PHYTOREMEDIATION OF FISH POND EFFLUENT IN CONSTRUCTED WETLAND USING THREE AQUATIC MACROPHYTES: WATER LETTUCE, DUCKWEED, AND WATER HYACINTH

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ABSTRACT
Fish pond wastewater (effluent) was collected from World Bank SEEFOR empowered fish farm in Umuoko-Aluu, Ikwerre Local Government Area (21º55' 46''S and 47º22' 24"W) Rivers State, for a period of four weeks. Within the first two weeks of the 28 days subjection of the macrophytes: water hyacinth (Eichhornia crassipes), water lettuce (Pistia stratiotes), duckweed (Lemna minor) and control (without plant) to fish pond wastewater (effluent), turbidity was reduced by 21-24.9% by the water lettuce, 13.98-27.98% by duckweed and 22.86-25.71% by water hyacinth. Total dissolved solids (TDS) were removed at 4.75 – 5.06% by water lettuce, 1.16 – 5.51% by duckweed and 4.48% by water hyacinth. Equally, Nitrate-Nitrogen (Nitrate-N) was reduced at 90.48% by water lettuce and 94.74% by duckweed. Foul smell vanished in all the test plant units within the first week. Duckweed (Lemna minor) was adduced the best in terms of the measured parameters and availability.
Keywords: Bioremediation, macrophytes, effluents, nitrate-n, TDS, turbidity**.**

INTRODUCTION

Aquaculture is the rearing of aquatic organisms in water enclosures under secured conditions for their survival (Naylor *et al.*, 2000) and the possibility of manipulating the life cycles of fish species to attain maximum biomass harvest. As production from aquaculture increases, fish feeds usage also increases with the resultant potential for pathogen propagation and wastewater generation (Naylor *et al.*, 2000).

This results in the concentration of organic matter suspended solids, and nutrients in the pond with consequent increases in oxygen demand, turbidity, and eutrophication of receiving waters (Naylor *et al.*, 2000; Lin and Yi, 2003). Basically, this is the case in developing countries where organic fertilizer and feed usage is high, particularly in the semi-intensive systems (Diana *et al.*, 1997; Ofori, 2000). About 80% of feed fed to fish is released back to pond as nutrients and fecal solids with about 20% only assimilated into fish flesh (Boyd and Tucker, 1998). These figures, according to Pillay (1992), vary on account of culture system, fish species used, feed quality and environmental conditions.

Though poor water quality does not seriously affects the fish, but when it is discharged into receiving water, the effect on natural biota becomes significant (Stephens and Farris, 2004). There exist an interrelationship between the impacts on fish species, the pond location and intensity of operations, the aquatic environment and its morphology, the limnology and hydrology, the adaptive capability of receiving water and trophic status (Boyd and Queiroz, 2001). Hence, fish ponds sited in a relatively fresh watershed are likely going to affect receiving waters greatly than those sited in agricultural watersheds. Equally, irrespective of methods used for fish production enhancement, it has been recorded that less than 30% of the feed or fertilizer used in aquaculture are recovered at harvest (SRAC, 1999), while the remainder of the nutrient load vanishes in the pond. The nutrients entering the water from un-ingested feed, fertilizer, fish faeces and fish metabolites enhanced the production of great amounts of organic matter such as phytoplankton (Ansah, 2010). Thus, expected pollutants accumulate in pond water at grow-out period, and are finally discharged from ponds following a rainstorm or when ponds are drained for harvest (Ansah, 2010).

The possible environmental effects of wastewater discharge from fish farming as enlisted by SRAC, (1998) include:

1) Organic matter in the effluent may increase the oxygen demand of waters downstream from the discharge.
2) Nitrogen and phosphorus in the effluent may stimulate algal blooms in receiving water.
3) Solids in the effluent may settle out at downstream.

Charbonnel, (1989) stated that wastewater is a real public health and continental environmental problem.

Bioremediation is the elimination or remediation of toxic compounds by living organisms such as algae, bacteria, fungi and aquatic plants (Sachdeva and Sharmia, 2012). Specifically, phytoremediation is the use of small aquatic plants (macrophytes) for the treatment (remediation) and reclamation of polluted aquatic eco-systems (Sachdeva and Sharmia, 2012). The most utilized macrophytes (aquatic plants) include water fern (*Azollafiliculoides*); duckweeds (*Lemna spp.*, *Spirodela spp.*, *Wolffiaspp*, and *Wolffiellaspp*); and water hyacinth (*Eichhornia* *crassipes*) as stated by Muradov *et al*., (2014). Most aquatic macrophytes occur naturally and are adapted to their surroundings (Srivastava *et al*., 2008) and have the ability to reduce nutrient concentration from the water. Fast-growing aquatic plants that have high nutritive value are recommended as excellent plants in bioremediation and such plants include free-floating plants like duckweeds (*Spirodela*, *Lemna*, *Wolffia*), and water hyacinth (*Eichhornia*) (Willett, 2005).

The high cost of installation and operation of 'conventional' methods of effluent treatment is very expensive and therefore, prompted the need for 'non-conventional' methods that expectedly will be inexpensive, easy to install and also easy to operate and maintained (Cunningham *et al*., 1995). Cunningham *et al*., (1995) recommended: "constructed wetlands" (CW) as a non-conventional phytoremediation technique which utilize floating aquatic plants. In view of this, Ansal *et al*., (2010) appraised "phytoremediation" as the ecologically and economically most suitable bioremediation method for village ponds because of proficiency it has in prevention and re-use of polluted water. The elimination of constituents of wastewater is achieved by different processes such as adsorption, filtration, chemical precipitation, microbial interactions, sedimentation and vegetation (Hammer, 1989), and the most effective of all is phytoremediation using Constructed Wetland. This system is simple, cost-effective and environmentally non-disruptive (Wei and Zhou, 2004; Roongtanakiat *et al*., 2007). Negroni, (2000) described the main types of constructed wetlands such as surface flow and sub-surface flow.

Study Area

The research was conducted in an *ex-situ* semi-greenhouse condition in Omuoko-Aluu, Ikwerre Local Government Area (21º55'46" S and 47º22'24" W) of Rivers State, Nigeria.

MATERIALS AND METHODS

Sample Collection

Fish pond wastewater (effluent) was collected from a fish farm in Umuoko-Aluu, Rivers State. The test plants (Water lettuce, Duckweed, and Water hyacinth) were collected from the wild in different locations (Water lettuce was obtained from Rivers State Agip Housing Estate swampland area, Duckweed from African Regional Aquaculture Centre fish pond, Aluu and Water hyacinth from the Aluu section of the New Calabar River). The test plants were held in borehole water for three days before assigning them to the test effluent. This procedure was expected to keep all the test plants in a uniform nutrient condition.

The research was conducted for four weeks (28 days; from 1st – 28th August 2017) in a completely randomized design with four treatments (*Eichhornia crassipes, Pistia stratiotes, Lemna minor*, and without macrophyte as “Control”). The test macrophytes were introduced into personally constructed outdoor concrete tank units of 50cm x 100cm x 30cm (0.5 m2 surface area) in triplicate, which served as a "surface flow constructed wetland (CW) system”. The treatment units were shaded under a transparent roof structure with open sides (semi-green-house condition).

Statistical analyses

Using Microsoft Excel 2012, the data were subjected to analysis of variance (ANOVA), and significant differences among the treatments were further subjected to the least significant difference (LSD). Statistical significance was assessed using P=0.05 probability level.

RESULTS

Biological oxygen demand (BOD) reduction:

The fortnightly analysis of BOD reduction indicated that water lettuce had 48.31% in the 1st fortnight and 44.07% by the 2nd fortnight. For duckweed, the BOD reduction was 63.38% and 88.85% on the 1st and 2nd fortnights while water hyacinth effected a reduction of 67.23% and 75.42% on the 1st and 2nd fortnights, respectively. The control tank equally had a BOD reduction of 68.31% and 83.38% on the 1st and 2nd fortnights as in Figure 1.

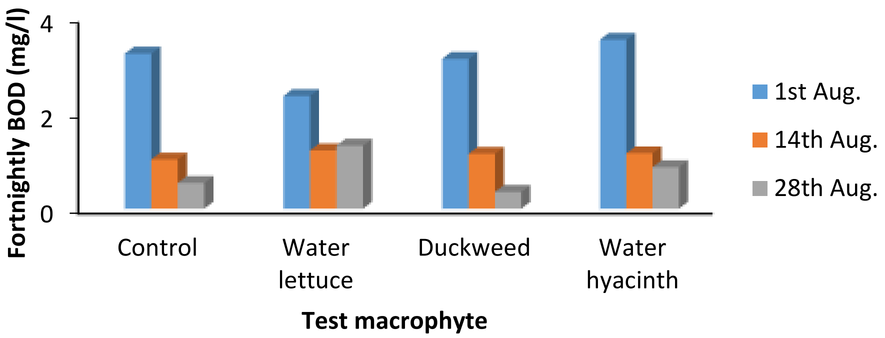

Figure1: BOD reduction in treatment units

Turbidity

Turbidity fluctuated throughout the experimental period in all units. By the 1st week, all units had got effective turbidity reduction level of 24.92% for water lettuce, 27.98% for duckweed and 22.86% for water hyacinth. Afterward, there was a reduction in all units with duckweed attaining a 44.94% reduction in the 3rd week and 42.86% in the 4th week. For water lettuce, the turbidity level reduced to 7.21% in the 3rd week and went up to 9.01% in the 4th week while water hyacinth treatment value reduced to 25.71% in the 2nd week and 16.29% in the 3rd and 4th weeks. The results are in Table 1.

Table 1: Turbidity removal in NTU (and percentage removal)

Treatment	1st Aug., 2017	7th Aug., 2017	14th Aug., 2017	21st Aug., 2017	28th Aug., 2017
Control	30.3	33.3 (9.90%)	33.0 (8.91%)	33.0 (8.91%)	26.0 (-14.19%)
Water lettuce	33.3	41.6 (24.92%)	40.3 (21.02%)	35.7 (7.21%)	36.3 (9.01%)
Duckweed	33.6	43 (27.98%)	38.3 (13.98%)	48.7 (44.94%)	48 (42.86%)
Water hyacinth	35.0	43.0 (22.86%)	44.0 (25.71%)	40.7 (16.29%)	40.7 (16.29%)

Total dissolved solids (TDS)

Total dissolved solids removal was at 4.75% for water lettuce, and 5.51% for duckweed for the 1st week while no removal effect was recorded in water hyacinth unit. The removal effect continued to fluctuate through the weeks with water lettuce having the highest removal of 47.78% in the 3rd week, water hyacinth 20.60% in the 4th week and Duckweed 18.84% in the 3rd week. These are in Figure 2.

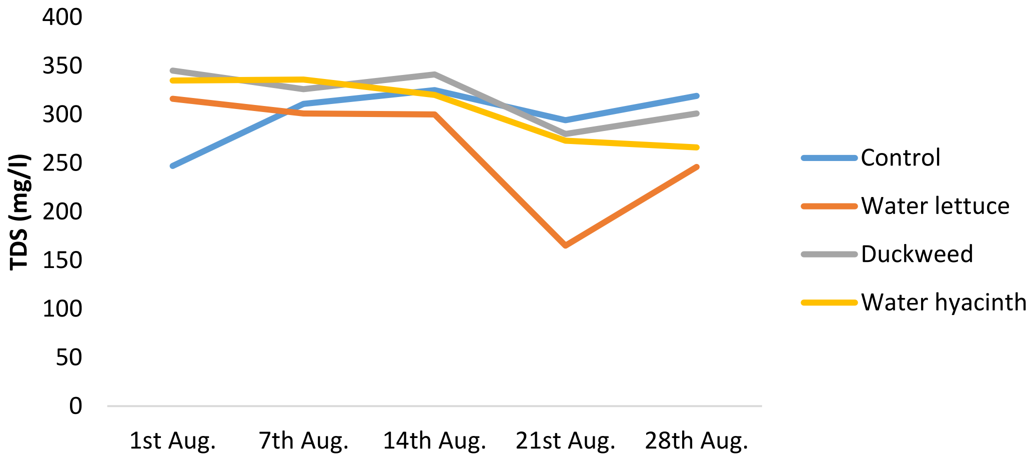

Figure2: Total dissolved solids (TDS) removal level

3.4 Nitrate-Nitrogen (Nitrate-N)

The biweekly analysis of nitrate-nitrogen removal indicated that water lettuce had removed 90.48% by the 2nd week and duckweed 94.74% while water hyacinth had not effected the removal of nitrogen. Also, the control was observed to had 14.71% in Nitrate-N reduction by the 2nd week. The 4th-week analysis indicated that a regeneration of Nitrate-N in all treatment units including the Control. The results are in Table 2.

Table 2:Nitrate-nitrogen (nitrate-n) removal in mg/l (and percentage removal)

Treatment	1st Aug., 2017	14th Aug., 2017	28th Aug., 2017
Control	0.34	0.29 (14.71%)	0.99 (-191.18%)
Water lettuce	0.42	0.04 (90.48%)	0.59 (-40.48%)
Duckweed	0.57	0.03 (94.74%)	1.28 (-124.56%)
Water hyacinth	0.47	0.47 (0%)	1.17 (-148.94%

Phosphate-Phosphorus (phosphate-p):

Phosphate-phosphorus analysis indicated no significant variance in all treatment units throughout the period. The values obtained in all units were <0.05 mg/l as in Table 3.

Table 3: Phosphate-phosphorus (phosphate-p) performance in the treatment units

Treatment	1st Aug., 2017	14th Aug., 2017	28th Aug., 2017
Control	<0.05	<0.05	<0.05
Water lettuce	<0.05	<0.05	<0.05
Duckweed	<0.05	<0.05	<0.05
Water hyacinth	<0.05	<0.05	<0.05

Foul smell

Before the introduction of test plants (macrophytes) to the trial units, the fish pond wastewater emits foul smell observed by the use of the physical sense of the nose. By the 2nd week, the foul smell had vanished up to the last day of the experiment.

DISCUSSION

The phytoremediation effect from test plants (macrophytes) at reducing measured parameters was much observed during the first and second weeks of the experiment as recorded in the major parameters such as turbidity, TDS and nitrate-n (Tables 1 and 2; Figures 2). The three test plants are all effective in the treatment of wastewater at a different degree of efficiency, particularly on the major parameters measured. Within the first two weeks period of the experiment, water lettuce reduced turbidity by 21 – 24.9%, duckweed by 13.98 – 27.98%, and water hyacinth by 22.86 – 25.71%. TDS was removed at the range of 4.75 – 5.06% by water lettuce, 1.16 – 5.51% by duckweed and 4.48% by water hyacinth. BOD was reduced by 48.31%, 63.38% and 67.23% by water lettuce, duckweed, and water hyacinth respectively. Equally, water lettuce and duckweed reduced nitrate-n by 90.48% and 94.74%, respectively. The achievement of 21 – 24% turbidity reduction by water lettuce is comparable to the 89.3% recorded by Henry-Silva and Camargo (2006) whose experiment ran for 14 weeks and was done in the hot season. Equally, the achieved 22.86 – 25.71% by water hyacinth is also comparable to the 90.6% recorded by the same authors. This experiment also recorded better results in nitrate-n removal (90.48%) by water lettuce compared to that recorded (48.8%) by Henry-Silva and Camargo (2006) for the same reason for 14 weeks experiment and carried out in the dry season. This experiment had a 94.74% reduction in Nitrate-N by duckweed which is a comparable achievement to that recorded by Korner and Vermaat (1998) whose duckweed-wastewater treatment study recorded 73% - 97% nitrate reduction in three days.

CONCLUSION

Under the prevailing weather conditions and pond leakages, *Lemna minor* (duckweed) and *Pistia stratiotes* (water lettuce) performed significantly in growth rate and in the remediation test. However, *Lemna minor* relatively performed better than *Pistia stratiotes*, and it is readily available in all seasons in flooded swampland, stagnant gutters and pools. *Pistia stratiotes* is season bound as it is only available in flooded swampland.

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