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Heavy metal contents in mangrove leaf, root and sediment from Eagle Island, Port Harcourt

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Abstract

Mangroves are sensitive ecosystems with prominent ecological value. Unfortunately, a lot of mangrove areas has been lost to pollution across the world. The present study investigated heavy metal contaminations in the mangrove forest of Eagle Island in Port Harcourt. Samples of sediment, Root and leaf of mangrove tree (*Avicenia marina*) were collected from two stations in Eagle Island. After preparation, the concentrations of four metals were measured using the Flame Atomic Absorption Spectrophotometer (FAAS). Concentrations of the heavy metals were: Ni (1.53-1.65), Pb (7.34-5.27), Zn (61.38-62.12), Cu (8.29-6.30) mg/kg in sediment. The results of concentrations for the plant's root were: Ni (1.35-1.76), Pb (3.28-2.39), Zn (54.51-68.52), Cu (4.82-4.70) mg/kg. The concentration for the plant leaves were: Ni (0.31-0.001), Pb (4.74-3.39), Zn (20.39-19.40), Cu (3.05-2.02) mg/kg. Their means for sediment were: 1.59, 6.3, 61.75, 7. 29. Roots: (1.55, 2.84, 61.5, 4.76). Leaves: (0.15, 4.06, 19.89, and 2.53) for Ni, Pb, Zn and Cu respectively. The highest metal in the Sediment was Zinc; whereas in the root, it was Zinc; while in the leaves, it was Lead. The order of accumulation of metals was observed as follows: Sediment > roots > leaves. Metal concentrations during the research study were in the order of accumulation: Zn>Cu>Pb>Ni respectively.

Keywords: Heavy Metals; Mangrove Root; Stem And Leaf; Eagle Island; Port Harcourt

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1. Introduction

Mangroves are widely reported as sensitive ecosystems with prominent ecological value. Unfortunately, a lot of mangrove areas has been lost to pollution across the world (Davari et al., 2010). Mangrove ecosystems have also been documented as the most productive in the world; hence their many benefits which entitle them to be used for numerous activities like coastal water enrichment, commercial production, coastlines preservation and increasing fisheries production (Kathiresan and Bingham, 2001; Keshavarz et al., 2012). Mangroves are widely documented as woody plants growing at the interface between land and sea in tropical and sub-tropical Latitudes. They exist in conditions of high salinity, extreme tides, strong winds, high temperatures and in muddy anaerobic soils (Kathiresan and Bingham, 2001). Because of their environment, mangroves have become resilient to high salt content and have the means to take up water despite strong osmotic potentials. Mangrove has a lot of lateral roots that are fastened to the trees in the slack sediments, where aerial roots are exposed for gas exchange (Kathiresan and Bingham, 2001). The most important mangrove types are *Avicennia marina* (white mangrove), *Rhizophora mangle* (Red mangrove) and *Avicennia germinans* (black mangrove) (Unlu and Gumgum, 1993). Pollution caused by heavy metals in normal environments has become an international concern (Irabien, 1999).

There is a plethora of information on heavy metal contents in mangrove sediments (Lacerda, 1988; Mackey et al., 1992; Marchand et al., 2006; Preda and Cox, 2002; Reid and Spencer, 2009; Yu et al., 2008; Tam and Wong, 1995, 1997, 2000; Clark, 1998; Clark et al., 1998); Information is scanty about metals in the mangroves of the Niger Delta of Nigeria. Little is known about the capacity of mangrove plants to absorb and concentrate heavy metals. Sediments that accrue in mangroves are potential sources of anthropogenic pollution because of high total organic carbon content, anaerobic properties and rapid turnover and burial (Marchand et al., 2006). Raised concentrations of heavy metals have been documented in mangrove sediments all over the world and this often reflects the long-term pollution caused by human activities (Harris and Santos, 2000; Tam et al., 2000).

Many studies have been done on the physico-chemistry of mangroves. One such study (Purves, 1985), undertook the determination of heavy metal concentrations (Fe, Zn, Mn, Pb and Cd) in three different mangrove species (*Avicennia marina, Avicennia officinalis* and *Rhizophora mueronata*) in India. The concentrations of metals were measured in sediment samples collected from the neighboring root zone of mangrove species, in the leaves and roots of the same plant species. Another study (Lester, 1983), examined metal accumulations in Grey Mangrove (*Avicennia marina*) in Eastern Saudi Arabia. Samples of mangroves, water and soil, were collected from ten locations in Tarut Bay and analyzed for eight substances including Boron and heavy metals: Iron, Manganese, Zinc, Lead, Nickel, Cadmium and Copper. Another study (Tam and Wong, 1995, 1997, 2000), determined the concentrations and bioavailability of Ni, Cu, Cd, Zn and Pb in the sediments and leaves of white mangrove (*Avicennia Marina*). Hossein et al. (2010), compared the concentrations of heavy metals (Cd, Cu, Ni and Zn) in the sediment in the different tissues of *Avicennia Marina* in Iranian Coasts of the Oman Sea. The concentration of metals was determined in the sediment and different tissues of *Avicennia Marina* (root, leaf, stem and flower) from different stations along the natural and artificial mangrove forests after acid digestion by Atomic Absorption Spectrophotometry. In another study, Fatemeh et al. (2013), reported human activities that release heavy metals into the environments thus increasing metal concentrations in biota.

The existence of metal contaminants, in excess of natural levels, has become a problem of increasing concern, especially with the rapid growth in population, increased urbanization and expansion of associated industrial activities (Fatemeh et al., 2013). Sahel (2013), *examined the* accumulation of heavy metals (Zn, Pb) in two mangrove species *Avicennia marina* and *Sonneratia apetala.* Lindquist and Block (1994), focused on the determination of heavy metal distribution in *Avicennia Marina* from Sonmiani, Pakistani Coast. The accumulation of heavy metals in *Avicennia marina* was studied in the Bhira village mangrove forest, Pakistan. Samples of leaves stem and roots were collected randomly from the selected species (*Avicennia marina*). Similarly, Almahasheer et al. (2014), reported the concentration of the heavy metals Cu, Ni, Pb, and Zn in sediments, roots, stem and leaves of *Avicenia marina* tissues in Qeshm Island, Iran. Literature so far reviewed has shown a plethora of information on mangrove studies carried out elsewhere but there is a dearth of information on mangrove studies in Eagle Island in Port Harcourt

Mangroves can act as a long term sink for heavy metals because of their precipitation with sulfides during digenetic reactions and the relative stability of these minerals (Hogarth, 1999). In general, very small amounts of heavy metals are found in leaf tissues as most absorbed heavy metals are accumulated in the stem and roots (Hansen et al., 1978). Metals occur naturally in the environment and are present in rocks, soils, plants and animals. These metals occur in different forms as ions dissolved in water, as vapour, or as salts or minerals in rock and soil. They can also be bound in organic or inorganic molecules or attached to particles in the air. Plants and animals depend on some metals as micronutrients (Harbison, 1986). Heavy metals such as Cu and Zn are essential for normal plant growth and development since they are constituents of many enzymes and proteins (Harbison, 1986). Literature review of studies on the mangrove environments show that leaves, roots and sediments in this zone could be a sink to a substantial quantity of toxic contaminants especially heavy metals without much damage to the vegetation. Mangrove vegetation therefore plays a significant role in regulating the concentration of major and micro-nutrient elements (including heavy metals) in root/sediment and leaf of mangrove habitat. Eagle Island has a rich mangrove forest. It is crucial to study and document the content of heavy metal accumulation in mangrove plants. The present study seeks to investigate heavy metal concentrations in the mangrove forest of Eagle Island in Port Harcourt

2. Description of the study area

The study area was Eagle Island. It is a town in Rumueme-Oroworukwo community located in Port Harcourt, Rivers State. It is situated at the upper reaches of Bonny Estuary of the Eastern Niger Delta, Nigeria. It lies within Latitudes 4º 47’ 10.2” to 4º 47’ 21.8’’ N and Longitudes 6° 53' 33.5” to 6° 58’ 31.3’’ E (Fig. 1).

The aim of this study was to determine and document the concentrations of heavy metals in Mangrove leaf, root and sediment collected from Eagle Island. It is also part of the objective to correlate the observed levels in leaves, roots and sediments of the *Avicennia marina* (White Mangroves) and to evaluate the possible implications of the current level of heavy metals present in the environment.

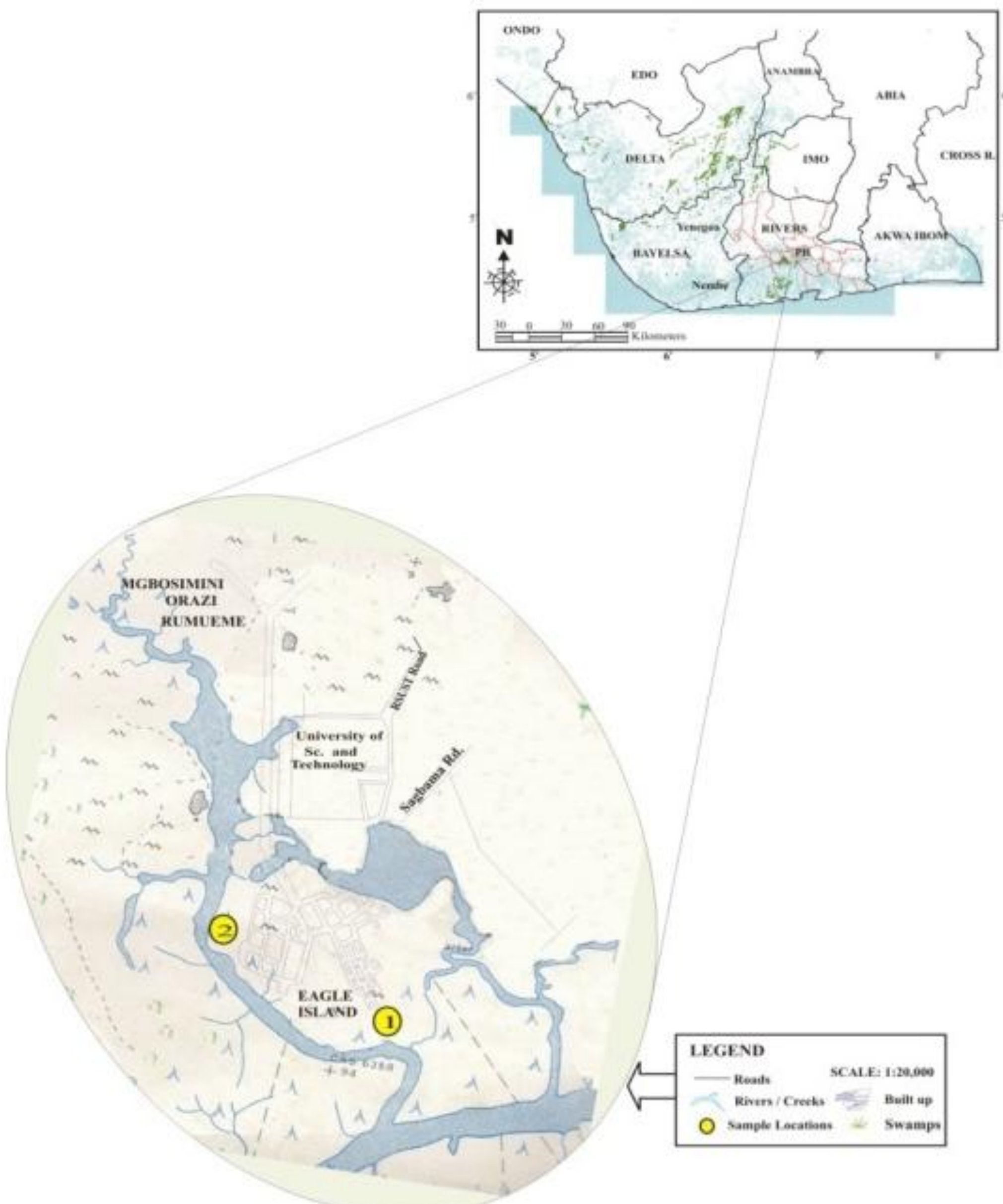

Figure 1. Map of Niger Delta Showing Port Harcourt, the study Area

3. Materials and methods

Samples were collected randomly by hand plucking of leaf, cutting of root with a knife and collection of the sediment of the mangrove species (Plates 1, 2 & 3) by hand trowel to form a uniform sample. The GPS of the sampling points are given in Table1. Samples were kept in polyethylene bags and clearly labeled for transportation to the laboratory, where they were well preserved at room temperature. The mangrove samples were then washed, dried and homogenized to a powdered form, sieved and stored in plastic bottles for analyses in the laboratory. In the laboratory, 2.0 gm of ground leaf and root were accurately weighed into a crucible and ashed. 5 mls of 10 % HCL solution and 5mls of 10 % Nitric acid were added and warmed on a water bath to dissolve and then transferred quantitatively into a clean dry 50 ml standard volumetric flask and made up with distilled water to the mark.

Table 1. GPS points of the study locations in Eagle Island (May, 2015)

Sites	Description	N	E
1	Island-Agip	04°47' 21.8	6° 53' 33.5”
2	Sir Collins Owhonda Road	04° 47’.10.2”	6° 58.31.3”

3.1. Acid digestion of sediments

5.00 g of sediment (Plate 3) was weighed out into a 100 ml glass beaker and 20 ml of 10 % HCL was added. It was placed on a hot plate and heated for 30 minutes to dryness and then allowed to cool after lifting it off the hot plate. The acid solution was decanted through a Whatman filter paper, rinsed severally with distilled water while making up the volume of acid digest to 50 ml in a 50 ml volumetric flask. It was transferred to a labeled sample bottle for determination of heavy metal contents of interest (Pb, Ni, Cu and Zn) on Atomic Absorption Spectrophotometer.

Plate 1. White Mangrove leaves sampled

Plate 2. White Mangrove roots sampled

Plate 3. White mangrove sediment sampled

4. Results

The results of analysis of Pb, Ni, Cu and Zn in mangrove sediment, root and leaf are presented in Figures 2 and 3 and Tables 1 – 4. The concentrations of Nickel were: sediment (1.53-1.65) mg/kg with a mean of 1.59±0.08 mg/kg; root (1.35-1.76) mg/kg with a mean of 1.55±0.29 mg/kg and leaf (<0.001-0.31) mg/kg. The root showed percentage uptake for Nickel ranging from 88.2% to 106% while that of the leaf ranged from 0 % to 20 % only (Table 1). Concentration was highest in sediment following this order: Sediment >Root > Leaf.

Table 1. Concentrations of Nickel in various samples studied (May, 2015)

Sample Identity	**Leaf**	**Root**	**Sediment**
Andoni Village (Station 1)	0.31	1.35	1.53
Back gate water side (Station 2)	0.001	1.76	1.65

Table 2. Heavy metal concentrations in *Avicennia marina* (White Mangrove) in Eagle Island (May, 2015)

	Nickel		**Lead**		**Zinc**		**Copper**	
Matrices	**Station 1**	**Station 2**	**Station 1**	**Station 2**	**Station 1**	**Station 2**	**Station 1**	**Station 2**
Leaf	0.31	<0.001	4.74	3.39	20.38	19.40	3.05	2.02
% Uptake	20	0	64.5	64.3	33.2	31.2	36.7	32
Mean	0.15±0.21		4.06±0.67		19.89±0.69		2.53±0.72	
Root	1.35	1.76	3.28	2.39	54.51	68.52	4.82	4.70
% Uptake	88.2%	106%	44%	45.3%	88.8%	110 %	58%	74%
Mean	1.55±0.29		2.84±0.62		61.5±9.90		4.76±0.08	
Sediment	1.53	1.65	7.34	5.27	61.38	62.12	8.29	6.30
Mean	1.59±0.08		6.3±1.46		61.75±0.52		7.29±1.40	

Table 3. Bio concentration factor (BCF) in *Avicennia marina* plant tissues (White Mangrove)

Matrices	**Heavy metals**			
	Ni	Pb	Zn	Cu
BCF in root	0.29	0.62	9.90	0.08
BCF in Leaf	0.21	0.67	0.69	0.72

(BCF)=Bio concentration factor

$$BCF = \frac{\text{Concentration}}{\text{Concentration}} \times 100$$

Bio concentration factor, BCF measured using the plant tissues, which is concentration ratio of each metal in root and leaf tissues to the sediment. This was calculated and presented in Table 3. The concentrations of lead were: Sediment (5.27 -7.34) mg/kg with a mean of 6.3±1.46 mg/kg; Root (2.39-3.28) mg/kg with a mean of 2.84±0.62 mg/kg and Leaf (3.39-4.74) mg/kg with a mean of 4.06±0.67 mg/kg (Table 4). The leaf showed percentage uptake for lead ranging from 64.3% to 64.5% higher than that of the root with (44 % to 45.3 %) only. Concentration of lead, Pb was highest in the sediment following this sequence: Sediment > Leaf > Root.

Table 4. Concentrations of Lead in various samples studied

Sample Identity	Leaf	Root	Sediment
Andoni Village (Station 1)	4.74	3.28	7.34
Back gate water side (Station 2)	3.39	2.39	5.27
Mean	3.39	2.84	6.3

The concentrations of Zinc (Zn) were: Sediment (61.38-62.12) mg/kg with a mean of 61.75±0.52 mg/kg; Root (54.51-68.52) mg/kg with a mean of 61.5±9.90 mg/kg and Leaf (19.40 - 20.38) mg/kg with a mean of 19.89±0.69 mg/kg. The root showed percentage uptake for Zinc ranging from 88.8% to 110% while that of the leaf was (31.2% to 33.2%) only (Table 5). Like lead, concentration of Zinc was highest in the sediment following this sequence: Sediment >Root > Leaf.

Table 5. Concentration of Zinc in various samples studied (May, 2015)

Sample Identity	Leaf	Root	Sediment
Andoni Village (Station 1)	20.38	54.51	61.38
Back gate water side (Station 2)	19.40	68.52	62.12
Mean	19.89	61.5	61.75

Table 6. Concentration of Copper In Various Samples Studied (May, 2015)

Sample Identity	Leaf	Root	Sediment
Andoni Village (Station 1)	3.05	4.82	8.29
Back gate water side (Station 2)	2.02	4.70	6.30
Mean	2.53	4.76	7.29

Copper **c**oncentrations were: Sediment (6.30 - 8.29) mg/kg with a mean of 7.29±1.40 mg/kg; Root (4.70 - 4.82) mg/kg with a mean of 4.76±0.08 mg/kg and Leaf (2.02-3.05) mg/kg with a mean of 2.53±0.72 mg/kg. The root showed percentage uptake of 58% to 74% while the leaf was 32 % to 36.7 % only (Table 6). Concentrations of Cu were highest in the sediment following this order: Sediment >Root > Leaf. The concentrations of all metals are shown in Figs. 2 and 3. Zinc was the most predominant metal in all matrices though in the sediment of Station 2, the concentration was low and Nickel was the least metal detected in leaf, roots and sediment (Figs.1&2). Figure 2 compared concentrations in the matrices (leaf, root and sediments) and showed sediment to contain more metals than leaf and root.

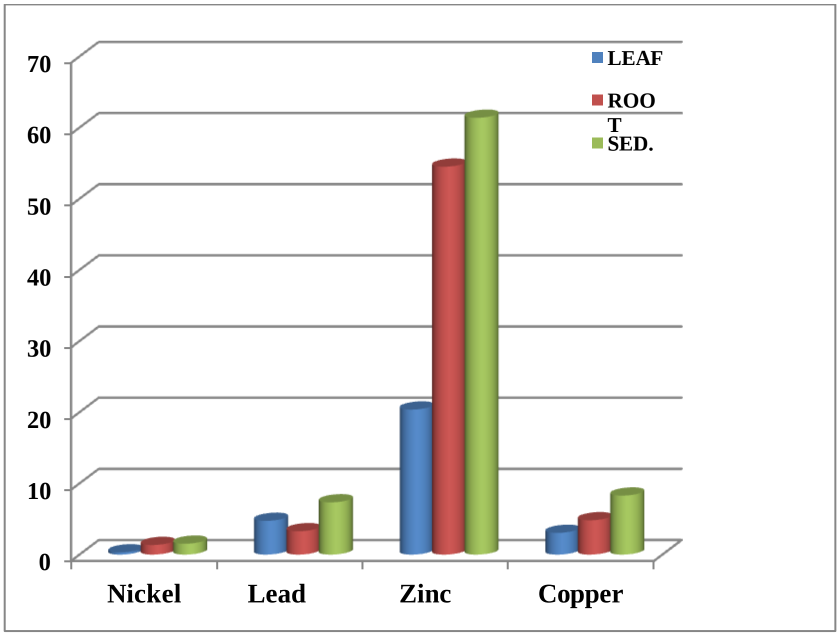

Figure 2a. Concentration of all the metals in the leaf, root and sediment of *Avicenna marina* in Station 1

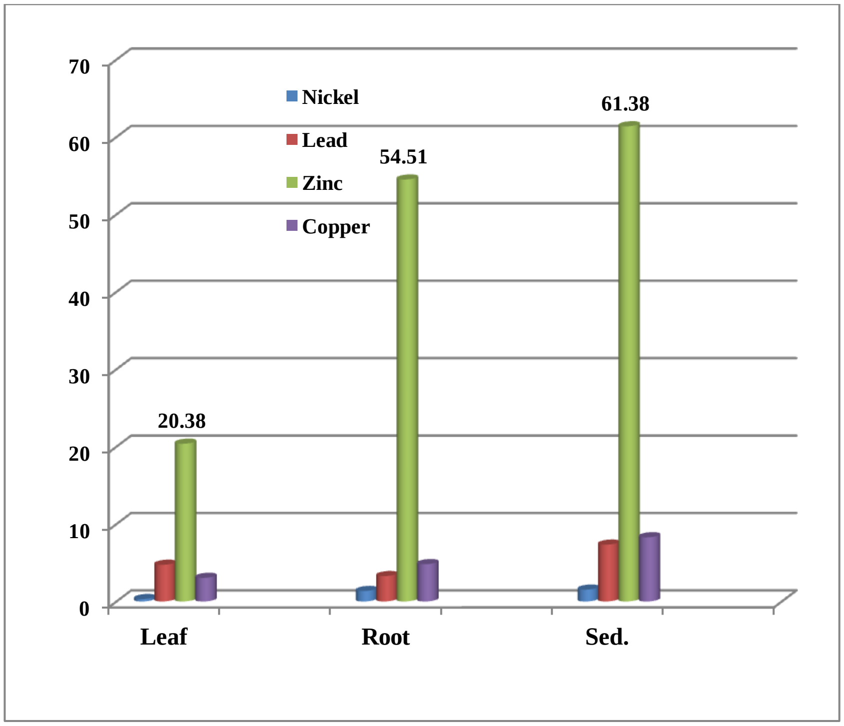

Figure 2b. Concentration of highest metal in the leaf, root, root and sediment of *Avicenna marina* in Station

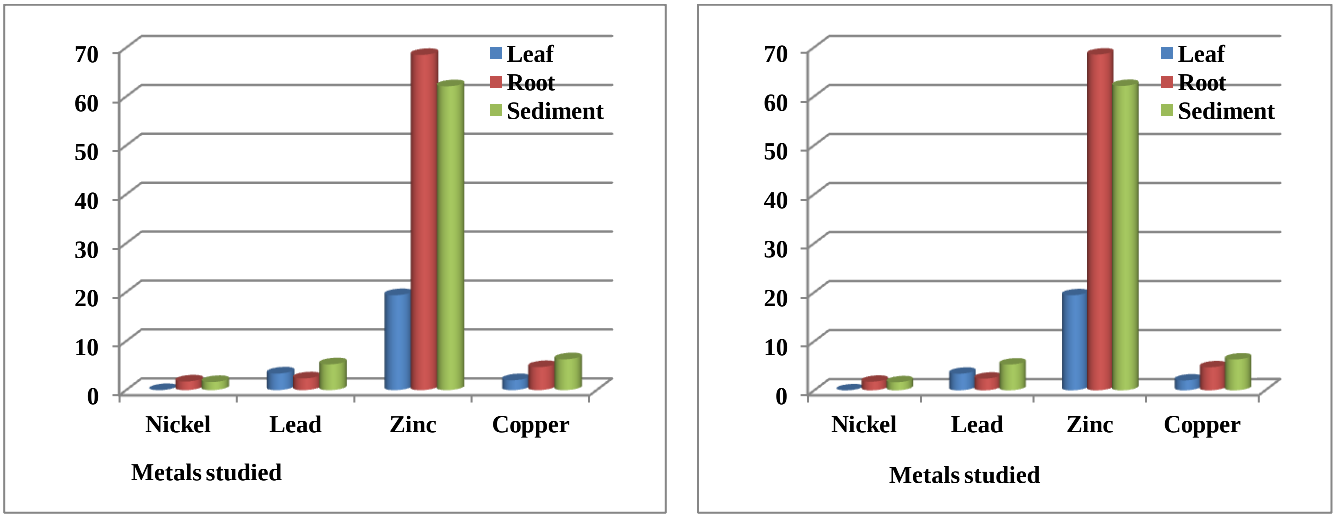

Figure 3. Concentration of all the metals in the leaf, root and sediment of *Avicenna marina* in Station 2

5. Discussion

5.1. Nickel

Nickel concentration in sediment (1.53-1.65 mg/kg (or ug/g) with a mean of 1.59±0.08 mg/kg) was considered low when compared with those of previous studies that reported Nickel ranges of 47.05-58.09 ug/g in sediment (Fatemah et al., 2013). The concentration of Ni in sediment is attributed to the fact that sediment is a sink for all pollutants and it is in contact with water. The concentration in the root (1.35-1.76 mg/kg with a mean of 1.55±0.29 mg/kg) comes from absorption from the sediment as metals exist in the sediment because of the high affinity of organic matter (OM) for heavy metals. This was lower than literature reported levels of 37.42- 41.68 mg/kg in roots (Almahasheer et al., 2014). Low levels observed in the leaf (<0.001-0.31 mg/kg) comes from the supply from the root. Literature values reported levels ranging from 1.88-3.07 mg/kg in leaf (Almahasheer et al., 2014). Though our findings are lower than reported levels, they corroborate low concentrations in the leaf. The root showed percentage uptake for Nickel ranging from 88.2% to 106% while that of the leaf ranged from 0% to 20% only (Tables 1 & 2). The root showed percentage uptake for Nickel ranging from 88.2% to 106% while that of the leaf ranged from 0% to 20% only.

Heavy metal concentrations in plant tissues (roots and leaf) are influenced by the metabolic requirements for essential micro-nutrients such as Zn and Cu as they play a part in chloroplast processes, protein synthesis, enzyme activities, growth hormones, and carbohydrate metabolisms (Philips, 1977). It was found that concentration of metals in samples collected from station 1(Andoni Village) and station 2 (Backgate waterside) varied because both were affected by discharge of effluents and waste dump.

Lead (Pb) concentration in sediment {(5.27 to 7.34 mg/kg) with a mean of (6.3±1.46 mg/kg)} though low, was within the ranges observed and reported for previous studies (10.18-52.03 mg/kg) (Fatemah et al., 2013). Like Ni, relatively high sediment concentration came from the fact that sediment is a sink to many substances. Concentration in root {(2.39 -3.28 mg/kg) with a mean of (2.84±0.62) mg/kg} shows amount transported from the sediment. This was lower than literature reported levels of lead (8.10 to 10.60 mg/kg) in roots (Almahasheer et al., 2014). Similarly, levels in the leaf {(3.39 - 4.74) mg/kg, with a mean of 4.06±0.67 mg/kg)} show migration and transport from the root (Tables 2 & 4). Our findings for lead concentration in leaf are higher than literature levels of (0.81 to 0.89 mg/kg) reported by (Almahasheer et al., 2014). The leaf showed percentage uptake for lead ranging from 64.5% to 64.3 %, higher than that of the root with range of 44% to 45.3% only.

5.2. Zinc

Zinc (Zn) sediment concentrations (range of 20.28-62.12 mg/kg with a mean of 61.75±0.52 mg/kg), though slightly higher, were in agreement with reported levels of previous studies of Zinc ranging from 26.71-54.24 ug/g in sediment (Almahasheer et al., 2014). Highest concentration of Zn in sediment is attributed to the fact that sediment is a sink for all pollutants and the fact that sediment is in contact with water. High concentration in the root (54.51-68.52 mg/kg with a mean of 61.5±9.90 mg/kg) comes from absorption from the sediment as metals exist in the sediment because of the high affinity of organic matter (OM) for heavy metals. This was lower than literature reported levels of 7.49-26.71 mg/kg in roots (Almahasheer et al., 2014). Though our findings are lower than reported levels, they corroborate low concentrations in the leaf. The root showed percentage uptake for Zinc ranging from 88.8% to 110% while that of the leaf ranged from 31.2% to 33.2% only (Table 4.5).

5.3. Copper

Copper (Cu) sediment concentration ranged from 6.30-8.29 mg/kg, with a mean of 7.29. Like Zn, highest sediment concentration comes from the fact that sediment is a sink to many substances. Concentration in root (4.70-4.82 mg/kg) with a mean of 4.76±0.08 mg/kg) shows amount transported from the sediment. This was lower than literature reported levels of Copper (23.62 to 26.94 mg/kg) in roots (Almahasheer et al., 2014). Similarly, levels in the leaf (2.02-3.05 mg/kg with a mean of 2.53±0.72 mg/kg) show migration and transportation from the root (Tables 4.2 & 4.6). Our findings are lower than the reported literature levels of (23.08-59.33 mg/kg) in leaf (Almahasheer et al., 2014). The root showed percentage uptake for copper ranging from 58% to 74% while that of the leaf ranged from 32% to 36.7% only (Table 4.6). According to the Bio concentration Factor (BCF), heavy metals do accumulate in plant tissues especially in roots and leaves as a good bio-indicator. The root is a good bio-indicator for Ni and Zn, leaf tissues are best for Cu. Excess metals are trans-located from root to stem, then to leaf and the degree of upward movement depends upon the mobility of heavy metals. The role of the mangrove plants to heavy metals are related to plant age, growth and biomass production.

6. Conclusion

The study has shown that *Avicenna marina* (white mangrove) possesses the capacity to take up selected heavy metals via its roots and store in the leaves without any sign of injury. It has also shown that white mangroves can absorb heavy metals from their surroundings, which demonstrates the importance of using mangrove plants in cleaning the coastal environments from metal pollution. As it grows more aged, its capability of accumulating heavy metals is also increasing. We recommend that more studies be done with wide ranging metals and different classes of mangroves to provide more information in this direction.

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