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Performance and cost evaluation of constructed wetland for domestic waste water treatment

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Abstract

Root zone treatment through constructed wetlands is an engineered method of purifying wastewater. The aim of the present research was to study the potential of wetland plants *Phragmites* and *Typha* in treatment of wastewater and to compare the cost of constructed wetlands with that of conventional treatment systems. A pilot wetland unit of size 2x1x0.9 m was constructed in the campus. 3x3 rows of plants were transplanted into the pilot unit and subjected to wastewater from the hostels and other campus buildings. The raw wastewater and treated wastewater were collected periodically and tested for Total nitrogen (TN),Total Phosphorous (TP), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD). It was observed that this pilot unit reduced the concentrations of TN, TP, BOD and COD by 76, 73, 83 and 86%, respectively, on an average. Root zone system achieved standards for tertiary treatment with low operating costs, low maintenance costs, enhance the landscape, provide a natural habitat for birds, and did not emit any odour.

Key words

Constructed wetland, *Phragmites*, *Typha*, Wastewater treatment

Introduction

Major environmental pollution occurs due to the outflow of effluents from various domestic and industrial sources. The water of rivers, lakes and oceans is nowadays being polluted on a large scale. Water pollution also interferes with growth of organisms living in water bodies, thus retarding the natural purification process caused by such organisms (Kivaisi, 2001).

Some of the suitable wastewater treatment processes for domestic wastewater include biological treatment processes such as activated sludge, trickling filter and rotating biological contractor systems. However, these treatment systems have high operation and investment costs, making them difficult to operate and maintain with stable removal efficiencies. Also, the treated wastewater from these types might require further treatment with a tertiary treatment process, such as a polishing pond, oxidation pond, or constructed wetland to improve the quality of treated wastewater (Metcalf and Eddy, 1998). Constructed wetland systems are shallow water bodies with wetland vegetation that utilize plant's uptake processes to remove pollutants from wastewater (Steer *et al.,* 2002; Mant *et al.,* 2006). They also result in rich microbial community that brings about the biochemical transformation of pollutants (Aslam *et al.,* 2007).

There are two types of constructed wetland: free water surface constructed wetlands and sub-surface constructed wetlands. In free water surface constructed wetlands, waste water flows as a shallow water layer over a soil substrate. Sub-surface constructed wetlands may be either subsurface horizontal flow or sub-surface vertical flow (Neralla *et al.,* 2000). In sub-surface horizontal flow constructed wetlands, waste water flows horizontally through the substrate. In subsurface vertical flow constructed wetlands, waste water is dosed intermittently onto surface of sand and gravel filters and gradually drains through the filter media before collecting in a drain at the base (Ellery *et al.,* 2003). Constructed wetlands may be planted with a mixture of submerged, emergent and, in the case of free water surface constructed wetlands, floating vegetation (Liu *et al.,* 2007).

The aim of the present research was to study the potential of wetland plants *Phragmites* and *Typha* in the treatment of wastewater generated from Sri Ramasamy Memorial(SRM

University)Tamil Nadu,India, premises and to compare the cost of constructed wetlands with that of conventional treatment systems.

Materials and Methods

The integrated subsurface flow constructed wetland system employed was located in SRM University, Chennai, India. The climate is characterized by a short rain period from mid-July to the end of September, a long rain period from October to mid-January, and a long dry period from mid-January to mid-July. The climate is tropical, with a temperature variation of 19–42° C and average annual rainfall of 1330 mm (India Meteorological Department, Chennai, 2006).

Local wetland species, *Phragmites* and *Typha*, capable of growing in tropical and subtropical conditions, were collected from the nearby area and grown prior to transplantation in the pilot unit. Plants were watered with fresh water on alternative days for its growth. After one month, plants were transplanted from the bags to a natural bed and maintained there. Wastewater was added slowly once the plants were well established to acclimatize them. Plants were monitored often and weeds were immediately removed.

Construction of wetland unit : A wetland unit of size 2x1x0.9 m was constructed with an inlet chamber, wetland chamber and outlet chamber (Fig. 1a). The inlet and outlet chambers were provided with facilities for entrance and exit of wastewater. The wetland chamber was separated into three zones by providing stone baffles. For this integrated wetland unit, eight holes were provided in each baffle for both horizontal and vertical movement of water. Plants were maintained in wetland chamber. A mild slope was provided to the unit to ensure smooth flow of wastewater from inlet to outlet and to prevent backflow (EPA, 1998). Plants were grown on a bed of native soil below which was a two-layered medium of sand and gravel. All the layers were of 30 cm each (Fig. 1b).

Treatment, sampling and analysis : Wastewater was subjected to primary treatment (skimming and primary sedimentation) prior being let into the constructed wetland. A design discharge of wastewater was let into the input chamber. Wastewater was allowed to stay in the wetland chamber according to design hydraulic retention time (HRT) corresponding to unit's capacity, after which it was exited to the outlet chamber.

Samples were collected at 24, 48, 72, 96, 144 and 192 hr, in the morning time. Nine samples were collected each at inlet and outlet, and they varied over the course of nine months, from July 2012 to March 2013. The samples were analyzed for COD, BOD, TN and TP according to the Standard Methods for Water and Wastewater Examination (APHA Manual, 2005). Treatment efficiencies were calculated as a percentage difference between inlet and outlet concentrations.

Results and Discussion

The constructed wetland performed exceptionally well for domestic wastewater. A good unit should be able to handle raw domestic wastewater without any dilution (Garcia et al., 2010). There was a good removal for all components by 8d of HRT, around 80% for inorganic components and close to 90% for organic components. The efficiency of reduction continued to rise at higher retention time (Mirunalini *et al.,* 2014). BOD and COD removal were more than 90 and 60%, respectively (Fig. 2a–d). Also, Typha should a marginally better performance than *Phragmites*, which has also been documented by Zhang *et al.* (2011).

It can be inferred from Fig. 3 that there was some variability in treatment in both Phragmites and Typha at 96 hr. At 192 hr, there was some stability as compared to other HRTs. *Typha* exhibited more variability than *Phragmites*. Evidence for inhibited microbial community function, measured as decreased removal rates of nitrogen and phosphorous, was also observed Fraser *et al.* (2004).

Considering the performance of species and the ease of maintaining plants, it is better to plant *Phragmites* than *Typha* in field conditions because *Phragmites* can survive in wet conditions whereas *Typha* needs standing water all the time. Constructing and maintaining a conventional Sewage Treatment Plant is a complex process (Russell, 1999). The costs involved include construction of the units, equipments, operation and maintenance including power charges, which can be substantial. A typical STP treating 0.5 million liters per day (MLD) costs around

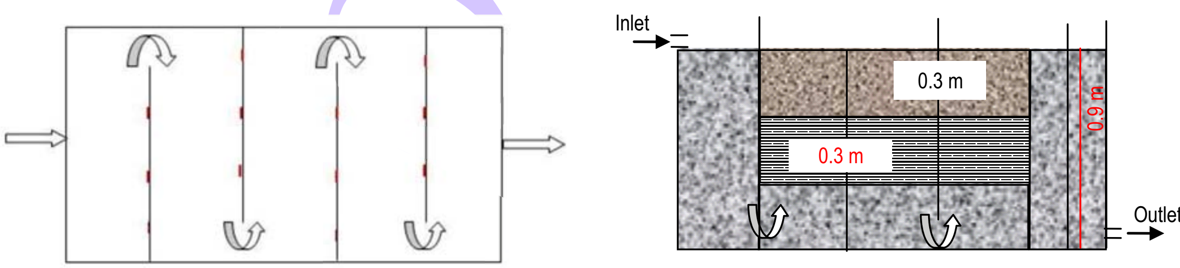

Fig. 1 : (a) Plan View and (b) Sectional View of Wetland Unit

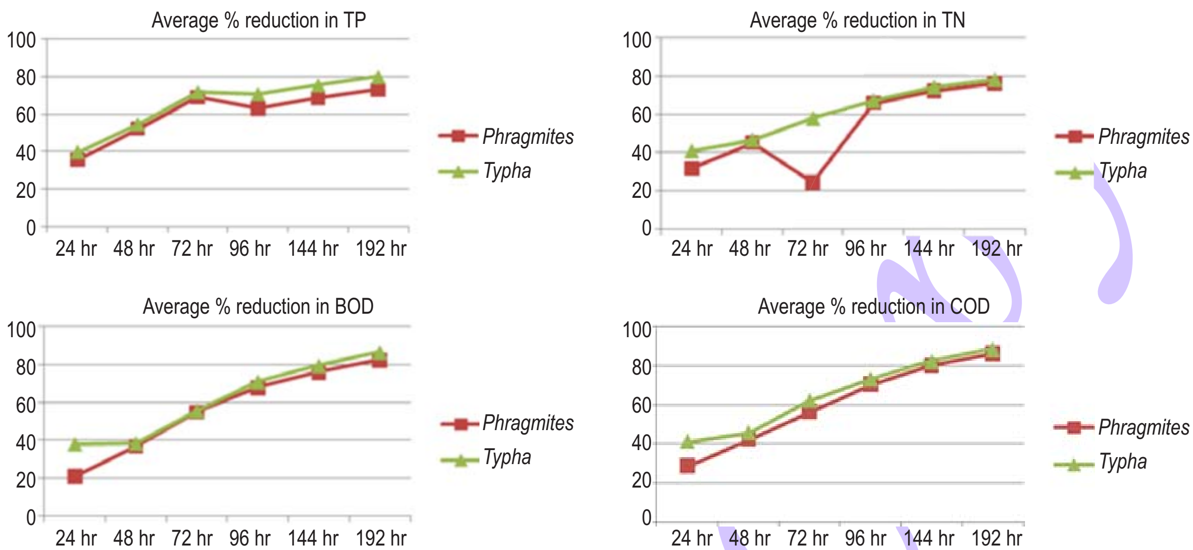

Fig. 2 : Average percentage reduction in (a) TP, (b) TN, (c) BOD and (d) COD

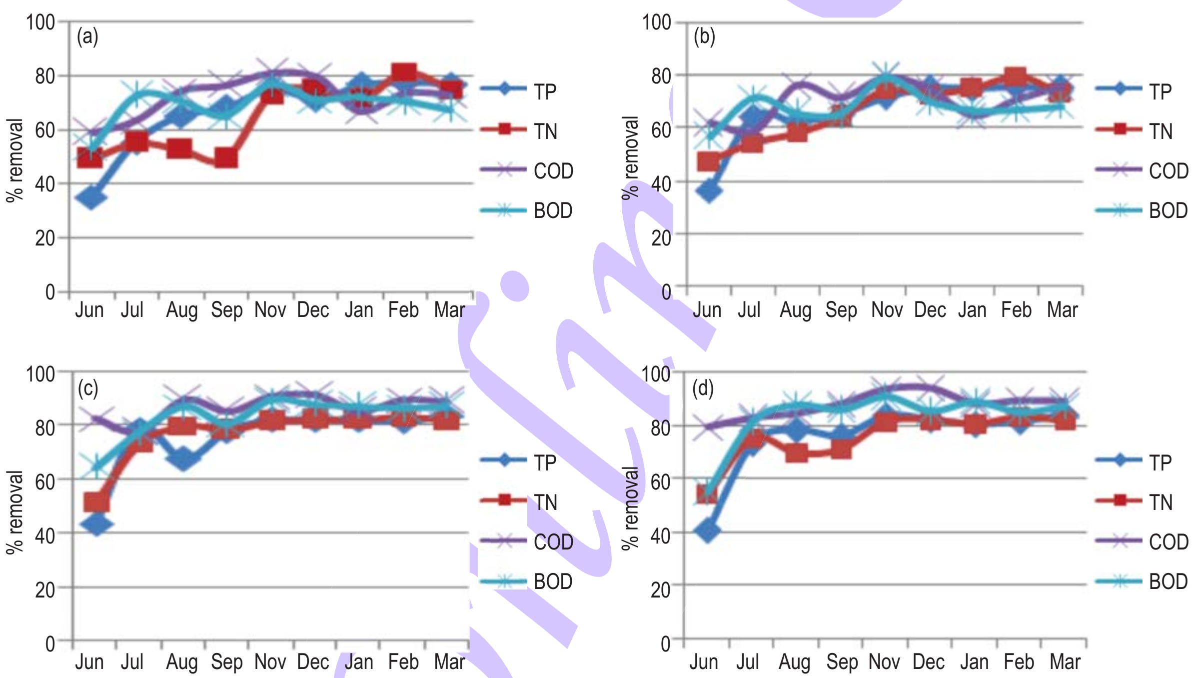

Fig. 3 : Percentage removal of TP, TN, COD and BOD over eight months by (a) *Phragmites* at 96 hr HRT (b) *Typha* at 96 hr HRT (c) *Phragmites* at 192 hr HRT and (d) *Typha* at 192 hr HRT

₹ 5.4 lakhs (USD 88000) including construction, equipment and Operation and Maintenance (O&M) per year for an area of 1500 m^2 of treatment plant. If a constructed wetland is considered for treatment of the same volume of liquid, the construction cost combined with the cost of media filling will be almost same for that of a conventional STP. However, the equipment cost and O&M costs would drastically come down. According to Karodpati and Kote (2013) there is a cost saving of 80% in O&M by using constructed wetlands. Applying the same projection and assuming equal construction cost and 10% of equipment cost, the constructed wetland for an equivalent influent discharge will turn out to be Rs. 23 lakhs only, which is a 57% saving over conventional design.

The present study conclusively proved that a multi culture plant species like *Phragmites* and *Typha* will help in good pollutant reduction and it will work very effectively in wastewater treatment (Kumari and Tripathi, 2015). It is also cost effective as compared to conventional STPs.

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