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Performance Evaluation of Surface Flow Constructed Wetland System by Using *Eichhornia crassipes* for Wastewater Treatment in an Institutional Complex

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Abstract:

Land areas which are wet during part or all of the year are referred as wetlands. Constructed wetlands are manmade systems that mimic the functions of natural wetlands and applied for wastewater treatment. Aim of the present study is to investigate the feasibility of using a macrophytes, *Eichhornia crassipes* in constructed wetland for treatment of wastewater in an institutional complex. The daily inlet and outlet wastewater physico-chemical parameters were analysed during the period of two months. The parameters studied were pH, BOD, COD, DO, Total Suspended Solids, Total Dissolved Solids, Nitrogen and Phosphorus. The percentage removal of the parameters were analysed and studied until the percent removal rate gets stabilised. The study showed that the surface flow constructed wetlands are best alternative among modern treatments.

Keywords: Constructed Wetlands, *Eichhornia crassipes,* Macrophytes, Wastewater Treatment, Wetlands,

1.0 Introduction:

Land areas that are wet during part or all of the year are referred as wetlands. These wetlands either natural or artificial (constructed) form, have a substantial capacity for wastewater treatment (Venus, 1987). Constructed wetlands are engineered systems that have been designed and constructed to utilise the natural processes involving wetland vegetation, soils and associated microbial assemblage to assist in treatment of wastewater. Constructed wetlands are based upon the symbiotic relationship between the micro organisms and pollutants in the wastewater (Stomp et al; 1994). Constructed wetlands have been used widely for the treatment of municipal, industrial and agricultural wastewater, as well as for urban storm water. This is owing to their high nutrient absorption capacity, simplicity, low construction, operation and maintenance costs, low energy demand, process stability, low excess sludge production and potential for creating biodiversity (Korkusuz et al., 2005). They are designed to take advantage of many of the processes that occur in natural wetlands, but do so within a more controlled manner. These systems can be used in almost in any environment for treatment of wastewater. Properly designed and constructed man-made wetland ecosystems are extremely efficient at utilizing and cleaning nutrient-rich waters (Mitsch and Gosselink, 1993).

Special concern in constructed wetland designing process is given to appropriate plant selection and pools and canals arrangement (Nicolic,2010). The constructed wetlands (CWs) for water pollution control are becoming an accepted technology world wide. It is being used in some countries that have been used in some countries that have either arid or semiarid climates such as England, in some states in U.S., Canada and Australia (Kandlec and Knight, 1996). for removing particular contaminants from wastewaters. The macrophytes have capacity to improve the water quality by absorbing nutrients with their effective root system. Small communities in which the population is scattered over large land areas face problem for treating the wastewater mostly in case of the high per capita cost. To overcome this difficulty, small communities have to use natural systems for wastewater treatment because they are low in cost and do not require high technology to operate nor do they require highly trained personnel (Al-Omari and Fayyad, 2003). Besides the low construction and operation –maintenance expenditure and ease of operation, wetlands have positive effects on the public with their aesthetic value. Once constructed wetlands enhance flora and fauna , it becomes favourable habitat for birds. Also, these wetlands have negligible effects on air quality since polluted water circulates underground, preventing odour appearance.

A vertical flow constructed wetland can work efficiently for reducing Biochemical Oxygen Demand, Chemical Oxygen Demand, Total

Potassium and Nitrogen, Total Suspended Solids and Total Coli forms (Gikas, 2007). Recent inventories have indicated that there are more than 7000 CWs in Europe and North America with the number increasing in Central and South America, Australia and New Zealand as well as Asia and Africa These systems have potential to treat variety of wastewater by removing organics, suspended solids, pathogens, nutrients and heavy metals. The system does not require high level expenses, technical experts, expensive maintenance and has low environmental impacts (Yasar, 2007).

The objective of the present study is to assess the wastewater quality performance in constructed pilot scale wetland system which examines the role of constructed wetlands in providing an efficient and economical means for treating wastewater. The study was carried out at Shivaji University campus using a sewage which has previously undergone for primary treatment. A surface flow constructed wetland planted with *Eichhornia crassipes* was constructed to treat institution complex sewage. It was supposed that use of such water weed will reduce TSS, BOD and COD load in the sewage.

2.0 Material and Methods:

Experimental Setup:

2.2 Description of Site: The integrated constructed wetland unit combined with surface flow and planted with *Eichhornia crassipes* was built near Technology Department, Shivaji University, Kolhapur (Latitude 16^0 40′ N, Longitude 74^0 15′ S). Maharashtra situated in Western part of India. The climate of this region is tropical with an average annual rainfall of 1025 mm. The mean minimum and maximum temperatures during the study period were 15° C and 34°C respectively.

2.1 Wetland Design: The integrated subsurface flow artificial wetland constructed with brickwork of size 3 m × 1.25 m having a depth of 0.6 m. The tank is plastered in cement mortar on both sides. The bottom of the tank is made up of 1:4:8 concrete portions to make it watertight. The necessary slope is provided at the bottom of the tank for sludge removal. The constructed wetland cell is of 3.06 m^2 area and length to width ratio 2.45:1.25. The depth of the bed is 0.6 m. The bed has regular rectangular shape and a necessary slope is provided at the bottom of the tank for sludge removal. The inlet and outlet chambers are made up of PVC pipe of 12.5 m in diameter with a control valve. At the base of the wetland unit two pipes of 10 cm diameter having inward holes at every 0.9 m distance run parallel in longitudinal direction from inlet chamber to outlet chamber to facilitate the drainage.

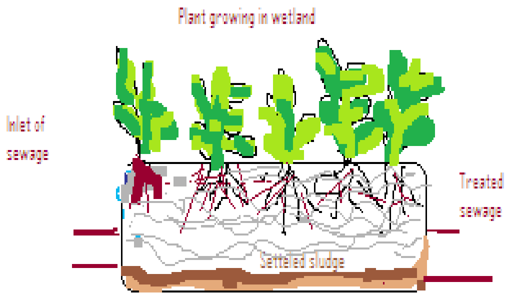


Fig.1 Constructed Wetland flow chart

2.3 Wetland Vegetation: The study was carried out with floating aquatic macrophytes, *Eichhornia crassipes* which are known to be suitable for usage in constructed wetlands (Dhote,2007) It was collected from local natural wetland and transplanted on the same day in a bucket filled with water and maintained for a period of 5 days to remove all previous impurities from the roots. These plants were transplanted from bucket to constructed wetland unit open to atmosphere in the campus. The 50-60 cm spacing was set between the plants.

2.4 Operation and Monitoring: The campus wastewater was let into the constructed wetland intermittently over 30 days. The plants were monitored for general appearance, growth and health. The length of the plant was found to be similar to that of wetland plants in natural wetlands. Any invasive plants like ordinary grass were uprooted and removed immediately. The plant density spread vigorously within 2 months.

Fig.2: Water Weed: *Eichhornia crassipes;* **Fig.3:** Filling the C.W. by sewage;
Fig.4: Placing the *Eichhornia crssipes* in the C.W.; **Fig.5:** Growth of *Eichhornia crssipes*

2.5 Sampling and Analysis: The study was performed in two sets A and B which were run in the months of December and January respectively. The parameters analysed for the study were pH, Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Suspended Solids, Total Dissolved Solids, Nitrogen and Phosphorus. Only quality of wastewater was analysed during the study period of 2 months i.e. December and January. The sampling took place daily at both inlet and outlet of constructed wetland system. All the analysis was carried out as per standard methods for examination of wastewater (APHA, 1999).

3.0 Results and Discussion:

The overall system treatment performance was high and stable during the observation period. The method essentially consist of using wetland plants (macrophytes) to treat wastewater, the plants through their stems ensure the presence of significant amount of air (O_2) in the zone of their root systems, enabling development of aerobic bacterial colonies in the root zone. Bacteria use harmful matter from the wastewater for their nutrition. Part of this matter is used by plants for their growth. The average concentrations of both influent and effluent from integrated constructed wetland system are displayed in Table 1 and 2.

3.1 pH:

pH is the measurement of the intensity of acidity or alkalinity and measure the concentration of hydrogen ion in water. There is always continuous change between acidic and alkaline nature of the wastewater samples. The range of pH between 6.4 to 7.7in the tank shows neutral nature of wastewater. This buffering effect by the water hyacinths was also observed in the previous study (Wolverton and McDonald, 1979)

Table 1: Physico-chemical parameters and percent removal at inlet and outlet of Set A.

Sr. No.	Parameter*	Inlet		Outlet		Average % removal
		Range	Average	Range	Average	
1.	pH	7.1-7.4	6.3	7-7.3	7.2	--
2.	Dissolved Oxygen	0	0	3.4-7.1	5.56	--
3.	Biochemical Oxygen Demand	122-1	163.2	14-21	21.9	86.19%
4.	Chemical Oxygen Demand	169.2-176.40	171.9	18-25	23.10	87.35%
5.	Total Suspended Solids	135-142	167.1	20-59	41	76%
6.	Total Dissolved Solids	465-505	537	99-120	119.1	69.95%
7.	Total Nitrogen	13.8-14.95	17.3	6.95-7.98	9.08	43.33%
8.	Total Phosphorus	3.41-3.9	4.4	1.6-2.01	1.99	45%

Table 2: Physico-chemical parameters and percent removal at inlet and outlet of Set B

Sr. No.	Parameter*	Inlet		Outlet		Average % removal
		Range	Average	Range	Average	
1.	pH	7.2-7.8	7.6	7.1-7.6	7.3	--
2.	Dissolved Oxygen	0-0.1	0	4.9-6.2	7.1	--
3.	Biochemical Oxygen Demand	132.4-141.8	136.9	9-24	22.6	95.89%
4.	Chemical Oxygen Demand	167.4-178.8	173.45	10-28	24.9	97%
5.	Total Suspended Solids	136.80-139.6	138.54	14-55	32.45	82%
6.	Total Dissolved Solids	467.4-486	433	90-110	109.81	71%
7.	Total Nitrogen	14.01-14.42	14.20	7.12-7.82	6.79	43.07%
8.	Total Phosphorus	3.45-3.66	3.25	1.42-1.92	1.5	49.03%

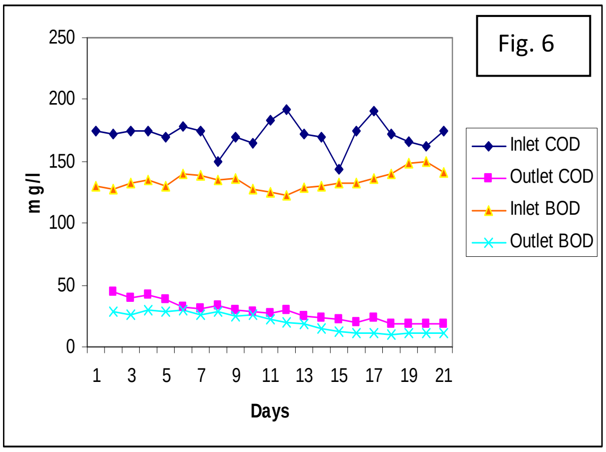
*** All parameters are in mg/l except pH.**

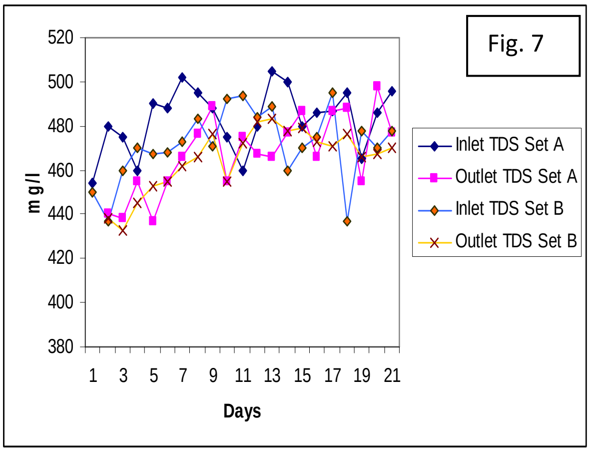
3.2 Dissolved Oxygen:

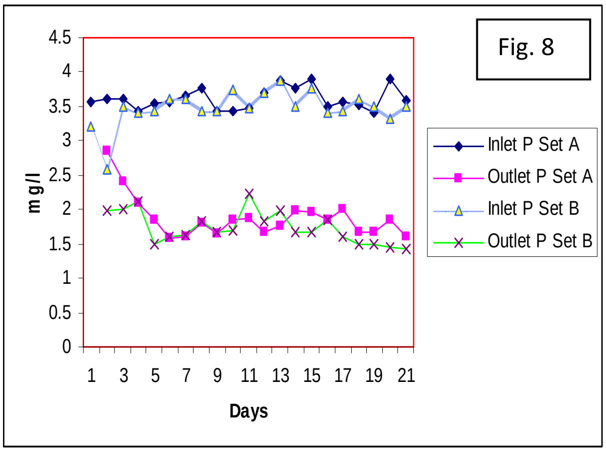
The Set A influent shows absence of dissolved oxygen before the treatment while after treatment the effluent showed increase in dissolved oxygen within the range of 3.4 mg/l to 7.1mg/l. The Set B also shows increasing range of dissolved oxygen in the effluent as compared to influent. The photosynthetic activities in plants increase the DO in water, thus creating aerobic conditions in the system which also favours the aerobic bacterial activity to reduce BOD. Improvement in DO signifies the efficient treatment level. (Bastviken, S., 2006).

3.3 Biochemical Oxygen Demand:

It is the amount of oxygen that will be consumed by microorganisms during the biological reaction of oxygen with organic material. In the present study, it was observed that the influent BOD varies from 122 mg/l to 150 mg/l in Set A (fig.6) and 128 mg/l to 150 mg/l in set B . The average percentage reduction is 86.19 % and 95.89 % respectively in set A and set B. The performance of BOD removal is more in set B than in set A. These variations may be due to different bio-activity of microbes with temperature. In set A, the metabolism and bio-activity of microbes were rather low whereas in set B, with the increasing temperature, the biomasses and activities of microbes increased at high speed, which resulted in higher BOD_5 removal (Steinmann et al., 2003). Also the water hyacinth effected a significant reduction in BOD_5 by directly absorbing and metabolizing oxygen-demanding organics. Because the process of anaerobic degradation requires a longer period of time for completion than aerobic decay, an anaerobic lagoon with approximately the same organic loading rate and detention time as an aerobic lagoon will not reduce the BOD_5 as effectively. Therefore, the significant increase in BOD_5 removal when water hyacinth covered the lagoon . (Wolverton and *et.al*., 1980).







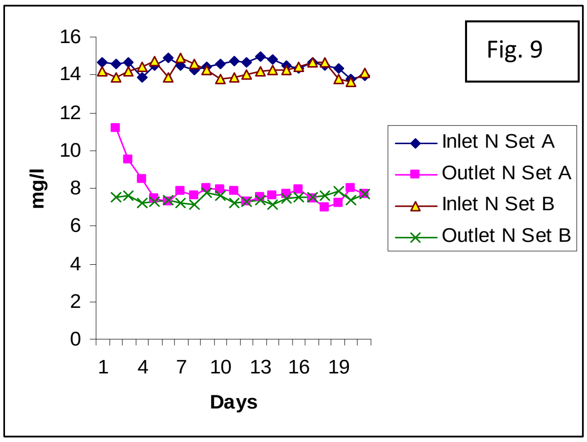


Fig.6: Variation in COD and BOD of Set A at inlet and outlet water; **Fig.7:** Variation in TDS of Set A and Set B at inlet and outlet water
Fig.8: Variation in Phosphorus of Set A and Set B at inlet and outlet water; **Fig. 9:** Variation in Nitrogen of Set A and set B at inlet and outlet water

3.4 Chemical Oxidation Demand:

The COD of the inlet was 144 mg/l to 192 mg/l in set A (fig.6) and 160 mg/l to 183mg/l in set B Under the action of *Eichhornia crassipes* the average reduction in COD is 87.35 % and 97 % in set A and set B respectively. The performance of set B shows better result than set A due to rise in temperature. Similar reduction in COD has been reported by Choudhary (2007) and about 87.17% reduction was found with *Eichhornia crassipes.*

3.5 Total Suspended Solids:

With low wetland water velocities and appropriate composition of influent solids, suspended solids will settle from the water column within the wetland. Sediment resuspension not only releases pollutants from the sediments, but also increases the turbidity and reduces light penetration. The mean value of Total Suspended Solids in influent wastewater ranges from 135 mg/l to 142 mg/l in Set A and 136.8 mg/l to 139.6 mg/l in set B. The reduction in TSS is found to be 76 % to 82 % respectively in set A and set B. The high percentage removal of TSS has reduced BOD load considerably. TSS mainly removed by physical process of sedimentation.

3.6 Total Dissolved Solids:

The reductions in Total Dissolved Solids were very less. The result shows that percentage removal in TDS varies from 2.54 mg/l to7.38 mg/l in set A (Fig.7) and -1.84 to 3.56 in set B (Fig.7) showing increased percentage of TDS. This may be due to the pond acting as equalisation tank.

3.7 Total Nitrogen and Total Phosphorus:

Nitrogen and Phosphorus are very important polluting constituents of domestic wastewater because of their role in algal growth and eutrophication of water bodies. In sewage Nitrogen is present in the organic form. Organic nitrogen and ammonia nitrogen (NH_3-N) are main nitrogen types in wastewater. Organic nitrogen is usually converted into NH_3-N under both aerobic and anaerobic conditions. Therefore, NH_3-N removal mainly contributed to total nitrogen (TN) removal. Three main processes involved in NH_3-N removal were: hydrophytes uptake, volatilization and nitrification/denitrification (Sommer, 2000). Total Nitrogen is normally reduced by denitrification, adsorption and incorporation into cell mass *(*Al-Omari, 2003*).* Plants need Nitrogen for their growth and reproduction. They uptake nitrogen by their floating roots to incorporate it in the form of biomass *(*Baskar,2009) It was also observed that the average Nitrogen in influent was 14.48 mg/l in set A and 14.22 mg/l in set B respectively. It was also observed that under the action of *Eicchornnia crassipes* the total Nitrogen reduced to 7.92 mg/l and 7.43mg/l in set A and set B (fig.9).

Phosphorus is an important nutrient required for plant growth and is usually act as a limiting factor for vegetative productivity. Phosphorus is transformed in the wetland by a complicated biogeochemical cycle. The removal of phosphorus is important since it is known to be major limiting nutrient for algae growth in freshwater ecosystems (Wetzel, 2001). The major processes responsible for phosphorus removal in the constructed wetland are typically by adsorption, precipitation and plant up-take rates. The frequent filtration materials used in surface flow constructed wetland has a gravel base which is commonly good in absorption compared to the plant roots (Vymazal, 2004).Similarly, the average Phosphorus observed in the influent was 3.6 mg/l and 3.48 mg/l in set A and set B respectively. After treatment it gets reduced to 1.87mg/l and 1.74 mg/l in set A and set B respectively (fig.8). Nitrogen and Phosphorus removal efficiency was found less than 50 % in both sets.

4.0 Conclusion:

The integrated constructed wetland system at Shivaji University Campus was observed to decrease all the observed water quality parameters of the campus wastewater, resulting in increasing water quality. The treated effluent values obtained were convenient with current Central Pollution Control Board regulations for domestic wastewater discharge. Implementing the constructed wetland technology is suitable for decentralised domestic wastewater treatment. This system is suitable as stand-alone treatment method for treating low middle strength wastewaters that show high variations in characteristics, especially originated from institutional campuses. The studied system proves to be best alternative to meet the prescribed standards of effluent which are set by Central Pollution Control Board. The Integrated surface flow constructed wetland system by using *Eichhornia crassipes* seems to be viable alternative for reducing the organic matter content from an institutional complex. Applying the wastewater treatment system on campus will support to enhance the environmental consciousness of the campus besides being readily functional on educational purposes.

5.0 Acknowledgement:

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