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Treatment of Grey Water Using Horizontal Flow Constructed Wetland

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ABSTRACT

The aim of this work was to study the pollutant removal efficiencies of two lab-scale horizontal flow constructed wetland systems treating real greywater with *Canna Indica* as a wetland plant. Both the wetland systems had an identical configuration. Horizontal Flow System 1 (HF1) acted as a control unit, without wetland plants whereas Horizontal Flow System 2 (HF2) acted as a constructed wetland, planted with *Canna Indica*. To understand the removal efficiencies of various pollutants in the greywater these systems were operated simultaneously under batch mode of flow for different Hydraulic Retention Time (HRT's) of 10, 6, and 4 days. Removal of TSS (89-95%), BOD (70-85 %), COD (72-80%), NH_3–N (32-43%), TP (45-52%) and Surfactant (50-56%) were obtained in the HF1 control wetland system and Removal of TSS (89-92%), BOD (75-91%), COD (80-95 %),NH_3–N (48-59%),TP (49-56%) and Surfactant (80-83%) were obtained in the HF2 constructed wetland system . These results indicates the percentage of TSS,BOD, COD, NH_3–N and TP removal values are in close proximity to each other in both planted and control wetland systems. However the removal efficiency of pollutants in constructed wetland system was high, especially in the removal of surfactant when compared to the control system. Hence the macrophytes play a major role in the removal of pollutants .Similarly as the HRT increases the treatment efficiency of the constructed wetland also increased.

1. Introduction

The constructed wetland (CWs) system is a sustainable treatment technology for treating wastewater by simulating natural wetlands, owing to lower cost, less operation and maintenance requirements, with little or no reliance on energy inputs. This system has been found to be able to remove various pollutants and nutrients from wastewater (Hammer, 1989; Wu et al., 2011). Constructed wetland system, mainly comprised of vegetation, substrates, soils, microorganisms and water, utilize complex processes involving physical, chemical, and biological mechanisms to remove various contaminants or improve the water quality (Vymazal, 2011; Saeed and Sun, 2012; Wu et al., 2015). Constructed wetland systems are considered as low-cost alternative for wastewater treatment, especially suitable for developing countries (Wittgren and Maehlum, 1997;Yalcuk and Ugurlu 2009). According to the wetland hydrology the constructed wetland is classified into free water surface and subsurface systems. In subsurface flow CWs water flows underneath and through the plant rooting media and water level is maintained below the tip of the substratum. Subsurface flow CWs could be classified according to the flow direction into horizontal and vertical. In the horizontal flow systems (HF), the wastewater is fed in the inlet continues its way under the surface of the bed in a horizontal path until it reaches the outlet zone. Due to a long retention time of the wastewater BOD, COD and TSS removal is possible to a high degree, normally higher then 80–90% in a HF system. In the vertical flow systems (VF), however, the wastewater is fed on the whole surface area through a distribution system and passes the filter in a more or less vertical path (Vymazal 2010; Yalcuk and ugurlu 2009).

Household wastewater can be divided into blackwater containing wastewater generated by the toilet (feces and urine) and greywater containing all other flows: from showers, bathtubs, sinks, kitchen, dishwashers, laundry tubs, and washing machines(Gross et al., 2015).It commonly contains soap, shampoo, and toothpaste, food scraps, cooking oils, detergents and hair. The amount of wastewater generated by any household will vary greatly according to the dynamics of the household, and is influenced by such factors as the number of occupants, the age distribution of the occupants, their lifestyle characteristics, water-usage patterns, the cost of water and the climate (WHO Manual).

Grey water makes up the largest proportion of the total wastewater flow from households in terms of volume. The total grey wastewater fraction has been estimated to account for about 75% of the combined residential sewage (Hansen & Kjellerup, 1994). Hence reuse of greywater will be an effective management of grey water. There are many problems related to the reuse of untreated grey wastewater. The risk of spreading of diseases, due to exposure to micro-organisms in the water, will be a crucial point if the water is to be reused for e.g. toilet flushing or irrigation (Eriksson et al., 2002). Hence proper treatment has to be done before reuse of greywater. Sustainable, low cost, effective, onsite decentralised treatment technology is needed. The aim of this research is to provide an effective onsite treatment technology in the field of greywater treatment at a household level in developing countries.

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2. Materials and methods

2.1 Study area and wastewater

The present study was conducted at the Sewage Treatment Plant (STP) located in Centre for Environmental Studies at Anna University, College of Engineering, Guindy campus, Chennai; Tamil Nadu. The wastewater was collected from residential houses at the campus and it was given primary treatment before being fed in the wetland system to avoid clogging problem.

2.2 Configuration of the Wetland Systems

The study was carried out in two plastic reactors (HF1 and HF2) of identical configuration of 60X40cm and 30cm depth. Volume of the reactor was 0.072m^2. Both the reactors were filled with gravel and sand in layers- length wise. Gravel of size 15mm to 20mm and porosity of 50% was filled at the inlet for a length of 10cm.The middle layer was filled with sand of size 2-4mm and porosity of 33% for a length of 40 cm. The outlet was again filled with gravel of size 15mm to 20mm to a length of 10cm. Horizontal Flow reactor (HF1), acted as a control unit without any wetland plants. Horizontal Flow reactor (HF2) was the constructed wetland system, planted with wetland plant kalvazhai (*Canna Indica*) nearly 10 saplings were planted .After plantation both the wetland systems were waterlogged for fifteen days, allowing the establishment of macrophytes. An influent tank was provided to hold the greywater to be passed into the system and influent was fed through a 1cm diameter pipe. A flow control valve was used to control the flow of greywater into the reactor.

2.3. Operation and Testing

2.3.1 Operation

After the establishment of the macrophytes, each wetland system was fed with 30 litres of grey water using two influent tanks 1 and 2 through the inlet valve for even distribution, and an outlet valve was provided at the bottom of the wetland system for the collection of treated water. Wastewater passed horizontally through the wetland system and the effluent was collected from the bottom of the wetlands and analyzed for TSS, BOD, COD, Ammonical Nitrogen, Total phosphate and surfactant. The same procedure was repeated for other HRT's 6 and 4.

2.3.2 Wastewater sampling and analysis

Initial characteristics of the greywater were studied and the results were tabulated in the Table 1. Effluents were collected from the outlet of each wetland system. In total, three sets of samples were collected for different HRT's. For each sample, the wastewater parameters such as pH, TSS, BOD, COD, NH_3-N, TP, and surfactant were measured using standard methods. BOD was analyzed by Winkler's method followed by titration. TSS and COD by Gravimetric method and Open Reflux titration method respectively. NH_3–N by distillation followed by titration, Analyses of TP by Spectrophotometry- Stannous Chloride method. All the tests were carried out as per the APHA manual, Surfactant using Methylene blue Method (IS: 13428 - 2005 (Annex-K)

Table 1 Mean Pollutant concentration across the experimental wetland systems, ± Standard deviations

2.3.3 Removal efficiency calculations

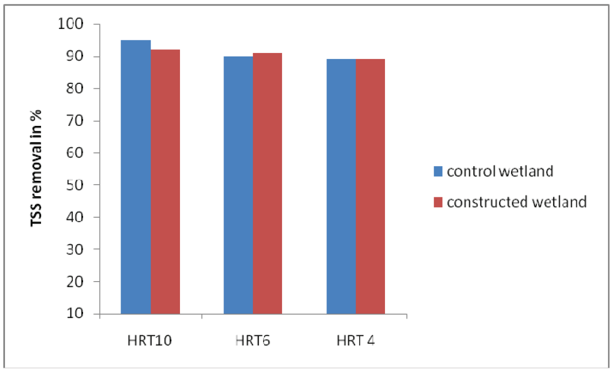
Removal efficiency calculations were based on mass balance

$$percentage\ efficiency = 1 - \frac{C_e}{C_i}\ X\ 100\%$$

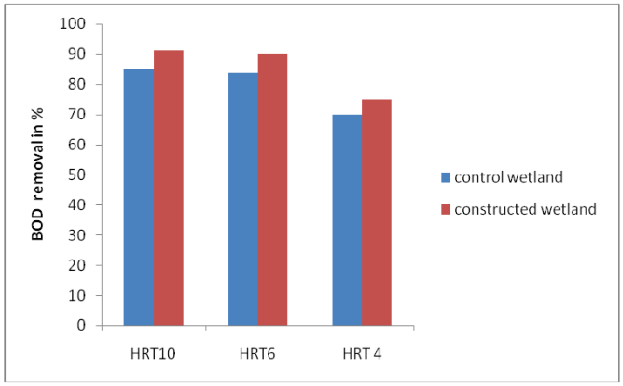
Where, C_i and C_e are the inlet and outlet concentrations in mg/L.

Fig.1 Percentage removal efficiencies of pollutants, for both control and constructed wetland systems (a) TSS (b) BOD (c) COD (d) NH_3-N (e) TP(f) Surfactant .

(a)



(b)



(c)

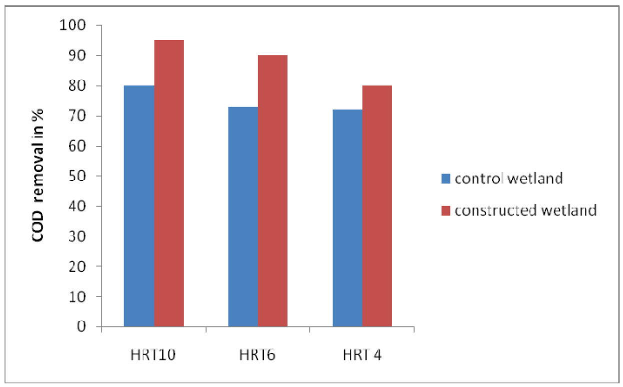
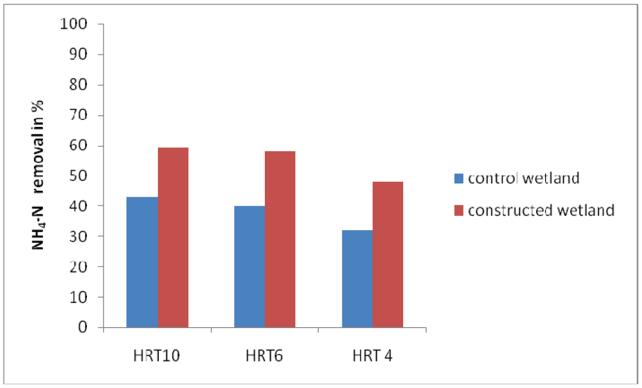


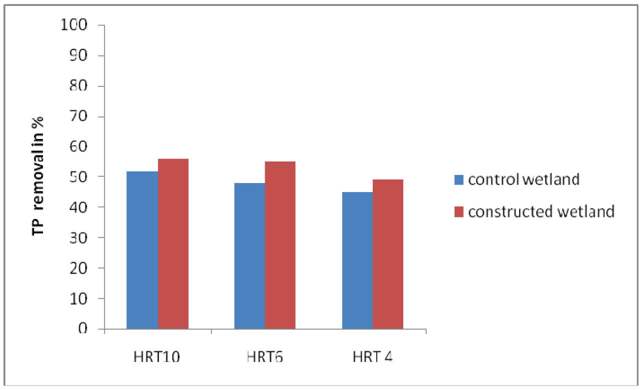
Table 1 Mean Pollutant concentration across the experimental wetland systems, ±Standard deviations

Parameters	Unit	Influent	Effluent conc.					
			10 DAY HRT		6 DAY HRT		4 DAY HRT	
			HF1	HF2	HF1	HF2	HF1	HF2
pH		7.8±0.4	6.9±0.2	5.8±0.4	7.1±0.18	6.1±0.13	6.7±0.3	5.8±1
Suspended Solids	mg/L	250±80	13±23	20±10.3	25±6	23±67	27±0.9	26±9
BOD	mg/L	216±139	33±12.2	18±1.2	35±18	21±0.8	63±34	53±42
COD	mg/L	426±23	85±5.5	20±0.3	115±	40±16	118±23.9	86±3.4
NH_3–N	mg/L	9.6±5.3	5.4±3.3	3.9±2.8	5.8±2.3	4±1.22	6.9±2.3	5±0.8
Total phosphate	mg/L	13.9±6.7	6.8±0.2	6.1±0.9	7.2±3.5	6.2±3.4	7.6±4.5	7.1±2.9
Surfactant	mg/L	6.5±4.5	2.82±1.4	1.7±0.9	2.83±4.7	1.79±6.7	1.95±0.9	3.25±1.4

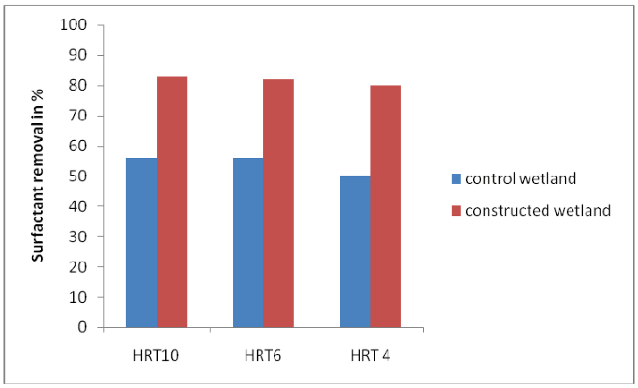
(d)



(e)



(f)



3. Result and Discussion

3.1 pH

The average value of pH in the influent was in the range of 7-8, slightly alkaline nature. But after passing through the constructed wetland, the value of effluent pH decreased in both the wetlands as shown in Table 1. This indicates that there is a decomposition of organic matter which may lower the pH value. And also the nitrification process in the wetlands consumes alkalinity and significant nitrification can result in substantial drop of pH in wastewater. Such a result is consistent with the fact that significant nitrification occurs in the wetland system.

3.2 Total Suspended Solids

Total Suspended Solids (TSS) removal efficiencies were above 88% in both wetlands. Both wetlands show good removal percentage of suspended solids irrespective of the HRT's. As per USEPA manual (1999) TSS are removed by flocculation, sedimentation and filtration/ interception. Wetland systems are effective in TSS removal because of the relatively low velocity and high surface area in the wetland media. Wetland system act like horizontal gravel filters and thereby provide opportunities for TSS separations by gravity sedimentation, straining, physical capture, and adsorption on biomass film attached to gravel and root systems.As the TSS are predominately removed by filtration, the media -sand and gravel in the wetland bed increases the chances for the suspended solids to be trapped and retained in the bed matrices thereby improving TSS reduction.

3.3 BOD and COD

The percentage removal of BOD in the control wetland system was 85%, 84% and 70% for 10,6 and 4 HRT's respectively and for constructed wetland it was 91%,90% and 75 %.The constructed wetland showed better removal efficiency than the control system. Wetland systems removes settlable organic compounds by filteration and deposition. Soluble organic compound are degraded aerobically or anaerobically .The oxygen supply for aerobic process is supplied by atmosphere diffusion or oxygen leakage from the roots of macrophytes. The COD removal efficiency of the constructed wetland system was 91%, 90% and 75 % for 10,6 and 4 HRT's respectively ,which was higher than control wetland system ,the macrophytes in the constructed wetland system have played a major role in oxygen supply to wetland system which is reflected in BOD and COD removal efficiency . This result indicates the macrophyes play a major role in organic compound pollutant removal mechanism.

3.4 $NH_{3-}N$ removal

Nitrogen removal in a constructed wetland system includes uptake by plants and other living organisms, nitrification, denitrification, ammonia volatilization and cation exchange for ammonium (Yang et al., 2001).Major nitrogen removal in constructed wetland is by microbial nitrification and denitrification process.NH_3-N, removal in control wetland (HF1) was 32%-43 %, whereas in constructed wetland (HF2) it was 48%-59%. Higher removal efficiency was noticed in constructed wetlands, this shows there is efficient oxygen diffusion from the atmosphere as well the plants act like snorkels, enhancing oxygen supply in their root-zones which is very essential for nitrification process. Plants root act as a attaching media for microbes .They also shade the water surface, limiting the growth of algae which would contribute to suspended solids levels in the effluent (Babatunde et al., 2009)..significant nitrification process occurs in that wetland system. The removal rate of $NH_{3-}N$ and subsequent drop of pH n in the effluent of this wetland system as shown in Table 1, support that NH_3–N removal process was achieved via nitrification (Saeed and Sun 2011).

3.5 Total phosphorous

The phosphorous removal efficiency in constructed wetland may take place due to plant intake, accretions of wetland soils, microbial immobilization, retention by substrates and precipitation in the water column (Ong et al., 2009). In this study the phosphorous removal efficiency of the constructed wetlands were 56%, 55% and 49% for 10, 6, 4 HRT's respectively for control wetland system it was 52%, 48% and 45% respectively .The phosphorous reduction in the constructed wetland may be due to adsorption of some phosphorous by the gravel media and due to the plant uptake which is unavailable in control wetland system. The total phosphorous removal may slowly decrease due to saturation of the adsorption capacity of the media, hence further studied is needed to investigate the phosphorous removal or mass- balance in the constructed wetland.

3.6 Surfactant

Surfactant removal in constructed wetland was 80-83%, but in control wetland system it was 50 -56%, very less compared to the constructed wetland system. The rhizosphere aeration via the constructed wetland plant roots strongly supported the anionic-surfactant removal (Síma et al., 2009). Similarly more surfactant accumulation was found in the roots of wetland sytem (Ramprasad and Ligy Philip 2015). This process was completely absent in the control system.This may be the reason for surfactant reduction in constructed wetland system.

4. Conclusion

Based on the above results it can be concluded that constructed wetland is an efficient treatment technique for grey water. The wetland system is efficient in removal of TSS , organic pollutant and surfactant, but the removal efficiency of ammonical nitrogen and total phosphorus is 50 - 60%, hence further research is needed in constructed wetland by changing media for the efficient removal of ammonical nitrogen and total phosphorus. if treated grey water is to be reused, then research can be carried on fecal coli form removal efficiency of constructed wetland.

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