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HEAVY METAL STATUS IN SOILS AND AMARANTHUS CRUENTUS FROM FARMLAND ON THE BANK OF OROGODO RIVER, AGBOR, DELTA STATE, NIGERIA.

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ABSTRACT

This study investigated the status of heavy metals in the soil and Amaranthus cruentus on the farmland at bank of Orogodo River at Agbor, Delta State, Nigeria. Soil and plant samples were collected at an area of 8000 m^2. The soil samples were collected at a depth of 0-15 cm, 15-30 cm and 30-45 cm while the plant samples were also sampled along with the sampling of the soil in December 2013. Both the soil and plant samples were analysed using an appropriate laboratory methods. Results showed that the Cr, Cd and Pb content of the soils at both sites decreased with increased soil depth and that these Cr, Cd and Pb content at the river bank soils were significantly ($P< 0.05$) higher than those of the control. However, at the control site the Cd content of the soil was fairly stable with the increased soil depth. The Cu, Fe and Mn which increased with increased soil depth were significantly higher at the river bank soils than the control. With the exception of Cd and Cr, significantly higher Cu, Fe, Mn and Pb content were recorded at the river bankAmaranthus cruentus compared to control. The Cr was however not detected at the river bank plants. Significantly($P < 0.05$) higher Transfer Factor was attained by the Cd compared to other heavy metals. The silt positively significantly correlated with Fe, Cu and negatively significantly correlated with Cr. The soil pH negatively significantly correlated with Fe, Cu and positively significantly correlated with Cr. The sand and organic matter neither positively nor negatively significantly correlated with the heavy metals studied.

Keywords: Heavy metals, Status, River bank, Farmland, Amaranthuscruentus

INTRODUCTION

Orogodo River is the major river that traverses the entire Agbor community and agricultural activities in the area are carried out along the bank of the river. Agricultural wastes, fertilizers, pesticides including sewage are discharged directly into the river as a run-off (Rim-Rukeh et al, 2006). Water from this river especially in dry season is used as a mean of irrigation and the sediment and water from the river have been reported by Issa et al (2011) to contain numerous heavy metals such as Cd, Pb, Ni, Mn,Zn, Cu and Fe. Heavy metals in general are not biodegradable, have long biological half-lives and have the potentials for accumulating in the different body organs leading to unwanted side effects (Sathawara et al 2004).The excess content of these metals in food is associated with etiology of a number of diseases especially with cardiovascular, kidney, nervous as well as bone diseases (Eslamic et al 2007).One of the ways these heavy metals can enter the food chain is via the consumption of the vegetables irrigated or treated with the water containing these metals.

The leafy vegetable in question (Amaranthus cruentus) grown on the bank of Orogodo river contains a lot of vitamins and is commonly consumed by the inhabitant even outside the community. Information on the heavy metal content before consumption and introduction to the market is scarce. Therefore, the purpose of this trial was to determine the level of heavy metal in the river bank soil and the cultivated Amaranthuscruentus plant.

MATERIALS AND METHODS

The study was carried out on Amaranthuscruentus farm land occupying an area of 8000 m^2 on the bank of Orogodo River in Agbor, Delta State, Nigeria. Orogodo River lies between latitude 5o 12' and 5o 31' and longitude 6o 20' and 6o 13'. Soil samples were collected at 0-15 cm, 15-30 cm, and 30-45 cm soil depth at 10 locations giving a total of 30 samples. The Amaranthus plants were also collected from the corresponding spots. Similar soil samples along with 10 plant samples were collected at Emuhu town about 5 km away from the river bank to serve as the control.Samplings were carried out in December, 2013. And the collected soil and plant samples were taken immediately to the laboratory for analysis. The plant samples were however washed with tap water and thereafter rinsed with distilled water, oven-dried at 78^{O}C for 48 hours. Soil samples from each site were air-dried for 7 days.

The particle size analysis was determined by hydrometer method of Gee and Or (2002) while the soil pH was measured potentiometrically in 1: 1 soil-water ratio. The soil organic carbon, N, P, K, Mg, Ca, Na, Pb, Fe, Cu, Mn, Cr and Cd were determined by methods of Udo et al (2009). The ground plant samples (< mm) were digested using 30 ml concentrated mixture of HNO_3 , $HClO_4$ and H_2SO_4 in 2: 1: 1 ratio. When the clear digested solution was achieved, the contents were allowed to cool and transferred to a 50 ml volumetric flask and made to mark. The Pb, Fe, Cu, Mn, Cr and Cd content of the plant were determined by Atomic absorption spectrophotometer. The Transfer Factor (TF) for each metal was calculated according to the formula of Harrison and Chirgawi(1989): TF = Ps (ugg-1 dry wt/St (ugg-1 dry wt) where Ps = Plant heavy metal content originating from soil. St = metal content in soil. Data obtained was analysed by Genstat Statistical Version. The Duncan Multiple Range Test was used in separating the means at 5 % level of probability.

RESULTS AND DISCUSSION

Physical and chemical properties of the studied soil

The soil physico-chemical properties of the sites are shown in Table 1. The soil pH of the river bank significantly ($P< 0.05$) increased with soil depth while that of the control site significantly decreased with soil depth. Both soils from each location were moderately acidic. The organic carbon and organic matter content of both sites decreased significantly ($P< 0.05$) with increased soil depth. The organic matter in both sites was deficient when compared to the critical level of 20-30gkg^{-1} reported by Enwezor et al (1989). The Ca content of the river bank soil had no significant corresponding increase with the soil depth. Although the Ca component of the control soil increased with increased soil depth, significant differenc-

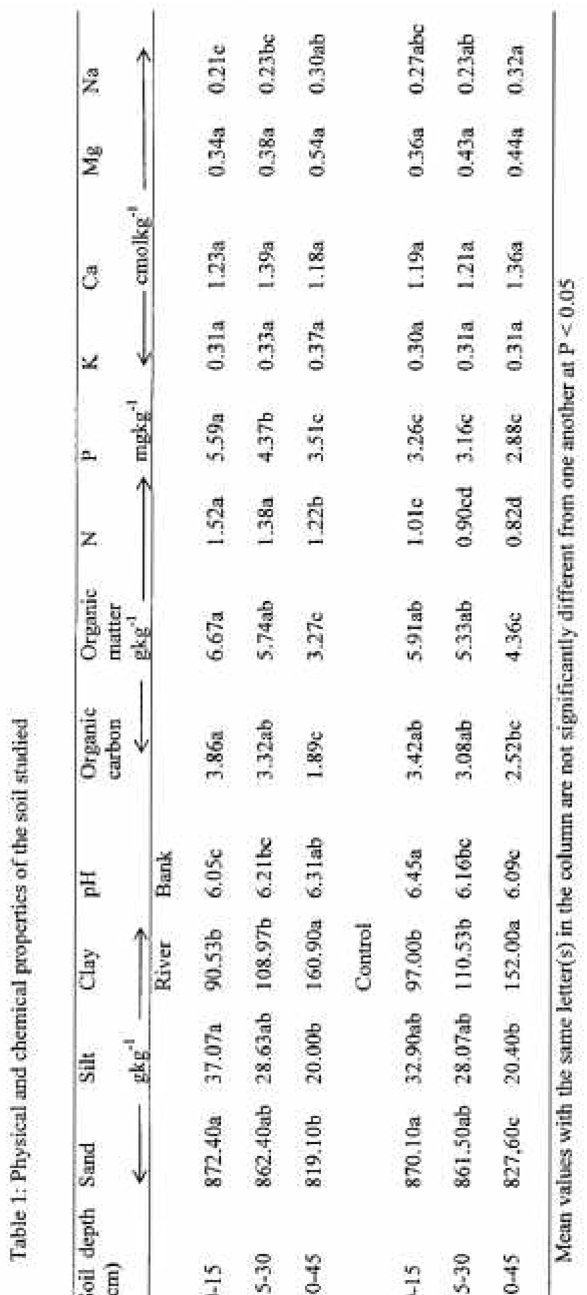


Table 1: Physical and chemical properties of the soil studied

Soil depth (cm)	Sand	Silt	Clay	pH	Organic carbon	Organic matter	N	P	K	Ca	Mg	Na
	←	gkg⁻¹	→		←	gkg⁻¹	→	mgkg⁻¹	←	cmolkg⁻¹		→
			River	Bank								
0-15	872.40a	37.07a	90.53b	6.05c	3.86a	6.67a	1.52a	5.59a	0.31a	1.23a	0.34a	0.21c
15-30	862.40ab	28.63ab	108.97b	6.21bc	3.32ab	5.74ab	1.38a	4.37b	0.33a	1.39a	0.38a	0.23bc
30-45	819.10b	20.00b	160.90a	6.31ab	1.89c	3.27c	1.22b	3.51c	0.37a	1.18a	0.54a	0.30ab
			Control									
0-15	870.10a	32.90ab	97.00b	6.45a	3.42ab	5.91ab	1.01c	3.26c	0.30a	1.19a	0.36a	0.27abc
15-30	861.50ab	28.07ab	110.53b	6.16bc	3.08ab	5.33ab	0.90cd	3.16c	0.31a	1.21a	0.43a	0.23ab
30-45	827.60c	20.40b	152.00a	6.09c	2.52bc	4.36c	0.82d	2.88c	0.31a	1.36a	0.44a	0.32a

Mean values with the same letter(s) in the column are not significantly different from one another at $P < 0.05$

es were not attained. The Ca content of both the control site and the river bank soils were deficient considering the 2.5 cmolkg^{-1} as the critical level reported by Akinrinde and Obigbesan (2000). The K and Mg increased non-significantly with soil depth while Na significantly increased with the depth of the soil in the two locations. The K and Mg content of the soils were adequate considering the 0.16-0.25 cmolkg^{-1} and 0.2-0.4 cmolkg^{-1} critical levels respectively as earlier reported by Adeoye and Agboola (1985). The N and P component of the river bank and control soils significantly increased with increase soil depth. The N in the top soil of river bank soil fall within the critical level of 1.5 gkg^{-1}-2.0 gkg^{-1} (Sobulo and Osiname, 1981) while P of both soils at various depths represented deficiency considering 10-16 mgkg^{-1} being the critical level for crop production (Adeoye and Agboola, 1985). The textural class revealed sandy loam for both soils at the sites.

Heavy metal content of the studied soils

Table 2 reveals the heavy metal content of the study soils. The Cd of the river bank soil decreased significantly with the soil depth while that of the control soil was fairly stable with increased soil depth. The Cr and Pb in both soils decreased with increased depth of the soil while the Cu, Fe and Mn increased with corresponding increase in soil depth in both sites. The value of these heavy metals in the river bank soils were significantly ($P< 0.05$) higher than those of the control sites. The occurrence of heavy metals in the river bank soils showed that Cu > Fe >Pb>Mn> Cr > Cd whereas in the control site, the trend was in order of Fe > Cu >Mn>Pb>Cr > Cd. The presence of these metals in both the river and control sites showed common sources of these metals which could be related to known geochemical association between the metals as earlier reported by Orhue and Izunwanne (2013). The values of these metals when compared to values reported by international regulatory body, the mean of the Cu and Pb were above the permissible level of 0.27 mgkg^{-1} and 0.006 mgkg^{-1} respectively (WHO/FAO, 2001) while the Fe and Cd components were below the permissible limits of 100 mgkg^{-1} (USEPA, 1986) and 3 mgkg^{-1} (MAFF,1992) respectively. The mean Cr content at the river bank soil was above the 0.3 mgkg^{-1} permissible limit reported by WHO(1984) but at the control sites, the mean value of Cr was discovered to be below the permissible level of WHO(1984). The mean values of Mn in both the

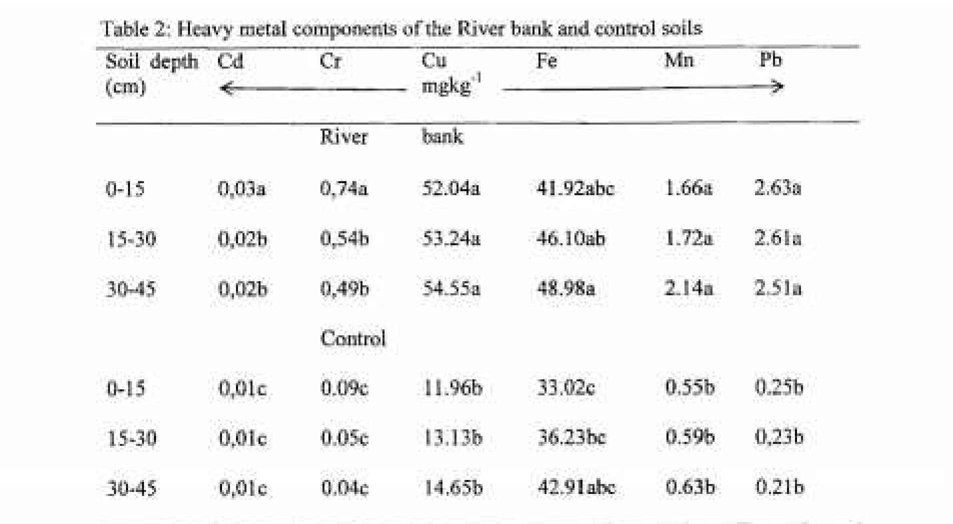


Table 2: Heavy metal components of the River bank and control soils

Soil depth (cm)	Cd ←	Cr —	Cu mgkg^{-1}	Fe —	Mn —	Pb →
		River	bank			
0-15	0,03a	0,74a	52.04a	41.92abc	1.66a	2.63a
15-30	0,02b	0,54b	53.24a	46.10ab	1.72a	2.61a
30-45	0,02b	0,49b	54.55a	48.98a	2.14a	2.51a
		Control				
0-15	0,01c	0.09c	11.96b	33.02c	0.55b	0.25b
15-30	0,01c	0.05c	13.13b	36.23bc	0.59b	0,23b
30-45	0,01c	0.04c	14.65b	42.91abc	0.63b	0.21b

Mean values with the same letter(s) in the column are not significantly different from one another at $P < 0.05$

river bank and the control soils were above the 0.3 mgkg^{-1} permissible level of WHO(1984). The persistent level of those heavy metals below the critical limit could result in high accumulation in the soil with time and this high accumulation could lead to higher concentration in plants cultivated on the soil. This result further confirms that of Orhue and Izunwanne(2013) who recorded accumulation of heavy metals in fluted pumpkin cultivated on Ikpoba River bank in Benin City.

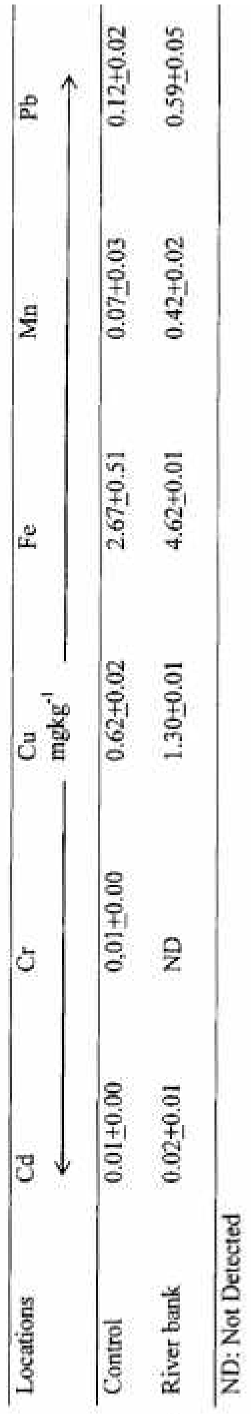
Concentration of heavy metals in the Amaranthuscruentus

The concentrations of heavy metals in the Amaranthus cruentus are depicted in Table 3. The result showed higher accumulations of heavy metals were achieved in the plants cultivated on the river bank compared to control sites. The mean heavy metal concentration at the river bank plants were in the order of Fe > Cu >Pb>Mn> Cd > Cr. The Cr was however not detected in the river site plants. At the control site, the mean value of heavy metal concentration was in order of Fe > Cu >Pb>Mn> Cd = Cr. The heavy metal content of the Amaranthus at the river site when compared to permissible limits set aside by international organisations, it was revealed that Fe, Cu, Mn, Cd and Pb were above the WHO/FAO (2001) permissible limits of 0.3 mgkg^{-1}. The Cr was however not detected in crops grown at the river site. The Fe and Cu concentrations in the control plants were above the WHO/FAO (2001) permissible limits of 0.3 mgkg^{-1}, while Mn and Pb were below WHO/FAO(2001) permissible limit of 0.3 mgkg^{-1}. The Cr content was also below WHO/FAO (2001) permissible limit of 2.30 mgkg^{-1} while the Cd content was equivalent to the WHO/FAO (2001) permissible level of 0.3 mgkg^{-1}. Similar results of high concentration of heavy metals in crops grown by the river bank have earlier been reported by Kashif et al (2000), Lawal and Audu (2011) and Orhue and Izunwanne (2013).

Transfer Factors (TF) for heavy metals from soil to the Amaranthuscruentus

Table 4 shows the Transfer Factor (TF) of the heavy metals from soil to the plant. Significantly higher TF was achieved in Cd compared to other heavy metals. The TF was in order of Cd >Mn>Pb> Fe >Cu > Cr. Generally, all the heavy metals determined fall below Klokeet al (1984) suggested ranges of 1-10. One of the key compounds of human exposure to metals through food chain is the Transfer Factors. The TF was determined to quantify the relative differences in

Table 3: Heavy metal concentrations in river bank and control *Amaranthus cruentus*



Locations	Cd	Cr	Cu mgkg^{-1}	Fe	Mn	Pb
Control	0.01±0.00	0.01±0.00	0.62±0.02	2.67±0.51	0.07±0.03	0.12±0.02
River bank	0.02±0.01	ND	1.30±0.01	4.62±0.01	0.42±0.02	0.59±0.05

ND: Not Detected

bioavailability of metals to plant or efficiency of plant species to accumulate a given metal. Therefore, high Cd TF suggested that Cd uptake by the Amaranth is higher. This further showed that Cd is less retained in the soil than other metals. The ability of the amaranth to accumulate the metals in question may be due to some soil factors such as sand, silt, clay, pH and organic matter as shown by the correlation coefficient as earlier reported by Orhue and Izunwanne (2013).

Correlation coefficient between the heavy metal concentration in the Amaranthuscruentusand some soilproperties

Table 5 shows the correlation coefficient between the heavy metal concentration in the Amaranthuscruentus and some soil physical and chemical properties. Although sand non-significantly correlated negatively with Fe, Cu, Mn and Cd, it non-significantly correlated positively with Cr and Pb. The silt significantly correlated positively with Fe and Cu and significantly correlated negatively with Cr. While the clay non-significantly correlated negatively with Fe, Cu, Pb and non-significantly positively correlated with Mn, Cr and Cd. The pH also significantly correlated negatively with Fe, Cu and significantly correlated positively with Cr. Non-significantly negative correlation was achieved between pH and Mn, Cd as well as Pb. With the exception of Cr which non-significantly correlated negatively with organic matter, the Fe, Cu, Mn, Cd and Pb non-significantly correlated positively with organic matter.

CONCLUSION

This study showed heavy metal accumulation in the river banks soils and the cultivated amaranths compared to control soils and plants. The significant relationship between the heavy metals and some soil properties shows the importance of these soil properties in the availability of heavy metals studied. Conclusively, continuous cultivation of this crop at the bank of the river may bring about increased accumulation of the heavy metals in the plants and regular consumption of this vegetable could lead to a long term health problems to the people of that community and the environs.

Table 4: Transfer Factors (TF) for heavy metals from soil to the *Amaranthus cruentus*

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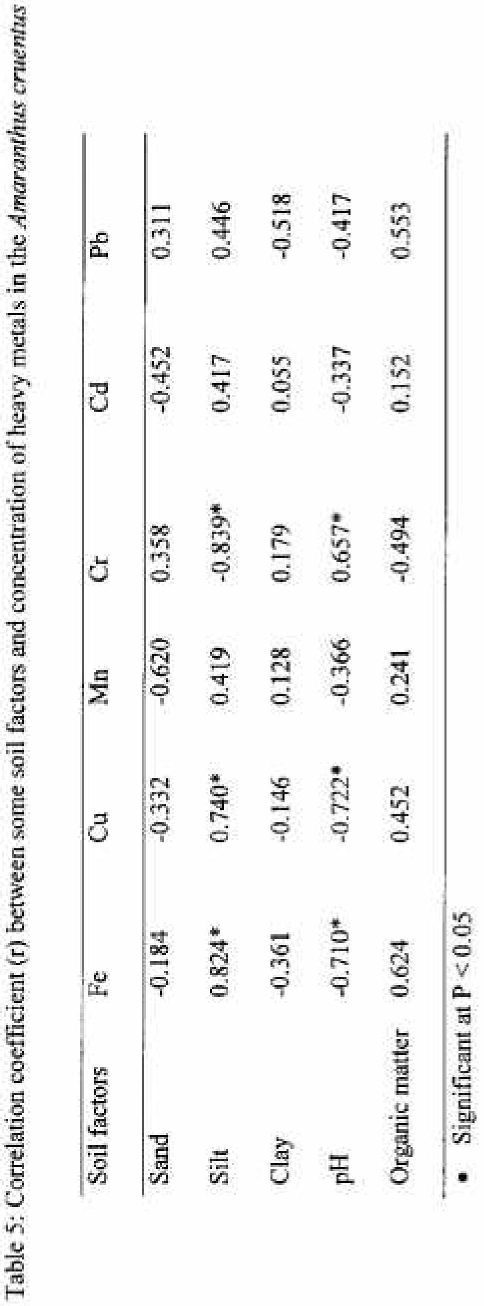

Table 5: Correlation coefficient (r) between some soil factors and concentration of heavy metals in the *Amaranthus cruentus*

Soil factors	Fe	Cu	Mn	Cr	Cd	Pb
Sand	-0.184	-0.332	-0.620	0.358	-0.452	0.311
Silt	0.824*	0.740*	0.419	-0.839*	0.417	0.446
Clay	-0.361	-0.146	0.128	0.179	0.055	-0.518
pH	-0.710*	-0.722*	-0.366	0.657*	-0.337	-0.417
Organic matter	0.624	0.452	0.241	-0.494	0.152	0.553

- Significant at $P < 0.05$

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