EVALUATION OF HEAVY METALS CONTENT IN SOIL AND *TALINUM TRIANGULARE* FROM KOLO CREEK, BAYELSA STATE, NIGERIA

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ABSTRACT

This study was conducted to evaluate heavy metals concentration in soil and Talinum triangulare from Kolo creek, Bayelsa state, Nigeria. Experimental samples (soil and T. triangulare) collected from Otuoke (control) and Kolo creek were subjected to heavy metals analysis using Atomic Absorption Spectrophotometry after acid digestion. Heavy metals analyzed include:iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), lead (Pb), cadmium (Cd), chromium (Cr), Nickel (Ni), arsenic (As), vanadium (V) and cobalt (Co).Results obtained showthat the average concentration of heavy metals (mg/kg) in the two studied sites are in the order: Fe>Mn>Zn>Cu>Pb and Fe>Mn>Zn>Cu>Pb in Otuoke and Kolo creek respectively while the concentrations of Co, Ni, Cr, As, V and Cd were below limits of detection by the equipment. The results also indicate high average Fe concentrations of 4493.2 mg/kg and 5971.1 mg/kg while the average Pb concentrations are 3.81 mg/kg and 3.80 mg/kg in Otuoke and Kolo creek respectively. Phytoremediation quotient of T. triangulare indicates that T.triangulare exhibited the highest bioaccumulation coefficient (BAC) for Zn and least for Fe. The high accumulating ability (BAC>1, TF>1 (Translocation factor)) of T. triangulare for Cu shows that T. triangulare could be a potential plant for phytoextraction of this metal and also could be employ as a phytoremediation species in soil.

Keywords: *Heavy metal accumulation, Talinum triangulare, Phytoremediation, bioaccumulation coefficient, translocation factor*

INTRODUCTION

Soil pollution by heavy metals has attracted considerable public attention in recent decades. Soil is a major sink for heavy metals released into the environment by anthropogenic activities such as industrial effluents and wastes, oil spillage, sewage treatment plants, agricultural fungicides run off, domestic garbage dumps, urban runoff and mining operations (Kirpichtchikova *et al.*, 2006). Unlike organic contaminants which are oxidized to carbon (IV) oxide by microbial degradation, most heavy metals do not undergo microbial or chemical degradation but remain for long period of time after their release into the environment. Apart from being toxic, some heavy metals are essential micro nutrients, for example, as cofactors of key metabolic enzymes; but when their concentration becomes high in soil especially above their permissible limits, they become toxic to the plants (Stobrawa and Lorenc-Plucinska, 2007).

Plants are sensitive to environmental conditions as they accumulate metals in their harvestable parts (via root uptake, foliar adsorption and deposition of specific elements in leaves) and the intensity of this uptake process can change the overall elemental composition of the plant (Olajire and Ayodele, 2003). A number of studies on metals accumulation in plants have been previously reported (Nkwocha *et al.*, 2011; Okoye and Okwute, 2014; Mohammed and Folorunsho, 2015; Ogunkunle *et al.*, 2016). Certain plants do not only accumulate heavy metals in the root but also translocate these heavy metals from the roots to the leaves or shoots (Ogunkunle *et al.*, 2016).

hence such plants could be used to assess heavy metal contamination in soil and also be employed in the process of phytoremediation.

The main objective of this study is to investigate the level of some heavy metal in Soil and *T. triangulare* from Kolo creek and Otuoke environs, Bayelsa state, Nigeria and to compute the phytoremediation quotient of *T. triangulare* using biological accumulation coefficient (BAC), biological concentration factor (BCF) and translocation factor (TF).

MATERIALS AND METHODS

Study Area

Kolo Creek and Otuoke are communities in Ogbia Local Government Area of Bayelsa State in the Niger Delta region of Nigeria. Kolo Creek has been urbanized and industrialized due to crude oil exploration activities. Oil fields are located in each settlement along the creek, where effluents are discharged into the atmosphere and water body, which have its impact in agricultural soil. The Creek is the source of drinking water and livelihood of the people. There are no such petroleum facilities in Otuoke hence, it served as control. The major occupation of indigenes in both Kolo Creek and Otuoke include fishing, farming of food crops (plantain, vegetables) and petty trading.

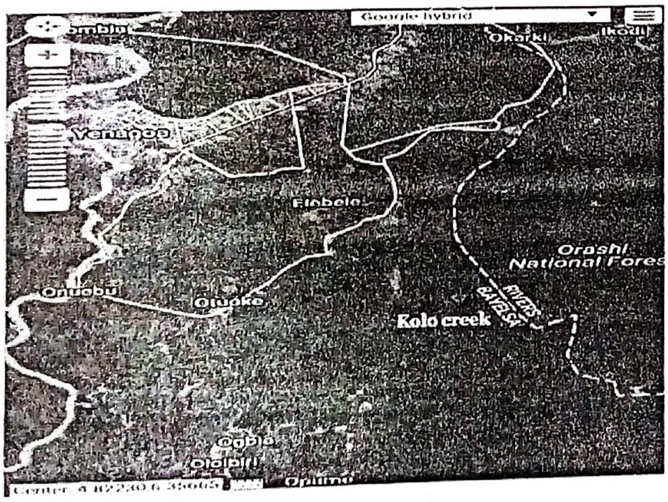

Fig. 1: Map of study area indicating sampling points.

Collection of soil sample

Soil samples were collected from three sites in Kolo Creek and Otuoke respectively. Three (3) soil samples were collected from each sampling site at depth of 0-15 cm using a soil auger and at each sampling point, approximately 0.50 kg of soil was collected, packed in pre-cleaned and well labelled polyethylene bags and taken to the laboratory where they were air-dried, mechanically ground with agate mortar and pestle and sieved with a 2 mm mesh size.

Collection of plant sample

Talinum triangulare (water leaf) was also collected from the various soil sampling sites using a stainless steel sampler (this helps in uprooting the plant from the soil) and was authenticated in the Herbarium unit (No. UPH/P/136), Department of Plant Science and Biotechnology, University of Port Harcourt, Rivers State Nigeria. The plant samples were also packed in pre-cleaned and well-labelled polyethylene bags and taken to the laboratory where they were washed with tap water and distilled water (to remove any soil attached to them). They were then separated into the shoots and roots, dried in an electro-thermal oven at 105°C, pulverized, and stored in a desiccator. The dried samples were ground using agate mortar and pestle and sieved with 2 mm mesh size.

Digestion of soil and plant samples

1.00 g of pulverized soil sample was placed in a 250 mL conical flask, 5 mL of nitric-perchloric acid (3:2) mixture was added, covered with a small glass funnel and left to stand overnight and. The mixture was then placed in a digestion block and first heated for 1h at 150 °C, then, at 235 °C until dense white fumes were given off. The mixture was removed from the block, cooled, followed by the addition of 1 mL 1:1 HCl and reheated until a colourless solution was obtained. The solution was allowed to cool, filtered through a Whatman No. 40 filter paper, transferred to a 25 mL volumetric flask and made up to mark with distilled water.

For plant samples, each of the separated parts (shoot and root) were placed in separate porcelain crucibles and put in a muffle furnace. The furnace temperature was slowly increased from room temperature to 450°C for one hour. The samples were ashed at this temperature for 4 h, forming a white/grey ash residues. 0.25 g of the residue was weighed, dissolved with nitric acid, filtered into a

25 mL volumetric flask and made to mark using deionized water (Radojevic and Bashkins, 1999).

The filtrates from both analyses were analyzed using an Atomic Absorption spectrophotometer (Thermo Jarrell Ash A.A. 12E) for the following metals: Pb, Cu, Zn, Mn, Fe, Cd, Cr, Ni, V and Co.

Quality control measures

All laboratory glass wares used were initially washed with detergent and tap water then soaked in 5% nitric acid for twenty four (24) h, then washed and rinsed with deionized water. Samples were prepared in duplicates and analyzed in triplicates to check for precision of the results obtained. Reagent's blanks were also included in analysis while spiked samples were analysed for validation of the chosen analytical method.

Determination of phytoremediation quotient

Biological accumulation coefficient (BAC)

The biological accumulation coefficient (BAC) was calculated as a ratio of metal level in shoots to that in soil (Yoon *et al.*, 2006):

$$BAC = \frac{[Metal]_{shoot}}{[Metal]_{soil}}$$

Biological concentration factor (BCF)

The biological concentration factor (BCF) was calculated as a ratio of metal level in plant roots to soil (Salah and Barrington, 2004):

$$BCF = \frac{[Metal]_{root}}{[Metal]_{soil}}$$

Translocation factor (TF)

The translocation factor (TF) was calculated as the ratio of metal level in plant shoot to plant root (APHA, 1998):

$$TF = \frac{[Metal]_{shoot}}{[Metal]_{root}}$$

RESULTS AND DISCUSSION

Metal levels in soil and *T. triangulare*

The level of metals in both soil and *T. tringulare* are shown in Tables 1 and 2 respectively. The Pb levels recorded in this study were less than 4 mg/kg and far lower than its regulatory limit in Nigeria (DPR, 2002). Similarly, there was no significant difference (p>0.05) in Pb levels in both locations. These results are similar to the report of Inengite *et al.* (2010) where Pb values less than 15 mg/kg were recorded in sediments from Kolo creek. Values lower than that of the Nigerian DPR limit have also been reported in soils around oil filling and servicing stations (Emmanuel *et al.*, 2014; Ogunkunle *et al.*, 2016). The presence of Pb in these soils may be attributed to automobile fumes. Zinc and copper were also detected but at levels far less than their respective limits. Lead levels lower than that of the World Health Organization (WHO) maximum permissible limit for Pb in medicinal plants (10 mg/kg) were also recorded in the shoot and root of *T.* triangulare (WHO, 2005). Levels of Cd, Cr, Ni, Co and V were below limit of detection by the equipment.

Table 1: Levels of metals (mg/kg) in soil samples

Metal	Level (mg/kg) Otuoke	Kolo	DPR limit (mg/kg)
Pb	3.81 ± 0.01	3.80 ± 0.00	85
Cu	10.9± 0.36	17.5± 0.12	36
Zn	53.7± 0.16	78.3± 0.29	140
Mn	57.6 ± 0.26	322.76 ± 0.41	NS
Fe	4490± 2.22	5970± 0.69	NS
Cd	<0.001	<0.001	0.8
Cr	<0.001	<0.001	100
Ni	<0.001	<0.001	35
V	<0.001	<0.001	NS
Co	<0.001	<0.001	20

<0.001 = below detection limit by the equipment.
NS = not specified

Table 2: Levels of metals (mg/kg) in *T. triangulare*

	Level (mg/kg)			
	Otuoke		Kolo	
Metals	Shoot	Root	Shoot	Root
Pb	3.81 ±0.01	1.43 ±0.02	1.43 ±0.03	1.43 ±0.02
Cu	14.2 ±0.32	10.9 ±0.16	20.9 ±0.16	14.2 ±0.16
Zn	14.3 ±0.33	24.1 ±0.16	181.3 ±0.32	147.3 ±0.24
Mn	40.9 ±0.28	74.0 ±0.44	293.5 ±0.53	249.2 ±0.18
Fe	346± 0.41	1350 ±0.32	3580 ±0.49	4290 ±0.52
Cd	<0.001	<0.001	<0.001	<0.001
Cr	<0.001	<0.001	<0.001	<0.001
Ni	<0.001	<0.001	<0.001	<0.001
As	<0.001	<0.001	<0.001	<0.001
V	<0.001	<0.001	<0.001	<0.001
Co	<0.001	<0.001	<0.001	<0.001

<0.001 = below detection limit by the equipment

Iron recorded the highest levels in both control and study locations and were greater than the permissible limit for Fe (150 mg/kg) in Agricultural soils (USEPA, 1986). Very high levels of Fe have been previously reported in sediments of Kolo creek (Inengite *et al.*, 2010). The exceptionally high level of Fe in soils of both the experimental and control sites could be responsible for the brown colouration of borehole water in Otuoke and Kolo Creek environments. High Fe levels in soils are reported to be toxic for plant growth (Onyeike *et al.*, 2000). Similarly, in *T. triangulare,* Fe recorded the highest concentration. The elevated Fe level in *T. triangulare* may be due to higher absorption capacity of plant's roots, or the very high amounts of iron in the soil. This implies that *T. triangulare* possesses the ability to absorb Fe from the soil. There is no recommended level for Fe in soil but WHO recommends a maximum level of Fe in medicinal plants to be 20 mg/kg, while its dietary intake is 10–28 mg/day (WHO, 2005). However, since *T. triangulare* is widely consumed in Bayelsa, the elevated Fe levels calls for concern as it could be linked to some human health implications such as vomiting, upper abdominal pain, diarrhea, dizziness, shock; diabetes, diseases associated with the liver, lungs and kidney (Dupler, 2001; Ferner, 2001).

The level of Mn in the experimental soil is slightly higher than the permissible limit of 100-300 mg/kg for agricultural lands but is within the limit of 100-300 mg/kg in the control soil, which implies mild contamination in the study location. In *T. triangulare*, Mn recorded 293.5 and 249.2 mg/kg in the shoot and root respectively, which exceed WHO's maximum permissible limit of Mn (200 mg/kg) in medicinal plants (WHO, 2005). Excessive Mn concentrations in plant tissues can alter various processes, such as enzyme activity, absorption, translocation and utilization of other mineral elements (Ca, Mg, Fe and P), causing oxidative stress (Ducic and Polle, 2005; Lei *et al.*, 2007).

Copper was detected in soil and all parts of *T. triangulare.* The highest level (20.9 mg/kg) was found in the shoot of *T. triangulare* from Kolo Creek area while the control soil had the least level (10.9 mg/kg). The levels recorded in both control and study soils were lower than that of the DPR permissible limit of Cu in soils (36 mg/kg). The levels of Cu present in the parts of the *T. triangulare* could be due to the plant'sability to absorb Cu from the soils, which is needed for the normal growth and development (Shah *et al.*, 2013). However, the levels exceeded WHO's permissible limit of Cu in medicinal plants (10 mg/kg) (WHO, 2005).

Phytoremediation Quotient of *T.triangulare*

The phytoremediation quotient for *T. triangulare* was described in terms of biological accumulation coefficient (BAC), biological concentration factor (BCF) and translocation factor (TF) and are depicted in Table 3. *T. triangulare* indicated a TF >1 for Cu and Pb in the two locations as well as for Zn and Mnin the experimental site (Kolo Creek). High translocation factors (TF> 1) of heavy metals indicate that this plant has vital characteristics to be used in phytoextraction of these metals (Ghosh and Singh, 2005). The results of this study compare well with the reports of Ebong *et al.* (2007).

Two basic strategies by which plants can tolerate the large amount of metals in their environment have been proposed. Excluders, which limit the levels of heavy metal translocation within them and maintain relatively low metal concentration in their shoot over a wide range of soil concentration; andexclusion (excluders) whereby transport of metals is restricted and low, and relatively constant metal concentrations are maintained in the shoot over a wide range of soil concentration; and accumulators, which concentrate heavy metals in their shoots at both low and high soil metal concentrations (Baker, 1981; Rotkittikhun *et al.*, 2006). Baker and Whiting (2002) suggested that accumulators can be characterized by a TFof metal concentration ratio greater than 1, because of the ability to translocate metal from root to shoot, whereas in excluders, the ratio is less than 1. BAC<1 indicates that the plant is an excluder (Ogunkunle *et al.*, 2016). Results from this study showthat BAC<1 for Mn, Pb, Fe and Zn except for Zn in study location.The findings of this study also suggest that *T. triangulare* could be an excluder for the metals studied. Similar results have been previously reported for *T. triangulare* in other locations (Arise *et al.*, 2016).

Generally, TF, BCF and BAC values >1 can be used to estimate a plant's potential for phytoremediation purpose (Yoon *et al.*, 2006; Li *et al.*, 2007). In this present study, the TF, BCF and BAC values were observed to be greater than 1 for Zn, Pb, Mn and Cu, indicating that *T. triangulare* would be a good choice for extracting Cu, Zn, Pb and Mn. TF, BAC and BCF was observed to be <1 in Fe thereby showing that *T. triangulare* might not be a good choice for extracting Fe.

Table 3: Phytoremediation coefficientof *T. triangulare* for metals

	Otuoke			Kolo		
Metals	BAC	BCF	TF	BAC	BCF	TF
Pb	1.00	0.38	2.66	0.38	0.38	1.00
Cu	1.30	1.01	1.29	1.19	0.81	1.47
Zn	0.26	0.45	0.58	2.32	1.85	1.23
Mn	0.71	1.27	0.56	0.91	0.78	1.17
Fe	0.08	0.29	0.26	0.60	0.95	0.84

BAC – Biological accumulation factor, BCF – Biological concentration factor, TF – Translocation factor

CONCLUSION

The study provides data on heavy metal analysis in soil and the shoots and roots of *T. triangulare*obtained from the two different (study and control) locations and the phytoremediation quotient of *T. triangulare*. The study reveals that with the exception of Pb, the levels of other detected metals are higher in the study location than in the control. Phytoremediation coefficients indicatethe order of mobility and bioavailability of the metals as: Cu>Zn>Mn>Pb>Fe. This suggests that *T. triangulare* possesses the potential for the phytoextraction of these metals and hence, can be used as a phytoremediation species in soil with toxic levels of these metals. However, the consumption of this plant grown in the vicinity of the study area may constitute possible health risk to human, considering the fact that it is a widely consumed vegetable in the locality.

ACKNOWLEDGEMENT

This research was supported by the 2014 TETFund Institution-based Research (IBR) 4th Batch Intervention granted to Dr. Ejovi Osioma of the Department of Biochemistry, Faculty of Science, Federal University Otuoke, Bayelsa State, Nigeria.

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