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Bioremediation of Aquacultural Effluents Using Hydrophytes

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Abstract: Pollutant of agricultural industries constitute a threat to aquatic environment, being as a recipient of untreated or partially treated effluents, the use of conventional methods has its own problems especially in developing countries, hence the use of an eco-friendly approach to reduce pollutant load before being discharge. The study aim was to assess the performance of hydroponically grown macrophytes in aquacultural effluent the macrophytes were grown in 5 L aquacultural effluent with 21 days retention period in plastic containers. 100g, 150g, 200g and 250g of plants samples were introduce into hydroponic unit. Physicochemical parameters were measured at interval of seven days for three weeks. The parameters measured were temperature, pH, DO, BOD, COD, nitrate, ammonia, phosphate and turbidity. The mean reduction values of temperature, pH, DO and nitrate were 27.07±0.07, 6.37±0.27, 2.07±0.09, and 0.90±0.15 for *Pistia stratiotes* respectively. While ammonia, phosphate and turbidity values are 0.70±0.15, 0.60±0.23 and 7.00±0.00 for *Eichhornia crassipes*. The performance of the plants was found to be increasing with increase in weight and duration. However, the overall performance may not meet the required effluent standards laid down by the national and international regulatory bodies.

Keywords: Aquaculture, Bioremediation, Effluent and Hydrophytes

1. Introduction

Aquaculture the cultivation of freshwater and marine plants and animals is one of the fastest growing segments of agriculture. From 1987 to 1992, sales of farm-raised fish increased by almost 20% in the United States [1]. Aquaculture industry has grown at an average rate of 8.9% per year since 1970, compared with only 1.2% for capture fisheries and 2.8% for livestock production systems [2]. Aquaculture involving fish production has marked transition from a ‘capture’ to a ‘culture’ economy [3]. However, the industry places great demands on water resources, and typically requires from 200-600 cm^3 of water for every kilogram of fish produced [4].

Aquaculture systems release large amounts of nutrients into the aquatic ecosystem, in the form of excretory products and excess feed [5-7]. Aquatic ecosystems are used either directly or indirectly as recipients of potentially toxic liquids from domestic uses, industries and agricultural wastes [8]. Freshwaters are perhaps the most vulnerable habitats, and are often changed by the activities of man. This essential resource is becoming increasingly scarce in many parts of the world due to severe impairment of water quality. Chemical analysis of water provides a good indication of the chemical quality of the aquatic system, but does not integrate ecological factors such as altered riparian vegetation or altered flow regime and therefore, does not necessarily reflect the ecological state of the system [9].

The pollutant causing adverse effects on physical, chemical and biological factors of water bodies is known as water pollution. It is very important to treat sewage before disposal [10]. Monitoring and prevention of pollution from aquatic bodies situated in public areas is important to environmentalist. Biological tools are being used as low cost alternatives in pollution abatement programs. This new technology has been grouped together under the term-Bioremediation [11]. Remediation or degradation is a technique to degrade rapidly hazardous organic contaminants to environmentally safe levels in soils, waters sludge and residues by using microorganisms, plants and animals [12].

Aquatic plants have the ability to remove organic and inorganic nutrients from waste water in a complete natural way called as Phytoremediation [13]. Now it has been realized that cost efficient methods are only possible means to recycle waste water into high quality pure water [14]. Flora acts as an efficient accumulator of such pollutant in their body without the production of any toxicity or reduction in growth [15]. Numerous aquatic macrophytes have demonstrated considerable potential for nutrient removal from various types of wastewaters [16]. Hence the use of Water Lettuce and Water Hyacinth to treat aquaculture wastewater the two macrophytes are locally available. This study was carried out with the aim of assessing potentials of the *Pistia stratiotes* and *Eichhornia crassipes* in reducing pollutant from aquacultural effluent.

2. Materials and Methods

2.1. Study Area

The experiment was conducted at Biological Garden, Department of Biological Sciences, Usmanu Danfodiyo University, Sokoto. Sokoto State is located between Latitudes 11^o 30 N and 13^o 50 N and Longitudes 4^o 0 E and 6^o 0 E it is 315 m above sea level. Sokoto falls within Sudan savanna agro-ecological zone of Nigeria [17]. It is characterized by erratic and scanty rainfall that last for about four months (Mid June- September) and dry period (October- May). The annual rainfall of the area is highly variable over the years and averaged around 700 mm [18] with minimum and maximum temperatures of the year fluctuating between 15 and 45^oC, respectively.

2.2. Collection of the Aquatic Macrophytes

The Macrophytes used for this study are *Pistia stratiotes* and *Eichhornia cressipes*. Water lettuce was collected from Kware Lake, while water hyacinth was collected from Sokoto River, along Usmanu Danfodiyo University main campus Road. The macrophytes were washed thoroughly to remove sand and other debris, and then transported to the Biological Garden Usmanu Danfodiyo University, Sokoto. The collected samples were kept in plastic containers (30 cm diameter and 40 cm height) of about 30 L, containing water from the natural habitat of the macrophytes for one week before the commencement of the experiment. Identification of the plants was authenticated at the Departmental herbarium.

2.3. Collection of Wastewater Samples

Raw aquaculture wastewater was collected from Premier Fish Farm, from Wamako Local Government Area of Sokoto State. The farm is located along Usmanu Danfodiyo University, Sokoto, main Campus Road, and is 350 m away from Bilya Sanda gate of the University. The farm is a commercial fish farm rearing two types of fish species, namely (Cat fish and Tilapia fish) the fishes are reared in concrete ponds of different dimensions. The Raw aquaculture wastewater collected for the purpose of the experiment was stored at room temperature in accordance with the standard procedure. One hundred and fifty (150) liter Aquaculture wastewater was collected from the farm, for the purpose of the experiment. A grab sample for qualitative analysis to determine the physicochemical parameters was used. The parameters analyzed were; Turbidity, Temperature, pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Phosphate (PO_4^{3-}), Nitrate (NO_3^-), and Ammonia (NH_3). Concentrations of these parameters were determined within 24 hours after sample collection.

2.4. Experimental Design

Hydroponics (water culture) systems, consisting of plastic growth containers (10 cm diameter and 16 cm height) containing five (5) liter of raw wastewater was set up in a Completely Randomized Design (CRD) along with control 4×3. Healthy water lettuce and water hyacinth of size (9 cm and 20 cm) was selected for the treatment of waste water. From the plant samples 100 g, 150 g, 200 g, 250 g, of the plants material was Weighed using weighing balance (Harvard trip balance) after been blotted out using blotter (15 minutes) and transferred in the respective containers containing the aquaculture wastewater except for the control.

3. Physicochemical Analysis of Effluents

The parameters mentioned were determined using APHA standards methods [19]. The analysis was carried out on weekly basis; samples from the twenty seven (27) growth containers were collected to determine their status of physicochemical parameters.

4. Statistical Analysis

Data was subjected to the analysis of variance (ANOVA) using Graph pad prism software version 5.02. Difference between means was evaluated using LSD at (5%).

5. Results and Discussion

The Tables represents the average values of three replicates for each treatment as compared with the initials values of the effluent collected. Physicochemical parameters are assessed weekly; the results indicate continuous reduction in polluted water, hence continuous recovery of polluted water. It is also clear from result section that weekly assessment shows increase in the reduction of pollutant. In general the physicochemical parameters did not indicate the potential for any polluted water quality-related stress of aquatic flora.

The treatment (weight) performance of *Pistia stratiotes and Eichhornia crassipes* culture and control experiment at 7, 14 and 21 days retention periods are shown in Table 1- 6 respectively. As the retention time increased, there was generally a continuous decrease in values of the physicochemical parameters. A comparison of the results in Table 1, 2 and 3 for *Pistia stratiotes* showed that after 28 days had reduced temperature from 29-27.40; COD 11.60-4.37; nitrate 5.60-0.90 and phosphate 3.31-0.33. On the other hand Table 4, 5 and 6 for *Eichhornia crassipes*, turbidity and pH decreased from 25-7.00 NTU and 7.60-6.10respectively. The quality of the effluent from plants culture after 21 days showed that it is suitable for non-drinking purposes like crop irrigation and discharge in water bodies.

According to Gray the optimum growth temperature for *Pistia stratiotes* was 22°C to 30°C while growth stop at temperature range of 8-15°C [20]. The optimum growth temperature of *Eichhornia crassipes* occurs between 25.0°C and 27.5°C and temperature above 33°C inhabit further growth [21]. This was close to the finding of Akinbile who works on aquaculture wastewater and reported temperature range of 25.0°C to 35.0°C [22]. The optimal water pH for growth of *E. crassipes* was neutral but it can tolerate pH values from 4 to 10 [21]. This result finding agrees with the work of Adeniran they reported pH of 7.76 in wastewater treated with *Typha latifolia*, and that of Rabiei they recorded mean pH of 8.7±0.3 using *Ulva reticulata* at 12 day retention time [23-24]. Adelere observed mean DO of 3.14±0.19 to 7.49±0.45. Gupta Suggested various contaminants like TDS, EC, BOD, COD, DO have been minimized using water hyacinth [25-26].

The result of [27] who work on dormitory and aquaculture wastewater report initial BOD of 302.7 mg/l and 79.16 mg/l with mean reduction of 118.21±0.028, 146.17±0.03, 97.73±0.02 and 53.74±0.06, 29.12±0.02, 41.97±0.13 for Hyacinth, Spinach and Cilantro respectively for duration of two week, and for the duration of four week they reported mean range of 78.20 to 28 mg/l and 21.72 to 12.54 mg/l for dormitory and aquaculture. The result of this work tally with the work done by [28] on comparative purification of aquaculture wastewater using three macrophytes reported effluent mean reduction of 34.70±0.60, 16.60±1.0, 27.70±1.0 and 24.70 mg/l at 6 day retention time for control, water hyacinth, water lettuce and parrot feather, at 12 retention time they recorded 45-23 mg/l. The results of this finding was close to the finding of [29] that treat nile tilapia pond effluent and obtained mean reduction of 35.3±16.1, 21.8±10.1, 25.1±11.6 and 48.4 + 21.5 mg/l for Control, *E. crassipes*, *P. stratiotes* and *S. molesta*. The results of Ammonia in this research agrees with that of [30] that reported mean reduction in aquaculture effluent treated with water hyacinth from 0.054 to 0.008 mg/l, 0.054 to 0.005 mg/l and 0.054 to 0.013 mg/l for water hyacinth, water lettuce and morning glory.

This work conform with that of [23] they reported mean reduction of turbidity from 108.75±4.80 to 0.05±0.01 HTU across the sampling point of 1to 11. While [31] recorded 175.00 to 61.00 FTU at retention time of 1 to 10 days

This result coincides with that of [27]. While Treating dormitory and aquaculture wastewater using aquatic plants Cilantro, Hyacinth and Spinach they report mean reduction of phosphate in Dormitory effluent as 16.2±0.028, 18.3±0.05 and 15.7±0.05 for hyacinth, Spinach and cilantro respectively. While 9.22 ± 0.03, 18.46 ± 0.05 and 13.72 ±0.01 for hyacinth, Spinach and cilantro for aquaculture respectively.

Figure 1. *Pistia stratiotes L. (Water Lettuce).*

Figure 2. *Eichhornia crassipes (Water Hyacinth).*

Table 1. *Physicochemical Parameters of Aquaculture Wastewater Treated with Pistia stratiotes.*

Parameters	Days	Treatments				
		Control	100 g	150 g	200 g	250 g
Temperature	7	30.00±0.00^{a}	28.93±0.06^{a}	28.07±0.52^{b}	27.77±0.62^{c}	27.07±0.06^{d}
	14	29.97±0.03^{a}	28.33±0.33^{b}	28.13±0.13^{c}	27.73±0.37^{d}	27.07±0.07^{e}
	21	28.37±0.12^{a}	28.03±0.09^{a}	27.77±0.28^{a}	27.47±0.29^{a}	27.40±0.31^{a}
pH	7	7.63±0.06^{a}	7.56±0.12^{a}	8.10±0.11^{a}	7.60±0.11^{a}	7.43±0.18^{a}
	14	7.37±0.19^{a}	7.20±0.06^{a}	7.07±0.07^{a}	7.37±0.23^{a}	6.s47±0.26^{b}
	21	7.17±0.17^{a}	6.37±0.09^{a}	6.27±0.27^{a}	6.97±0.54^{a}	6.37±0.27^{a}
DO	7	8.40±0.60^{a}	5.77±0.43^{b}	4.93±0.15^{c}	5.07±0.06^{d}	4.10±0.06^{e}
	14	6.43±0.03^{a}	3.20±0.12^{b}	3.67±0.20^{c}	2.73±0.37^{d}	2.70±0.36^{e}
	21	5.57±0.35^{a}	2.97±0.03^{b}	2.57±0.35^{c}	2.53±0.18^{d}	2.07±0.09^{e}
BOD	7	14.27±0.77^{a}	12.77±0.61^{a}	12.70±0.17^{a}	12.40±0.53^{a}	11.27±0.64^{b}
	14	10.23±0.15^{a}	12.17±0.33^{b}	11.73±0.27^{a}	10.80±0.23^{a}	9.33±0.67^{a}
	21	9.20±0.12^{a}	8.10±0.06^{a}	6.97±0.73^{b}	6.03±0.09^{c}	5.03±0.50^{d}

Parameters	Days	Treatments				
		Control	100 g	150 g	200 g	250 g
COD	7	11.23±0.50^{a}	10.37±0.19^{a}	10.07±0.07^{b}	9.90±0.45^{c}	9.20±0.15^{d}
	14	9.73±0.19^{a}	9.23±0.15^{a}	8.33±0.24^{b}	7.07±0.07^{c}	6.63±0.32^{d}
	21	9.30±0.15^{a}	7.90±0.21^{b}	6.30±0.15^{c}	5.70±0.25^{d}	4.37±0.23^{e}
Nitrate	7	4.13±0.24^{a}	3.57±0.23^{a}	2.27±1.05^{a}	3.40±0.20^{a}	2.90±0.60^{a}
	14	3.27±0.22^{a}	2.73±0.15^{b}	2.90±0.06^{a}	2.53±0.24^{a}	1.77±0.19^{c}
	21	3.40±0.06^{a}	1.57±0.23^{b}	1.23±0.28^{c}	1.17±0.03^{d}	0.90±0.15^{e}
Ammonia	7	4.60±0.16^{a}	2.90±0.21^{b}	3.40±0.23^{c}	2.40±0.23^{d}	2.13±0.13^{e}
	14	4.27±0.15^{a}	2.50±0.36^{b}	2.67±0.28^{c}	2.10±0.06^{d}	2.03±0.03^{e}
	21	4.23±0.15^{a}	1.80±0.35^{b}	1.30±0.15^{c}	1.77±0.12^{d}	0.73±0.15^{e}
Phosphate	7	3.18±0.09^{a}	3.30±0.06^{a}	3.00±0.03^{a}	2.50±0.15^{b}	2.10±0.06^{c}
	14	2.13±0.09^{a}	2.37±0.22^{a}	2.27±0.15^{a}	2.17±0.12^{a}	1.57±0.09^{a}
	21	2.10±0.06^{a}	1.57±0.09^{b}	1.23±0.15^{c}	0.80±0.12^{d}	0.33±0.09^{e}
Turbidity	7	12.00±1.16^{a}	9.00±.1.73^{a}	7.33±2.03^{a}	6.33±1.86^{a}	9.67±1.45^{a}
	14	18.00±2.00^{a}	7.00±2.00^{b}	6.33±0.88^{c}	8.00±1.53^{d}	8.00±1.53^{e}
	21	14.00±0.58^{a}	6.67±1.76^{b}	6.33±1.86^{c}	5.33±0.33^{d}	5.00±0.00^{e}

Note: Means followed by same superscript on same row are not significant at P<0.5. All units are in mg/l except Temperature °C and Turbidity NTU. DO - Dissolve Oxygen, BOD - Biological Oxygen Demand and COD – Chemical Oxygen Demand.

Table 2. *Physicochemical Parameters of Aquaculture Wastewater Treated with Eichhornia crassipes.*

Parameters	Days	Treatments				
		Control	100 g	150 g	200 g	250 g
Temperature	7	30±0.00^{a}	28.23±0.28^{b}	28.53±0.26^{c}	27.53±0.29^{c}	27.50±0.25^{e}
	14	29.97±0.03^{a}	27.33±0.18^{b}	27.23±0.12^{c}	27.10±0.10^{d}	27.00±0.46^{e}
	21	28.37±0.12^{a}	27.80±0.61^{a}	27.17±0.46^{a}	26.83±0.27^{a}	26.93±0.18^{a}
pH	7	7.63±0.07^{a}	7.10±0.06^{a}	7.60±0.23^{a}	7.23±0.15^{a}	7.40±0.20^{a}
	14	7.37±0.19^{a}	7.20±0.12^{a}	7.07±0.07^{a}	6.30±0.15^{b}	6.10±0.06^{c}
	21	7.17±0.17^{a}	6.53±0.24^{a}	6.93±0.18^{a}	5.53±0.24^{b}	6.47±0.29^{a}
DO	7	8.40±0.62^{a}	4.31±0.25^{b}	3.57±0.28^{c}	3.33±0.12^{d}	3.20±0.12^{e}
	14	6.43±0.03^{a}	4.07±0.07^{b}	3.63±0.32^{c}	2.63±0.22^{d}	2.03±0.03^{e}
	21	5.57±0.35^{a}	3.63±0.32^{b}	3.13±0.19^{c}	2.17±0.12^{d}	1.53±0.24^{e}
BOD	7	14.27±0.77^{a}	11.63±0.34^{b}	11.50±0.29^{c}	10.73±0.18^{d}	10.37±0.20^{e}
	14	10.23±0.15^{a}	9.73±0.37^{a}	9.40±0.40^{a}	9.13±0.13^{a}	8.23±0.09^{b}
	21	9.20±0.12^{a}	8.47±0.29^{a}	7.23±0.15^{b}	6.07±0.66^{c}	4.23±0.15^{d}
COD	7	11.23±0.15^{a}	10.17±0.12^{a}	9.67±0.24^{b}	9.83±0.34^{c}	8.37±0.27^{d}
	14	9.37±0.19^{a}	9.10±0.06^{a}	8.23±0.12^{b}	6.97±0.03^{c}	6.03±0.33^{d}
	21	9.30±0.15^{a}	7.47±0.29^{b}	6.57±0.35^{c}	5.80±0.50^{d}	3.83±0.44^{e}
Nitrate	7	4.13±0.24^{a}	4.03±0.09^{a}	3.07±0.07^{b}	2.63±0.09^{c}	2.40±0.31^{d}
	14	3.27±0.22^{a}	1.53±0.18^{b}	1.20±0.12^{c}	1.27±0.18^{d}	1.20±0.12^{e}
	21	3.40±0.06^{a}	1.27±0.18^{b}	0.63±0.19^{c}	0.83±0.34^{d}	0.70±0.6^{e}
Ammonia	7	4.60±0.16^{a}	3.23±0.15^{b}	3.23±0.12^{c}	2.97±0.03^{d}	2.77±0.09^{e}
	14	4.27±0.15^{a}	2.60±0.31^{b}	2.23±0.12^{c}	2.33±0.24^{d}	1.67±0.18^{e}
	21	4.23±0.15^{a}	1.50±0.25^{b}	1.33±0.18^{c}	1.30±0.26^{d}	0.70±0.15^{e}
Phosphate	7	3.18±0.09^{a}	3.27±0.04^{a}	3.30±0.15^{a}	2.20±0.12^{b}	2.00±0.00^{c}
	14	2.13±0.09^{a}	2.23±0.04^{a}	2.27±0.13^{a}	1.87±0.09^{a}	1.33±0.24^{b}
	21	2.10±0.06^{a}	1.77±0.15^{a}	1.10±0.32^{b}	1.73±0.09^{a}	0.60±0.23^{c}
Turbidity	7	12.00±1.16^{a}	6.67±1.67^{a}	8.00±1.53^{a}	7.67±2.67^{a}	11.33±3.33^{a}
	14	18.00±2.00^{a}	5.33±1.33^{b}	5.67±0.08^{c}	7.67±1.20^{d}	7.00±0.00^{e}
	21	14.00±0.58^{a}	4.67±0.33^{b}	4.00±0.58^{c}	5.00±0.00^{d}	7.00±1.53^{e}

Note: Means followed by same superscript on same row are not significant at P<0.5. All units are in mg/l except Temperature °C and Turbidity NTU. DO - Dissolve Oxygen, BOD - Biological Oxygen Demand and COD – Chemical Oxygen Demand.

6. Conclusions

The removal efficiencies of water hyacinth was found to be most effective macrophyte, while considerable removals of pollutants was also found with water lettuce. The performance of the plants was found to be increasing with increase in weight and duration and is also an alternative method to the conventional methods. It is efficient and cost effective, considerable amount of biodegradable minerals constituents are removed. However, the overall performance may not meet the required effluent standards laid down by the national and international regulatory bodies.

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