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Role of Integrated Constructed Wetland for Wastewater Treatment

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ABSTRACT

Wastewater treatment has always been a problematic issue involving complex components. The constructed wetlands have evolved as a reliable wastewater treatment technology for various types of wastewater. Constructed wetlands are man-made wetlands built to remove various types of pollutants present in wastewater. A detailed investigation was made on the configuration and mechanism of constructed wetlands. Three types of constructed wetlands were created with locally available plants, cattail (Typha species) and reed (Phragmites species). Treatment efficiency was evaluated for the following parameters Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Total Nitrogen (TN) and Total Phosphorous (TP). Constructed wetlands reduced the parameters by 79.5% for domestic wastewater and by 53.5% for dairy wastewater. Integrated constructed wetland was found to be more efficient in treating domestic and dairy wastewater and it is also proved to be an "Eco-friendly" alternative for tertiary wastewater treatment.

Key words: Wastewater treatment, constructed wetlands, wetland plants, integrated constructed wetland, dairy and domestic wastewater, tertiary wastewater treatment

INTRODUCTION

Constructed wetlands are artificial wastewater treatment systems constituting channels which have been planted with aquatic plants such as Typha and Phragmites and which are based upon natural microbial, biological, physical and chemical processes to treat wastewater. Wetlands are generally characterized on the basis of four basic parameters: Soils, hydrology, type of flow and vegetation (Kivaisi, 2001).

There are two types of constructed wetland: Free water surface constructed wetland (FWS CWs) and sub-surface constructed wetland. In FWS CW wastewater flows in a shallow water layer over a soil substrate. Sub-surface CW may be either subsurface horizontal flow constructed wetlands (SSHF CWs) or sub-surface vertical flow constructed wetlands (SSVF CWs). In SSHF CW wastewater flows horizontally through the substrate. In SSVF CW, wastewater is dosed intermittently onto the surface of sand and gravel filters and gradually drains through the filter media before collecting in a drain at the base (Vymazal, 2002). Constructed wetlands may be planted with a mixture of submerged, emergent and in the case of FWS, floating vegetation. Constructed wetlands can treat contaminants such as Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), organic compounds and inorganic constituents to meet regulatory targets (Singh *et al.*, 2003).

Phytoremediation can be defined as the application of plants as well as microorganisms of the rhizosphere to remove or render harmless pollutants from contaminated sites. The most applicable technology using phytoremediation strategy is CW technology. Besides water quality improvement and energy savings, CWs have other features related to the environmental protection such as promoting biodiversity, providing habitat for wetland organisms and wildlife (e.g., birds and reptiles in large systems), serving climatic (e.g., less CO_2 production), hydrological functions, heavy metal bioaccumulation and biomethylation.

Total Nitrogen (TN) and Total Phosphorus (TP) are the nutrients of concern for removal in wetland systems. The removal mechanisms for N include uptake by plants and microorganisms, ammonification, nitrification, denitrification, ammonia volatilization and cation exchange for ammonium. The removal mechanisms for P include chemical adsorption and precipitation in substrate and biological transformations and also plant uptake in a lower percentage (Sudarsan, 2012).

MATERIALS AND METHODS

The model was designed based on the design manual of EPA for constructed wetlands (USEPA, 1999) as shown in Fig. 1. It was developed in such a way that it should enhance wastewater distribution to maximize contact between wastewater, substrate and vegetation by minimizing short circuiting. It also considers the degree of pretreatment, required treatment area, available land and slope, length to width ratio, desired bed slope, substrate type and operation and maintenance flexibility. The design is as per Darcy's law. The wetland model of cross section 0.65 m^2 has been designed with hydraulic loading of 0.02 m^3 and average flow of 2.8 m^3/day. Length to width ratio is taken as 2.6:1 with 1% slope. The retention times are 24, 48 and 72 h to get the treated wastewater from horizontal, vertical and integrated flow constructed wetland systems (Campbell and Ogden, 1999). The effluent yield is approximately 0.12 m^3.

The influent samples were collected manually from outlet pipe of dairy industry. The discharge standards for the wetland treated wastewater are based on Bureau of Indian Standards (BIS), Indian Standards Institute (ISI) standards for the Discharge of sewage and Industrial Effluents

Fig. 1: Model of Integrated Constructed Wetland System (ICW)

Table 1: Characteristics of sample water

Description	Dairy wastewater (mg L^{-1})	Domestic wastewater (mg L^{-1})
pH	10.04	7.12
Biological Oxygen Demand (BOD)	557	190
Chemical Oxygen Demand (COD)	1150	258
Total Suspended Solids (TSS)	1861	257
Total Dissolved Solids (TDS)	3065	223
Nitrogen (N)	48.38	43
Phosphorus (P)	12.36	8

in surface water sources and public sewers (IS 4764:1973). The raw effluent from dairy industry includes residual milk (milk remaining in pipelines, bulk tank after emptying), cleaning chemicals (detergents, acids, resins), manure, bedding, feed, grit and dirt from floor. The domestic wastewater samples were collected from SRM campus treatment plant taken using a gouge from the depth of 10 cm. The samples were stored in polyethylene plastic bottles, transported to the laboratory on the same day and stored in the dark at 4°C until the experiment (Standard methods for the examination of water and waste water: American Public Health Association (APHA, 2005)). Table 1 lists the characteristic influent values of the parameters considered for dairy and domestic wastewater samples.

The minimum dilution to bring the dairy wastewater parameters to acceptable limit is taken as 1:10 since it has got higher values of BOD and COD (Sudarsan, 2008). The values for BOD, COD, TSS, TDS, nitrogen and phosphorus for dairy wastewater after dilution were 9.54, 75, 95, 252, 390, 6.53 and 1.72 mg L^{-1}, respectively.

RESULTS AND DISCUSSION

Domestic wastewater and dairy wastewater were collected as per the guidelines of central pollution control board its composition and characteristics have also been studied. After studying complete details of design of wetland model, the tank was designed. Three wetlands, namely, integrated, horizontal and vertical wetlands are designed and practical prototype models were made and the wetland plants were also planted. When the domestic wastewater was allowed into the constructed wetland the different layers in the constructed wetland acted as filter medium and they removed the impurities and other unwanted substances from the water. The effluent was collected by an outlet for 24, 48 and 72 h through the outlet provided at the bottom of the last chamber. The same procedure was repeated for effluent from dairy industry. Finally all the characteristics and parameters were tested in the lab and they are compared with the inlet characteristics of wastewater. Table 2 presents the percentage removal efficiency of dairy and domestic wastewaters.

It is clear from Table 2 that the Integrated Constructed Wetland is very efficient in treating domestic wastewater. All the parameters BOD, COD, TSS, TDS, TN and TP were found to be efficiently reduced when domestic wastewater was used in Integrated Constructed Wetland. The percentage of removal efficiency was slightly lower when dairy wastewater was used.

It is evident that the percentage removal efficiency of domestic wastewater effluent is much higher than dairy wastewater effluent in Integrated Constructed Wetland System. The percentage removal of BOD, COD, TSS, TDS, nitrogen and phosphorus of dairy wastewater are 25, 66, 79, 72, 37 and 42%, respectively. Similarly percentage removal of BOD, COD, TSS, TDS, nitrogen and

Table 2: Percentage removal efficiency of dairy and domestic effluent in integrated constructed wetland system

	Removal of dairy wastewater (%)			Removal of domestic wastewater (%)		
Parameters	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
BOD	20.0	30.6	25.3	65.7	79.4	92.6
COD	56.0	62.1	66.0	50.7	69.7	86.8
TSS	73.4	76.9	79.3	58.3	91.8	96.8
TDS	69.2	69.7	72.3	60.9	70.8	84.3
Nitrogen	29.8	35.0	37.3	13.9	25.5	44.1
Phosphorus	14.5	35.4	42.5	37.5	62.5	75.0

phosphorus of domestic wastewater are 92, 86, 96, 84, 44 and 75%, respectively. For all the parameters except BOD, the percentage removal continues to rise on day three. The higher retention time may further improve the efficiency of the constructed wetlands.

Domestic wastewater: The constructed wetland performs exceptionally well in treating domestic wastewater. The constructed wetland is able to handle raw domestic wastewater without any dilution. Only TN reduction is slightly low. These results are compared with published literature (Garcia *et al*., 2010). The higher reduction for TSS and TDS is achieved because the raw wastewater was taken from the outlet of the primary settling tank. For the domestic wastewater also the efficiency continues to rise on day three indicating that the performance of the wetland model might peak at a higher retention time.

Dairy wastewater: The BOD reduction for dairy wastewater is very low, 25% even after three days of retention time. The efficiency also reduces after day two. Similar results were noticed in an earlier study (Sudarsan *et al*., 2012). This this is probably because the incoming wastewater was organically very strong. This implies that the higher dilution may be needed for treating dairy wastewater in constructed wetland. The parameters COD, TSS and TDS were reduced considerably indicating that the constructed wetland is an efficient method of treatment. Total nitrogen and total phosphorous are also reasonably reduced. These values are comparable with earlier studies except for COD (Sudarsan *et al*., 2012).

CONCLUSION

Constructed wetlands are an effective option for on-site wastewater treatment when properly designed, installed and maintained. This study proves that the concentrations of parameters BOD_5, COD, TSS, TDS, TN and TP were substantially reduced for domestic wastewater and to a reasonable extent for dairy wastewater. Higher retention times are likely to result in better performance for both waste waters. The dairy wastewater needs higher dilution for BOD reduction.

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