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Bio Concentration Factor and Translocation Ability of Heavy Metals within Different Habitats of Hydrophytes in Nairobi Dam, Kenya

Ndeda, L. A. [1*] and Manohar, S. [1]
[1]*Department of Environmental Sciences, Kenyatta University, Kenya. P.O Box 43844,00100, Nairobi, Kenya.*

Abstract: *Bio-Concentration Factor (BCF) and Translocation Ability (TA) of Copper (Cu), Cadmium (Cd), Lead (Pb) and Nickel (Ni) in different habitats of hydrophytes within Nairobi dam was carried out during wet and dry seasons. Freshwater plant species from three habitats: (i) free floating; (Eichhornia crassipes), (ii) emergent (attached); (Typha domingensis, Vernonia lasiopus, Cyperus papyrus, Polygonum salicifolium, Rumex bequaertii, Colocasia esculenta, Amaranthus spinosus), and (iii) submerged; (Ceratophyllum demersum); water and sediments were sampled and analysed. Bio Concentration Factor (BCF) of heavy metals was the highest in free floating plants than submerged and lowest in emergent during the wet than dry season. The Translocation Ability (TA) was better in free floating plants in comparison to emergent hydrophytes in the dry season. It is concluded that the free floating specie Eichhornia crassipes has the highest Bio Concentration Factor and Translocation Ability of heavy metals in both dry and wet seasons. Therefore, it is recommended that Eichhornia crassipes should be used for removal of heavy metals from contaminated freshwater bodies and these should not be consumed by animals and humans.*
Keywords: *Bio Concentration Factor, Translocation Ability, Heavy metals, Nairobi dam*

I. Introduction

Heavy metals are widespread pollutants of great environmental concern as they are non degradable, toxic and persistent with serious ecological ramifications and passes through food chains to humans [1]. These metals disturb growth, development, reduce haemoglobin, create cancer, damage the organs and nervous system, and in extreme cases causes, death [2,3].

The behaviour of heavy metals in natural waters is a function of the substrate, suspended sediment composition, and water chemistry. The water chemistry of the system controls the rate of adsorption and desorption of metals to and from sediment. Adsorption removes the metal from the water column and stores the metal in the substrate. Desorption returns the metal to the water column, where recirculation and bio-assimilation may take place. Metals may be desorbed from the sediment if the water experiences increased salinity, decreased redox potential, or decreased pH [4].

Living organisms require traces of some heavy metals, including cobalt, copper, iron, zinc, manganese and strontium however, excessive levels of essential metals can be harmful to organisms. Non-essential heavy metals of particular concern to surface water systems are Lead, Cadmium, Chromium, Mercury, Arsenic, and Antimony [5].

The Bio-concentration factor refers to the most important plant feature in phytoremediation: the uptake of metals, their mobilization into plant tissues, and storage in the aerial plant biomass [6]. In the aquatic systems, hydrophytes have the potential to uptake heavy metals, and extract large concentrations of heavy metals into their roots and translocate metals to surface biomass [7]. The ecological tolerance of different categories of aquatic plant species vary depending on their specific habits and habitats. Most of the species show different behaviour regarding their ability to accumulate elements in roots, stems and/or leaves, therefore, it is useful to identify the plant and its organ that absorbs the greatest amount of these elements [8]. Phytoremediation has been successfully tested and used in many locations and Superfund sites [9]. A study on removal of heavy metal in wastewater showed that *Lemna minor* L. and *Azolla pinnata* R. Br. accumulated 78 times more concentrations of Cu and Fe than in the wastewater [10].

Kibera is the largest slum dwellings in Africa on the North eastern bank of Nairobi dam, it is an informal settlement by all standards, and a major contributor to pollution of the Motoine-Ngong river (Fig. 1) mostly due to large quantities of waste emanating from unserviced households, solid and liquid waste, including human waste dumped into trenches that drain into the river, and ends into Nairobi Dam [11]. Therefore, this work intended to analyse bio-concentration factor and translocation ability of heavy metal(s) in the free floating, emergent and submerged hydrophytes of Nairobi dam during wet and dry seasons.

II. Materials And Methods

Study Area

Nairobi dam is in Langata constituency, Nairobi (Kenya) (Fig. 1) at a latitude of 1° 19' (1.3167°) south; longitude of 36° 48' (36.8°) east. Water accumulation capacity of the dam is 98,422cu. metres (3,477,800 cu ft) and surface area of 356,179m^2 (approximately 86 acres). It is situated at an average elevation of 1,686 meters above the sea level.

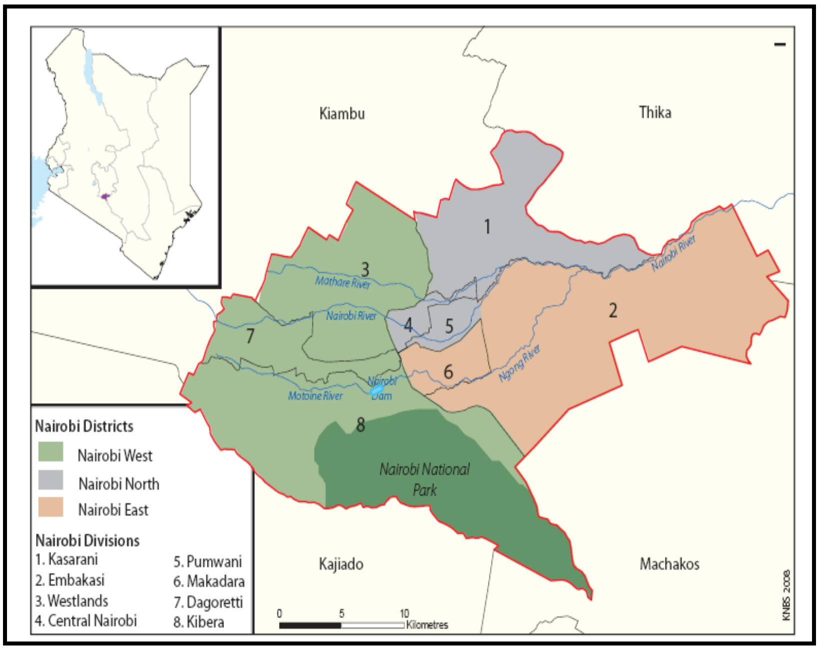

Figure 1: Map of Kenya showing study area i.e. Nairobi Dam

III. Data Collection and Analysis

Dominant peripheral swamp plant species (*Typha domingensis, Vernonia lasiopus, Cyperus papyrus, Polygonum salicifolium, Rumex bequaertii, Colocasia esculenta, Amaranthus spinosus)*; free floating (*Eichhornia crassipes)*; submerged angiosperm, (*Ceratophyllum demersum)*; water and bed sediments were collected once in a month during the wet season (November 2012 to early January 2013) and the dry season (February to early April 2013) from seven selected sites within Nairobi dam: (1st sample station was along the stream entering Nairobi dam 10m before discharge into the dam; 2nd station: at a distance of 5m after discharge into the dam; 3rd station: 5m inwards of the west shore; 4th station: 5m inwards of the outlet; 5th station: 5m inwards of the east shore; 6th station: approximately at the centre of dam; and 7th station: 1m from the outlet of the dam). The samples were stored in clean, labelled plastic bags, bottles and jars [12]; then transported to the laboratory where the water was preserved with 1.5ml/L Conc.HNO_3 and stored in the fridge at 4°C; sediments were oven dried at 105^{o}C for 24hrs and plants cleaned with clean water and later on, dried in an oven at 80^{o}C to constant weight. The dried sediments and plants were ground, after this the sediment(s), plants and water samples were digested separately in Conc.3HNO_3:HCl [12]. Heavy metals (Pb, Cu, Cd, Ni) in samples were determined using Shimadzu flame Atomic Absorption Spectrophotometer (AA-630).

Mean metal(s) levels and standard errors were calculated. The Bio concentration factor (BCF) [13] and Translocation Ability (TA) [14] of heavy metal(s) within hydrophytes were calculated as shown below:

$$BCF = \frac{\text{Plant tissue concentration (mgkg}^{-1}\text{)}}{\text{Concentration in external environment (mgL}^{-1}\text{ or mgkg}^{-1}\text{)}}$$

Higher ratio of BCF implies better phytoaccumulation capabilities.

$$TA = \frac{\text{Root concentration (mgkg}^{-1}\text{)}}{\text{Shoot concentration (mgkg}^{-1}\text{)}}$$

Higher values of TA imply poorer translocation

IV. Results And Discussion

The BCF and TA of heavy metals (Cu, Cd, Pb, Ni) in different habitats of hydrophytes within Nairobi dam during wet and dry seasons were analysed. The mean± standard errors are tabulated as shown in Table 1 and discussed as follows:

Table 1: Bio-Concentration factor (BCF) and Translocation Ability (TA) of heavy metals in different habitats of hydrophytes in Nairobi dam during wet and dry seasons

Heavy Metals	Season(s)	BCF (Mean ±SE)				TA (Mean ±SE)ppm	
		Free floating	Emergent (Attached)		Submerged	Free floating	Emergent
			Sediment	Water			
Cu	Wet	5.34±0.12	0.33±0.01	2.10±0.08	4.68±0.09	1.13±0.01	1.58±0.07
	Dry	3.68±0.20	0.38±0.01	1.69±0.10	3.29±0.17	1.20±0.02	1.55±0.08
Cd	Wet	5.46±0.23	0.28±0.01	1.95±0.09	4.19±0.17	1.16±0.01	1.35±0.05
	Dry	4.47±0.17	0.31±0.01	1.84±0.08	3.53±0.13	1.10±0.01	1.33±0.06
Pb	Wet	2.55±0.05	0.53±0.02	1.54±0.05	1.77±0.03	1.08±0.01	1.36±0.05
	Dry	1.96±0.03	0.55±0.01	1.24±0.03	1.36±0.02	1.07±0.01	1.32±0.06
Ni	Wet	1.23±0.17	0.27±0.02	1.35±0.16	0.37±0.04	2.20±0.18	1.58±0.14
	Dry	1.37±0.11	0.37±0.02	1.47±0.11	0.39±0.03	1.65±0.08	1.41±0.15

Sequence of Bio Concentration Factor of heavy metal(s) within the different habitats of hydrophytes during wet and dry seasons was: Free floating > Submerged > Emergent plants in water > Emergent plants in sediments. BCF of Cadmium (Cd) was highest in all the plants and its level in free floating hydrophytes was 4 to 5 times more than those in water (Table 1). This explains the high metals tolerance of *Eicchornia crassipes* compared to the other categories of hydrophytes.

The hydrophytes had higher BCF values in the wet season than dry season except for the peripheral emergent plants in relation to sediments of Nairobi dam (Table 1). This is due to decreased redox potential in the water column, precipitation that enhanced plant growth, and dilution of heavy metals in the water column in comparison to hydrophytes body during the wet season which resulted to larger ratios (BCF).

"Aquatic macrophytes take up metals from the water, producing an internal concentration several fold greater than their surroundings. Many of the aquatic macrophytes are found to be the potential scavengers of heavy metals from water and wetlands" [15]. Similar results were observed in this study. A study on heavy metals in plants of Sultan Marsh showed that, higher heavy metals concentrations occurred in submerged than in emergent macrophytes [16]. It has also been revealed that submerged plants tend to accumulate higher levels of metals consistently more than emergent or free floating plants [17,18].

The free floating hydrophytes had lower TA values of Cu, Cd and Pb except of Ni compared to emergent hydrophytes (Table 1). This shows that the free floating plants had better metals translocation ability than the emergent hydrophytes. This is due to larger surface area to volume ratio of the free floating plants.

Better heavy metals translocation was observed within free floating and attached (emergent) hydrophytes in dry than wet seasons (Table 1). This can be attributed to elevated temperatures in dry season, that enhances evapotranspiration therefore, transporting metals at a faster rate from the soil solution to roots, leaves and stems. Higher temperatures in the dry season also accelerated physical, chemical and biological processes in general thus greater availability of substrate metals as well as higher interior mobility of metals. Lower pH in water and sediments during dry season increased metals bioavailability in hydrophytes.

A study on ability of *Eichhornia crassipes* to absorb and translocate Cd, Pb, Cu, Zn, and Ni in the Erh-Chung wetlands, revealed that the concentration of these five elements in the roots was 3 to15 times higher than those in the shoots; and also trace element BCF in water exceeded those in sediment, except for Cu [19]. Translocation of heavy metals takes time and varies with: hydrophyte species, presence of transporters (carriers and channels), availability of binding sites, energy, environmental conditions (pH, photosynthesis, temperature etc.), metabolic levels and regulatory proteins among other factors [7,20-24].

V. Conclusion

Bio concentration factor (BCF) of heavy metals is highest within the free floating plants than submerged and lowest in emergent (attached) plants of the swamp during wet than dry season. Translocation Ability (TA) of heavy metals in the free floating plants is better than emergent (attached) plants during the dry season. Bio-concentration and translocation of heavy metals are mainly influenced by bioavailability of the heavy metals in both external (sediment and water--associated) and internal (plant and animal--associated) environmental factors. Therefore, it is recommended that free floating *Eichhornia crassipes* should be adviced for removing heavy metals from polluted water bodies and such plants and their products should not be allowed for cultivation, domestic use and commercial purposes.

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