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Assessment on suitability of water hyacinth for organic fertilizer production

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Abstract

Water hyacinth is a noxious aquatic weed mostly found in nutrient-rich water bodies. They are invasive species, and increasingly becoming a threat to local fishing industries, drainages, irrigation and navigation in many waterways in southwestern Nigeria. This is largely due to rapid urbanization and industrialization of the region over the years, resulting in extensive pollution of the waterways. This study examines the quality of four major waterways (Awba dam, Eleyele river, Epelagoon and Majiduncreek) within the southwestern Nigeria and nutrient contents of their water hyacinth weed compositions for organic fertilizer production. Twenty samples each of water hyacinth, surface water and sediments were collected from the four water bodies'. The physico-chemical properties of surface water, sediment and water hyacinth samples were analyzed along with heavy metals (Pb, Cd, Cr, Co, Cu and Ni). Standard analytical techniques were employed for chemical analysis. The surface water bodies recorded very high levels of organics (72.0±3.87 to 154±8.44 mg/L) and nitrate (7.36±0.17 to 19.4±1.05 mg/L) indicating gross organic pollution. Sediments similarly showed high organic content with values ranging between 4.87±0.53 to 47.0±17.3 %. Water hyacinth from the four surface water bodies showed proportional levels of organic carbon, nitrogen and phosphorous with C/N ratios of 11.2 to 13.1%. The NPK ratios of these water hyacinths were comparable with commercially available fertilizers suggesting their suitable as alternatives. Analysis of variance (*0.05*) showed no significant differences in quality parameters among the four sample locations of surface water, sediment and water hyacinth. The water hyacinth weeds were rich in nutrients needed by food crops. This potential could be harnessed to transform this aquatic nuisance to organic fertilizer in order to reduce cost of fertilizer, boost food production and create job opportunities. Further research is needed to determine economically suitable methods of converting water hyacinth to commercially available organic fertilizer.

Key words: Water hyacinth, surface water, sediments, organic fertilizer.

Introduction

Water hyacinth (*Eichhornia crassipes*) is an aquatic plant native to tropical South America but widely found in North America, Asia, Australia and Africa due to human and environmental factors [1]. They are often times integral component of many lakes and river ecosystems. However, when there is exponential growth, they are considered an environmentally harmful aquatic weed [2,3].They are known as pollution indicators because they thrive in polluted water bodies rich in organics and nutrients such as nitrate [4]. Proliferation of water hyacinth threatens survival of aquatic species, transportation, municipal, socio-economic and human health. Though water hyacinth is considered a menace responsible for many environmental and human problems, a lot has been done by way of research in order to turn the problem around and find useful applications of the plant [5,6]. The plant has a fibrous tissue with high water, energy and protein contents. It has therefore found use as animal feeds [7], paper production [8], biogas generation [9] and fertilizers [10,11].

In Nigeria, the first surge of the plant was observed in the early 1980's along the Badagry creek [12] in

Lagos State. Over the years, increasing urbanization and industrialization arising from population surge in southwestern Nigeria has resulted in extensive pollution of the inland fresh water ways along with the lagoons and creeks. Recently, in Ogun state of southwestern Nigeria, a major inland water way was completely blocked by the plant causing serious public concern. Controlling the plant growth which is considered a seasonal problem is giving government and its agencies challenges in terms of its management: collection, transportation and onward disposal [13]. With absence of a major policy on the management of the plant and little or no integrated approach on its utilization, it has therefore become necessary to assess the water quality at peak surge of the water hyacinth in order to predict its growth pattern and invariably control its bloom and positive utilization. This study therefore examined the quality of four major waterways (Awba dam, Eleyele river, Epe lagoon and Majidun creek) within the southwestern Nigeria and nutrient contents of their water hyacinth compositions for organic fertilizer production.

Materials and method

Description of study areas

Samples of water hyacinth, surface water and sediment were collected from four water bodies. They included: Awba dam, Eleyele river, Epelagoon and Majidun creek all in Southwestern Nigeria (Figure 1). The Awba Dam is located within the premises of the University of Ibadan in Oyo State at an altitude of 185m above sea level. The Dam is a small man-made lake with surface area of 6 hectares and an average depth of 5.5 m. Eleyele River, situated in Eleyele quarters of Ido local government of Oyo State occupies an area of about 150 hectares. It is about 10 km from Awba Dam and were interconnected, itself originating from the Ose River and its tributaries from Akinyele local government near the International Institute of Tropical Agriculture, Ibadan. Both waterways receive human waste on daily basis from the surrounding settlements. Epe lagoon which has a total coverage of 234 km^2 is connected to the Lagos lagoon and receives fresh water from River Osun. The low brackish water condition occurs from the Palaver Island to Epe town. The lagoon houses a major jetty at Epe where different forms of wastes from human activities in and around the jetty are deposited indiscriminately. Majidun is an extension of the Epe lagoon which has meandered through several villages and sub-communities before expanding further through Lagos/Ogun State Boundary Bridge. It covers almost 100 hectares and is surrounded by groups of small hamlets (Ewe nla community) whose only means of economic survival is sand dredging and fishing. The Ewé-nlá community located on the marsh land near the banks of Majidun Creek depends mainly on the Majidun water for disposal of both solid and human waste.

Sampling and Analysis

Five sampling points were each identified within Awba dam, Eleyele river, Epelagoon and Majidun creek for water hyacinth, surface water and sediment collections. Twenty samples each of water hyacinth, surface water and sediments were collected from the four water bodies making a total of sixty samples. Surface water samples were collected by immersing polyethylene plastic bottles just below the surface at about 5m away from the bank at each sampling point. Water hyacinth and sediment samples were also taken at these points. Surface water samples were stored at 4^0C in ice chest and all samples transported to the laboratory. Sediment samples were air-dried at ambient temperature while water hyacinth was sun dried. The sediment and water hyacinth (root and shoot) were ground and sieved using a 2mm sieve and packaged for analysis.

Standard methods by APHA, 1985 [14] and Society for Analytical Chemistry, 1973 [15] were used to analyze surface water for pH (electrometric method), dissolved oxygen (Winkler titrimetric method), total dissolved solids (gravimetric method), alkalinity (titrimetric method), total hardness and calcium hardness (EDTA method), chemical oxygen demand (reflux oxidation and titrimetric methods), biochemical oxygen demand (dilution Winkler method), sulfate (spectrophotometric method), nitrate (phosphomolybdate colorimetric method) and ammonia (Nessler's colorimetric method).A 200mL portion of water sample was concentrated to 25mL standard volume using 1mL concentrated HNO_3 for metals analysis. Sediments were analyzed for pH by electrometric method in a 1:2 sediment water mixture, granulometric fractions using the hydrometer method, organic carbon content by Walkley and Black method [16,17]. Metals were determined by digesting 1.0g of sediment with 20 ml of 6M HNO_3 for 2 hours on a hot plate. The extracts were then filtered into 25 ml volumetric flasks and made up to mark. The water hyacinth samples were analyzed for moisture content (gravimetric method), ash content, phosphate (phosphomolybdate colorimetric method), organic carbon (Walkley and Black method), nitrogen (Kjeldahl method) while for metals 0.5 g of sample was digested with 10 ml of combined perchloric and nitric acid (ratio 1:2) for 2 hours on a hot plate. The digest was filtered and made up to mark in a 25 ml standard flask. Heavy metals (Pb, Cd, Cr, Co, Cu and Ni) in the water, sediment and plant extracts were then determined using Flame Atomic Absorption Spectrophotometry (FAAS) Buck Scientific Model 200 A.

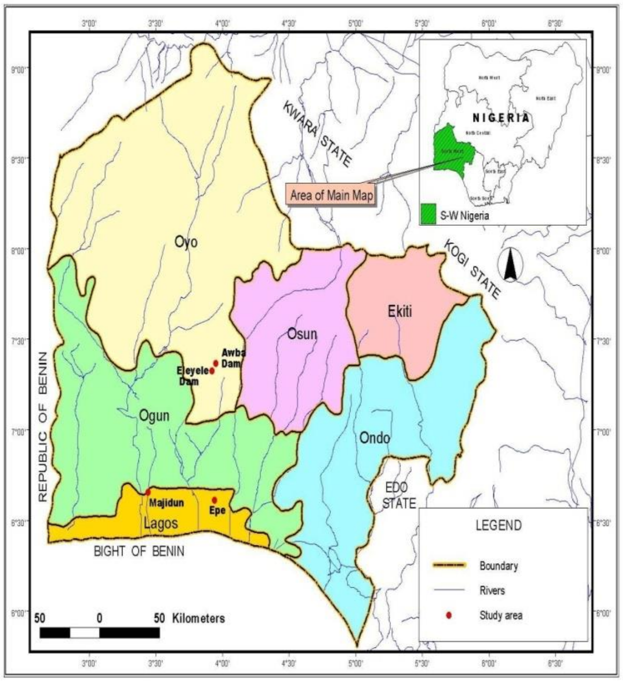

Figure 1. Map of Southwestern Nigeria Showing Study Locations

Results and discussion

Surface Water Characterization

The average surface water quality characteristic is shown in Table 1. The average pH values ranged between 5.95±0.02 and 6.92±0.11 with Epelagoon and Majiduncreek slightly out of acceptable regulatory range of 6.5 to 8.5 [18]. Average dissolved oxygen content of the water bodies were in the range of 3.68±0.64 to4.92±0.13 mg/L which were below allowable limit for aquatic life [19]. Dissolved Oxygen (DO) levels below 5.0 mg/L are known to impact stress on aquatic ecosystem [20]. Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) ranged between 72.0±3.87 to 154±8.44 mg/L and 134±9.05 to 219±7.23 mg/L respectively. Eleyele river had the highest BOD value. The BOD load for Epelagoon was much higher than values previously reported by Edokpayiet. al., 2010 [21] which ranged between 14.8 to 32.3 mg/L. This indicated an increase in organic matter content of the Lagoon which may be due to anthropogenic factors. Eleyele river showed a higher level of pollution compared to other water bodies sampled as indicated by the mean BOD and COD values. The four surface water bodies indicated gross organic pollution which can only be attributed to anthropogenic impact associated with discharge of both human and animal wastes. The nitrate levels were similar except for Majiduncreek which had the highest value of 19.4±1.05 mg/L. All the water bodies had nitrate and sulphate levels well below the WHO, [22] standard limits for drinking water. However, Majidun creek recorded ammonia levels higher than both standards for drinking water [22] and aquatic life [19]. The average phosphate values varied between 0.11±0.02 and 0.17±0.01 mg/L, falling within the maximum allowable limit stipulated by WHO [22] of 0.1mg/L. Except for Majidun creek, all the other water bodies had slightly high lead levels exceeding the drinking water and aquatic water standards. This showed substantial anthropogenic impact on the water quality. The Eleyele river and Majidun creek water quality compared closely with previous studies [23]. Analysis of variance (*at 0.05 confidence limit*) showed no significant difference in water quality of all four studied locations.

Table 1. Surface water quality characteristics (± means standard deviation)

Parameter	Awba Dam	Eleyele River	Epe Lagoon	Majidun Creek	WHO, 2011	FMINEV 1993
pH	6.80±0.03	6.92±0.11	6.35±0.35	5.95±0.02	6.5-9.5	6.0-9.0
Alkalinity (mg$CaCO_3$/L)	122±2.94	158±11	53.5±13.8	63.3±6.24	-	-
Total Hardness (mg$CaCO_3$/L)	211±26	182±8.0	151±1.80	290±49	-	-
Total Dissolved Solids (mg/L)	589± 27	166±53	175±13	1147±28	<1200	-
Dissolved Oxygen (mg/L)	4.92±0.13	3.68±0.64	4.39±0.62	3.81±1.12	6.0	6.8
BOD (mg/L)	84.7±9.33	154± 8.44	72.0±3.87	96.0±8.01	0	4.0
COD (mg/L)	134±9.05	219±7.23	151±11.4	176±7.71	-	-
Sulphate (mg/L)	6.24±0.31	11.7±0.74	14.5±0.20	38.9±5.62	500	-
Nitrate (mg/L)	7.36±0.17	11.17±0.09	8.21±0.03	19.4±1.05	50	-
Ammonia (mg/L)	0.06±0.23	0.91±0.11	0.92±0.08	6.27±0.40	<1.5	2.2
Phosphate (mg/L)	0.11±0.02	0.12±0.03	0.17±0.01	0.13±0.01	0.1	-
Calcium (mg/L)	79.2±25	66.9±4.15	56.4±4.81	110±43	-	-
Magnesium (mg/L)	6.18±0.61	8.24±4.17	5.47±3.33	9.85±6.23	-	-
Lead (mg/L)	0.31±0.02	0.26±0.03	0.15±0.02	ND	0.01	0.0017
Cadmium (mg/L)	ND	ND	ND	ND	0.003	0.0002-0.0018
Chromium (mg/L)	0.05±0.01	ND	ND	ND	0.05	0.02-2.0
Cobalt (mg/L)	0.04±0.02	ND	ND	ND	-	-
Copper (mg/L)	0.11±0.01	0.05±0.01	ND	0.03±0.01	2.0	0.002-0.004
Nickel (mg/L)	0.06±0.02	0.06±0.02	ND	ND	0.07	0.025-0.15

BOD-Biochemical Oxygen Demand, COD-Chemical Oxygen Demand, ND-Not Detectable, World Health Organization (WHO), 2011 drinking water standard, Federal Ministry of Environment (FMINEV),1993 standard for aquatic life.

Sediment Characterization

Table 2 shows average quality characteristics of sediments obtained from the four water bodies. The average pH values for sediment were slightly lower than corresponding values for surface water. Mean values ranged from 4.85±0.24 to 6.22±0.31. Awbadam, Epelagoon and Majudun creek had slightly acidic sediments which indicated the presence of week organic acids arising from organic matter decomposition. Sediments from the four water bodies were relatively sandy with low percentage clay and silt. Average organic matter content of the all sediments ranged from 4.87±0.53 to 47.0±17.3 %. Awba dam recorded the highest value of 47.0±17.3 % which could be attributed to accumulation of dead plant matters and organic wastes in the sediment over time. Lead, chromium and copper levels were higher in sediment samples obtained within the Awba dam and Eleyele river. This two water bodies are interconnected and these levels might be due to common anthropogenic sources. The level of chromium in Awba Dam far exceeded the maximum permissible concentration set by the Great Lakes Water Quality Board Dredging Subcommittee for non-polluted natural sediments which is 25 mg/kg. Heavy metal levels in Eleyele river and Majidun creek sediment compares closely to previously reported study [23]. Average Pb, Cd, Cr and Cu in the sediments from the four locations were, however, below the Canadian Interim Sediment Quality Guideline of 35.0, 0.6, 37.3 and 37.7 mg/kg for the protection of freshwater aquatic life [24]. Analysis of variance (*at 0.05 confidence limit*) showed no significant difference in sediment quality of the four locations. Meanwhile, a positive correlation was found between heavy metals levels in sediments and surface water for Eleyele river (*0.55*) and Majiduncreek (*0.96*).

Table 2. Sediment quality characteristics (± means standard deviation)

Parameter	Awba dam	Eleyele river	Epe lagoon	Majidun creek
pH	4.85±0.24	6.22±0.31	5.83±0.13	5.49±1.20
% sand	82.4±3.19	90.0±4.04	97.7±0.12	95.7±2.00
% clay	7.90±6.70	3.93±3.21	0.83±0.06	2.83±2.00
% silt	9.73±6.66	6.0±2.0	1.43±0.06	1.43±0.06
% Organic Matter	47.0±17.3	5.31±0.30	4.87±0.53	14.6±11.3
Lead (mg/L)	21.4±1.91	30.2±8.13	6.04±1.79	4.37±1.10
Cadmium (mg/L)	0.01±0.01	0.31±0.08	0.14±0.11	0.08±0.14
Chromium (mg/L)	43.3±8.43	6.94±3.63	1.81±1.66	2.07±0.60
Cobalt (mg/L)	7.86±1.80	2.57±0.20	0.63±0.18	2.37±0.43
Copper (mg/L)	14.2±1.75	33.6±1.89	5.42±3.09	9.14±2.92
Nickel (mg/L)	3.61±0.19	4.97±3.54	0.77±0.68	ND

Water Hyacinth

Water hyacinth samples obtained from Awba dam and Eleyele river were identified as *Eichhorniacrassipes* while samples from Epe lagoon and Majidun creek as *Eichhornianatans* all belonging to the family *Pontederiaceae*. The water hyacinth characteristics are shown in Table 3. Average percentage moisture content of identified water weeds was significantly high, about 90% which is typical of most aquatic plant. The weeds are supported on water surfaces by network of exposed root systems, aiding absorption of significant amount of water and nutrient which explains the high moisture content. The two water hyacinth species had relatively about the same values of % organic carbon, % nitrogen, % phosphorus, % potassium, % ash and C/N ratio. The C/N ratio is a good indicator of the suitability of the weed for fertilizer application. These values ranged between 11.2±1.74 to13.1±2.60 which is within 12.1 suitable for organic fertilizer production. The NPK ratio: Awba dam (42:1:67), Eleyele river (24:1:20), Epe lagoon (15:1:34) and Majidun creek (33:1:23) also indicates the suitability of these water hyacinth for organic fertilizer production. There were no significant differences in the water hyacinth quality across the four locations Average concentration of metals in the water hyacinth was higher than levels in corresponding water samples. These points to the ability of the weeds to absorb heavy metals from their watery environment. A strong positive correlation between metal levels in surface water and water hyacinth was found for Awbadam (*0.86*), Eleyele river (*0.60*) and Majiduncreek (*0.99*) further attesting to the ability of the weeds to absorb metals from the water.

Table 3. Water hyacinth quality characteristics (± means standard deviation)

Parameter	Awba dam	Eleyele river	Epe lagoon	Majidun creek
% Moisture	91.0±1.78	90.4±1.17	92.2±0.35	90.9±2.27
% organic carbon	34.1±1.00	36.9±1.80	24.5±4.69	45.4±2.99
% nitrogen	2.93±0.08	3.33±0.34	1.91±0.50	3.90±0.25
% phosphorous	0.07±0.01	0.14±0.03	0.13±0.02	0.12±0.03
% potassium	4.70±0.31	2.74±0.77	4.48±0.14	2.71±1.06
% ash	15.5±0.39	15.8±0.21	17.1±0.19	16.5±1.29
C/N ratio	11.6±0.04	11.2±1.74	13.1±2.60	11.6±0.06
NPK	≈42:1:67	≈24:1:20	≈15:1:34	≈33:1:23
Lead (mg/kg)	7.56±1.25	4.94±3.80	5.56±8.80	4.71±2.60
Cadmium (mg/kg)	0.33±0.28	ND	0.14±0.38	ND
Chromium (mg/kg)	1.07±1.19	0.31±0. 25	0.80±0.17	0.24±0.11
Cobalt (mg/kg)	0.15±0.61	0.12±0.95	0.12±0.14	0.18±0.14
Copper (mg/kg)	3.60±5.15	4.77±5.61	1.10±2.33	9.77±1.73
Nickel (mg/kg)	0.61±0.41	0.61±0.35	0.63±0.10	0.22±0.10

Conclusion

The four major waterways i.e: Awba Dam, Eleyele River, Epe Lagoon and Majidun Creek, all supported healthy water hyacinth population. *Eichhorniacrassipes* were mostly found around Awba dam and Eleyele river while *Eichhornianatans* were found around Epelagoon and Majudun creek. All four surface water bodies indicated gross organic pollution with low dissolved oxygen contents. The two water hyacinth weed identified showed promise of being a potential source of organic fertilizer because of their high Carbon/Nitrogen ratio. Further study is needed to optimize the correct processing methods for efficient used of the weed for fertilizer application.

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