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INTEGRATED WETLAND ECOSYSTEM FOR SUSTAINABLE TREATMENT OF WASTEWATER

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Abstract: Nutrient removal from sewage water require either additional of chemicals or other energy requirement process. Constructed wetland, a solar driven green technology can be used as an alternative for this. The aim of the study was to find treatment efficiency of an integrated wetland system by analyzing physiochemical parameters of water. It also focused on analyzing nutrient content present in macrophyte sample covered in the wetland. Seven sampling sites (inlet to outlet) were chosen to understand the treatment efficiency of the integrated system. Onsite parameters like dissolved oxygen, total dissolved solids (TDS), pH, electrical conductivity (EC) were measured in situ and further analyses of various physio-chemical parameters (nitrate, phosphate, COD and BOD) were carried out using standard protocols. Macrophytes were collected from same sites and total Carbon, Nitrogen and Phosphorus in the samples were determined. DO, TDS, EC showed a decreasing trend from inlet to outlet. Total removal percentage of nitrate and phosphate in the system was 72% and 50% (from inlet to outlet). Results showed that, this integrated system removed 32% of BOD and 35% COD by the combined function of both wetland and lake system. *Alternanthera* species showed high carbon content of 40% and *Ludwigia* species showed high nitrogen content of about 4%. Among all the species, *Typha* species showed low carbon content and low nitrogen content. Highest phosphorus content was observed in *Ludwigia* species with ~ 0.9% and lowest in *Typha* species ranging between 0.2 to 0.6%.
Keywords: Wastewater, Bangalore, Macrophytes, Integrated Wetland, Nutrient.

Introduction

Nutrients like nitrogen and phosphorus are present in sewage effluents. Its removal is the final process in the treatment of waste water treatment. This require either additional of chemicals or other energy requirement process. Constructed wetland, a solar driven green technology can be used as an alternative for this. It is a natural, low cost, eco-technological biological waste water treatment technology designed to mimic processes found in natural wetland ecosystems, which is now standing as the potential alternative or supplementary system for treatment of waste water (UN-HABITAT, 2008). Compared to conventional

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tertiary treatment technologies, the use of constructed wetlands (CWs) as a cost-effective, extensive and efficient wastewater treatment technology has been increasing over recent decades (Vymazal, 2007).

Nutrients in waste water effluent are also essential elements for plant growth and development (Greenway, 2007). Key nutrients (Nitrogen (N) and Phosphorus (P)) along with other essential minerals are mainly applied to synthesize plant proteins and promote the formation of seed or root (Rai P.K, 2009). Hence unlike conventional treatment, this avoids the need to excavate or dispose the waste produced in treatment process. This method of using plants to concentrate or metabolize contaminant is called phytoremediation. It is defined as a cleanup technique of various degraded ecosystems using plants as remediators of the pollutants (Ahalya and Ramachandra T.V., 2006). It proves to be a low cost and an environment-friendly technology compared to numerous physical and chemical remediation methods (Reeves, R.D. and A.J.M. Baker, 2006).

The present study is on an integrated wetland system at Jakkur, Bengaluru, where secondary treated water is fed to the system for further purification and nutrient removal. It consists of a free water surface constructed wetland and lake. Plants inhabiting these wetlands potentially remove nutrients and pollutants in the water. Research related to N uptake in wetlands indicates that planted wetlands facilitate greater overall removal of nitrogen than unplanted wetlands (Tanner et.al, 1995, Iamchaturapatra et.al, 2008). In some constructed waste water wetlands about 20-30% of the total removal nitrogen is derived from plant uptake (Spieles, D.J. and W.J. Mitsch, 2000). Iamchaturapatra *et al.* (2007) investigated nutrient removals by 21 aquatic plants in a constructed wetland and found that about half of all plants (11 of 21 species) could almost completely reduce N within 2 weeks, and among the 11 species, three species almost completely reduced both nitrogen and phosphorus from raw water. These aquatic plants are termed as macrophytes in constructed wetland technology (EPA, 2000). Studies show that, macrophytes do greatly differ in their nutrient and metal uptake ability depending on the species, stress environment, presence of multi-elements in the contaminated site, and physicochemical parameters of the ecosystem.

Studies on wetland systems also require a thorough understanding of the nature, type and characteristics of the plant and its interactions with the environment. Studies on plant tolerance shows that factors like extreme conditions of wastewater (Surrency, D., 1993), environmental stresses including eutrophication, excessive amount of ammonia (Xu et.al, 2006) can affect physiology of plants and its treatment potential. Hence studies on conditions and resources of macrophytes environment, can make its studies comparable and also to understand plant tolerance. In all the above mentioned interactions the physiochemical nature of water governs the system dynamics. So in this study, along with nutrient analysis of plant, water quality analysis is also done.

The aim of the present study is to find treatment efficiency of an integrated wetland system by analyzing physiochemical parameters of water. It also focuses on analyzing nutrient content present in macrophyte sample covered in the wetland and tries to identify the suitable one for the study area.

Materials and methods

A. Study Area

The present study was conducted in an integrated wetland system at Jakkur, in Bangalore, India (N: 13.084803, E: 077.60940 figure 1). Bangalore is fifth largest metropolitan city in India. It has 9.5 million inhabitants (Census of India, 2011). This city is characterized by Lakes also called as tanks were constructed to meet its irrigation and domestic needs. But now, degradation in the quality and quantity of these tanks is observed.

The study area consists of a manmade wetland, following Jakkur Lake. Both treated water from a nearby sewage treatment plant and untreated treated water enters the 4.63 hectares wetland for further treatment. The manmade wetland is a free water surface wetland containing macrophytes like *Typha angustata*, *Eichhornia crassipes*, *Ludwigia* sp., *Alternanthera philoxeroides* sp. in the shallow region followed by deeper algal basin. The water is then followed into Lake region of 49.63 hectare where further purification is also done.

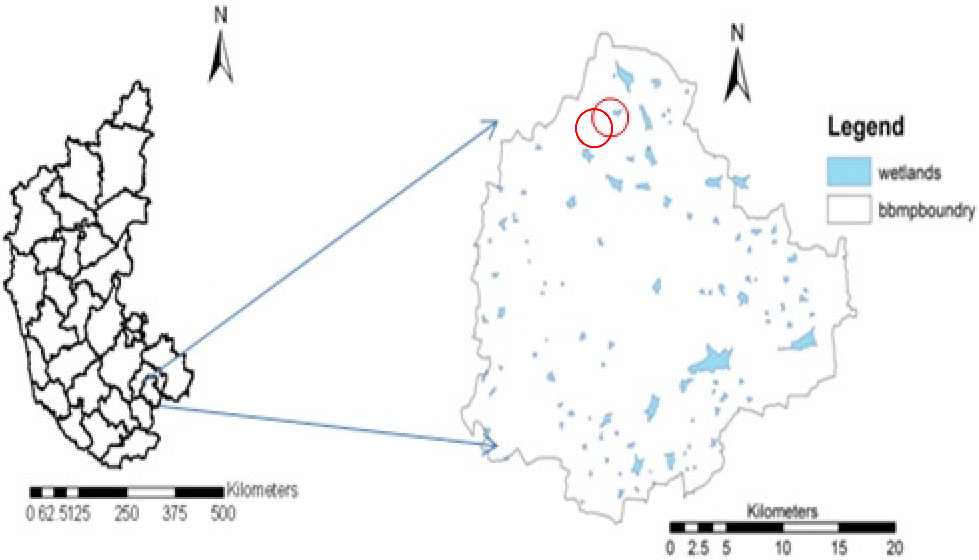

Figure 1: Bangalore Map showing Study area marked in red

B. Water sample collection and analysis

Sampling was done during August to October 2017. Samples were collected once in 30 days interval. Water samples were collected in acid washed, dried polythene one liter bottles. Seven sampling sites (figure 2) were chosen to understand the treatment efficiency of the integrated system. They are, two inlets consisting of both treated and partially treated water, one from after wetland, inlet of lake, centre of lake and two outlets. Onsite parameters like dissolved oxygen (DO), total dissolved solids (TDS), pH, electrical conductivity (EC) were measured in situ during sampling. Samples were preserved at 4°C. Further analyses of various physio-chemical parameters were carried out in laboratory. It include determination of nitrate, phosphate, BOD and COD as per standard methods (APHA).

C. Macrophyte collection and nutrient analysis

Macrophytes like *Typha, Eichhornia, Ludwigia, Alternanthera species* were collected from same sites where water samples were collected (random method, 0.5m^2 transects) and labelled. They were thoroughly washed and dried at 70°C in a hot air oven to get a constant weight. Then samples were ground and sieved to get fine powders. Total Carbon and Nitrogen in the samples were determined by using CHN analyser Leco Truespec 600 series. Total Phosphorus was analyzed according to (Tandon, 1993) after digestion of sample using HNO_3:H_2SO_4:$HClO_4$.

Figure 2: Google earth image of the study area

Results and Discussion

Water quality:

pH: pH ranges between 6.5 (inlet) to 8.28 (outlet) in the study area (Table1). The high pH in the outlet can be due to decrease in carbonic acid by the consumption of carbon- dioxide by algae for photosynthesis.

DO: Dissolved oxygen is an important onsite parameter that gives an indication of pollution in water body. Its level is maintained by the combined activity of dissolution of oxygen and photosynthetic activity. Its value ranged between 0 to 9.0 (Table1). The low DO value at one of the outlet may be because of anoxia condition by algal bloom. Very low DO value was observed in inlet portion. Decaying of macrophyte *Eichhornia crasspies* in the sampling period could have increased organic load resulting low oxygen level.

Total Dissolved Solids: TDS gives the measure of mobile charged ions comprising minerals, salts and metals dissolved in water. The values of TDS ranged from 640 to 1044 mgl^{-1}. It was higher in the inlets and decreased in middle and outlets.

Electrical Conductivity (EC): Electrical conductivity is an indirect measurement of salt concentrations in water. It ranged from 1459 (inlet) to 893 (outlet) µS. It showed a decreasing trend from inlet to outlet.

Sampling sites	pH	TDS (mgl^{-1})	EC (µS)	DO (mgl^{-1})
Untreated water Inlet	6.50	1044.00	1459.00	0.00
Treated	7.62	805.00	1204.00	3.41

water Inlet				
After wetland	7.45	811.30	1193.00	7.06
Inlet to lake	7.62	709.67	1069.00	8.63
Centre	7.71	647.00	988.67	8.44
Outlet1	7.83	650.67	972.00	5.21
Outlet2	8.28	640.00	898.33	9.00

Table 1: Onsite parameters of Water (mean values)

Nitrate: This essential nutrient for photosynthetic autotrophs is usually present in trace quantities in surface water. It can also cause excessive algal bloom in water bodies. In the present study the values of nitrate ranged between 0.25 to 0.07 mgl^{-1} (Table2 and figure 3). Nitrate concentration was 0.25 mgl^{-1} in the inlet. After treatment of wetland, high nitrate removal was observed. Since major mechanism of nitrate removal in wetland is dentrification (Vymazal, 2007), a favourable condition for it may be present in this phase. This can be explained by low D.O and high BOD value in the region which promote anaerobic condition, suitable for denitrification. Another reason may be presence of macrophytes like *Ludwigia* and *Alternanthera* species. Lake also showed nitrate removal, but less than wetland. Total removal percentage of nitrate was 72% (from inlet to outlet).

Phosphate: Phosphorus occurs in natural and waste water almost solely as phosphate (APHA). Its source in water include faecal matters, additives in detergents, food materials etc. Algal bloom in water is an indication of phosphate content in it. EPA water quality criteria states that concentration of phosphorus in lake does not exceed greater than .025mgl^{-1} (Kathryn A. Bartenhagen et al.).Also surface water maintained at .01 to .03 mgl^{-1} of total phosphate decreases occurrence of algal bloom (Kathryn A. Bartenhagen et al.). In the present study, range of phosphate varies between 10.8 to 5.3 mgl^{-1} (Table 2 and Figure 4). A 50% of phosphorus removal was observed for entire system. And it is comparable with previous study which finds 40% phosphorus removal in the same study area (Ramachandra et al. 2014). Also lake system showed a nominal decrease in phosphorus content of about 4%.But concentration of phosphate is high in the present study. This can be due to the increase in inlet concentration. The high phosphate concentration agrees with the algal bloom present in the lake.

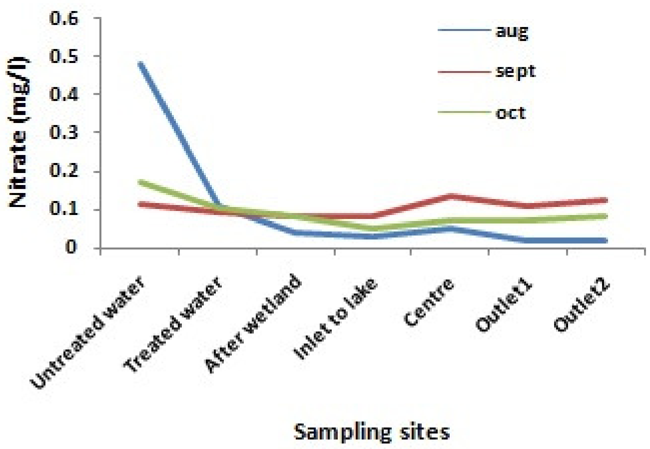

Figure 3: Variation of Nitrate among sampling sites

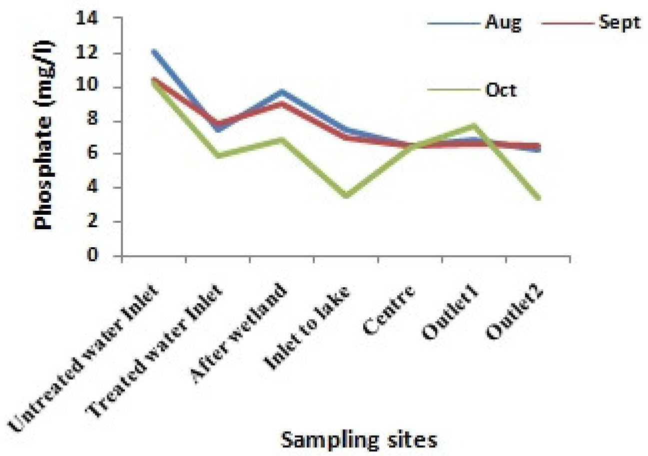

Figure 4: Variation of Phosphate among sampling sites

Sampling sites	Nitrate (mgl^{-1})	Phosphate (mgl^{-1})	COD (mgl^{-1})	BOD (mgl^{-1})
Untreated water Inlet	0.25	10.84	38.00	23.10
Treated water Inlet	0.10	6.98	24.67	15.48
After wetland	0.07	8.50	30.00	13.58
Inlet to lake	0.05	5.97	26.00	18.37
Centre	0.08	6.42	22.00	10.07
Outlet1	0.07	7.00	20.00	12.67
Outlet2	0.07	5.39	24.67	15.61

Table 2: Nutrient analysis of Water (mean values)

Biological oxygen demand (BOD): This is a measure of organic matter present in the water. It is the amount of oxygen consumed by microorganisms present in water, under aerobic condition during a period of five days. Higher BOD value indicates high pollution load. High BOD removal rates of 66% were observed in previous study of the same study area. During this study period the values of BOD varied between 24 to 10 mgl^{-1} (Table 2 and Figure 5). Influent concentration in the present study was about 24 mgl^{-1}. At the end of the system, it attained BOD value, less than 15mgl^{-1}. Results show that, this integrated system removed 32% of BOD by the combined function of both wetland and lake system. However BOD of effluent from wetland was slight greater than to our expectation. And this may be due to dormant stage of *Eichhornia crasspies*, which covered the whole wetland system. The decaying matter of this macrophyte input organic load to the wetland system. It points out need for harvesting of macrophytes.

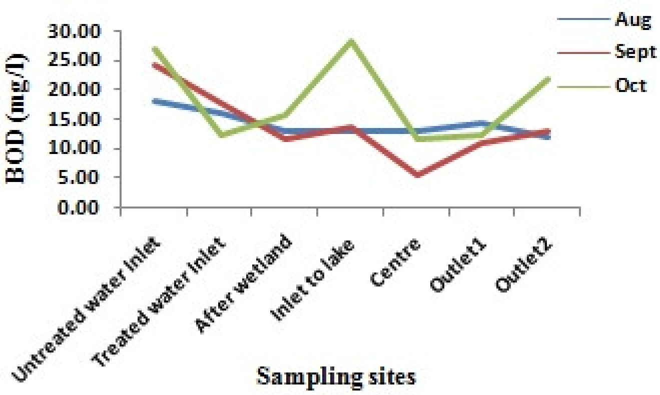

Figure 5: Variation of Biochemical Oxygen Demand (BOD) among sampling sites

Chemical oxygen demand (COD): It is another parameter that indicates the pollution load of water. It gives a measure of both organic and inorganic matter by oxidizing the toxic pollutants and non-biodegradable material using strong oxidizing agent. In the present study, range of COD lies between 38mgl^{-1} and 20 mgl-1 (Table 2 and figure 6). The entire system had removal efficiency of 35 % for COD. Both BOD and COD were high in inlet compared to middle and outlets. This shows treatment capabilities of system.

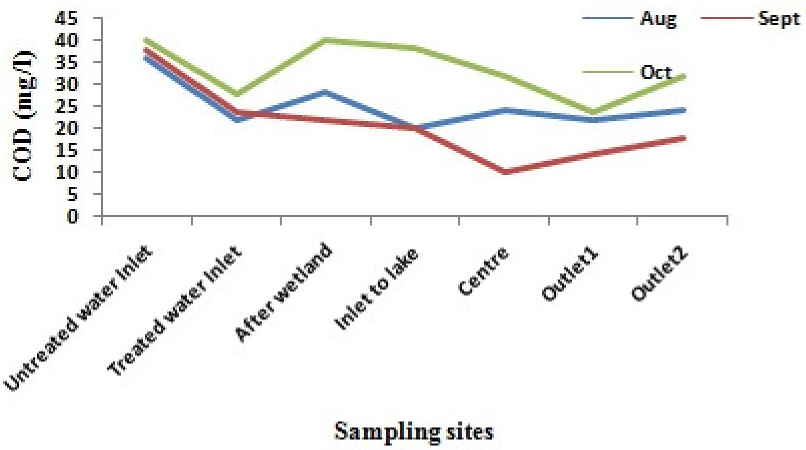

Figure 5: Variation of Chemical Oxygen Demand (COD) among sampling sites

Nutrient Analysis of Macrophytes:

Alternanthera species showed high carbon content of 40% and *Ludwigia* species showed high nitrogen content of about 4%. Among all the species, *typha* species showed low carbon content and low nitrogen content. This can be due to difference in location of site. *Alternanthera* and *Typha* at the outlet showed similar nitrogen content. High carbon content in *Alternanthera* species is comparable to earlier study having carbon content of 38-40% (Mahapatra et al., 2011). Nutrient content also changes with the plant and leaf age (Greenway et al., 2002). Samples from inlet *Typha* species showed significant variation in nitrogen content between mature and young. Studies show that, young leaves contain high nitrogen content, though bioaccumulation of nitrogen is more in mature plant (high biomass).This is because, upon senescence nitrogen from mature shoot is either transferred to young leaves or storage organs (Greenway et al., 2002). High nitrogen content in below ground than above ground is evident from this. Thus dead shoots have less nutrients. This shows that harvesting the dead shoots does not remove nutrients for rooted emergent macrophytes. Highest phosphorus content is observed in ludwigia species with ~ 0.9% and lowest with typha species ranging between 0.2 to 0.6%. The concentration of phosphorus in the plant tissue varies between type of species and sites (Vymazal, 2007). A comparison of site of macrophyte shows that, those near wetland portion have more phosphorus in their tissue. In *Alternanthera s*pecies, those at outlet has less phosphorus content than at after wetland. *Typha* at the inlet has only low phosphorus in its tissue, though it was present in high phosphate water. This confirms that, main source of phosphate uptake by rooted emergent is from sediments than water.

Conclusion

A high nutrient removal of 72% nitrate removal and 50% phosphate removal was observed in the studied integrated system. However a decrease in BOD and COD removal is observed in contrast to our expectation, which can be due to high influent load of organic matter. In the sampling period decayed *Eichhornia crasspies* covered the wetland increased the organic load resulting in effluent BOD value greater than 10 mgl^{-1}. This shows that good management practices like harvesting of floating macrophyte can maintain treatment efficiency of wetland system. A high nitrogen and carbon content is observed in *Alternanthera* and *Ludwigia* species present in after wetland portion. An increase in nitrogen content is noticed in young plant than the mature *Typha* species present in the inlet. Also below ground portion showed high nitrogen content than above ground. This confirms the nutrient translocation seen in mature plants from above ground to below ground.

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