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A Study on Domestic Wastewater Treatment by Pilot-Scale Constructed Wetlands

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Abstract : Explosion in population has resulted in enormous generation of wastewater, warranting an economically feasible and efficient method for its treatment. To offset the cost associated with conventional treatment method and to bring about a degree of treatment, fit for agricultural applications, the present study of wastewater treatment with constructed wetlands was carried out. The performance of pilot scale constructed wetlands in treating a pretreated domestic wastewater was done, with select plant species such as *TyphaLatifolia*, and *Croton Plants*. Various kinds of constructed wetlands such as horizontal flow types, vertical flow type and hybrid type were tested. The characteristics such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Solids (TS), Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) of effluents, treated with these pilot scale constructed wetlands wereanalyzed at different Hydraulic Retention Times (HRT). On observation it was found that hybrid type constructed wetland exhibited the best removal efficiency in terms of all the characteristics of wastewater tested. At optimum HRT, brought down the BOD value from 370mg/L to 59.2mg/L, COD value from 480 to 103mg/L,TSvalue from 3200mg/L to 1820mg/L, TSS value from 500mg/L to 10mg/L and TDS value from 2700mg/L to 1810mg/L. which is within the permissible limit for irrigation standards (BOD is 100mg/L, TSS is 200mg/L, TDS is 2100mg/L and TS is 2300mg/L).The results indicate that bio-degrading micro-organisms could have played an active role in BOD reduction and the root zone could have acted as a filter media. This constructed wetlands can be used as an economic alternative for treating domestic wastewater.
Key words: Constructed Wetlands, Hydraulic Retention Time, Domestic Wastewater, Croton plants, TyphaLatifolia.

1. Introduction

Due to explosion in population, the quantum of generation of domestic effluents has also increased proportionately[1]. The initial cost of installation of conventional wastewater treatment plant is high and such facilities are yet to be provided adequately to cater to the needs of the ever increasingly quantity of wastewater being generated[2]. Constructed wetlands seem to provide a viable and economic alternative to this problem[3].

A constructed wetland (CW) is an artificial wetland created for the purpose of treating anthropogenic discharge such as municipal or industrial wastewater and storm water runoff. This process is a clean, economic and eco-friendly method that can be used as an alternative to conventional systems. Constructed Wetlands can be considered treatment systems that use natural processes to stabilize, sequester, accumulate, degrade, metabolize, and/or mineralize contaminants[4].

Constructed Wetland treatment systems use rooted wetland plants and shallow flooded or saturated soil for wastewater treatment. Constructed wetlands are designed to take advantage of the chemical and biological processes of natural wetlands to remove contaminants from wastewater[5]. Constructed wetlands are artificial wetlands with the purpose of mitigating organics, inorganics, nutrients, municipal and domestic sewage, industrial effluent, mine drainage, and leachate[6]. Constructed wetlands are being employed more frequently as a means of wastewater treatment facilities for areas with smaller populations because they are less energy intensive and require less maintenance compared to conventional municipal wastewater treatment plants[7]. Wetlands provide a low-cost, easily-managed systems that can treat water to acceptable levels. Good aesthetic properties and effective treatment capabilities make subsurface flow wetlands an appropriate choice for small-scale, individual or small group residential situations[8,9]. Though several studies have been carried out on constructed wetlands, the influence of HRT on the functional efficiency of a constructed wetland has not been comprehensively performed.

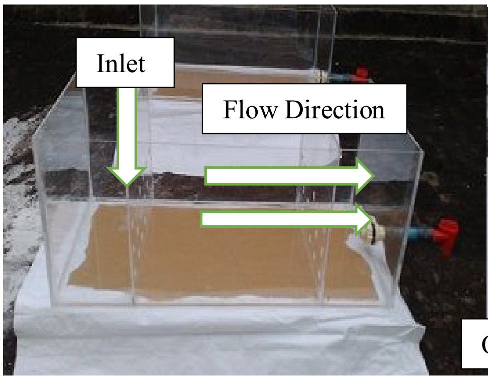
In this paper a study has been made on the influence of HRT on various wastewater parameters such as BOD, COD, TS, TSS and TDS.

2.Materials and Experimental Methodology

In the present study, pilot scale constructed wetlands were investigated. The models were constructed with plastic-fiber for better visibility of filter media and flow of wastewater. Three kinds of constructed wetlands were adopted viz., horizontal subsurface flow constructed wetland (HSSFCW), and vertical subsurface flow constructed wetland (VSSFCW) and Hybrid CWs. The dimensions of the tanks are 0.75 m long, 0.4 m wide and 0.3 m deep. To enable the flow of wastewater under gravity a longitudinal slope of 1 in 100 was maintained. A free board of 0.1m was provided for each wetland cell.

In the HSSFCW, the wastewater flows horizontally and parallel to the surface as shown in Fig.1, whereas in the VSSFCW, the wastewater flows vertically from the planted layer down through the substrate and is shown in Fig.2.

A hybrid constructed wetlands is combination of vertical and horizontal systems, in which the firstly wastewater flows through vertical system and next into the horizontal system.



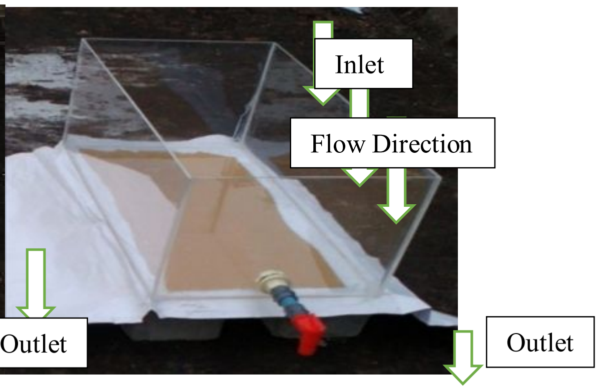


Figure 1: HSSFCW Model without FillingFigure 2: VSSFCW Model without Filling

2.1 Collection of Domestic Wastewater Sample:

Grab sampling was adopted from Municipal Sewage Treatment Plant, near Renigunta, Tirupati in Chittor District, for the performance analysis of BOD, COD, TS, TDS and TSSusing Pilot Scale Constructed Wetland Models.

2.2 Filter Media:

A soil medium is necessary as a matrix in both HSSFCW and VSSFCW systems for supporting emergent vegetation.

The system is made of plastic-fiber. It was filled as follows (from bottom to top):

- In HSSFCW, at both inlet and outlet (1" pipe), a 0.15m thickness of gravel (50mm) was provided to ensure uniform distribution of wastewater. Vertically, the reactor was divided into two layers. The bottom most layer consisted of coarse aggregate (6 mm) of thickness 0.15m. Above it a layer of soil (0.3-0.5 mm) of thickness 0.05m was provided as shown in Fig.3.
- In VSSFCW, the reactor was divided into three layers, The top and bottom layers consisted of coarse aggregate (6 mm) of thickness 0.05mand the middle layer was filled with soil (0.3-0.5 mm) of thickness 0.1m as shown in Fig.4.

Figure 3:Layers of media in HSSFCWFigure 4:Layers of media in VSSFCW

2.3Vegetation Establishment:

Two types of plants viz.,*Thypalatifolia*and *Croton plants* were used for HSSFCW and VSSFCW respectively, and the same are depicted in Fig.5 and Fig.6 respectively. Each unit was planted with 6 plants arranged in 2 rows and 3 columns. Width of each root was approximately 0.12m. Plant spacing was 0.12 m along the length and 0.10 m along the width. Depth of roots was 0.15 m and surface plant density of each wetland cell was 20 plants/m^2.

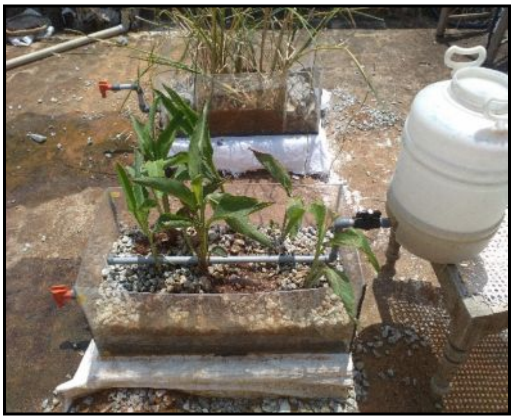


Figure.5 HSSFCW with ThypaLatifolia **Figure.6 VSSFCW with Croton Plants**

2.4 Methodology:

Wastewater flow rate was adjusted at the inlet valve. For all reactors as the volume is known, required time was calculated according to the formula given in (Eq.1).

$$T = \frac{V}{Q} \qquad (1)$$

The details of various time intervals taken are provided in Table 1.Wastewater was supplied at the inlet at calculated intervals of time.

Table. 1 Details of HRTs for varying Flow Rates (Q)

Types>>>	HSSF CWs	VSSF CWs	Hybrid CWs (VSSFCW +HSSFCW)
Volume (V)	V=L×B×H =0.45×0.4×0.2 =0.036m3	V=L×B×H =0.75×0.4×0.2 =0.06m^3	V=L×B×H =1.2×0.4×0.2 =0.096m^3
Discharge (Q)	Q=100ml/25sec=345 lit/day		
	Q=100ml/30sec=288 lit/day		
	Q=100ml/36sec=240 lit/day		
	Q=25ml/12sec=180 lit/day		
HRTs (hours), T=V/Q	2.5 Hours (150 min)	4.17 Hours (250 min)	6.67 Hours (400 min)
	3 Hours (180 min)	5 Hours (300 min)	8 Hours (480 min)
	3.6 Hours (216 min)	6 Hours (360 min)	9.6 Hours (576 min)
	5 Hours (300min)	8 Hours (480 min)	12.8 Hours (768 min)

3. Results and Discussion

3.1 Performance of Constructed Wetlands without Vegetation

Wetland models were evaluated without plants to estimate the potential of the reactor as a natural filter alone, in absence of plants. Also a reactor without plants acts as a blank model to estimate the role of plants in the purification process.

The characteristic parameters of wastewater treated in the absence of vegetation with both HSSFCW and VSSFCW at a HRT of 8hrs is depicted in Fig.7. It can be observed from the figure that TSS removal was high and TDS removal was low. So, it can be inferred that the reactor acted more like a filter medium.

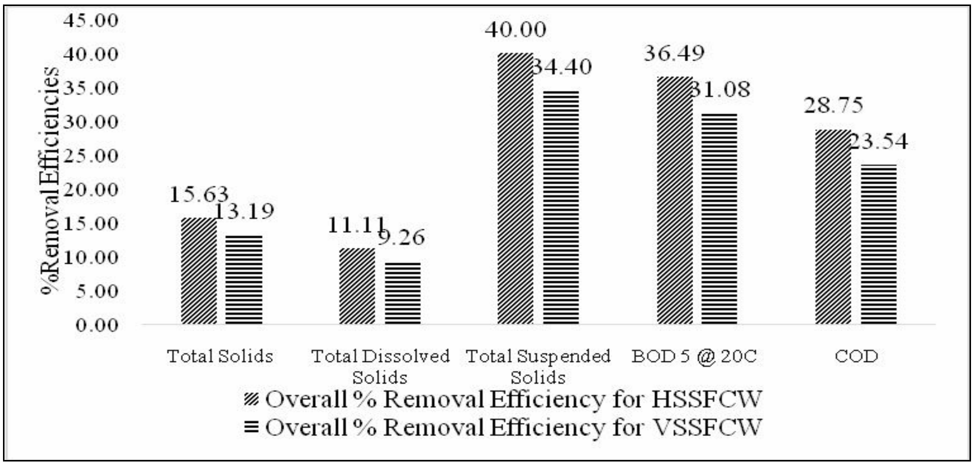


Figure.7 Removal Efficiency for Unplanted HSSFCW and VSSFCW(Initial TSS=500mg/L, TDS=2700mg/L, TS=3200mg/L, BOD=370mg/L, COD=480mg/L)

3.2 Performance of Horizontal Subsurface Flow Constructed Wetland (HSSFCW) with *TyphaLatifolia*

The HSSFCW was planted with *TyphaLatifolia* and supplied with wastewater at four different HRTs and analyzed forvarious wastewater characteristics.

The percentage removal efficiencies of BOD, COD, TS, TSS and TDS are presented in Fig.8.

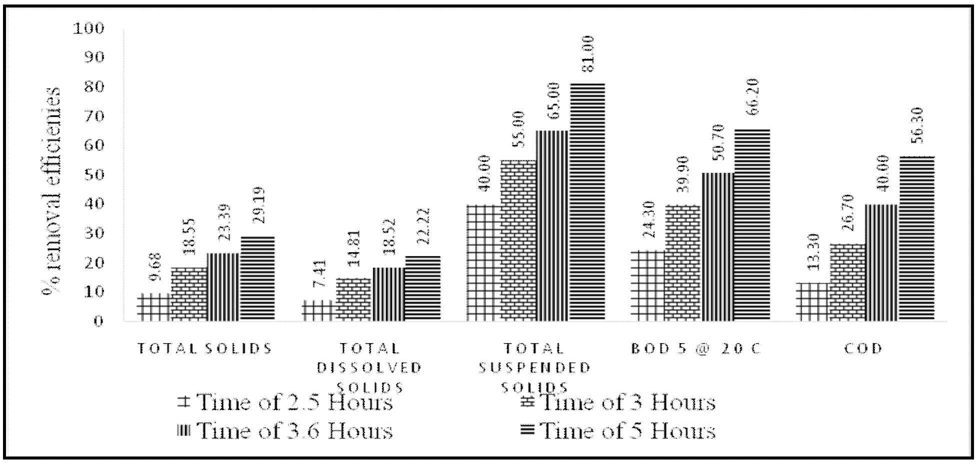


Figure.8 Removal Efficiencies of HSSFCW (Initial TSS=500mg/L, TDS=2700mg/L, TS=3200mg/L, BOD=370mg/L, COD=480mg/L)

It can be observed from Fig.8 that highest removal with respective to time of TSS was at HRT 5hrs. So it can be inferred that root zones of the plants have contributed as filter media to a great extent and as bio-digesters to a lesser extent[10]. The maximum removal of both COD and BOD occurred at HRT 5hrs. Also it can be noticed that percentage removal of BOD is higher compared to COD owing to a dominance of biological activity. The higher removal of BOD could be due to active participation of bio-degrading micro-organisms and also due to vigorous uptake by the plants[11].

3.3 Performance of Vertical Subsurface Flow Constructed Wetland (VSSFCW) with *Croton Plants*

The VSSFCW were planted with croton plants and supplied with wastewater at four different HRTs and analyzed for wastewater characteristics such as Total Solids, Total Dissolved Solids, Total Suspended Solids, BOD and COD.

The percentage removal efficiencies of BOD, COD, TS, TSS and TDSare presented in Fig.9.

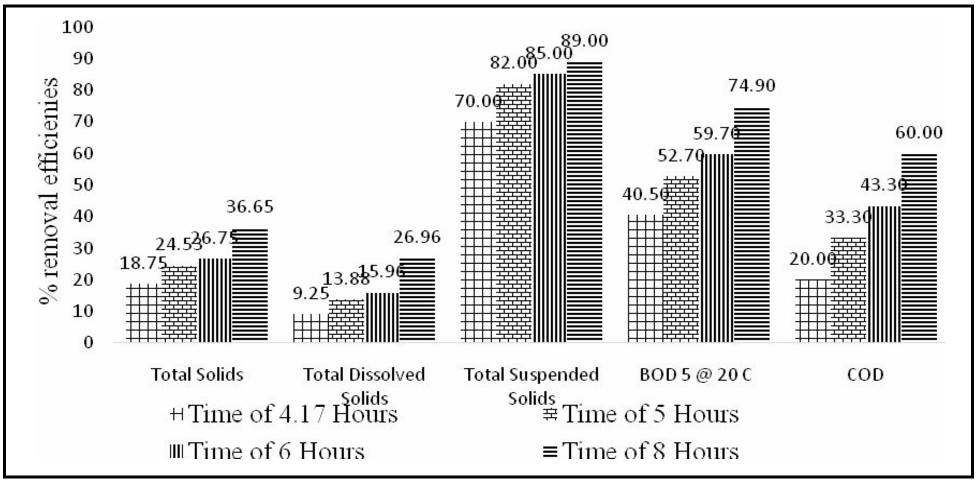


Figure 9.Removal Efficiencies of VSSFCW (Initial TSS=500mg/L, TDS=2700mg/L, TS=3200mg/L, BOD=370mg/L, COD=480mg/L)

It can be observed that the highest removal of all parameters was at HRT of 8hrs. It can be observed that removal percentage of TSS was high with VSSFCW compared to HSSFCW. This could be due to the dominant activity of root zones in the vertical flow reactor as a filter bed compared to horizontal flow reactor.

Also it could be noted that TSS removal was high with VSSFCW compared to HSSFCW. This could be probably due to active uptake of nutrients by the roots of plants. It appears that higher retention time allows for more biological activity to take place rather than mere action as a filter media. From the Fig.9, it can be seen that removal rates of BOD and COD were high with VSSFCW compared to HSSFCW. This can presumably be due to involvement of the total root zone from top to bottom and also due to an increased area of contact of wastewater with the roots. From this it can be inferred that there is a direct proportionality between HRT and removal efficiencies of TSS, BOD and COD. It can be observed that percentage removal of all parameters show an increasing trend with increase in HRT.

3.4 Performance of Hybrid Constructed Wetlands

A Hybrid CW is a combination of VSSFCW and HSSFCW. It was supplied with wastewater at four different HRTs to analyze various wastewater characteristics.

The removal efficiencies of various characteristics of wastewater by a hybrid CWs in terms of percentage are shown in Fig.10.

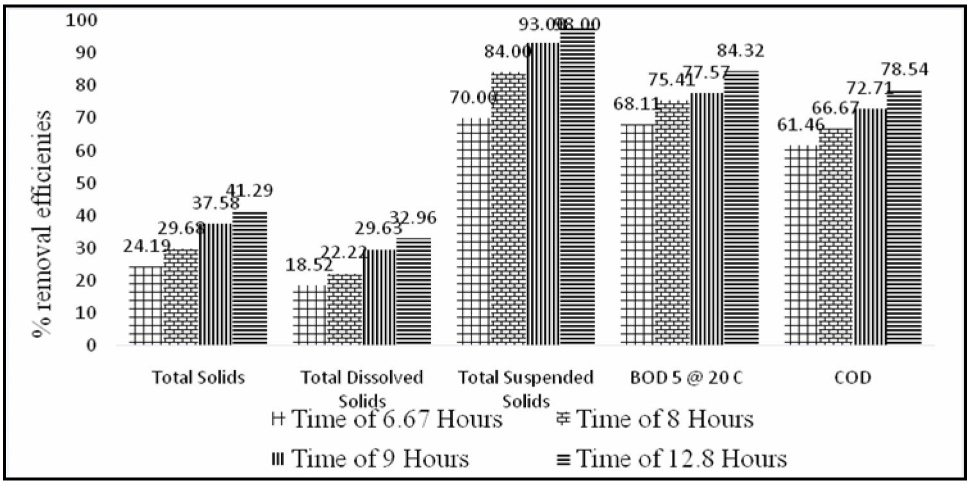


Figure 10. Removal Efficiencies of Hybrid CW (Initial TSS=500mg/L, TDS=2700mg/L, TS=3200mg/L, BOD=370mg/L, COD=480mg/L)

It can be observed that highest removal efficiency of all parameters was at HRT 12.8hrs. Among all the parameters tested, removal of TSS was found to be the highest by a Hybrid CWs. TSS removal in wetlands is mainly due to physical processes, such as sedimentation and filtration. It has been recorded that most suspended solids are retained within the bed, owing to the quiescent conditions and the shallow depth of liquid in the system. Also it can be seen that the Hybrid CWs performed better than either HSSFCW or VSSFCW for removal of TSS. The maximum removal of both COD and BOD occurred at higher HRT. It can be seen that percentage removal of BOD is higher compared to COD owing to a dominance of biological activity. The removal percentage of all parameters show an increasing trend with increase in HRT. When HRT increases the removal efficiencies also increase because the suspended solids settle down and the organic matter present in the wastewater get utilized by the macrophytes in a Hybrid CWs[12]. At optimum HRT, BOD is 59.2mg/L, COD is 103mg/L, TSis 1820mg/L, TSS is 10mg/L and TDS is 1810mg/L. Which is within the permissible limit for irrigation standards i.e., BOD is 100mg/L, TSS is 200mg/L, TDS is 2100mg/L and TS is 2300mg/L.Hybrid CWs model treated water canbe used for different purposes such as irrigation, gardening, toilet flushing, street cleaning, golf courses and laundry etc.

Removal efficiencies of almost all parameters were high in Hybrid CWs compared with HSSFCW and VSSFCW. This suggests that the active activity of microbes, filtration by roots and action of bed as filter media as well as sedimentation in a Hybrid CWs have together contributed towards its higher performance [13]. A depiction of wastewater before and after treatment is presented in Fig.11 for visual comparison.

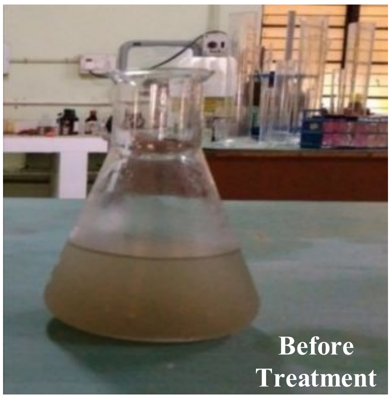


Figure 11. Before Treated and After Treated Using Hybrid CWs

4. Conclusions

In this work constructed wetland of various types, viz., HSSFCW, VSSFCW and Hybrid CWs types were investigated for wastewater treatment at different HRTs. It was observed that the performance of wastewater treatment of hybrid constructed wetlands was the best among all the reactors investigated. At a HRT of 12.8hrs, hybrid bio-reactor treated wastewaters conforming to agricultural standards. Mechanical straining, bio-degradation and gravity settlement together seem to contribute towards wastewater purification.

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