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Bioconcentration and Translocation Factors of Heavy Metals in *Rhizophora racemosa* and Sediments from Egbokodo Mangrove Swamp, Delta State, Nigeria

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ABSTRACT: The mangrove ecosystem is well known to be impacted by anthropogenic activities such as oil spillage, agricultural run-off, industrial effluents, and mining in coastal areas. These activities increase heavy metals accumulated by mangroves, which are eventually released back into the environment via decomposition. This study aimed to analyze the concentration of heavy metals including cadmium (Cd), Zinc (Zn), lead (Pb), and copper (Cu) in the roots and leaves of *Rhizophora racemosa* and mangrove sediments obtained from Egbokodo mangrove swamp in Delta State, Nigeria. The results showed that the concentrations of Cu, Cd, Pb, and Zn ranged between 0.048 – 1.343 mg/g in the sediments and was higher than the concentration in the roots (0.023- 0.667 mg/g) and leaves (0.026- 0.530 mg/g) of the plant. Bioconcentration factor (BCF) was in the order of Cd> Zn> Pb> Cu with values greater than one (>1) except for Cu and Pb with less than 50% accumulation. Translocation factor (TF) was in the order of Cu> Pb> Cd> Zn. TF for Pb, Cd, and Zn were less than one (<1) except for Cu with a value of 1.14. This result suggests that the uptake and accumulation of heavy metals were higher in the roots of *R. racemosa* than in its leaves and that the plant may be a suitable extractor for Cu.

Keywords: mangrove, heavy metals, translocation, bioconcentration, accumulator.
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Introduction

Mangrove forests are situated mainly in tropical and sub-tropical regions (Lee *et al*., 2014; Moreira *et al*., 2013) and are one of the most biologically productive ecosystems globally (Sandiyan and Kathiresan, 2012; Sandiyan and Thiyagesan, 2010). They possess several ecological functions as nurseries for numerous aquatic faunas, including birds, crustaceans, fishes, and other micro-and macrofauna comprising the food web (Fernández-Cadena *et al*., 2014; Abohassan *et al*., 2012; Lewis *et al*., 2011; Walters *et al*., 2008). The root systems of mangrove trees help stabilize adjacent coastal landforms reducing soil erosion. Several reports confirmed that mangrove sediments act as a sink for heavy metals which enter the local ecosystems from anthropogenic sources (Alzahrani *et al*., 2018). Heavy metals are non-biodegradable and may be accumulated through the food chain to levels that are harmful to plants (Weber *et al*., 2013; Yi *et al*., 2011). Heavy metal pollution in the mangrove ecosystem has been widely reported (Titah and Pratikno (2020); Wang *et al*., (2021); Khan *et al*. (2020); Maharani *et al*. (2019)**;** Nwoha *et al*. (2019); Nwawuike and Ishiga (2018); Dudani *et al*., (2017); Richter *et al*. (2016); Kaewtubtim *et al.* (2016); Edu *et al*. (2015); Kathiresan *et al*. (2014) and Qiu *et al*. (2011).
The mangrove ecosystem is continuously impacted by anthropogenic activities such as oil spilling, dredging, agricultural run-off, urban sewage, industrial effluents, mining, port activities, etc. Among the numerous pollutants released from these activities, heavy metals are among the most severe pollutants due to their toxicity, persistence, and bioaccumulation.
Concentrations of heavy metals in plants can reach toxic levels in which metals are excluded from the plant via translocation to senescent leaves; litterfall containing high levels of excluded heavy metals can, in turn, release a

substantial amount of heavy metals through decomposition into the sediment, and when accompanied by tidal actions, export metals to adjacent systems (Silva *et al*., 2006).
This study aims to quantify the concentration of heavy metals (Zn, Pb, Cd, and Cu) in the roots and leaves of *Rhizophora racemosa* and the sediments from the Egbokodo mangrove swamp in Delta State, Nigeria.

Materials and methods

Study area: The study was conducted at Egbokodo mangrove swamp ($5^0$58'12" N; $5^0$67'18" E) in Warri South Local Government Area of Delta State, Nigeria (Figure 1).

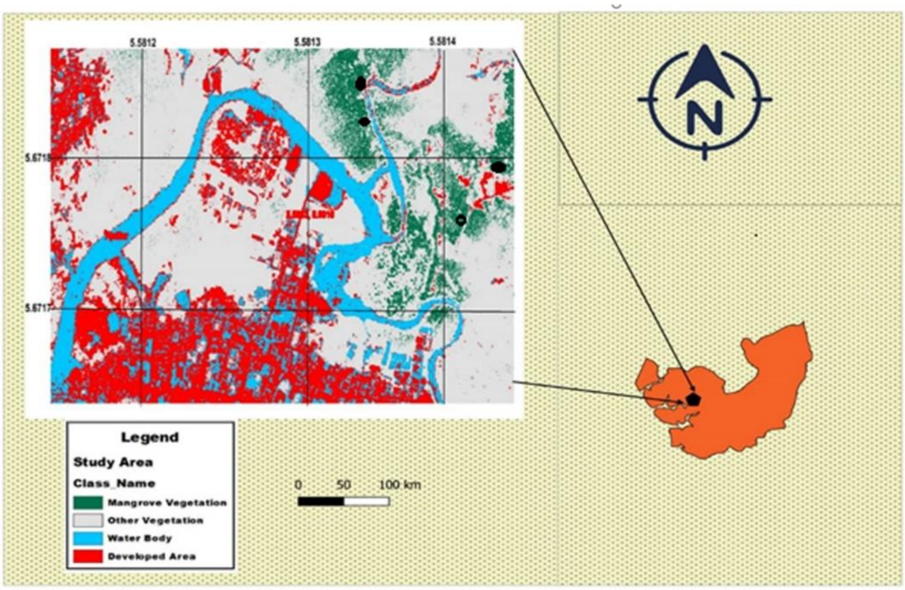

Figure 1: Map of Egbokodo mangrove swamp in Delta State

Sample collection: Fresh samples of *Rhizophora racemosa* leaves, roots, and the mangrove sediments were collected randomly. Leaves were handpicked, roots were neatly cut with a sharp knife, and sediments samples adjacent to the mangrove trees (0-6 cm depth) were collected simultaneously using a core sampler of 5 cm diameter.
Sample preparation and heavy metal analysis: The plant samples were rinsed with distilled water. Sediments and plant samples were oven-dried at 60 °C to a constant weight, ground, and sieved through a 2 µm mesh screen. 1 g of each sample was placed in volumetric flasks, and 20 ml of Aqua Regia solution was added (HCl: HNO_3 in 3:1 ratio) for heavy metal digestion. The solution was digested by gentle heating until it became clear and was filtered through an ashless *Whatman* filter paper no. 2 into a 100 ml volumetric flask. Distilled water was added to make the mark (Khan *et al*., 2020). The following heavy metals: Pb, Zn, Cu, and Cd, were analyzed in triplicates using an atomic absorption spectrometer (AAS, Unicom 969).
Sediment quality guidelines: Threshold effect level (TEL) and probable effect level (PEL) was applied as described by Burton (2002) and Alzahrani *et al*. (2018).
Bioconcentration and Translocation Factor
Bioconcentration factor (BCF): The bioconcentration factor (BCF) reflects the capacity of plants to accumulate metals from the soil (Kamari *et al*., 2014). The bioconcentration factor was calculated as follows:

$$\text{BCFroot} = \frac{Croot}{Csediment} \text{ (extractable metal)}$$

*C*root and *C*sediment are the metal concentrations in root and sediment, respectively.
Translocation factor (TF): The translocation factor (TF) value>1 indicates the plant's ability to translocate metal efficiently from root to shoot (Rezvani and Zaefarian, 2011). The equation was as follows:

$$\text{TFleaf} = \frac{Cleaf}{Croot}$$

*C*leaf and *C*root are the metal concentrations in leaf and root, respectively.

Statistical analysis: One-way analysis of variance (ANOVA) followed by Duncan's multiple range test was used to determine the statistical differences between the means using Statistical Package for the Social Sciences (SPSS), version 20.0.

Results and Discussion

Heavy metals concentration in the studied mangrove swamp sediments, as presented in Table 1, showed that the Cu concentration of 0.086 mg g^{-1} was less than the values obtained from previous studies on sediments from the Red Sea coast of Saudi Arabia (Alzahrani *et al*., 2018). Pb values from this study were higher than those recorded by Maharani *et al*. (2019) and Soraya *et al*. (2019), both at East and West Java, respectively. The average concentration of Zn was also higher than the average concentrations in sediments from West Java and India but was lower than that from Malaysia (Khan *et al*., 2020). The concentration of Cd was below the level reported by Alzahrani *et al*. (2018). In terms of sediment quality guidelines (SQGs), the results obtained revealed that the average concentrations of Cu, Pb, Zn, and Cd were lower than the Threshold Effect Level (TEL) and Probable Effect Level (PEL) (Table 1).

Table 1: Total heavy metals (mg g^{-1}) in mangrove sediment from Egbokodo mangrove swamp in Delta State, Nigeria and available literature

Locations	Cu	Pb	Zn	Cd	References
Egbokodo, Delta state	0.086	1.343	0.656	0.040	Current study
Red Sea coast of Saudi Arabia	22.870	3.820	-	0.750	Alzahrani *et al*. (2018)
Canadian Sediment quality guidelines					CCME (2001)
Threshold effect level (TEL)	18.700	30.200	124	0.700	
Probable effect level (PEL)	108	112	271	4.200	
East Java, Indonesia	0.014	0.008	-	-	Maharani *et al*. (2019)
West Java, Indonesia	0.008	0.023	0.089	-	Soraya *et al*. (2019)
Malaysia	0.130	-	0.990	-	Khan *et al*. (2020)
Cuddalore, India	0.196	0.008	0.065	1E-4	Kathiresan *et al*. (2014)

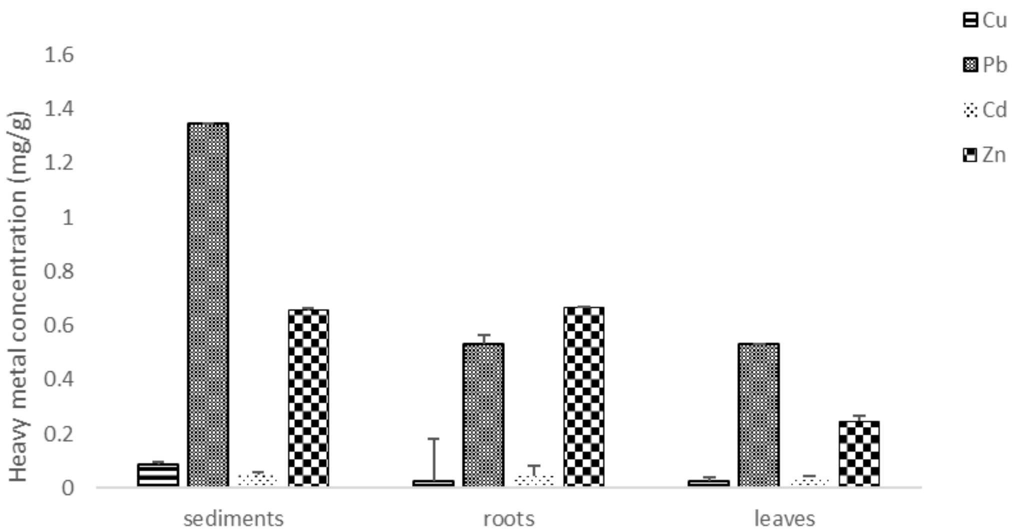

Figure 2: Heavy Metal concentration in roots, leaves of *R. racemosa*, and sediments.

The heavy metals analyzed for *R. racemosa* were found to be significantly different ($p<0.05$) in both plant tissues and sediments (Fig. 2). Concentrations of the studied metals in sediments showed a decreasing order of Pb>Zn>Cu>Cd. The accumulation of metals in the plant tissues was lesser when compared to the sediment. The concentration of Pb (1.34 mg/g), Cu (0.08 mg/g), and Cd (0.04 mg/g) were significantly higher in the sediment than in the plant tissues. The concentration of the studied metals in *R. racemosa* was higher in the roots than in the leaves. Hence, the ability to accumulate is greater in the roots than in the leaves. This was similar to the findings of Alzahrani *et al*. (2018). Heavy metals in the roots followed a decreasing order of Zn> Pb> Cd> Cu, while in the leaves, it was in the order of Pb>Zn>Cd>Cu. The variations of metal concentration in the mangrove tissues may result from the metal demand of specific tissues (Dudani *et al*., 2017; Edu *et al*., 2015).

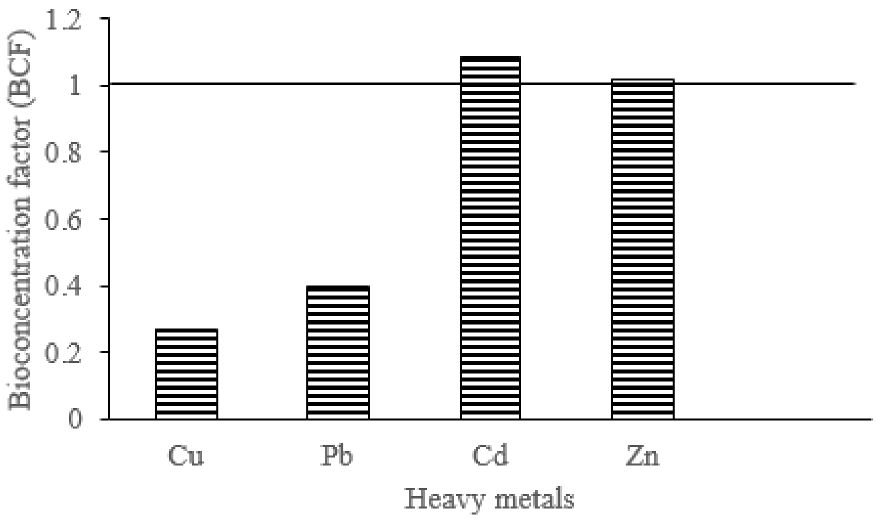

Figure 3: Bioconcentration factor (BCF) of heavy metals in *R. racemosa* roots

BCFs for Cu, Pb, Cd, and Zn in the roots of *R. racemosa* are shown in Figure 3. BCF greater than 1 for Cd and Zn was observed in the root except for Cu (0.26) and Pb (0.39) with BCF of less than 50% accumulation. The low BCF of Cu and Pb could be due to the low bioavailability of the metals in the sediments (Alzahrani *et al*., 2018). Plants act as either accumulators or excluders (Yam *et al*., 2020; Soraya *et al*., 2019; Kathiresan *et al*., 2014). The accumulator plants absorb pollutants and retain them in their tissues, while excluders limit the pollutants from entering into their tissues. Luthansa *et al*. (2021) showed BCF is divided into three categories, namely the indicator (BCF = 1), accumulator (BCF>1), and excluder (BCF<1). Therefore, *R. racemosa* possesses the ability of an accumulator of Cd, Zn, and an excluder of Cu and Pb. The black line indicates BCF=1.

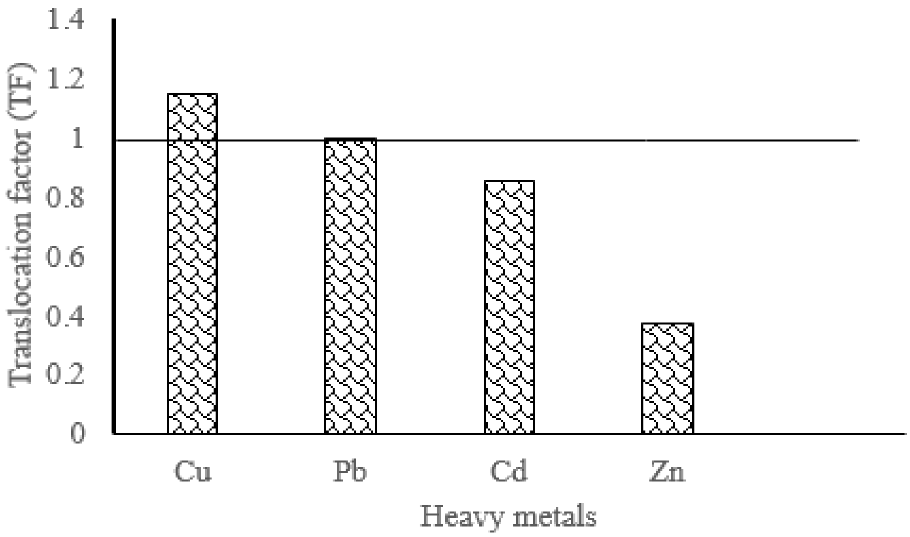

Figure 4: Translocation Factor (TF) of heavy metals in *R. racemosa*

Figure 4 shows the TF for Cu, Pb, Cd, and Zn in *R. racemosa.* According to Luthansa *et al*. (2021), TF could either be grouped as phytoextraction (TF > 1) or phytostabilization (TF < 1). TF of *R. racemosa* for Cu (1.14) was greater than 1 (TF> 1), indicating the heavy metal was efficiently translocated from the roots to leaves

(Yoon *et al*., 2006), and the plant can accumulate a considerable amount of Cu. The concentration of Cu absorbed is mainly influenced by the metabolic requirements of the plant. Cu is involved in many physiological and biochemical processes; Cu is required in chloroplast and mitochondria reactions, cell wall lignification, enzyme systems related to photosystem II, electron transport, protein synthesis, and carbohydrate metabolism (Dudani *et al*., 2017). Pb, Cd, and Zn with less than 1 TF in the plant indicate a poor heavy metal translocation from root to leaves. The phytostabilisation mechanism of *R. racemosa* was able to slow down the absorption and translocation of these metals through its roots (Majid *et al*., 2014; Al-Qahtani. 2012). This implies that the amount of heavy metals accumulated in the root tissues exceeded those in the leaves of *R. racemosa*.

Conclusion

R. racemosa can absorb, translocate and accumulate heavy metals in its root and leaf tissues. This study has shown that *R. racemosa* is an accumulator and extractor of Cu, however, the TF for Cd, Zn, and Pb showed values less than 1, indicating the mangrove could only tolerate these heavy metals in its roots, therefore *R. racemosa* can probably be a suitable sink for Cu in coastal areas.

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