APPLICATION OF FLOATING WETLANDS AT TROPICAL CONTEXT FOR LAKE WATER RECLAMATION

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Abstract: Pollution of lakes increases rapidly due to the urbanization in developing countries. Therefore, it is necessary to set up feasible mitigatory measures to address eutrophication issues, concurrently considering the lack of land availability as well as low cost involvement. This study was carried out to find out possible application aspects of floating wetland units for lake reclamation. Hence, two types of macrophytes, i.e. *Typha angustifolia* and *Canna iridiflora,* were employed in the pilot scale experiments with two floating wetland systems and monitored water quality for the removal of BOD_5 and inorganic nitrogen. Over 80% of BOD_5 and NH_4^+-N removal capabilities were obtained while NO_3^--N removal was recorded as over 40%. On the other hand, the root growth and its density of *T. angustifolia* was higher than that of *C. iridiflora*, resulting relatively better performance by *T. angustifolia* compared with *C. iridiflora*. Consequently, floating wetlands with *T. angustifolia will be an app*ropriate solution in lake restoration, especially located at congested areas.

Keywords: Eutrophication, Floating wetlands, Lake restoration

1 Introduction

Kandy (N 7° 17' 47", E 80° 38' 6"), the last kingdom of Sri Lanka, has been recognized as a world heritage city by UNESCO for its archeological importance. Kandy Lake is one of the most important manmade structure, constructed during 1810- 1812 A.D. by the last king before becoming Sri Lanka a British Colony. The lake covers an area of 0.18 km^2 and a maximum depth of 13m. It has a capacity of 0.348 MCM within a perimeter of 3.25 km [1]. However, any recreation activity other than riding boats is prohibited and the lake water is used neither for irrigation nor any other domestic activity as the lake water is extremely polluted due to effluent discharges and surface runoff.

It has been reported in the previous studies that Kandy Lake is enriched with P and N compounds and polluted by some heavy metals [1]. Usually, the first flush of storm water from the adjoining residential and commercial areas is a major cause of pollution in similar types of lake surrounded by urban settlements [2]. In addition, the increasing inhabitant bird population, such as resident cormorant (about 250) and roosting bats (about 2500), makes direct contribution to the nutrient pool in lake body [1]. Quality of lake water is speculated to change topographically and seasonally.

Further, Kandy Lake water was studied for several metal ions and found that the Fe^{2+} concentration (> 100 μg/l) was increased in offshore area towards the deepest point, which is found in between the sluice gate and the island at centre [3]. Hence, relatively more reducing conditions prevail in offshore region. Because of the high traffic jam in the peripheral road of the lake, particularly vehicular emissions containing Pb likely to be entered to the lake water while Zn and Cd are added from the small scale industries scattered in lake catchment [3]. Consequently, large fish mortality was observed from mid to end of year 2009, reporting maximum as 150 deaths per day.

In order to mitigate the water pollution on these water bodies, it is necessary to have proper feasible mitigatory measures. Using plants to purify wastewater is feasible option due to its cost effectiveness and environmental sensitivity. Within highly urbanized catchments, where land utilization is limited, more innovative treatment options will be needed. In that case, floating treatment wetlands may represent a potentially suitable solution for improving the water quality in lakes considering their various advantages such as; 1) improvement of the water quality, 2) immediate greening, 3) durable construction in stainless steel, 4) simple installation, 5) almost maintenance free, 6) root horizon as colonization space for microorganisms, 7) nest and brooding spaces for birds, 8) spawning space for fish and 9) shadowing and cooling of shallow water.

Artificially created floating wetlands have been used for a limited range of applications to date, such as water quality improvement, habitat enhancement [4] and aesthetic purposes in ornamental ponds and lakes. In terms of water quality improvement, the main application was the treatment of storm water, combined storm water-sewer overflow, sewage [5], acid mine drainage, piggery effluent [6], poultry processing waste water and water supply reservoirs [7]. However, there is no research found on floating wetland systems done in Sri Lanka at its environmental conditions. Hence, in this research it was expected to determine the viability of using floating wetland systems for water quality improvement establishing general guidelines in application.

2 Objectives and Methodology

The main objective was to evaluate the performance of a pilot scale floating wetland system for lake water reclamation in tropical climate. In this regards, the following methodology was employed:

1. Developed a floating wetland system using locally available material with a sufficient uplift and sustainability at prevailing ambient conditions.
2. Compared the plant growth characteristics and nutrient removal capabilities of two emergent macrophytes (*Typha angustifolia* and *Canna iridiflora*) in pilot scale floating wetland systems.

2.1 Design of floating mats

Premises in Bio technical research center (Faculty of Agriculture, University of Peradeniya, Sri Lanka) was selected to establish the experimental setup and carryout the experiment. The existing three identical tanks were allocated for launching the floating wetland system. The floating wetland models (each of 100 x 50 cm^2) were consisted of a floater and a frame for keeping the vegetation (PVC pipes), media for growth of vegetation (coconut coir pith, PVC net and GI mesh), an anchoring system (cement weights) and vegetation The total weight of the model (initially) was 18.3 kg and the maximum weight that could be carried by the model using the bouncy was estimated as 25.4 kg, keeping a maximum weight of 7.1 kg for the vegetation.

T. angustifolia and C .iridiflora were selected as macrophytes for experiment purpose since these two types of macrophytes were available and sustainable at the environment in Kandy. Macrophytes approximately of 20 cm shoot height were chosen carefully and planted in the wetland units with a density of 10 no of plants/ m^2.

2.2 Experimental procedure

Batch reactor method was selected to test the model of floating wetland system with 12-14 days as hydraulic retention time. After running in tap water for a period of one week to acclimatize the systems, the two floating wetland units were put in to the tanks filled with wastewater coming from

Akbar hall residence at Faculty of Engineering, University of Peradeniya, Sri Lanka. A control volume was maintained near to the tanks with floating wetland units.

Experiment was carried out at three stages and three effluent samples were taken at each stage as initial (prior to launch the system), intermediate and final (prior to remove the system) and were taken at surface level of water body. Each sample was tested for BOD_5, NH_4^+ -N, NO_3^- -N at the environmental engineering laboratory in University of Peradeniya [8]. In addition, shoot height and root depth were measured at predetermined occasion.

3 Results and Discussion

3.1 Monitoring of plant morphology

The root structure and the length observations (Figure 01) have shown that the growth rate of *C. iridiflora is greater than T. angustifolia.* However, the root density was relatively high in *T. angustifolia*. On the other hand, *T. angustifolia* showed a gradual increment in average shoot height through out the experimental period while *C .iridiflora* shoot height was increased in early days and saturated at around 42 days. It indicates that *T. angustifolia* plants still could not reach to the maturation level while *C .iridiflora* plants were observed getting into the matured conditions. After 52 days, one out of eight mother plants of *C .iridiflora* were observed to deliver flower buds. In general, plants growing at nutrient poor conditions will often develop more extensive root systems in order to increase the surface area available for nutrient uptake.

The growth rates of *Canna* sp. was recorded as 3100 $gDWm^{-2}yr^{-1}$ [9] while it was observed greater in *Typha* sp. as 4000 $gDWm^{-2}yr^{-1}$ [10]. Hence the biomass production of *T. angustifolia* could be greater and therefore, *T. angustifolia* impacts much on nutrient removal by harvesting. It has been also estimated that C*anna sp.* may remove an amount of 85 $gNm^{-2}yr^{-1}$ by above-ground biomass harvesting [9] and that for *T. angustifolia* has reached to a much better level of 266 $gNm^{-2}yr^{-1}$ [11].

However, it is possible to manipulate the dissolved oxygen concentration in the water column by including open water zones that allow for re-aeration through algal photosynthesis diffusion across the air-water interface. The effect of nutrient concentration on root development may be less straight forward. On one hand, a ready availability of nutrients generally promotes good plant growth and vigor.

3.2 Evaluation of treatment efficiencies

The experiment done at a HRT of 14 days shown that *T. angustifolia* performs well in removal of BOD_5 than that of *C .iridiflora* (Stage 1 & 2, Table 1). However, at early stages, both macrophytes proved their capacity on making higher reduction of BOD_5 than the removal at the absence of macrophytes (Stage 3, Table 1). However, with the maturation of plants, *C .iridiflora* could improve its contribution on reduction of BOD_5 than that of *T. angustifolia*. Comparing two macrophytes, *C .iridiflora* showed a higher root growth rate at early days while root density of *T. angustifolia* was increased at later stage. Hence, the radial oxygen lose (ROL) in *C .iridiflora* could be high at early days and it might have caused on the better performance in BOD_5 removal at early stage.

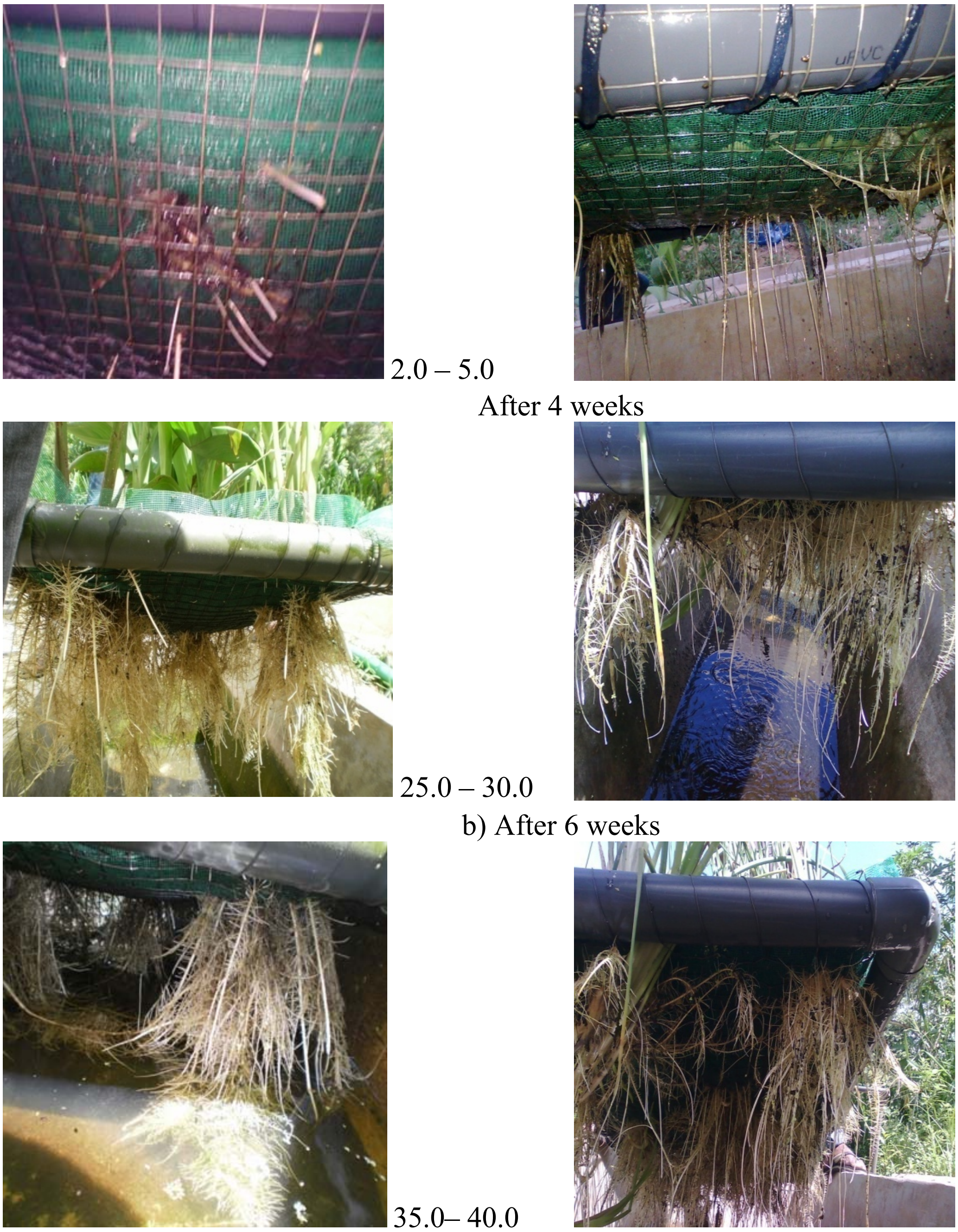

Figure 1: Comparison of the root development patterns of *T. angustifolia* and *C .iridiflora* at different time intervals (*all values are in cm*)

Usually, ROL creates aerobic conditions in the rhizosphere. The oxygen transfer rate to below ground was about 80 $gm^{-2}day^{-1}$ in a well matured wetland system [12]. The macrophyte root and rhizomes in the rhizosphere leak oxygen into the microzones in anaerobic condition. Hence, the addition of oxygen stimulates the breakdown of carbonaceous compounds resulting in BOD_5 removal of 78–91% at 165–237 mgl^{-1} of inflow BOD concentration with *Typha sp.* [13].

On the hand, N removal has varied with the type of macrophytes (Table 2). As well, there was no significant different at the presence and absence of floating wetland systems ($p<0.05$). This could be created due to the interference of high algae growth in the control system. However, the algal growth was controlled in the planted systems due to the competition for nutrients. NH_4^+-N and NO_3^--N were recorded over 80% and 40% respectively in floated wetland systems.

Table 1: *The variation of BOD_5 removal efficiency of each macrophytes specie with the time (n=3)*

Days	BOD_5 values (mgl^{-1})			BOD_5 removal efficiency (%)		
	T. angustifolia	*C .iridiflora*	*Control*	*T. angustifolia*	*C .iridiflora*	*Control*
Stage 1						
0	22.1	22.1	22.1			
5	11.3	5.5	15.8	48.5	75.3	28.6
14	10.3	3.3	10.4	53.2	85.0	53.0
Stage 2						
0	20.1	20.1	20.1			
5	8.8	7.3	9.2	56.2	63.5	54.4
14	4.8	5.8	6.6	76.1	71.3	67.4
Stage 3						
0	28.1	28.1	28.1			
1	20.2	21.6	26.3	28.1	23.1	6.4
2	13.7	15.3	22.0	51.2	45.6	21.7
3	10.2	12.3	19.6	63.7	56.2	30.2
4	8.5	9.7	18.8	69.8	65.5	33.1

Table 2: *Comparison of the averaged nitrogen removal efficiencies of two floating wetland systems with time (n=6)*

Wetland system	Sampling duration (days)	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
Control	0	25.0	7.8		
	7	13.8	-	44.8	
	14	6.9	4.4	72.4	43.6
T. angustifolia	0	25.0	7.8		
	7	12.5	2.7	50.0	65.4
	14	3.4	4.6	86.4	41.0
C .iridiflora	0	25.0	7.8		
	7	10.4	3.3	58.4	57.7
	14	4.6	3.9	81.6	50.0

In general, nitrification followed by denitrification, volatilization, plant uptake and substrate adsorption are the major NH_4^+-N removal mechanisms in a wetland system [14]. At regular ambient conditions, denitrification is probably the most significant pathway of NO_3^--N removal from a wetland system [15]. The loss through volatilization of NH_4^+-N represented, on average, 20% of the initial concentrations at the similar pH range (7.8 – 8.4) as observed in this experiment [16]. This could be greater in the control system than planted system due to its greater exposure to the atmosphere. On the other hand, the contribution to total nitrogen removal by direct plant uptake was limited as 4-11% [15]. Also, the adsorption by sediment might contribute extensively in nitrogen removal [15].

Usually, floating wetland systems and the root and rhizome system assist in nutrient removal by providing space for the attached growth of micro-organisms colonies, creating the bio-film, and take nutrients out of the water. Hence, when nitrogenous compounds pass through the metabolism or the micro-organisms and are thus transformed into an easier digestible form, and then the plants take them in and build with them the biomass above the water level as leaves, stems and sometimes flowers. Finally, the biomass harvesting assists in taking the excess nutrients effectively and permanently out of the water. Therefore, Plant roots are believed to play a major role in treatment processes within floating wetland systems.

However, further fundamental experimental researches are required in order to establish a relationship between loading rate per unit surface area of floating wetland. This would then enable to produce guidelines on the surface area of floating wetland systems.

4 Conclusions

The experimental results have proven the effectiveness of floating wetland systems in removing both carbonaceous and nitrogenous compounds from polluted water. However, comparing two macrophytes species, *T. angustifolia* performs well in removal of BOD_5 and inorganic nitrogen than those of *C .iridiflora*.

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