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The Effects of Water Hyacinth (*Eichhornia crassipes* [Mart.] Solms) Infestation on the Physico-Chemistry, Nutrient and Heavy Metal Content of Badagry Creek and Ologe Lagoon, Lagos, Nigeria

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ABSTRACT

Some physico-chemistry, nutrients and heavy metal content of Badagry Creek, Ologe Lagoon, Agbara and Ojo were compared to ascertain the effects of water hyacinth (*Eichhornia crassipes*) on these variables of the water bodies. Three of the water bodies (Ologe Lagoon, Agbara and Badagry Creek) have water hyacinth infestation and the control (Ojo) was free from water hyacinth through out the period of the study. This study was carried out between January, 2010 to August, 2010. Eleven physico-chemical parameters, 4 nutrients and 5 heavy metals were measured. The observed values shows that their was significant difference ($p<0.05$) in the conductivity, total dissolved solid, salinity, dissolved oxygen, Biological Oxygen Demand (BOD) and total hardness among the sampling stations. The highest values in conductivity (9272±994 µS cm^{-1}), salinity (5.00±1.69 ppt), total hardness (1848±396 mg L^{-1}) and Total dissolved solid (5460±841 mg L^{-1}) were recorded in Ojo which has no water hyacinth infestation while the lowest values {conductivity (183±81 µS cm^{-1}), salinity (0.11±0.01 ppt), total hardness (87±8 mg L^{-1}) and total dissolved solid (92±15 mg L^{-1})} were obtained in Agbara which is one of the sampling stations with water hyacinth infestation. However, BOD was highest in Agbara (97.38±28.60 mg L^{-1}) but lowest in Ojo (35.37±9.67 mg L^{-1}). Sulphate and chloride were significant ($p<0.05$) among the sampling stations while magnesium was the only significant ($p<0.05$) heavy metal. Although, water hyacinth may have negative impacts on water quality, its ability to passively absorb heavy metals and nutrients can be put into good use.

Key words: Water quality, aquatic macrophyte, phytoremediation, lagos lagoon complex, pollution

INTRODUCTION

Water hyacinth has become a source of concern to ecologists and fisher-folks in Nigeria since it entered our aquatic ecosystem two decades ago. Several attempts which include mechanical, chemical and biological remedies, were made to eradicate or at least control it growth to a manageable level. However, all these efforts were not very successful because of the plant's prolific rate of reproduction (Chukwuka and Uka, 2007; Ndimele, 2010). The weed was first reported in Africa in River Nile in 1956. After a decade, it was found to have invaded the Jebel Aulia Dam near Kherfoun (Nyananyo *et al.*, 2007). It made its entrance into Nigerian waters through Republic of Benin in 1984 and since then has constituted nuisance to navigation and fisheries (Ndimele and Jimoh, 2011).

Water hyacinth grows in shallow aquatic ecosystems especially lentic water bodies. It has also been found in lotic waters and they are probably brought into such aquatic environment by current. They are hardy, very difficult to eradicate because they can survive extremely harsh conditions. During unfavourable condition such as drought, the plant sinks into the water bottom and remains dormant until the condition of its environment becomes conducive for growth. It then emerges from the bottom of the water and starts growing. Water hyacinth grows well in nutrient-rich waters but do not tolerate brackish water because of the salinity level (Sooknah and Wilkie, 2004). The conducive temperature and seasonally low salinity of the Lagos Lagoon complex has supported the proliferation of water hyacinth. Coupled with this is its high rate of reproduction which has made it a serious threat to the continued use of the affected Nigerian waters as a resource. This poses a great hindrance to the socio-economic potentials of these water bodies if appropriate and effective controls are not introduced (Ndimele *et al*., 2011).

Amongst the menaces caused by water hyacinth is that, it forms a thick mat covering rice paddies, blocking canals and channels, impeding navigation, halting fishing, sweeping away buildings for mosquito (Chukwuka and Uka, 2007; Ndimele *et al*., 2010a; Ndimele *et al*., 2011). It rapidly invades water ways and it has been causing problems to the dependants of the Lagos Lagoon complex which includes Ologe Lagoon and Badagry Creek. It impedes water transportation preventing people access to their sources of livelihood. It also reduces or totally prevents accessibility to fishing grounds especially during the rainy season which interestingly is the period when fishing activities is intense and more profitable. It has been found to drastically increase evapo-transpirational losses as well as fish losses (Ndimele *et al*., 2011).

Water hyacinth has some beneficial attributes. It can be used in the production of paper, fibre boards, biogas, fertilizer, fish feed and in phytoremediation (the clean up of polluted water bodies by aquatic plants like water hyacinth) (Khan and Sarwar, 2002; Uka *et al*., 2007; Ndimele, 2008; Dar *et al*., 2011). Phytoremediation became popular when physical and chemical measures to rid aquatic ecosystems of pollutants were found to be more harmful than the pollutants themselves (Ndimele *et al*., 2010b). Some of these pollutants are heavy metals and nutrients. Heavy metals are aquatic pollutant of major concern to ecologists because they are non-biodegradable that is, once they enter an aquatic ecosystem, they can not be eliminated by ordinary biological processes. Consequently they bio-accumulate along the food chain causing different types of ailments. These could range from low intelligent quotient in infants (lead poisoning) to severe effects like teratogenicity that is, foetal malformation caused by mercury poisoning as was reported in minamata, Japan in 1960's (Ndimele *et al*., 2009; Kumolu-Johnson *et al*., 2010). Water hyacinth have also been reported to absorb nutrients (nitrate, phosphate, suphate), thus eliminating or reducing excess nutrients not required by plants for growth (Ndimele, 2003).

It economic significance stems from its potential to produce negative consequences for the quality of the water bodies which it invades. The 'mat' of aquatic plants which covers aquatic ecosystem during severe infestation reduces dissolved oxygen by restricting the exchange of oxygen across the water interface. They also affect the chemistry of surface water which could render such water body unfit to support aquatic lives (Chukwuka and Uka, 2007). Water hyacinth and other aquatic weeds also generate large amounts of organic matter because of their large biomass. As the organic matter decomposes, biological oxygen demand increases due to the activities of decomposing bacteria. These bacteria use dissolved oxygen for their metabolic functions. The result is that the water quality deteriorates. This results in loss of aquatic biodiversity (Muli, 1996). This study is the first in a series of studies that will examine the nature of this plant and how it can be controlled in order to successfully reduce its negative effects and maximize its potentials. The objective of this study was to investigate the effects of water hyacinth on the environment in terms of physico-chemistry, nutrients and heavy metal contents of the study areas.

MATERIALS AND METHODS

Sampling sites: Ologe Lagoon (S_1) (Fig. 1) is one of the prominent lagoons in Lagos State. It is a fresh water lagoon system that lies between latitudes 6°27'N and 6°30'N and longitudes 3°02'E and 3°07'E (Anetekhai *et al.*, 2007). It is the smallest of the four lagoons in Lagos, south western Nigeria with a surface area of 9.4 km^2 (Kumolu-Johnson *et al.*, 2010). The main body of the lagoon lies within Badagry Local Government Area of Lagos State, Nigeria and it opens into the Atlantic Ocean via the Lagos Harbour and Dahomey in the republic of Benin. The major sources of water are Rivers Owo, Ore and Opomu in Ogun State, Nigeria (Odewunmi, 1995). Ologe Lagoon is surrounded by many fishing villages while an industrial town-Agbara is situated at the northern border of the lagoon. Agbara (S_2) which is part of Ologe Lagoon was chosen as a sampling site because of it proximity to the effluent discharge point from the Agbara Industrial Estate (Ndimele *et al.*, 2009). The industrial estate is the location of a number of industries which produces agro-allied, chemical and pharmaceutical products (Kusemiju *et al.*, 2001). Badagry Creek (S_3) lies between latitudes 6°22'N and 6°42'N; and longitudes 2°42'E and 3°42'E (Agboola *et al.*, 2008) while Ojo (S_4) is the control. Ologe Lagoon, Agbara and Badagry Creek have water hyacinth growing on them but Ojo is free from water hyacinth infestation.

Methodology: This study was conducted over a period of eight month (8 months), from January, 2010 to August 2010. There were four sampling stations (Fig. 1); three sampling sites were infested by water hyacinth and a control sampling site (Ojo) which was water hyacinth-free. Data were collected on a monthly basis from these sites. These data are physico-chemical parameters, nutrients and heavy metals.

Physico-chemical analysis: Water samples were collected from each sampling station in 1-Litre plastic containers. Prior to sampling, the plastic containers were washed with tap water and later rinsed with 10% nitric acid to remove contaminants which may affect the values of the physico-chemical parameters to be evaluated. Temperature was determined *in situ* by using a mercury-in-glass thermometer and hydrogen ion concentration (pH) by pH meter (Extec 407227). Conductivity, salinity and Total dissolved solids were determined using a combined conductivity-TDS-salinity meter (Hanna portable EC/TDS/Salinity meter Model HI 9835, Hanna Instruments Inc., USA).

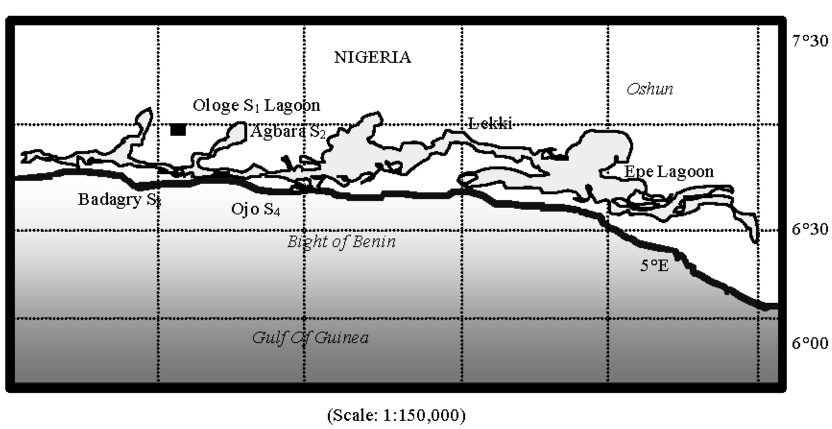

Fig. 1: Map of lagos lagoon complex with the sampling stations indicated

Biological oxygen demand was measured by the method described by Ademoroti (1996) where dissolved oxygen was determined before and after incubation for 5 days at 20°C. Chemical oxygen demand was determined by closed reflux method as described by Ademoroti (1996). Total alkalinity and total hardness were determined according to the methods described by American Public Health Association (APHA, 1998). Dissolved oxygen was measured by titration (Boyd, 1981) while turbidity was measured using nephelometer (Analite portable nephelometer Model 156, Mcvan Instrument, Mulgrave).

Nutrient analysis: The concentrations of nitrate, sulphate and phosphate were determined by DR/2010 HACH Portable Data Logging Spectrophotometer. Nitrate as nitrogen was measured by the cadmium reduction method (Strickland and Parsons, 1972), sulphate by Sulfa Ver methods 8051 while phosphate was determined by the molybdenum-blue method {Department of Water Affairs and Forestry (DWAF, 1992)}. Chloride was measured using the titrimetric method (APHA, 1998).

Heavy metal analysis: In each sampling station, water samples were collected at a depth of about 20 cm below water surface in 250 mL capacity plastic bottles. The bottles were pre-treated by soaking in 10% nitric acid for 24 h after which they were rinsed with distilled water prior to being used for sample collection (Laxen and Harrison, 1981). In order to reduce adsorption of metals onto the walls of the sampling bottles, the water samples were acidified immediately after collection by adding 5 mL nitric acid (Analar grade) (APHA, 1985; Ademoroti, 1996). Water samples were mixed vigorously before aspiration into the flames of an Atomic Absorption Spectrophotometer (Alpha-4 cathodeon) for metal determination. Values were expressed in mg L^{-1}.

Statistical analysis: The data collected was analyzed for significant differences ($p<0.05$) by one-way Analysis of Variance (ANOVA) using computer Statistical Package for Social Sciences (SPSS) for windows (v. 17.0). Where significant differences exist, they are partitioned by Fisher's Least Significant Difference (LSD) at $p = 0.05$.

RESULTS

The values of the physico-chemical parameters in the sampling stations are presented in Table 1. There was no significant difference ($p>0.05$) in the pH, turbidity, Chemical Oxygen Demand (COD), total alkalinity and temperature among the sampling stations. However, conductivity, Total Dissolved Solid (TDS), salinity, dissolved oxygen, Biological Oxygen Demand (BOD) and total hardness varied significantly ($p<0.05$) among the sampling stations. The highest values in conductivity (9272±994 µS cm^{-1}), total dissolved solid (5460±841 mg L^{-1}), salinity (5.00±1.69 ppt) and total hardness (1848±396 mg L^{-1}) were recorded in Ojo (control) which had no water hyacinth infestation while the lowest values (conductivity, 183±81 µS cm^{-1}; total dissolved solid, 92±15 mg L^{-1}; salinity, 0.11±0.01 ppt and total hardness, 87±8 mg L^{-1}) for these parameters occurred in Agbara which is one of the sampling stations with water hyacinth infestation. The highest (4.48±0.19 mg L^{-1}) and lowest (3.44±0.36 mg L^{-1}) values for dissolved oxygen were recorded in Badagry and Agbara respectively while the highest (97.38±28.60 mg L^{-1}) and lowest (35.37±9.67 mg L^{-1}) values of biological oxygen demand occurred in Agbara and Ojo (control), respectively.

Table 2 shows the concentrations of nutrients (sulphate, phosphate, nitrate and chloride) in the water columns of the four sampling stations (Badagry, Agbara, Ologe and Ojo). There was no

Table 1: Physico-chemical parameters of the sampling stations

Parameter	Ologe (S_1)	Agbara (S_2)	Badagry (S_3)	Ojo (S_4) (control)
Temperature (°C)	26.50±1.34^a	25.25±1.31^a	25.25±0.77^a	26.00±0.80^a
pH	7.30±0.11^a	7.79±0.17^a	7.64±0.05^a	7.56±0.14^a
EC (μS cm^{-1})	292±53^a	183±81^a	2833±582^a	9272±994^b
TDS (mg L^{-1})	149±26^a	92±15^a	1752±93^a	5460±841^b
Salinity (ppt)	0.16±0.03^a	0.11±0.01^a	1.51±0.83^a	5.00±1.69^b
Turbidity (NTU)	68.38±24.16^a	72.88±21.11^a	33.75±3.68^a	54.38±19.92^a
DO (mg L^{-1})	3.60±0.40^b	3.44±0.36^b	4.48±0.19^a	4.18±0.17^a
BOD (mg L^{-1})	50.75±39.98^a	97.38±28.60^b	43.38±3.14^a	35.37±9.67^a
COD (mg L^{-1})	235±63^a	384±81^a	153±18^a	216±91^a
Alkalinity (mg L^{-1})	108±20^a	142±18^a	136±8^a	123±15^a
Hardness (mg L^{-1})	102±19^a	87±8^a	323±86^a	1848±396^b

Values in the same row and with the same superscript letters are not significantly ($p>0.05$) different. All values are expressed as Mean±SE

Table 2: Nutrient content of the sampling stations

Sampling station	SO_4^{2-} (mg L^{-1})	PO_4^{2-} (mg L^{-1})	NO_3^{2-} (mg L^{-1})	Cl^- (mg L^{-1})
Ologe (S_1)	3.73±0.37^b	1.77±0.76^a	2.45±0.62^a	76.18±17.99^a
Agbara (S_2)	3.13±0.29^b	1.52±0.80^a	2.16±0.29^a	47.63±3.82^a
Badagry (S_3)	102.48±58.87^a	0.59±0.16^a	1.51±0.16^a	740.40±155.02^a
Ojo (S_4) (control)	889.89±136.21^c	0.93±0.36^a	2.20±0.37^a	7703±537^b

Values in the same column and with the same superscript letters are not significantly ($p>0.05$) different. All values are expressed as Mean±SE

Table 3: Heavy metal concentrations of the water column of the sampling stations

Sampling station	Cu (mg L^{-1})	Fe (mg L^{-1})	Pb (mg L^{-1})	Mg (mg L^{-1})	Zn (mg L^{-1})
Ologe (S_1)	0.04±0.01^a	0.17±0.01^a	0.01±0.01^a	17.70±4.31^b	0.14±0.06^a
Agbara (S_2)	0.04±0.02^a	0.17±0.01^a	0.01±0.01^a	11.91±2.10^b	0.11±0.03^a
Badagry (S_3)	0.04±0.01^a	0.15±0.01^a	0.01±0.01^a	283.21±51^a	0.11±0.02^a
Ojo (S_4) [control]	0.03±0.01^a	0.17±0.01^a	0.01±0.01^a	417.31±76.86^a	0.06±0.01^a

Values in the same column and with the same superscript letters are not significantly ($p>0.05$) different. All values are expressed as Mean±SE

significant difference ($p>0.05$) in the concentrations of phosphate and nitrate among the four sampling stations but sulphate and chloride varied significantly ($p<0.05$). The highest concentration of sulphate (889.89±136.21 mg L^{-1}) and chloride (7703±537 mg L^{-1}) were found in Ojo (control) while their lowest concentrations {sulphate (3.13±0.29 mg L^{-1}); chloride (47.63±3.82 mg L^{-1})} were recorded in Agbara.

In Table 3, the heavy metal contents of the four sampling stations were compared. The concentrations of all the heavy metals studied were not significant ($p>0.05$) among the sampling stations except magnesium. The highest concentration (417.31±76.86 mg L^{-1}) of magnesium was recorded in Ojo (control) while the lowest (11.91±2.10 mg L^{-1}) occurred in Agbara.

DISCUSSION

Physico-chemical parameters of the water columns: The range of values of some of the physico-chemical parameters are pH (7.32-8.28), salinity (0.15-4.40 ppt), BOD (18.67-105 mg L^{-1}), temperature (23.5-27.7°C), DO (3.20-4.53 mg L^{-1}), total hardness (107-768 mg L^{-1}) and total alkalinity (93.38-162 mg L^{-1}). The values recorded for pH, temperature and salinity fall within the range recommended by the Federal Environmental Protection Agency (FEPA, 2003) for the culture of fish. However, dissolved oxygen concentrations (4.53-3.20 mg L^{-1}) were below the value of 5.0 mg L^{-1} recommended by FEPA (2003). On the other hand, total alkalinity (93.38-162 mg L^{-1}) and total hardness (107-768 mg L^{-1}) were above the values recommended by FEPA (2003).

The result of the analysis of the physico-chemical parameters revealed that there was no significant difference ($p>0.05$) in temperature between the water hyacinth infested sites (Badagry Creek, Agbara and Ologe Lagoon) and the control (Ojo) which had no water hyacinth. However, one of the sites infested with water hyacinth had the highest mean temperature (26.50±1.34°C). This observation agrees with the findings of Uka and Chukwuka (2007). They opined that the small increase in temperature was caused by the dense mats of water hyacinth which cover the water surface. This water hyacinth covering prevents the exchange of heat between the water column and the atmosphere.

The dissolved oxygen content of the control (Ojo) was significantly higher ($p<0.05$) than two (Agbara and Ologe Lagoon) of the sampling stations. However, it was not significantly different ($p>0.05$) from the dissolved oxygen concentration of the other water hyacinth-infested site (Badagry Creek). Previous study by Frodge *et al.* (1995) had reported that dissolved oxygen content was lower in patches of the *Brasenia schereberi* in lake Northwest of United States of America. The mean value of dissolved oxygen recorded in Badagry Creek (4.48±0.19 mg L^{-1}) was higher than the value (4.18±0.17 mg L^{-1}) in Ojo (control). However, the relatively high value of dissolved oxygen recorded in Ojo (control) compared to the two other stations that had water hyacinth (Agbara and Ologe Lagoon) might be due to the dredging activities in the site. This could cause frequent mixing of atmospheric oxygen with the water and this could result in increased oxygen content of the water.

Conductivity has a direct correlation with total dissolved solids, salinity (total salt content), mineralization and nutrient status of an aquatic ecosystem (Uka and Chukwuka, 2007; Akan *et al.*, 2008). The range of conductivity (183±81-2833±582 μS cm^{-1}) observed in the sampling stations with water hyacinth infestation in the present study is within the range reported by Akan *et al.* (2008). Their study was on the physico-chemistry of waste-water from Kano metropolis in Northern Nigeria. However, conductivity was significantly ($p<0.05$) higher in Ojo (sampling station without water hyacinth infestation) than the three stations that had water hyacinth growing on them. This observation is at variance with the report of Uka and Chukwuka (2007). The cause of the high level of conductivity could have been due to dredging activity in the Ojo. Dredging could cause increased mineralization which might lead to increase in conductivity, total dissolved solids and salinity as was observed in the present study.

Biological Oxygen Demand (BOD) is a measure of the biological activities of a water body. It is an indication of the organic load and it is a pollution index especially for water bodies receiving organic effluent. The least BOD (35.37±9.67 mg L^{-1}) was recorded in Ojo, though, it was only the BOD of Agbara (97.38±28.60 mg L^{-1}) that was significantly ($p<0.05$) higher than it. This observation is in conformity with the study by Nyananyo *et al.* (2007). The high BOD in water hyacinth-infested aquatic ecosystem might have been due to the decomposition of the plant. Organic matter decomposition requires oxygen from the water. This increase in BOD, will reduces the dissolved oxygen available to aquatic organisms for survival.

Heavy metal concentration in the water column: The concentrations of heavy metals in the water columns of all the sampling stations were below the World Health Organization (WHO) limits for drinking water (Cu = 2.0 mg L^{-1}, Fe = 2.0 mg L^{-1} and Zn = 3.0 mg L^{-1}) (WHO, 2008). All the heavy metals studied showed no significance ($p>0.05$) among the sampling stations except magnesium. The highest value (417.31±76.86 mg L^{-1}) occurred in Ojo (control). This might be due to the absence of water hyacinth in this station. Previous studies by Ndimele *et al.* (2009, 2010a) have shown that water hyacinth can absorb heavy metals and other pollutants present in aquatic environment. Ndimele and Jimoh (2011) reported that water hyacinth absorbed heavy metals from water column in about 3-28 fold despite the low levels of the metals in the water column.

Nutrient concentration in the water column: The concentrations of sulphate and chloride in Ojo (control) were significantly higher than the other sampling stations which had water hyacinth infestation. The fact that sulphate and chloride were significantly lower in the water hyacinth-infested areas could be due to the absorption of the nutrients by water hyacinth (Ndimele, 2003; Uka and Chukwuka, 2007). Ogunlade (1996) reported that water hyacinth has the ability to remove nutrients from aquatic environments.

CONCLUSION

Invasions of aquatic ecosystems by water hyacinth have become a nuisance worldwide. Originally perceived as a practical problem for fishing and navigation, it is now considered as well a threat to biological diversity because of its effects on water chemistry. It can also serve some useful purpose by actively and passively absorbing pollutants like heavy metals and nutrients, thereby ridding the environment of these dangerous pollutants.

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