



Biomonitoring of Heavy Metals Level in Wetland Plants of Lagos Lagoon, Nigeria

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ABSTRACT: The purpose of this research was to monitor the distribution of Cd, Cr, Cu, Ni, Pb and Zn in plants of Lagos lagoon wetlands in Nigeria. Water, soil and dominant plants were collected from 46 sampling points for a period of 1 year and analysed using ICP-AES. The order of heavy metals presence in soil samples was as follow: Zn>Cr>Cu>Pb>Cd>Ni. The Zn concentration was the highest whereas the lowest concentration was Ni. All water samples showed varying degrees of contamination across all the sampling points in these wetlands. A greater percentage of all metals concentration for Pb, Cd, Cr and Ni were higher than the permissible limit set by World Health Organisation. Pb ranged from 0.01±0.00 to 0.91±0.04 mg/L, Cd from 0.01±0.00 to 0.31±0.02 mg/L, Cr from 0.05±0.00 to 1.15±0.01 mg/L, Ni from 0.01±0.00 to 0.52±0.03, Cu from 0.21±0.01 to 1.11±0.01 mg/L and Zn ranged from 0.15±0.00 to 10.28±0.02 mg/L. The median values of each metal that the shoots and roots of individual plants accumulated metals in the order: Zn>Cu>Pb>Cr>Ni>Cd. *Ipomea aquatica* had the highest concentration of Pb in its shoot (1.12 mg/kg) while *Ludwigia adscendens* had the least (1.12 mg/kg) in its shoot. Pb level in the roots was highest in *Eichonia crassipes* (5.69 mg/kg). The highest level of Cr in shoot (2.23 mg/kg) and root (5.41 mg/kg) was observed in *Commelina benghalensis* while Cr concentration is lowest in the shoot (0.04 mg/kg) and root (0.18 mg/kg) of *Althernathera philoxerrides*. *Ludwigia adscendens* had the lowest concentration of Ni in its root (0.01 mg/kg). The highest shoot concentration of Cu (4.21 mg/kg) was observed in *Eichonia crassipes* while *Ipomea aquatica* had the lowest concentration in its shoot (0.23 mg/kg). *Paspalum vaginatum*'s root had the highest Cu concentration (12.32 mg/kg) while lowest concentration of Cu was observed in the root of *Sagittaria sagittifolia* (0.69 mg/kg). Transfer factors for most of the plants species were less than 1, indicating that metals accumulated by these plants were largely retained in the roots. *A. philoxerrides* had translocation factor greater than one for Ni (10.30), while for Cr was 1.25 and 1.40. This present findings indicate that, despite ecological similarities, the different plant species tend to respond differently to exposure to heavy metals and also in their ability to accumulate the various metals. Thus, heavy metals sequestration from the soil to these plants characterized them as metals pollution indicators.

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Nigeria is richly endowed with large numbers of wetlands ecosystem, and the Lagos lagoon has been identified as one of the fourteen major wetland belts in the country (Oyebande, *et al.*, 2003; Asibor, 2009). Wetlands are very important subsystem of the general ecosystem as they play vital roles in the sustenance of both surface and ground water resources of the earth. The importance of any wetland is sited within its functions and values. Notably, the functions of wetlands include flood control, groundwater recharge, coastal protection, sediment traps, atmospheric equilibrium and waste treatments. As well as providing nurseries for aquatic life and habitat for upland mammals (Ramsar Convention, 2007; Chidi and Ominigbo, 2010). As an ecosystem, wetlands are valued for their contribution to ecological balance and biodiversity. They also aid in food production especially in the cultivation of rice and vegetables. Rapid urbanization and industrialization have led to increase in pollution from landfill leachates, industrial

effluents, vehicular emissions, fossil fuels, fertilizer erosion from agricultural run-off, herbicides and pesticides, sewage and municipal wastes. All these contributed to the accumulation of pollutants in nearby aquatic systems (Adesuyi *et al.*, 2015a; Adesuyi *et al.*, 2016). Among the worst environmental contaminants are the heavy metals (Njoku *et al.*, 2013). They are serious pollutants due to their toxicity, persistence in natural conditions and ability to be incorporated into food chains (Akinola *et al.*, 2008; Adesuyi *et al.*, 2015b). Some of these metals includes lead (Pb), cadmium (Cd) copper (Cu), zinc (Zn) nickel (Ni) and chromium (Cr). For an area to be designated a wetland, it must possess water, wetland plants and wetland soils (Asibor, 2009). Wetlands as an ecosystem is characterized by the presence of plants that are adapted to life in the soil formed under saturated conditions (Mitsch and Gosselink, 1993). Some of these plants include *Alternanthera philoxeroides*, *Commelina benghalensis*, *Eichhornia crassipes*, *Enhydra*

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fluctuans, *Ipomoea aquatica*, *Ludwigia adscendens*, *Sagittaria sagittifolia* *Pistia stratiotes* and the sedges. These plants enable the direct assessment of the response of wetland vegetation to changes in aquatic discharge. In the past few decades, an increasing use of higher plant leaves as biomonitors for heavy metal pollution has been on the increase especially in sensitive and urban areas (Yasar *et al.*, 2010; Akguc *et al.*, 2010). A study by Ghavzan *et al.*, (2006) demonstrated that *Pistia stratiotes* was associated with high pollution rates in water bodies, while Niaz and Rasul (1998) showed that *Pistia stratiotes* and *Eichhornia crassipes* could be used as biological indicators in wetland habitats. A good biomonitor will indicate the presence of the pollutant and also provide additional information about the quantity and intensity of the exposure (Wolterbeek, 2002). Metal uptake by vegetation can be element specific, plant species specific and plant tissue specific (Du Laing *et al.*, 2009; Matache *et al.*, 2013). Rai *et al.* (1995) identified *Ceratophyllum demersum* as a hyperaccumulator species for cadmium. *Salvinia minima* was discovered to have the capacity to remove lead from aqueous solutions (Estrella-Gómez *et al.*, 2009), whilst *Cladophora sp.* is able to hyperaccumulate arsenic (Pell *et al.*, 2013). The capacity of plants to hyperaccumulate trace elements is influenced by the presence of humic substances or other chelating substances, temperature and salinity (Fritioff *et al.*, 2005; Matache *et al.*, 2013). Knowledge about the bioaccumulation of heavy metals in wetlands plant species in Lagos lagoon wetlands is limited. Hence, the aims of this paper are to investigate the amount of heavy metals in dominant plants species collected from Lagos lagoon wetlands; and to assess the opportunity of using these aforementioned plant species as indicators of the aquatic ecosystems pollution level with heavy metals and also their feasibility for phytoremediation.

MATERIALS AND METHODS

Study Area: The Lagos lagoon wetlands forms part of an intricate system of water ways made up of lagoons and creeks that are found along the coast line of Nigeria, Benin Republic. It is located between longitudes 3° 23' and 3° 40' E, and latitudes 6° 22' and 6° 38' N (Figure 1). Lagos lagoon is the largest of the four lagoon systems, mainly of the Gulf of Guinea, 2 covering an area of 257.49 km² (Philips *et al.*, 2012). The area surrounding the Lagos lagoon is probably the most urbanized and industrialized in Nigeria (Okoye *et al.*, 1991). This urban expansion in an unsystematic manner has had serious repercussions on the environmental quality of many parts of the wetlands (Obiefuna *et al.*, 2013).

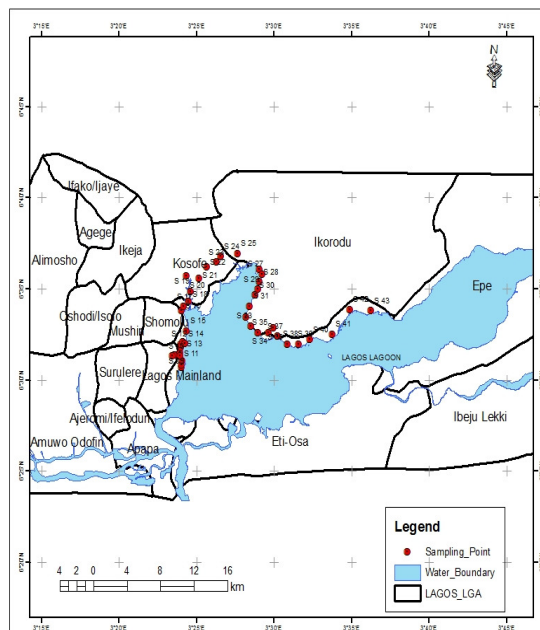


Fig 1: Lagos Lagoon showing the Study areas

Sampling and data collection: The samples were collected in these wetlands for a year (June 2015 and May 2016) during different vegetation seasons from 46 sampling points, in order to obtain accurate data set. For each location, a sample was composed of three plants of the same species collected and pooled into a uniform sample. Thus the water samples were collected at the depth of 0.5 m below the surface and stored in 500 ml polyethylene bottles pre-cleaned with deionized water and rinsed with the sample to be collected from different sites. The soil samples used in this study were collected at each site of plant collection from 0-10 cm depth and the exact location was obtained using Garmin GPS and coordinates recorded. Plant samples were randomly collected and labeled, put in individual polythene bags and brought to the laboratory. They were identified and authenticated in the Herbarium unit, Department of Botany, University of Lagos, Lagos.

Sample preparation and chemical analyses: The roots and the aboveground parts were separated and stored in the zipped polyethylene bags, respectively. The samples were washed thoroughly with tap water and rinsed with deionized water, then dried at 70 °C for 24 h in an oven. After the measurement of dry weights, the samples were ground into fine powder in an agate mortar. Precise weigh of each sample (0.2000 g) were used to prepare the solution of digestion reaction. A mixture of concentrated HNO₃ (2 ml) at 65% and H₂O₂ (1 ml) at 30% was used for digestion reaction. After cooling to the room temperature, the residue was

diluted with deionized water to 10 ml and analyzed for metals by ICP-AES (Zhang *et al.*, 2010).

The water samples were filtered through 0.45µm Millipore filters and acidified to pH <2 using concentrated nitric acid and then stored in the dark at 4 °C. The concentrations of heavy metals were measured by inductively coupled plasma-atomic emission spectrometry (ICP-AES). All of soil samples were air-dried at room temperature immediately after collection and sieved through a 2-mm nylon sieve to remove coarse debris. For each sample, 30 g sub-

sample of soils was ground with an agate mortar until all particles passed a 100-mesh nylon sieve. A 0.1000 g sub-sample of dried and homogenized soil was accurately weighed and digested with 2 ml HNO₃, 1 ml HClO₄ and 5 ml HF at a temperature of 90±190 °C for 16 h. The residue was then dissolved in 2 ml of 4 mol/L HCl and diluted to 10 ml with deionized water and analyzed for a number of heavy metals (Pb, Cd, Cr, Ni, Cu, and Zn) by inductively coupled plasma-atomic emission spectrometry (ICP-AES) (Zhang *et al.*, 2010).

Bioaccumulation factor (BAF) and Translocation factor (TF): BAF of the heavy metal was calculated by:

$$BAF = \frac{\text{level of metal in shoot (mg/kg)}}{\text{level of metal in growing medium (mg/kg)}} - (\text{Rezvani and Zaefarian, 2011})$$

Translocation from shoot to root was measured by TF which is given below:

$$TF = \frac{\text{Level of metal in shoot}}{\text{level of metal in root}} - (\text{Rezvani and Zaefarian, 2011})$$

Statistical analysis: Statistical analysis of data was performed using GraphPad 7.0. Nonparametric test was used to determine any significant difference in metal contents among different sample sites at the level of $p \leq 0.05$. Correlations among metal concentrations in the water, soils and plants samples were evaluated using Pearson correlation coefficients.

RESULTS AND DISCUSSIONS

Mean heavy metals in sediments and soils of wetlands:

The level of heavy metals in soils obtained from the wetlands is presented in table 1. The concentrations of metal displayed a wide variation as reflected by the large standard deviation values and high coefficient of variation, suggesting the spatial variation of metals is obvious (Tam *et al.*, 2010). Also, analysis of variance revealed a significant ($p < 0.05$) variation in the spatial distribution of all the heavy metals of concentrations which is an indication of anthropogenic influence and the extent of metal pollution in the Lagos lagoon wetland soils. The order of heavy metals presence in soil samples was as follow: Zn>Cr>Cu>Pb>Cd>Ni. The Zn concentration was the highest whereas the lowest concentration was Ni. This is in agreement with earlier studies by Gupta *et al.* (2009) and Zhang *et al.* (2010) that Zn was maximally concentrated in riverine sediments collected from Ganges at Allahabad and soils from riparian wetlands in the Pearl River Estuary, South China. Pb concentration in the soils ranged from 0.05 to 7.89 mg/kg with coefficient of variation of 108.22%. The mean concentrations of Pb were all below the WHO/FAO (2001) permissible limit of 50.00 mg/kg for soils. The major sources of Pb in the

wetlands soils might be attributed to industrial waste water discharge, pesticides, and fertilizer impurities, emissions from mining and smelting operations and atmospheric fallout from the combustion of fossil fuels. Typical mean Pb concentration for surface soils worldwide is 32 mg/kg and ranges from 10 to 67 mg/kg (Kabata-Pendias and Pendias, 2001). Cd ranged from 0.00 to 2.01 mg/kg with the highest coefficient of variation of 143.30%. The mean concentrations of Cd recorded at all sites were below the WHO/FAO (2001) permissible limit of 3 mg/kg for soils. Cadmium is very much connected with non-residual fractions of heavy metals and thus makes them mobile and potentially bio-available for uptake by plants (Zhang *et al.*, 2009). A typical characteristic of flooded wetland soils is the development of anoxic, reduced conditions. This results in accumulation of organic matter in the soil, formation of metal sulfides, and commonly near-neutral pH. Cd can remain immobilized in wetland soils under these conditions (Jacob *et al.*, 2013). Another important source of Cd is the use of mineral phosphate fertilizer, which typically contains high Zn and Cd concentrations in addition to other elements. Phosphate fertilizer application can directly increase both the Pb and Cd concentrations in the soil solution (Lambert *et al.*, 2007). Wetland soils are also known to show different biogeochemical behavior when compared with dryland soils. Cr ranged from 0.01 to 6.53 mg/kg with coefficient of variation of 122.58%. The high concentration of Cr recorded in this wetland soils could be as a result of the open dumping of municipal and e-wastes, and effluent discharge at some of the sites. The mean concentrations of Cr recorded at all sites were below

the WHO/FAO (2001) permissible limit. The occurrence of Cr in soils could be due to disposal of waste consisting of lead-chromium batteries, coloured polythene bags, discarded plastic materials and empty paint containers (Amos-Tautua *et al.*, 2014). Chromium mobility in wetlands depends on sorption characteristics of the soil, including clay content, iron oxide content, and the amount of organic matter present, and they are transported by surface runoff to surface waters in its soluble or precipitated form (Wuana and Okieimen, 2011). Ni has the lowest concentration with the value range of 0.01 to 1.10 mg/kg, with a coefficient of variation of 101.29%. The mean concentrations of Ni recorded at the various sites were below the WHO/FAO (2001) permissible limit of 50 mg/kg for soils. Nickel is an element that occurs in the environment only at very low levels and is essential in small doses, but it can be dangerous when the maximum tolerable amounts are exceeded (Wuana and Okieimen, 2011).The major sources of nickel contamination in the soil are metal plating industries, combustion of fossil fuels, and nickel mining and electroplating (Khodadoust *et al.*, 2004). Cu ranged from 0.46 to 3.55 mg/kg with a coefficient of variation of 53.09% which is the lowest of the heavy metals

assessed. The mean concentrations of copper recorded were below the WHO/FAO (2001) permissible limit of 100 mg/kg for soils. Zn has the highest concentration value that ranged from 0.10 to 15.06 mg/kg with a coefficient of variation 132.15%. There was a high variation in the spatial distribution of Zn. The variation in concentration level of Zinc in these soils showed the impact of pollution from anthropogenic activities rather than lithogenic one. However, the maximum mean concentration of Zn recorded was lower than the WHO/FAO (2001) permissible limit of 300.00 mg/kg for soils. Cu and Zn are two important essential elements for plants, microorganisms, animals, and humans. The connection between soil and water contamination and metal uptake by plants is determined by many chemical and physical soil factors as well as the physiological properties of the plants. Soils contaminated with trace metals may pose both direct and indirect threats: direct, through negative effects of metals on crop growth and yield, and indirect, by entering the human food chain with a potentially negative impact on human health (Wuana and Okieimen, 2011).

Table 1: Heavy metals in wetlands sediments and soils, and the international maximum allowable standards

S/N	Sampling points	Pb	Cd	Cr	Ni	Cu	Zn
1	S 01	1.25±0.00	0.01±0.00	1.09±0.02	0.01±0.00	2.55±0.05	4.15±0.05
2	S 02	1.59±0.02	0.01±0.00	0.50±0.05	0.01±0.00	3.00±0.00	1.09±0.02
3	S 03	1.05±0.03	0.01±0.00	0.41±0.06	0.01±0.00	2.75±0.03	1.06±0.00
4	S 04	0.95±0.01	0.01±0.00	0.13±0.01	0.01±0.00	3.1±0.00	0.78±0.06
5	S 05	0.76±0.01	0.01±0.00	0.17±0.02	0.03±0.00	3.55±0.05	0.96±0.02
6	S 06	0.05±0.02	0.12±0.02	0.89±0.06	0.05±0.00	1.60±0.06	0.79±0.09
7	S 07	0.12±0.02	0.46±0.34	0.67±0.07	0.19±0.03	1.57±0.05	0.88±0.07
8	S 08	0.59±0.02	0.06±0.01	0.54±0.04	0.10±0.00	1.26±0.00	0.10±0.00
9	S 09	0.42±0.01	0.03±0.01	0.47±0.07	0.07±0.00	1.55±0.05	1.01±0.01
10	S 10	0.34±0.04	0.51±0.40	0.56±0.04	0.17±0.00	1.85±0.04	2.57±0.10
11	S 11	2.15±0.01	0.01±0.00	1.23±0.02	0.20±0.03	0.96±0.03	2.56±0.04
12	S 12	1.96±0.02	0.03±0.00	3.91±0.08	0.32±0.03	0.56±0.06	8.34±0.04
13	S 13	1.89±0.01	0.01±0.00	1.17±0.02	0.67±0.03	0.89±0.06	1.45±0.05
14	S 14	1.82±0.03	0.01 ±0.00	1.05±0.00	0.54±0.10	0.46±0.04	4.89±0.04
15	S 15	2.23±0.01	0.10±0.00	4.67±0.03	0.65±0.00	0.89±0.07	2.67±0.05
16	S 16	0.71±0.01	0.20±0.02	0.34±0.02	0.05±0.00	0.87±0.02	1.45±0.03
17	S 17	0.53±0.00	0.15±0.00	6.53±0.03	0.01±0.00	1.65±0.01	1.01±0.00
18	S 18	0.99±0.00	0.18±0.00	3.90±0.09	0.03±0.00	1.09±0.00	0.75±0.10
19	S 19	0.56±0.02	0.27±0.00	4.05±0.03	0.01±0.00	1.19±0.02	0.34±0.02
20	S 20	1.65±0.03	0.29±0.03	0.34±0.02	0.15±0.03	1.54±0.04	0.48±0.07
21	S 21	7.89±0.01	1.56±0.04	6.53±0.03	1.10±0.00	3.20±0.00	15.06±0.03
22	S 22	7.45±0.01	1.99±0.00	3.90±0.09	0.89±0.09	2.95±0.04	3.66±0.06
23	S 23	3.62±0.02	2.01±0.00	4.05±0.03	1.05±0.00	2.85±0.05	2.09±0.02
24	S 24	2.99±0.00	1.55±0.00	2.96±0.03	0.85±0.05	1.55±0.03	1.26±0.04
25	S 25	3.09±0.03	0.81±0.00	0.95±0.03	0.94±0.04	2.20±0.00	2.58±0.08
26	S 26	1.07±0.04	0.56±0.06	0.56±0.04	0.92±0.04	0.89±0.08	1.45±0.03
27	S 27	0.95±0.02	0.4±0.00	0.67±0.07	0.62±0.04	0.97±0.02	0.87±0.06
28	S 28	0.88±0.03	0.19±0.00	0.59±0.10	0.52±0.00	1.05±0.00	0.67±0.10
29	S 29	0.65±0.01	0.36±0.00	0.66±0.06	0.44±0.04	0.91±0.06	0.78±0.05
30	S 30	0.95±0.02	0.4±0.00	0.93±0.05	0.31±0.00	1.10±0.01	1.19±0.02
	WHO/FAO (2001)	50.00	3.00	-	50.00	100.00	300.00
	EU standard	300.00	3.00	150.00	75.00	140.00	300.00

Heavy metals in surface water: Table 2 summarizes the total mean concentrations and standard error of mean of Pb, Cd, Cr, Ni, Cu and Zn (mg/L) in water from the wetlands of Lagos lagoon. All metals showed varying degrees of contamination across all the sampling points in these wetlands. A greater percentage of all metals (Pb, Cd, Cr and Ni) were

higher than the permissible limit set by WHO (2011) and NIS (2007) except Cu and Zn. This clearly reflects the influence of the urbanization and advancement in industrialization of Lagos on the wetlands environments. Analysis of variance of metals in surface water for all sampling points showed no significant differences ($p>0.05$).

Table 2: Mean heavy metal level (\pm SEM) in surface water of Lagos lagoon wetlands (mg/L)

S/N	Sampling points	Pb	Cd	Cr	Ni	Cu	Zn
1	S 01	0.84 \pm 0.04	0.01 \pm 0.00	0.10 \pm 0.00	0.14 \pm 0.03	0.85 \pm 0.06	0.17 \pm 0.01
2	S 02	0.91 \pm 0.04	0.02 \pm 0.00	0.16 \pm 0.02	0.12 \pm 0.02	0.63 \pm 0.04	0.20 \pm 0.01
3	S 03	0.45 \pm 0.05	0.08 \pm 0.01	0.21 \pm 0.02	0.09 \pm 0.00	0.86 \pm 0.06	0.40 \pm 0.03
4	S 04	0.65 \pm 0.03	0.06 \pm 0.00	0.73 \pm 0.03	0.07 \pm 0.00	1.02 \pm 0.00	0.19 \pm 0.02
5	S 05	0.74 \pm 0.03	0.15 \pm 0.01	0.67 \pm 0.04	0.05 \pm 0.00	0.91 \pm 0.06	0.38 \pm 0.03
6	S 06	0.23 \pm 0.02	0.01 \pm 0.01	0.12 \pm 0.00	0.10 \pm 0.00	0.78 \pm 0.05	0.60 \pm 0.03
7	S 07	0.23 \pm 0.03	0.01 \pm 0.01	0.18 \pm 0.01	0.11 \pm 0.02	0.65 \pm 0.07	0.54 \pm 0.02
8	S 08	0.10 \pm 0.00	0.01 \pm 0.02	0.23 \pm 0.02	0.19 \pm 0.04	0.72 \pm 0.04	0.32 \pm 0.02
9	S 09	0.05 \pm 0.00	0.01 \pm 0.02	0.59 \pm 0.03	0.21 \pm 0.01	0.83 \pm 0.04	0.21 \pm 0.00
10	S 10	0.09 \pm 0.00	0.02 \pm 0.01	0.90 \pm 0.04	0.14 \pm 0.06	0.92 \pm 0.07	0.15 \pm 0.00
11	S 11	0.10 \pm 0.01	0.01 \pm 0.01	1.07 \pm 0.00	0.09 \pm 0.01	0.75 \pm 0.04	10.28 \pm 0.02
12	S 12	0.15 \pm 0.01	0.00 \pm 0.00	0.90 \pm 0.03	0.11 \pm 0.00	0.79 \pm 0.04	2.31 \pm 0.02
13	S 13	0.09 \pm 0.01	0.00 \pm 0.00	0.87 \pm 0.02	0.30 \pm 0.07	0.85 \pm 0.03	0.26 \pm 0.03
14	S 14	0.15 \pm 0.00	0.00 \pm 0.00	0.94 \pm 0.04	0.22 \pm 0.03	0.76 \pm 0.04	0.34 \pm 0.03
15	S 15	0.19 \pm 0.01	0.00 \pm 0.00	0.88 \pm 0.03	0.19 \pm 0.02	0.69 \pm 0.05	0.29 \pm 0.02
16	S 16	0.68 \pm 0.02	0.17 \pm 0.02	0.15 \pm 0.00	0.01 \pm 0.00	0.96 \pm 0.04	0.19 \pm 0.01
17	S 17	0.75 \pm 0.03	0.09 \pm 0.01	0.20 \pm 0.02	0.00 \pm 0.00	0.26 \pm 0.05	0.32 \pm 0.02
18	S 18	0.88 \pm 0.02	0.15 \pm 0.02	0.35 \pm 0.02	0.05 \pm 0.01	0.21 \pm 0.01	0.72 \pm 0.19
19	S 19	0.57 \pm 0.02	0.12 \pm 0.02	0.60 \pm 0.05	0.03 \pm 0.00	0.24 \pm 0.04	0.80 \pm 0.32
20	S 20	0.45 \pm 0.03	0.09 \pm 0.01	0.52 \pm 0.02	0.10 \pm 0.01	0.35 \pm 0.07	0.67 \pm 0.03
21	S 21	0.03 \pm 0.01	0.05 \pm 0.02	0.97 \pm 0.02	0.39 \pm 0.09	1.11 \pm 0.01	3.88 \pm 0.04
22	S 22	0.01 \pm 0.01	0.03 \pm 0.00	1.05 \pm 0.00	0.42 \pm 0.03	1.05 \pm 0.00	4.01 \pm 0.00
23	S 23	0.06 \pm 0.02	0.05 \pm 0.00	1.15 \pm 0.01	0.34 \pm 0.06	0.92 \pm 0.07	1.12 \pm 0.01
24	S 24	0.03 \pm 0.01	0.12 \pm 0.02	0.78 \pm 0.03	0.21 \pm 0.03	0.88 \pm 0.04	0.86 \pm 0.02
25	S 25	0.21 \pm 0.01	0.11 \pm 0.01	0.55 \pm 0.03	0.15 \pm 0.03	0.76 \pm 0.04	0.65 \pm 0.03
26	S 26	0.01 \pm 0.00	0.25 \pm 0.03	0.05 \pm 0.00	0.52 \pm 0.03	0.65 \pm 0.04	0.89 \pm 0.04
27	S 27	0.01 \pm 0.00	0.31 \pm 0.02	0.23 \pm 0.03	0.45 \pm 0.06	0.60 \pm 0.05	0.34 \pm 0.03
28	S 28	0.15 \pm 0.01	0.18 \pm 0.02	0.77 \pm 0.02	0.39 \pm 0.04	0.50 \pm 0.04	6.33 \pm 0.03
29	S 29	0.09 \pm 0.00	0.21 \pm 0.01	0.84 \pm 0.04	0.36 \pm 0.07	0.32 \pm 0.32	0.19 \pm 0.01
30	S 30	0.07 \pm 0.00	0.29 \pm 0.03	0.34 \pm 0.02	0.32 \pm 0.03	0.49 \pm 0.04	0.42 \pm 0.03

Heavy Metals in plants species parts: The overall Pb, Cd, Cr Ni, Cu, and Zn contents in the above and below ground portions of the plants studied have been provided in Table 3. In this study, it is clearly evident from the median values of each metal that the shoots and roots of individual plants accumulated metals in the order: Zn>Cu>Pb>Cr>Ni>Cd. Heavy metals concentration in the shoot and root of sampled plants showed varying accumulation and translocation values. This varying trend is similar among the sampled plants. *Ipomea aquatica* had the highest concentration of Pb in its shoot (1.12 mg/kg) while *Ludwigia adscendens* had the least (1.12 mg/kg) in its shoot. Pb level in the roots was highest in *Eichonia crassipes* (5.69 mg/kg) and least was in the roots of *Ludwigia adscendens* (0.15 mg/kg). All the plants harvested for this study were healthy and did not show any toxicity symptoms, however, excess Pb in plants had been reported to inhibit growth while Cd can

inhibit photosynthesis and mineral assimilation causing leaf chlorosis, necrosis, and abscission (Adesuyi *et al.*, 2015a; Jha *et al.*, 2016). *Ipomea involucrata* also had the highest level of Cd in its shoots (0.45 mg/kg) while the shoots of *Phragmites australis*, *Eichonia crassipes*, *Ludwigia adscendens*, and *Phragmites australis* all had the least Cd level (0.01 mg/kg) in their shoots. But the root of *Cyperus rotundus* had the highest concentration of Cd (1.50 mg/kg) while the root of *Pistia stratiotes* had the lowest concentration (0.01 mg/kg). This lagoon wetlands foster plants and animals that contribute to food webs and are eaten by humans. Cd uptake in organisms is strongly affected by the Zn concentrations in the substrate (Brzóška and Moniuszko-Jakoniuk, 2001; Jacob *et al.*, 2013), because both metals compete for the same uptake mechanisms. As a result, higher uptake and translocation in plants are observed when the Cd/Zn ratio is relatively high (Chaney, 2010).

Table 3: Heavy metals in wetlands plants species parts (mg/kg)

Plants species	Sampling points	Part	Pb	Cd	Cr	Ni	Cu	Zn
<i>Ludwigia adscendens</i>	1	Shoot	0.21	0.01	0.35	0.01	1.88	2.65
		Root	2.05	0.01	0.89	0.01	2.95	4.01
	3	Shoot	0.05	0.01	0.18	0.02	1.34	0.63
		Root	0.15	0.03	0.60	0.05	1.50	1.10
	9	Shoot	1.01	0.09	0.08	0.16	1.45	0.67
		Root	3.58	0.35	0.90	0.51	2.01	2.42
13	Shoot	0.31	0.18	0.11	0.14	0.62	1.15	
	Root	0.75	0.72	0.67	0.60	1.30	2.54	
<i>Eichonia crassipes</i>	2	Shoot	0.09	0.01	0.21	0.01	2.09	0.95
		Root	1.19	0.05	0.75	0.02	3.31	1.31
	26	Shoot	1.62	0.19	0.42	0.16	4.21	3.65
		Root	5.69	0.65	0.55	0.30	7.56	4.87
29	Shoot	0.96	0.32	0.19	0.56	2.97	3.23	
	Root	3.65	1.21	0.65	1.62	5.63	4.89	
<i>Althernathera philoxeroides</i>	6	Shoot	0.09	0.03	0.04	0.01	0.56	0.98
		Root	0.50	0.15	0.18	0.03	1.02	1.23
	10	Shoot	0.10	0.05	0.22	0.05	0.76	0.23
		Root	0.35	0.20	0.97	0.30	1.05	1.52
	14	Shoot	0.89	0.38	0.87	1.03	1.45	1.89
		Root	2.50	1.05	2.50	0.10	2.56	2.86
	19	Shoot	1.10	0.07	0.35	0.08	2.21	4.64
		Root	4.21	0.25	0.28	0.19	4.10	10.55
21	Shoot	0.12	0.08	0.21	0.07	2.32	1.56	
	Root	0.24	0.22	0.15	0.16	4.04	2.87	
<i>Commelina benghalensis</i>	7	Shoot	0.24	0.21	2.23	0.18	2.01	1.96
		Root	1.78	1.12	5.41	0.67	2.98	14.25
	11	Shoot	0.19	0.23	1.16	0.21	0.56	2.02
		Root	1.60	1.19	3.52	0.76	1.00	4.21
20	Shoot	0.97	0.10	0.30	0.11	2.29	1.29	
	Root	1.81	0.30	0.25	0.25	3.55	2.45	
<i>Enhydra fluctuans</i>	8	Shoot	0.31	0.10	0.92	0.22	1.54	1.72
		Root	2.30	0.94	3.53	1.00	2.66	3.35
18	Shoot	0.13	0.01	0.08	0.05	2.08	0.99	
	Root	0.39	0.05	0.10	0.10	2.67	1.25	
<i>Ipomea aquatica</i>	15	Shoot	1.12	0.21	0.24	0.09	0.23	2.10
		Root	3.33	0.65	0.88	0.30	0.77	5.18
	23	Shoot	1.01	0.32	0.36	0.18	2.19	5.21
		Root	3.28	0.89	1.00	0.30	6.56	14.54
28	Shoot	0.21	0.21	0.26	0.11	1.54	2.12	
	Root	0.85	0.78	1.02	0.30	3.56	4.40	
<i>Nymphaea lotus</i>	25	Shoot	0.10	0.02	0.08	0.12	1.26	1.54
		Root	0.25	0.15	0.10	0.20	3.54	1.89
	30	Shoot	1.09	0.18	0.12	1.86	1.78	10.43
<i>Cyperus rotundus L</i>	17	Shoot	0.16	0.01	0.06	0.01	1.98	2.56
		Root	0.30	0.05	0.21	0.05	5.50	4.01
	27	Shoot	0.23	0.12	0.28	0.05	3.19	3.51
24	Shoot	1.03	1.50	0.98	0.24	4.62	4.78	
	Root	0.21	0.05	0.32	0.05	1.98	1.98	
<i>Sagittaria sagittifolia</i>	5	Shoot	1.08	0.73	0.64	0.14	4.44	3.12
		Root	0.30	0.10	1.95	0.09	0.34	2.27
<i>Phragmites australis</i>	4	Shoot	1.75	1.12	4.12	0.42	0.69	4.15
		Root	0.49	0.01	1.56	0.04	1.54	4.43
<i>Ipomoea involucrata</i>	12	Shoot	1.80	0.03	2.97	0.12	1.70	7.52
		Root	0.23	0.45	0.78	0.19	0.15	1.56
<i>Pistia stratiotes</i>	16	Shoot	1.05	1.01	1.20	0.68	0.84	2.19
		Root	0.12	0.01	0.25	0.10	1.97	1.54
<i>Paspalum vaginatum</i>	22	Shoot	0.42	0.02	0.10	0.32	3.00	5.75
		Root	0.22	0.28	0.21	0.05	3.69	8.95
		Shoot	1.21	1.01	0.71	0.20	12.32	16.54
		Root	1.21	1.01	0.71	0.20	12.32	16.54

The highest level of Cr in shoot (2.23 mg/kg) and root (5.41 mg/kg) was observed in *Commelina benghalensis* while Cr concentration is lowest in the shoot (0.04 mg/kg) and root (0.18 mg/kg) of *Althernathera philoxeroides*. *Nymphaea lotus* had the highest concentration both in its shoot (1.86 mg/kg) and its root (1.11 mg/kg) while *Ludwigia adscendens* and *Eichonia crassipes* both had the lowest shoot concentration (0.01 mg/kg). *Ludwigia adscendens* had the lowest concentration of Ni in its root (0.01 mg/kg). The highest shoot concentration of Cu (4.21 mg/kg) was observed in *Eichonia crassipes* while *Ipomea aquatica* had the lowest concentration in its shoot (0.23 mg/kg). *Paspalum vaginatum*'s root had the highest Cu concentration (12.32 mg/kg) while lowest concentration of Cu was observed in the root of *Sagittaria sagittifolia* (0.69 mg/kg). The highest Zn concentration in plant shoots was observed in *Nymphaea lotus* (10.43 mg/kg) while *Althernathera philoxeroides* had the lowest Zn concentration (0.23 mg/kg) in its shoot. *Paspalum vaginatum* had the highest concentration of Zn in its root (16.54 mg/kg) while *Ludwigia adscendens* had the lowest concentration (1.10 mg/kg). In this study, the general trend of higher concentration of heavy metals in plants roots than in shoots was obvious which seems to indicate bioaccumulation. Heavy metal species can have different bioavailability to wetlands plants because of physiological differences with respect to uptake sites and uptake mechanisms (Jha *et al.*, 2016). Soil geochemistry influences metal speciation in soils and sediments while plant physiology and genotypic differences control the ability of plants to accumulate plant-available forms of metals (Brook and Robinson, 1998).

The bioaccumulation factors for shoots (BAF) and the transfer factors (TF) have also been provided to understand their accumulation potential (Table 4). Bio-accumulation Factor (BAF) is used to quantify the toxic element accumulation efficiency in plants by comparing the concentration in the plant part and an external medium (Rezvani and Zaefarian, 2011). BAF has been categorised as: <1 excluder, 1 - 10 accumulator and >10 hyperaccumulator (Jha *et al.*, 2016). It can be seen from table 4 that the extent of accumulation of heavy metals by individual plants differed not only with the type of metal but also with the sampling points. For this study, Zn was the widely most accumulated in the plants, followed by Cu, Ni, Pb, Cr and the least was Cd. This is similar with the findings reported by Zhang *et al.* (2010) that the increasing accumulation of Zn in wetlands plant is positively correlated with the increasing soil or sediment metal concentrations. The plants bioaccumulation of Zn and Cd were highest and lowest, respectively, as also in the plants of this study. For, our hyper accumulating plants species, *Ludwigia adscendens* (Cd), *P. australis* (Cr), *I. involucreta* (Cd), *C. benghalensis* (Cd), *S. sagittifolia* (Cd and Cr), *E. fluctuans* (Cd and Cr) and *A. philoxeroides* (Cd) satisfy the criterion of BAF greater than 10. A plant's ability to translocate metals from the roots to the shoots is measured using the translocation factor (TF),

and TF greater than 1 (>1) signifies that the plant effectively translocate heavy metals from roots to the shoots (Rezvani and Zaefarian, 2011). Transfer factors for most of the plants species were less than 1, indicating that metals accumulated by these plants were largely retained in the roots. High accumulation of heavy metals in roots and low translocation in shoots may indicate appropriateness of a plant species for phytostabilisation (Archer and Caiwell, 2004). This mechanism of partitioning is a common strategy of plants to concentrate harmful ions in the roots in order to prevent toxicity to the leaves which is the site of photosynthesis and other metabolic activities (Jha *et al.*, 2016). *A. philoxeroides* had translocation factor greater than one for Ni (10.30), while for Cr was 1.25 and 1.40. It is clearly evident from this study that *A. philoxeroides* were potential accumulator of Ni and Cr (TF>1) in three of the sampling points across the wetlands. *N. lotus*, *C. benghalensis*, and *P. stratiotes* (TF>1) also exhibited considerable translocation potential for Ni (1.68), Cr (1.21) and Cr (2.50) respectively. This study corroborates the results of Jha *et al.* (2016) who suggested that *A. philoxeroides* shows considerable promise not only as an efficient accumulator of Pb and Cd in its roots but its ability to rapidly uptake heavy metals even at very low ambient levels could also make it an efficient indicator of the aquatic ecosystem quality.

Table 4: Bioaccumulation factor and Translocation factor

Plants species	Pb		Cd		Cr		Ni		Cu		Zn	
	BAFs	TF	BAFs	TF	BAFs	TF	BAFs	TF	BAFs	TF	BAFs	TF
<i>L. adscendens</i>	0.17	0.10	1.00	1.00	0.32	0.39	1.00	1.00	0.74	0.64	0.64	0.66
	0.05	0.33	1.00	0.33	0.44	0.30	2.00 ^a	0.40	0.49	0.89	0.59	0.57
	2.41 ^a	0.28	3.00 ^a	0.26	0.17	0.09	2.29 ^a	0.31	0.94	0.72	0.66	0.28
<i>E. crassipes</i>	0.16	0.41	18.00 ^b	0.25	0.09	0.16	0.21	0.23	0.69	0.48	0.79	0.45
	0.06	0.08	1.00	0.2	0.42	0.28	1.00	0.50	0.69	0.63	0.87	0.72
	1.51 ^a	0.28	0.34	0.29	0.75	0.76	0.17	0.53	4.73 ^a	0.56	2.52 ^a	0.75
<i>A. philoxeroides</i>	1.48 ^a	0.26	0.89	0.26	0.29	0.29	1.27 ^a	0.35	3.26 ^a	0.53	4.14 ^a	0.66
	1.80 ^a	0.18	0.25	0.20	0.05	0.22	0.20	0.33	0.35	0.55	1.40	0.79
	0.29	0.29	0.09	0.25	0.39	0.23	0.29	0.17	0.41	0.72	0.09	0.15
<i>C. benghalensis</i>	0.49	0.36	18.00 ^b	0.36	0.83	0.35	1.91 ^a	10.30 [*]	3.15 ^a	0.57	0.39	0.66
	1.96 ^a	0.26	0.26	0.28	0.09	1.25 [*]	8.00 ^a	0.42	1.86 ^a	0.54	13.7 ^a	0.44
	0.02	0.50	0.05	0.36	0.03	1.40 [*]	0.70	0.44	0.73	0.58	0.10	0.54
<i>E. fluctuans</i>	2.00 ^a	0.13	0.46	0.19	3.32 ^a	0.41	0.95	0.27	1.28 ^a	0.68	2.23 ^a	0.14
	0.09	0.12	23.0 ^b	0.19	0.94	0.33	1.05 ^a	0.28	0.58	0.56	0.79	0.48
	0.59	0.54	0.35	0.33	0.88	1.20 [*]	0.73	0.44	1.42 ^a	0.65	2.69 ^a	0.53
<i>I. aquatica</i>	0.53	0.13	1.70 ^a	0.11	1.70	0.26	2.20 ^a	0.22	1.22 ^a	0.58	17.2 ^b	0.51
	0.13	0.33	0.06	0.20	0.02	0.80	1.67 ^a	0.50	1.90 ^a	0.78	1.32	0.79
	0.50	0.34	2.10	0.32	0.05	0.27	0.14	0.30	0.26	0.29	0.79	0.41
<i>N. lotus</i>	0.28	0.31	2.10	0.32	0.09	0.36	0.17	0.60	0.77	0.33	2.49 ^a	0.36
	0.24	0.25	1.11	0.27	0.44	0.25	0.21	0.37	1.47 ^a	0.43	3.16 ^a	0.49
	0.03	0.40	0.03	0.13	0.08	0.80	0.13	0.60	0.57	0.36	0.59	0.81
<i>C. rotundus</i>	1.15 ^a	0.90	0.45	0.62	0.13	0.30	6.00 ^a	1.68 [*]	1.62 ^a	0.46	8.77 ^a	0.67
	0.30	0.53	0.07	0.20	0.01	0.29	1.00	0.20	1.20 ^a	0.36	2.53 ^a	0.64
	0.24	0.22	0.30	0.08	0.42	0.29	0.08	0.21	3.29 ^a	0.69	4.03 ^a	0.73
<i>P. stratiotes</i>	0.07	0.19	0.03	0.07	0.10	0.50	0.06	0.36	1.28 ^a	0.45	1.57 ^a	0.63
	0.39	0.17	10.0 ^b	0.09	11.47 ^b	0.47	3.00 ^a	0.21	0.09	0.49	2.37 ^a	0.55
	0.52	0.27	1.00	0.33	12.00 ^b	0.53	4.00 ^a	0.33	0.49	0.91	5.68 ^a	0.59
<i>P. australis</i>	0.12	0.22	15.00 ^b	0.45	0.20	0.65	0.59	0.28	0.27	0.18	0.19	0.71
	0.17	0.29	0.05	0.50	0.74	2.50 [*]	2.00 ^a	0.31	2.26 ^a	0.66	1.06 ^a	0.27
	0.03	0.18	0.14	0.28	0.05	0.29	0.06	0.25	1.25 ^a	0.29	2.45 ^a	0.54

^{*}TF greater than 1, ^aBAF less than 10, ^bBAF greater than 10

Numerous studies have shown *P. stratiotes* to be good accumulators of heavy metals as also observed (Valitutto *et al.*, 2006; Adamu *et al.*, 2015).

Conclusion: This present findings indicated that, despite ecological and morphological similarities across the wetlands, these plant species tend to respond differently to exposure to heavy metals and in

their ability to accumulate and detoxify the various metals. Thus, heavy metals sequestration from the soil to these plants characterized them as metals pollution indicators. The present investigation also revealed that *A. philoxeroides*, *N. lotus*, *C. benghalensis*, and *P. stratiotes* could be great potential for phytostabilisation and phytoextraction of Ni and Cr.

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