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WATER HYACINTH AND DUCKWEED AS INDICATOR OF HEAVY METAL POLLUTION IN RIVER ASA

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ABSTRACT

An investigation into the potentials of duckweed and water hyacinth as possible biomonitors of aquatic environment was carried out in River Asa. Water, duckweeds and water hyacinths were collected from six different locations along River Asa. The water and plant samples were analysed for physico-chemical and heavy metal contents with standard methods. Result showed that temperature ranged from 25.35 to 31.20 °C. pH was high at site 1 and low at 5. Site 2 was more turbid (21.35 N.T.U.) and TSS range was 182.0 – 218.4 mg/L. BOD and COD ranges were 7.78 - 13.90 mg/L and 129.00 - 150.30 mg/L respectively. Dissolved O_2, alkalinity and total hardness ranged between 12.00 and 20.32 mg/L, 5.41 and 16.90 mg/L, 12.90 and 14.40 mg/L respectively. Phosphate and nitrate levels ranged between 0.44 and 3.43 mg/L, 0.64 and 1.41 mg/L respectively. Of all the heavy metals in the plant tissues, Cd and Cr levels were highest. Except for Pb, no significant difference exists in heavy metal levels within the tissues of the two aquatic plants. The positive correlation of Cd, Cr, Ni and Pb levels in duckweed as well as those of Cd and Pb in water hyacinth to the levels in the river reflect the ability of the plants to monitor these metals. The study concluded that duckweed and water hyacinth could therefore serve as useful tools to monitor heavy metal pollution in rivers and other wetlands.

INTRODUCTION

Water is vital to the existence of all living organisms, but this valued resource is increasingly being threatened as human populations grow and demand more water of high quality for domestic purposes and economic activities (United Nations Environment Programme Global Environment Monitoring System / Water Programme, 2000). Water bodies are complex matrices that require careful use to ensure sustainable ecosystem functioning but their quality is a function of either or both natural influences and human activities (Kolawole *et al.*, 2011).

The emissions of pollutants to the environment are strongly associated with different types of human activities that discard wastewater of domestic and industrial origin. These pollutants are scavenged by the sediments or mobilized in solutions associated with biological and chemical mechanisms, thereby contaminating the environment and biota and causing serious impacts to the receiving ecosystems (Gismera *et al*., 2003; Pagnanelli *et al*., 2004; Rangel *et al*., 2011).

Rivers; the most important freshwater resources

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for man, are being polluted by indiscriminate disposal of sewage, industrial wastes and plethora of human activities, which affect their physicochemical characteristics and microbiological quality (Koshy and Nayar, 1999).

Rivers are used as site for the disposal of refuse, human sewage, waste waters from kitchens, abattoirs and industries. Streams and rivers running through areas of significant human influence such as farms, cities and industrial locations are therefore prone to pollution, especially in Nigeria where environmental protection regulations are not strictly enforced (Egborge, 1991; Adewoye, 2010). Although, these water bodies are continually being renewed by underground waters, many of the contaminants would still persist or become reinforced by indiscriminate waste disposals or other human activities (Healing and Greenwood, 1991; Adewoye, 2010). These contaminants are potential sources of heavy metal in the aquatic environment (Agtas *et al*. 2007; Muley *et al*. 2007).

Aquatic plants are known to accumulate metals from their environment (Ali and Soltan, 1999) and affect metal fluxes in those ecosystems (Jackson *et al*., 1994; Kara, 2005). From water, all plants have the ability to accumulate heavy metals which are essential for their growth and development (Kara *et al*., 2003). The bioaccumulation of heavy metals by aquatic macrophytes such as duckweed and water hyacinth is well documented in the literature (e.g. Vesk and Allaway, 1997; Khan *et al*., 2000; Kara *et al*., 2003, Kara, 2005; Lokeshwari and Chandrappa, 2006; Alka and Tripathi, 2007; Buta *et al*., 2011; Jafari and Akhavan, 2011). This property of bioaccumulation in duckweeds and water hyacinths has been found useful in monitoring and ameliorating the water bodies (Wang and Williams, 1988; Dunhabin and Bowner, 1992; Whitton and Kelley, 1995; Vajpayee *et al*., 1995) and is attributed to fast growth and increased reproduction in these plants (Kara *et al*., 2003; Kara, 2005).

Many cities in developing countries have been developed without adequate and proper planning (Tijani *et al*., 2002). This has led to indiscriminate actions including dumping of wastes into water, washing and bathing in open rivers among others especially in Nigeria where environmental protection regulations are not strictly enforced (Adekola and Eletta, 2007; Adewoye, 2010).

In an impacted environment by heavy metals, it is necessary to assess the bioavailability of heavy metals in order to understand their mobility in wetland ecosystem, monitor and control the sources of the pollutants and characterize the potential risks induced (Campbell and Tessier, 1989; Warren and Haack, 2001). The aim of the present study was to assess the heavy metals content in duckweeds and water hyacinths growing in river Asa in relation to the pollution level of the river.

MATERIALS AND METHODS

The study site

Asa River is a major water body in Ilorin which has a long history of contaminant input that has resulted in high levels of trace metals in its system. This process of pollution is linked mainly to the fact that this river is located in an industrialized and urbanized area of Ilorin that receives large amounts of domestic and industrial effluents (Kolawole *et al*., 2011).

Adekunle and Eniola (2008) reported that the major identified source of pollution of Asa River was direct runoff of effluents from the industries. However, domestic and faecal deposits linked to result in high level of eutrophication have also been reported (Eletta *et al*., 2005; Kolawole *et al*., 2011).

Six locations were selected for the study. The choice of locations was based on the ease of access to the River and the activities carried out along the River at such points. Location 1 is the Asa river dam which has a relatively low level of human activities and was taken as the control. Location 2 is behind the Nigerian Bottling Company while location 3 is beside Asa dam water treatment plant. Location 4 is along Gadabridge while location 6 is Railway station bridge. Location 5 is beside Kwara State House of Assembly (Fig. 1).

Sample collection

Water samples and representative samples of duckweed (*Lemna minor* L.) and water hyacinth (*Eichhornia crassipes* (Mart.) Solms.) were collected from the six sampling locations. The plant samples were collected from each location in polyethylene bags, washed thoroughly with distilled water and oven dried at 80 ºC while the water samples were collected from the bottom of the water in pre-cleaned plastic bottles. All the sample bottles containing the water samples were properly labelled and test was carried out on replicate samples. The physical parameters determined were temperature, pH, electrical conductivity, turbidity, total suspended solid (TSS). Temperature was measured using mercury in glass thermo- meter. Electrical conductivity was measured using HACH Wil-



Fig. 1 Aerial map showing the study area (Google, 2013)

son Grimes conductivity meter calibrated using 0.001 M KCl. Turbidity was measured using turbidity meter. TSS was determined by filtration method using pre-weighted filter paper. Total hardness, alkalinity and chemical oxygen demand (COD) were determined by titrimetric methods. Biochemical Oxygen Demand (BOD) was determined by titrating each samples against 0.01 M $Na_2S_2O_3$ after incubating with 1:1 KI – H_2SO_4 solution for 5 days. Winkler's test was used to determine dissolved oxygen (DO). Nitrate-nitrogen determination was done with the use of phenol disulphonic acid method (Jagessar and Sooknundun, 2011). Phosphate-phosphorus and heavy metals concentration were determined by digestion and spectrophotometric quantification.

Digestion and analysis of samples

The digestion of water and plant samples was done by the wet digestion according to the method by Plank (1992). The digested water and plant samples were subjected to heavy metal analyses with the use of Atomic Absorption Spectrophotometer UNICAM model 929.

The data generated were subjected to descriptive and inferential statistics. The means were compared with analysis of variance (ANOVA) and significant differences among means were separated with Duncan Multiple Range test. The strength and nature of relationship was done using Pearson's correlation coefficient and regression respectively.

RESULTS

The physical and chemical properties of water from the six points are shown in Table 1. Temperature range was 25.35 - 31.20 °C. pH was high at site 1 and low at 5. Site 2 was more turbid (21.35 N.T.U.) and TSS range was 182.0 - 218.4 mg / L, BOD and COD range were 7.78 - 13.90 mg / L and 129.00 - 150.30 mg / L respectively. Dissolved O_2, alkalinity and total hardness rangedbetween 12.00 and 20.32 mg / L, 5.41 and 16.90 mg / L, 12.90 and 14.40 mg / L respectively. Phosphate phosphorus and nitrate-nitrogen levels were 0.44 - 3.43 mg / L and 0.64 - 1.41 mg / L respectively.

Mean temperature was high at Site 5 with a corresponding lowest pH and electrical conductivity. Turbidity was high at Site 2 but TSS was highest at site 3. Site 4 had high COD, but site 1 had the high BOD and low DO due to its high organic / carbon load. Alkalinity and total hardness were high at sites 1 and 3 respectively. Site 4 had the highest phosphate phosphorus level (3.43 mg / L) while sites 1 and 6 both had

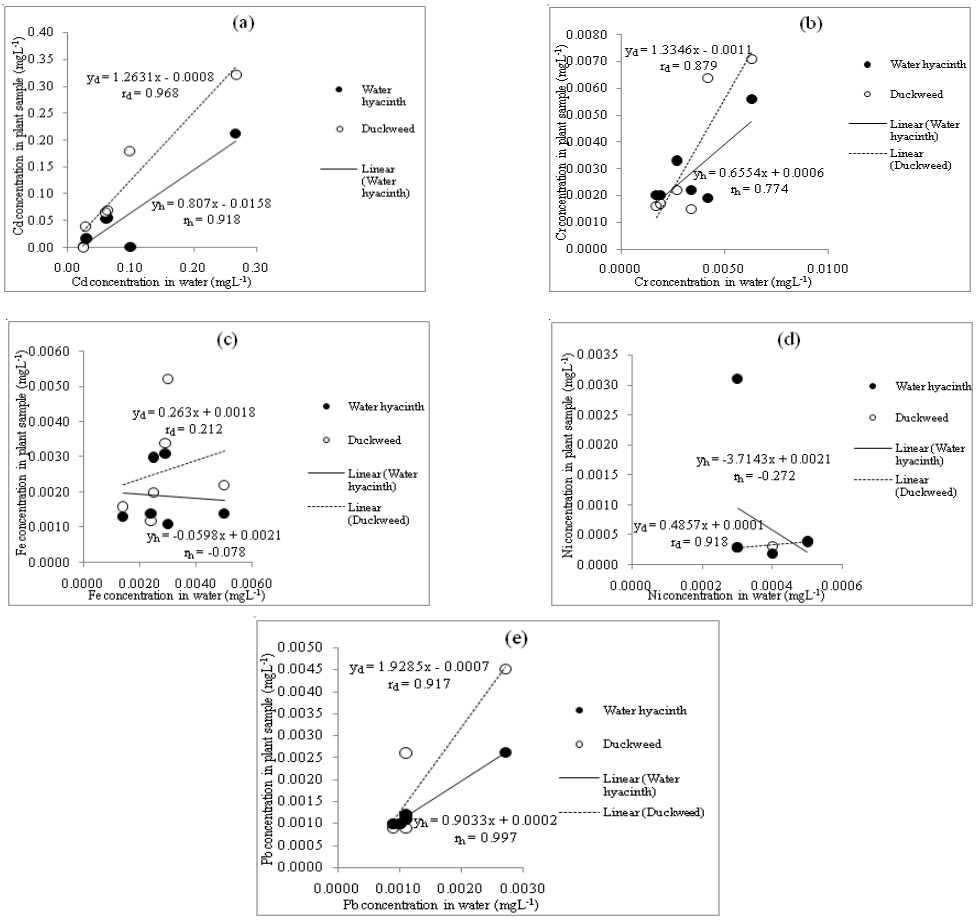


Fig. 2 Scattered graphs of (a) Cadmium (b) Chromium (c) Iron (d) Nickel and (e) Lead levels in duckweed and water hyacinth against their respective concentrations in water samples.

the highest nitrate-nitrogen levels (1.41 mg / L).

Cd levels in both duckweed (0.3213 mg / L) and water hyacinth (0.2119 mg / L) from Site 2 was high (Table 2). The plants from site 3 had the highest Cr levels with 0.0071 mg / L (duckweed) and 0.0056 mg / L (water hyacinth). Fe level in duckweed from site 2 was highest while site 5 had the highest in the water hyacinth. Ni levels in both plants were relatively low. Pb level in duckweed from site 6 was significantly highest (0.0045 mg / L) but no significant difference exist in those of the water hyacinth from the six sites (Table 2).

There was no significant difference in the level of the metals in the plant tissues across the sites except for Cd and Cr (Table 3). Except for Pb, the levels of the heavy metals in duckweed to those in water hyacinth were not significantly different.

Figures 2a to 2e showed the relationship between the heavy metal content in duckweed and water hyacinth to the concentration in the water sample. Except for Fe, there were positive correlation in Cd, Cr, Ni and Pb levels in duckweed to those in the River ($r_{1, 4(0.05)}$ = 0.811). Only Cd and Pb levels in the water hyacinth showed a positive association with their respective levels in the River. Fe and Ni levels in the water hyacinth followed a down trend although not significant (r_h = -0.078 and -0.272 respectively). This shows that duckweed is a better monitor than water hyacinth.

DISCUSSION

Water quality cannot be defined by the measurement of only one parameter but a range of chemical, physical and biological components. The mean temperatures across the sites fall within the normal temperature range of 0 °C to 30 °C supportive of good water quality (Chapman, 1996), with the exception of site 5 which measured 31.20 °C. Higher pH values as in Site 1 may result in retention of metals which

Table 1. Physico-chemical analysis of water from six points along Asa River, Ilorin, Kwara State, Nigeria.

Parameters	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Temperature (°C)	25.35^{b}	25.80^{b}	27.00^{b}	26.02^{b}	31.20^{a}	27.40^{b}
pH	7.63^{a}	7.43^{a}	6.83a^{b}	6.22^{bc}	5.31^{c}	5.71^{c}
Conductivity (µS/cm)	7.19^{a}	7.05^{ab}	7.14^{a}	5.97^{ab}	5.52^{b}	6.12a^{b}
Turbidity (NTU)	9.35^{c}	21.35^{a}	16.00^{b}	17.00^{b}	17.50^{b}	16.50^{b}
TSS (mg/L)	182.00^{a}	195.50^{a}	218.40^{a}	188.10^{a}	192.90^{a}	183.60^{a}
COD (mg/L)	139.30^{ab}	138.00^{ab}	138.00^{ab}	150.30^{a}	126.00^{b}	129.00^{b}
BOD (mg/L)	13.90^{a}	9.91^{b}	8.80^{bc}	7.78^{c}	8.61c	7.78^{c}
DO (mg/L)	12.00c	14.75^{b}	15.55^{b}	20.32^{a}	14.85^{b}	16.35^{b}
Alkalinity (mg/L)	16.90^{a}	8.60^{c}	12.50^{b}	6.22^{d}	5.41^{d}	5.71^{d}
Total Hardness (mg/L)	13.50a^{a}	13.30^{a}	14.40^{a}	12.90^{a}	12.90^{a}	13.00^{a}
Phosphate (mg/L)	3.28^{a}	0.59^{b}	0.44^{b}	3.43^{a}	0.76^{b}	0.56^{b}
Nitrate (mg/L)	1.41^{a}	0.64^{b}	0.80^{b}	1.39^{b}	0.64^{b}	1.14^{a}

Means with the same letter (s) across the rows are not significantly different ($p < 0.05$).

Table 2. Heavy metal concentration in duckweed and water hyacinth from six points along Asa River, Ilorin, Kwara State, Nigeria.

Metals (mgL^{-1})	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
			Duckweed			
Cd	0.0705^{bc}	0.3213^{a}	0.0402^{c}	0.1800^{b}	0.0670^{bc}	0.0012^{c}
Cr	0.0017^{b}	0.0015^{b}	0.0071^{a}	0.0016^{b}	0.0064^{a}	0.0022^{b}
Fe	0.0012^{b}	0.0052^{a}	0.0022^{b}	0.0016^{b}	0.0034^{ab}	0.0020^{b}
Ni	0.0003^{a}	0.0003^{a}	0.0004^{a}	0.0003^{a}	0.0003^{a}	0.0003^{a}
Pb	0.0009^{b}	0.0009^{b}	0.0010^{b}	0.0010^{b}	0.0026^{ab}	0.0045^{a}
			Water hyacinth			
Cd	0.0557^{b}	0.2119^{a}	0.0174^{bc}	0.0018^{c}	0.0534^{b}	0.0023^{c}
Cr	0.0020^{b}	0.0022^{b}	0.0056^{a}	0.0020^{b}	0.0019^{b}	0.0033^{ab}
Fe	0.0014^{a}	0.0011^{a}	0.0014^{a}	0.0013^{a}	0.0031^{a}	0.0030^{a}
Ni	0.0003^{a}	0.0003^{a}	0.0004^{a}	0.0003^{a}	0.0003^{a}	0.0002^{a}
Pb	0.0010^{a}	0.0012^{a}	0.0010^{a}	0.0010^{a}	0.0011^{a}	0.0007^{a}

Means with the same letter(s) across the rows are not significantly different ($p < 0.05$).

Table 3. Probability values from analysis of variance and t-test comparison for site and aquatic plants respectively.

Metal	Cd	Cr	Fe	Ni	Pb
Site	< 0.001	0.001	0.065	0.338	0.103
Plant	0.053	0.441	0.147	0.335	0.046

possibly translated to the corresponding higher conductivity in this site (Malik *et al*., 2011). The emptying of effluents into the river from Nigerian Bottling Company and other industries around site 2 possibly accounted for the significantly higher turbidity (21.25 N.T.U.). The turbidity range in this study is in agreement with Adekunle and Eniola (2008) report of 1.5-189 N.T.U. for Asa River. The TSS of between 182.0 and 218.4 mg/L in this study was higher than those previously reported for Asa River (Eletta and Adekola, 2005; Okeola *et al*., 2010) but within the standard limit of >500 mg/L by the World Health Organisation (Jain *et al*., 2006). The highest BOD and COD in sites 1 and 4 respectively were indicative of the presence of organic and inorganic pollutants (Kolawole *et al*., 2011). The COD levels for this study fell within the reported range (60 - 292 mg/L) by Eletta and Adekola (2005) but the DO was higher 0.5-1.6 mg/L earlier reported. The total alkalinity was lower than WHO limit of 200 mg/L (Jain *et al*., 2006) and 33.75 mg/L reported by Okeola *et al*. (2010) for Asa River. Total hardness was below those of Okeola *et al.* (2010) but within the range of 13.0 - 40.0 reported by Eletta and Adekola (2005). The phosphate level (0.44 - 3.43 mg/L) was well above the 5µg/L that was perceived to reduce the likelihood of algal bloom and growth of aquatic plants (Eletta and Adekola, 2005). The nitrate

level was below the 3.15 mg/L (Eletta and Adekola, 2005) and 5.81 mg/L (Eletta *et al*., 2005) earlier reported for River Asa, as well as the 40-50 mg/L permissible limit by W.H.O. (Jain *et al*., 2006). The higher nitrate levels at site 6 may be due to the contribution from fertilizers and manures used during cultivation of vegetables beside the water course around Site 6 especially during the dry season when water from the river is used for irrigating the crops. There is also the possibility of nitrate leaching downstream and accumulating at Site 1 (Asa Dam) due to erosion. Heavy metals in rivers have been linked with various sources ranging from natural to anthropogenic (El Bouraie *et al*., 2010). Even the heavy metals from anthropogenic sources are carried to river by erosion (Zeidler, 2005), and wind current. The levels of all the heavy metals in the tissues of the plants and the River in this experiment were generally lower than those reported by Adekola and Eletta (2007).

Cd sources in the environment include its use in rechargeable batteries, vehicle radiators and solders (when alloyed with copper). The oxide and cyanide are also used as anti-corrosive treatments for steel while cadmium chloride is used for dyeing and printing (Water UK, 2001). Cr contamination is attributable to sources like chemical industry during paints production, electroplating, and manufacturing processes such as leather tanning, anodising of aluminium, and steel works (Vasilatos *et al*., 2010). Fe is one of the earth's most plentiful resources, making up at least 5% of the earth's crust and not considered hazardous to health.as its help in the transport of oxygen in the blood. The level of Fe was below 0.3 mg/L limit above which the water may turn red, brown, or yellow staining laundry, glassware, dishes and household fixtures such as bathtubs, sinks as well as generate offensive odour and taste (Dima *et al.*, 2006). Ni is naturally occurring but wide use of its alloy in metallurgical, chemical and food processing industries, especially as catalysts and pigments have increased its concentration in the environment (Cempel and Nikel, 2006). Pb is distributed in surface waters due to atmospheric deposition of contaminated dusts as well as industrial and technical uses (Emoyan *et al.*, 2006).

Aquatic macrophytes do absorb heavy metals selectively through their roots, stems or leaves, and accumulate them in organs. The accumulation and distribution of these heavy metals in the plant depends on the plant species, bioavailability, pH, cation exchange capacity, dissolved oxygen, temperature and secretion of roots (Buta *et al*., 2011). Plants are employed in the decontamination of heavy metals from polluted water and have demonstrated high performances in treating mineral water and industrial effluents (Cheng, 2003). The positive linear trend observed in the concentrations of metals in duckweed to the actual concentration in water is indicative of the metals content in the plant tissues increasing with increased concentration in the river, most especially for Cd, Cr, Ni and Pb which showed a significant positive correlation. Except for Ni, plants absorb several elements such as arsenic, chromium, cobalt, fluorine, iodine, lead, lithium, and selenium which appear not to play any role in their metabolism (De Luccia, 2012). The result of this study corroborates those of Kara (2005) which implicated duckweed for the take up of Pb, Cu, Fe, Cd and Ni from contaminated aqueous streams. It can therefore be inferred that duckweed can be used to monitor the presence of the heavy metals selected for this study.

Although, positive linear trends were observed for Cd, Cr and Pb contents in water hyacinth in relation to those in the river, but those of Fe and Ni followed a negative trend. It is possible that the relationship between these two metals in the water hyacinth to their levels in the River may not be linear. There is also the possibility of the plant (water hyacinth) converting Fe and Ni into useful forms necessary for growth and productivity as both are essential elements for plants (Aksoy *et al.*, 2012) or the displacement of the metals by other available metals in the plant tissues. The use of water hyacinth for indicating the presence of these two heavy metals using linear relationship may thus be misleading. The significant positive correlation for Cd and Pb supports the ability of water hyacinth in removing these metals from polluted water (Soltan and Rashed, 2003).

The result of this study corroborates those of Zayed *et al.* (1998) and Zhu *et al*. (1999) which implicated water hyacinth and duckweed as excellent accumulators of Cd.

CONCLUSION

The physicochemical properties of the river reflect varying degrees of contamination across the selected sites except for TSS and total hardness which showed no significant difference. The levels of heavy metals in the plants and River were generally low. However, Cd and Cr had the highest concentrations across the sites indicating the high availability of Cd and Cr

sources around the sites. The positive correlation in Cd, Cr, Ni and Pb levels in duckweed as well as Cd and Pb in water hyacinth to that in River Asa could serve as a tool in monitoring these metals in rivers and other wetlands. The use of water hyacinth to monitor Fe and Ni levels in the river may be misleading as the relationship may not necessarily be linear as those of the other metals. The ability of the duckweed and water hyacinth to accumulate some levels of these heavy metals is a reflection of their inherent potentials as a tool in bioremediation and monitoring of polluted waters.

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