1</sup>	0.70	0.82 <sup>b</sup>	0.78 <sup>a-c</sup>	1.68
30 t ha <sup>-1</sup> PC + 80 kg NPK ha <sup>-1</sup>	0.64	0.40 <sup>b</sup>	0.74 <sup>a-c</sup>	1.49
10 t ha <sup>-1</sup> BC + 40 kg NPK ha <sup>-1</sup>	0.68	0.47 <sup>b</sup>	0.66 <sup>bc</sup>	0.51
10 t ha <sup>-1</sup> BC + 80 kg NPK ha <sup>-1</sup>	0.51	0.37 <sup>b</sup>	0.52 <sup>bc</sup>	0.97
20 t ha <sup>-1</sup> BC + 40 kg NPK ha <sup>-1</sup>	0.56	0.52 <sup>b</sup>	1.02 <sup>a-c</sup>	0.88
20 t ha <sup>-1</sup> BC + 80 kg NPK ha <sup>-1</sup>	0.43	0.78 <sup>b</sup>	0.47 <sup>bc</sup>	0.60
30 t ha <sup>-1</sup> BC + 40 kg NPK ha <sup>-1</sup>	0.76	2.02 <sup>a</sup>	0.51 <sup>bc</sup>	0.61
30 t ha <sup>-1</sup> BC + 80 kg NPK ha <sup>-1</sup>	0.81	0.71 <sup>b</sup>	0.68 <sup>bc</sup>	0.64
SE (+)	NS	0.080	0.040	NS
Interaction				
PC*BC*Fert	NS	NS	NS	NS

Means with the same letter(s) are not significantly different.

NS: Not significant.

**Table 5:** Effects of combined fertilizer and biochar application on bioaccumulation factor of Pb

Treatments	Bioaccumulation factor of Pb			
	Bagega		Barrakallahu	
	First trial	Second trial	First trial	Second trial
0 kg NPK ha <sup>-1</sup>	0.006	0.0100 <sup>a</sup>	0.014 <sup>ab</sup>	0.027 <sup>cd</sup>
40 kg NPK ha <sup>-1</sup>	0.006	0.0100 <sup>a</sup>	0.014 <sup>ab</sup>	0.026 <sup>d</sup>
80 kg NPK ha <sup>-1</sup>	0.006	0.0059 <sup>bc</sup>	0.014 <sup>ab</sup>	0.026 <sup>d</sup>
10 t ha <sup>-1</sup> PC + 0-Fert ha <sup>-1</sup>	0.007	0.0067 <sup>bc</sup>	0.010 <sup>b</sup>	0.027 <sup>cd</sup>
20 t ha <sup>-1</sup> PC + 0-Fert ha <sup>-1</sup>	0.007	0.0073 <sup>a-c</sup>	0.017 <sup>ab</sup>	0.036 <sup>a-d</sup>
30 t ha <sup>-1</sup> PC + 0-Fert ha <sup>-1</sup>	0.006	0.0056 <sup>bc</sup>	0.019 <sup>ab</sup>	0.035 <sup>a-d</sup>
10 t ha <sup>-1</sup> BC + 0-Fert ha <sup>-1</sup>	0.006	0.0076 <sup>a-c</sup>	0.021 <sup>a</sup>	0.040 <sup>ab</sup>
20 t ha <sup>-1</sup> BC + 0-Fert ha <sup>-1</sup>	0.006	0.0071 <sup>a-c</sup>	0.023 <sup>a</sup>	0.040 <sup>ab</sup>
30 t ha <sup>-1</sup> BC + 0-Fert ha <sup>-1</sup>	0.007	0.0082 <sup>a-c</sup>	0.022 <sup>a</sup>	0.042 <sup>a</sup>
10 t ha <sup>-1</sup> PC + 40 kg NPK ha <sup>-1</sup>	0.007	0.0070 <sup>a-c</sup>	0.015 <sup>ab</sup>	0.028 <sup>b-d</sup>
10 t ha <sup>-1</sup> PC + 80 kg NPK ha <sup>-1</sup>	0.007	0.0076 <sup>a-c</sup>	0.015 <sup>ab</sup>	0.035 <sup>a-d</sup>
20 t ha <sup>-1</sup> PC + 40 kg NPK ha <sup>-1</sup>	0.007	0.0083 <sup>ab</sup>	0.016 <sup>ab</sup>	0.035 <sup>a-d</sup>
20 t ha <sup>-1</sup> PC + 80 kg NPK ha <sup>-1</sup>	0.006	0.0058 <sup>bc</sup>	0.018 <sup>ab</sup>	0.034 <sup>a-d</sup>
30 t ha <sup>-1</sup> PC + 40 kg NPK ha <sup>-1</sup>	0.007	0.0051 <sup>bc</sup>	0.019 <sup>ab</sup>	0.036 <sup>a-d</sup>
30 t ha <sup>-1</sup> PC + 80 kg NPK ha <sup>-1</sup>	0.006	0.0048 <sup>c</sup>	0.020 <sup>a</sup>	0.036 <sup>a-d</sup>
10 t ha <sup>-1</sup> BC + 40 kg NPK ha <sup>-1</sup>	0.006	0.0068 <sup>a-c</sup>	0.019 <sup>ab</sup>	0.037 <sup>a-d</sup>
10 t ha <sup>-1</sup> BC + 80 kg NPK ha <sup>-1</sup>	0.007	0.0063 <sup>bc</sup>	0.020 <sup>a</sup>	0.036 <sup>a-d</sup>
20 t ha <sup>-1</sup> BC + 40 kg NPK ha <sup>-1</sup>	0.006	0.0071 <sup>a-c</sup>	0.022 <sup>a</sup>	0.039 <sup>a-c</sup>
20 t ha <sup>-1</sup> BC + 80 kg NPK ha <sup>-1</sup>	0.007	0.0071 <sup>a-c</sup>	0.022 <sup>a</sup>	0.039 <sup>a-c</sup>
30 t ha <sup>-1</sup> BC + 40 kg NPK ha <sup>-1</sup>	0.007	0.0077 <sup>a-c</sup>	0.019 <sup>ab</sup>	0.044 <sup>a</sup>
30 t ha <sup>-1</sup> BC + 80 kg NPK ha <sup>-1</sup>	0.008	0.0081 <sup>a-c</sup>	0.020 <sup>a</sup>	0.041 <sup>a</sup>
SE (+)	NS	0.00028	0.001	0.001
Interaction				
PC*BC*Fert	NS	NS	NS	NS

Means with the same letter(s) are not significantly different.

NS: Not significant



**Table 6:** Effects of combined fertilizer and biochar application on Bioaccumulation factor of Cd

Treatments	Bioaccumulation factor of Cd			
	Bagega		Barrakallahu	
	First trial	Second trial	First trial	Second trial
0 kg NPK ha <sup>-1</sup>	0.073	0.52 <sup>ab</sup>	0.020 <sup>ab</sup>	0.026
40 kg NPK ha <sup>-1</sup>	0.071	0.46 <sup>b</sup>	0.023 <sup>a</sup>	0.025
80 kg NPK ha <sup>-1</sup>	0.064	0.37 <sup>b</sup>	0.017 <sup>bc</sup>	0.026
10 t ha <sup>-1</sup> PC + 0-Fert ha <sup>-1</sup>	0.080	0.70 <sup>ab</sup>	0.010 <sup>d</sup>	0.029
20 t ha <sup>-1</sup> PC + 0-Fert ha <sup>-1</sup>	0.090	0.47 <sup>b</sup>	0.016 <sup>bc</sup>	0.039
30 t ha <sup>-1</sup> PC + 0-Fert ha <sup>-1</sup>	0.063	0.29 <sup>b</sup>	0.019 <sup>bc</sup>	0.029
10 t ha <sup>-1</sup> BC + 0-Fert ha <sup>-1</sup>	0.082	0.38 <sup>b</sup>	0.021 <sup>ab</sup>	0.022
20 t ha <sup>-1</sup> BC + 0-Fert ha <sup>-1</sup>	0.080	0.33 <sup>b</sup>	0.021 <sup>ab</sup>	0.024
30 t ha <sup>-1</sup> BC + 0-Fert ha <sup>-1</sup>	0.086	0.47 <sup>b</sup>	0.019 <sup>bc</sup>	0.024
10 t ha <sup>-1</sup> PC + 40 kg NPK ha <sup>-1</sup>	0.083	0.54 <sup>ab</sup>	0.014 <sup>cd</sup>	0.031
10 t ha <sup>-1</sup> PC + 80 kg NPK ha <sup>-1</sup>	0.086	1.01 <sup>a</sup>	0.013 <sup>cd</sup>	0.037
20 t ha <sup>-1</sup> PC + 40 kg NPK ha <sup>-1</sup>	0.072	0.68 <sup>ab</sup>	0.012 <sup>cd</sup>	0.035
20 t ha <sup>-1</sup> PC + 80 kg NPK ha <sup>-1</sup>	0.073	0.34 <sup>b</sup>	0.017 <sup>bc</sup>	0.034
30 t ha <sup>-1</sup> PC + 40 kg NPK ha <sup>-1</sup>	0.073	0.34 <sup>b</sup>	0.015 <sup>cd</sup>	0.028
30 t ha <sup>-1</sup> PC + 80 kg NPK ha <sup>-1</sup>	0.060	0.22 <sup>b</sup>	0.021 <sup>ab</sup>	0.024
10 t ha <sup>-1</sup> BC + 40 kg NPK ha <sup>-1</sup>	0.088	0.42 <sup>b</sup>	0.017 <sup>bc</sup>	0.020
10 t ha <sup>-1</sup> BC + 80 kg NPK ha <sup>-1</sup>	0.082	0.37 <sup>b</sup>	0.017 <sup>bc</sup>	0.024
20 t ha <sup>-1</sup> BC + 40 kg NPK ha <sup>-1</sup>	0.080	0.33 <sup>b</sup>	0.023 <sup>a</sup>	0.025
20 t ha <sup>-1</sup> BC + 80 kg NPK ha <sup>-1</sup>	0.086	0.37 <sup>b</sup>	0.020 <sup>ab</sup>	0.020
30 t ha <sup>-1</sup> BC + 40 kg NPK ha <sup>-1</sup>	0.080	0.57 <sup>ab</sup>	0.014 <sup>cd</sup>	0.025
30 t ha <sup>-1</sup> BC + 80 kg NPK ha <sup>-1</sup>	0.085	0.41 <sup>b</sup>	0.020 <sup>ab</sup>	0.035
SE (+)	NS	0.037	0.0370	NS
Interaction				
PC*BC*Fert	NS	NS	NS	NS

Means with the same letter(s) are not significantly different.

NS: Not significant

## DISCUSSION

The low TF obtained could be due to the ability of plants to retain Pb in the root tissues. Many plants tend to retain Pb in their roots via sorption and precipitation with only a minimal transport to plant portions above the ground (Rahman *et al.* 2013). This result obtained, is similar to the reports of Ibrahim and Salem (2017) that obtained TF ranges of 0.53 to 0.80 and reported observations of high accumulation of heavy metals in the roots of *Amaranthus cruentus* than in other parts of plants. Transport of Pb from the roots to the aerial parts of plants' parts is still a subject of importance (Singh *et al.* 2010). Metal translocation indicates the ability of fertilizer and amendments to affect metal transfer from roots to shoots. Fertilizers have been reported to enhance Pb translocation as observed by Zhao *et al.* (2003) who reported an increase in Pb content of plant shoot with fertilizer application. This was largely due to the reducing effect of the fertilizer on the soil pH. This low pH leads to high concentration of Pb in its available forms resulting in its high bioavailability and concentrations in plant shoots (Rahman *et al.* 2013).

Translocation values of Pb in the plant tissues were higher under the residual influence of fertilizer and biochar than the initial values obtained from the previous experiment for data obtained from Barrakallahu. This is evident with the comparable low fertility status of the soil in the second trial, there is aggressive and unselective uptake of metallic ions by the plant roots, which is fuelled by transpiration demand of the plant (Tangahu *et al.* 2011). Transpiration pull is an important mechanism that aids heavy metal ions transport in the transpiration stream as it moves from the xylem to the transpiring shoot parts thereby redistributing the ions in the shoot (Miyadate *et al.* 2011)

Translocation of Cd in the plant tissues was observed to be higher under the residual influence of fertilizer and biochar for soils of Barrakallahu in the second trial mostly under the influence of fertilizer and PC. This increase in TF of Cd could be due to increase in solubility of Cd ions in solution with increases in the levels of dissolved organic carbon from the biochar amendments and ultimately the effects of transpiration demand of the plant as well as the positive influence of the soil properties (Tangahu *et al.* 2011).

Comparative results on the translocation factors of Pb and Cd obtained from Bagega and Barrakallahu show many differences under the two trials. Increases in percentages of TF values greater than one were obtained from the second trial under the residual influence of fertilizer and biochar for data obtained from Barrakallahu. The low values of TF values of Pb and Cd obtained in the first trial from Bagega and Barrakallahu indicated higher accumulation of the metals in the root than other parts of the plant. This result is similar to that obtained by Khoramnejadian and Saeb (2015), who made similar reports of 0.21 and 0.34 as TF values obtained from tissues of *Amaranthus cruentus*. Lead is heavy metal known usually to accumulate in plant roots rather than in the shoot while Cd due to its high mobility easily moves from plant root to the shoots. The metals' ions could as well have been sorbed by the biochars thereby making them unavailable for plant uptake in the first trial. Additions of biochar to contaminated soils are known to impede heavy metal uptake by plants and slow down phytoremediation processes (Lu *et al.* 2014).

The low Pb content in the plant roots did not reflect a linear relationship with the high concentrations of extractable Pb in the soils especially concerning the values obtained from Bagega. Bioaccumulation values obtained from

Bagega were much lower than the values obtained from Barrakallahu across treatments in both trials. This shows that *Amaranthus cruentus* under the influence of biochar could be an excluder of Pb. The low residual bioaccumulation factors of Pb and Cd obtained from the experiment could have possibly resulted from the observed poor root development as a result of plant nutrient stress. The plant nutrient stress resulted from the low fertility status of the soil used for the second phase of the screenhouse experiment. Poor root development does affect its effective and efficient mechanisms for accumulating heavy metal ions from soil solution as a lot of energy is required to control the kinetics of heavy metal removal from the soil by plant roots (Tangahu *et al.* 2011).

Our previous sequential extraction experiments performed on the soils revealed the forms of Pb and Cd ions present under the influence of biochar as well as indicated the outcome of plant uptake (Onokebhagbe *et al.* 2018b). Metal uptake by plants is a function of its mobility and activity of its free ion state. This has been validated by a plant nutrition model where plant response correlates highly with uncomplexed free metal ions in soil solution (Parker *et al.* 1995). These metals (Pb and Cd) in the soils treated with biochar occurred in the form of Fe-Mn oxides bound (Onokebhagbe *et al.* 2018b). Heavy metals that occur in this form are usually not bioavailable hence the possible low values of BAF obtained from tissues of the plants on both soils. Also, this form of Pb and Cd are prone to reducing effect of pH change which will ultimately make them bioavailable but as observed in our sequential extraction experiment, they increased in magnitude under the influence of the biochar probably due to the resultant increase in pH (Onokebhagbe *et al.* 2018b).

## CONCLUSION

Heavy metals translocation and bioaccumulation were affected by the application of biochar. The application of biochar reduced bioaccumulation of Pb and Cd in the two experiments carried out. The low bioaccumulation values obtained were also influenced by the forms of occurrence of Pb and Cd in the soils. The low Pb and Cd content in the plant roots did not reflect a linear relationship with the high concentrations of extractable Pb in the soils especially concerning the values obtained from Bagega.

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