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# Pollutant Removal Efficiency of Hybrid Constructed Wetland System for Recycling the Sewage by Utilizing Aquatic Plants

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**The sewage waters are used as potential source of irrigation for raising vegetables and fodder crops around the sewage disposal sites. Soil contamination by sewage and industrial effluents has affected adversely both soil health and crop productivity. A study was conducted to evaluate the pollutant removal efficiency of lab scale hybrid constructed wetland system (HCWS) for recycling the sewage water for agriculture. Native aquatic plants *viz., Brachiaria humidicola* and *Typha angustifolia* were selected and utilized for the lab scale study. The results of this HCWS showed that removal efficiencies of BOD, COD was higher with the hydraulic retention time (HRT) of 5 days due to the combined effect of HF and VF by using the native aquatic plants like *Brachiaria humidicola* and *Typha angustifolia*.**

**Key words:** Hybrid constructed wetland, Aquatic plants, BOD, COD

Recycling of wastewater for irrigation has been practiced for centuries throughout the world. Utilization of untreated wastewater for crop irrigation poses substantial risks to public health, not only to the farmers, but also the surrounding communities and the consumers of the crops. Sewage and industrial effluents may have high concentration of several heavy metals such Cd, Ni, Pb and Cr (Narwal *et al*., 1993). Their continuous disposal on agricultural soils has resulted in accumulation of some of the toxic metals in soil which may pose serious human and animal health. Recycling of wastewater after adequate treatment and its utilization for crops is the need of the hour. Constructed wetlands are one of the engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation, soils, and the associated microbial assemblages to assist in treating wastewaters (Vyamazal Jan, 2010). Hybrid constructed wetland systems are derived from original hybrid systems developed by Kathe Seidel at the Max Plank Institute in Krefeld, Germany, comprise of horizontal flow (HF) and vertical flow (VF) arranged in a staged manner. The hybrid constructed wetlands take advantages of each of HF and VF and combine them for improving the quality of reclaimed water. Therefore in the present study, an attempt has been made to evaluate the pollutant removal efficiency of HCWS by utilizing the native aquatic plants for recycling the sewage.

## Material and Methods

### *Description of wetland systems*

The study was carried out in the Department of Environmental Sciences, Tamil Nadu Agricultural University (TNAU), Coimbatore from Dec 2015 to September 2016. A lab scale Hybrid Constructed Wetland System (HCWS) was designed with both horizontal and vertical flow treatment (HF-VF) system. Total of four cells were installed in the HCWS. All the cells were uniform in size of 80 x 57 x 42.5 cm (L x W x H). Sewage was collected from Tamil Nadu Agricultural University (TNAU) sewage collection area near TNAU staff quarters, periodically and used for experimental purposes. The first cell was screening cell, where stainless steel filter mesh was used for filtering the solid materials and sewage was pumped into the first cell. The second cell was the horizontal flow (HF) treatment system. From the screening cell, sewage effluent entered the HF cell through gravity. The third cell was the vertical flow system, where the perforated pipes were installed for the vertical movement of sewage from the HF cell. Both HF and VF cells were packed with pre-sterilized media *viz.,* pebbles (40mm), gravels (20mm), coarse sand, and soil. The fourth cell was the treated water collection cell. Native aquatic plants *viz., Brachiaria humidicola and Typha angustifolia* were collected from Muthanakulam tank of Coimbatore district and used in horizontal flow and vertical flow cell, respectively. A uniform slope of 1% was maintained between the cells for the easy movement of wastewater among the cells. Hydraulic retention time (HRT) of 1, 3, 5 days were maintained throughout the experimental period for evaluating the treatment efficiency of HCWS. Sewage samples were analysed as per standard analytical procedures. Treated wastewater samples from each cell were collected periodically during Dec 2015 - Feb 2016 (SI); Mar 2016 - May 2016 (SII); June 2016 – Aug 2016 (SIII) at HRT of 1, 3, 5 days interval.

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## Results and Discussion

### *Characteristics of sewage effluent*

The quality of the collected sewage was assessed by analysing its pH, Biological oxygen demand (BOD), chemical oxygen demand (COD), Total Suspended Solids (TSS), Total dissolved solids (TDS) and total coliforms. The mean value of the parameters analysed are presented in the Table 1. In general, the BOD values ranged from 121- 209 mg $L^{-1}$. The highest BOD range of 168 - 209 mg $L^{-1}$ was recorded at S I and the lowest was recorded in SIII period of study. BOD level of the water increases if the dissolved oxygen content of the water is very low. Dissolved oxygen levels change and vary according to the time of day, the weather and the temperature (Muigai *et al*., 2010). An increase in the BOD levels is usually an indication of an influx of some type of organic pollutant in the collected water. The COD value of the sewage effluent recorded the same trend as that of BOD level. Since the level of COD was very high it pointed towards the high loading of both organic and inorganic pollutants. The high BOD and COD values of collected sewage water samples exceeded the prescribed levels of 100 and 250 mg $L^{-1}$ (CPCB) for irrigation.

**Table 1. Characteristics of sewage used for HCWS experiment**

| Duration | BOD mg L-1 | COD mg L-1 | TSS mg L-1 | TDS mg L-1 | Coliforms (MPN / 100 ml) | pH |
|---|---|---|---|---|---|---|
| SI | 168 - 209 | 312 - 418 | 825 - 894 | 1624 - 1846 | 11 -17 | 7.86 - 7.98 |
| SII | 121 - 139 | 264 - 280 | 712 - 754 | 1424- 1538 | 7 - 11 | 7.67- 7.56 |
| SIII | 158 - 174 | 290 - 302 | 790 - 806 | 1640 -1724 | 9 -12 | 7.48 -7.58 |

*SI - Dec 2015 - Feb 2016; SII- Mar 2016 - May 2016; SIII - June 2016 – Aug 2016

Hence, the sewage water should be treated before its usage for crop irrigation. The sewage effluent collected at various stages had the TSS values ranging from 712 to 894 mg $L^{-1}$. TSS value seems to be high during the SI stage. Karthika Velusamy and Kannan (2016) also indicated that TSS was significantly high ($p<0.05$) in the post- monsoon season. TDS values also varied between 1424-1846 mg $L^{-1}$. This could be due to the presence of inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and some small amounts of organic matter that are dissolved in the sewage water.

**Table 2. Average COD removal efficiency (%) ± SE of HCWS**

| Duration | Hydraulic Retention Time (HRT) - days | | |
|---|---|---|---|
| | 1 | 3 | 5 |
| SI | 43.2±0.50 | 48.3± 1.04 | 51.2±0.76 |
| SII | 70.8±0.58 | 74.3±0.29 | 80.2±0.29 |
| SIII | 65.8±0.76 | 68.2±0.58 | 70.2±0.58 |

At all the stages of sampling *viz*.., SI, SII, and SIII, the pH ranged between 7.48 to 7.98. Yadav *et al*. (2002) also reported that the sewage water will have alkaline pH. The total coliforms concentration was extremely high with the range of 11-17 MPN/100 ml at SI stage. This may be due to the incorporation of the domestic waste from the staff quarters *i.e.,* residence into the sampling site. Emily C. Sanders *et al.* (2013) also reported that the fecal coliform and *E. coli* concentrations are highly variable, especially along urban streams and generally increase with streamflow and precipitation events.

### *BOD removal*

The BOD removal efficiency of the HCWS was recorded at HRT of 1, 3 and 5 days during all the sampling periods (SI, SII and SIII). The BOD removal efficiency at the HRT of 1 day (68.5%) was low when compared to 3 days (72.5%) and 5 days (80%) during SII. BOD removal efficiency was significantly higher at HRT of 5 days followed by 3 days and 1 day, respectively. This may be due to the effect of constructed wetlands, which are artificial wetland systems that are designed to exploit the physical, chemical and biological treatment processes that

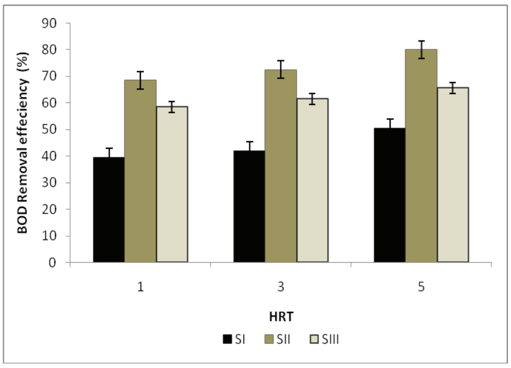


**Fig.1. Average BOD Removal efficiency of HCWS**

occur in wetlands and provide a reduction in organic material, total suspended solids, nutrients, and pathogenic organisms. Constructed wetlands emulate the natural treatment processes involving wetland vegetation, soils, and their associated microbial assemblages to improve water quality (Ashwani Kumar Dubey and Omprakash Sahu, 2014). The aquatic plants species utilized in the HCWS may vastly contribute to the BOD removal. Studer and Brändle (1984) also reported that the wetland plants are morphologically adapted to growing in waterlogged sediment by virtue of large internal air spaces for transportation of oxygen to roots and rhizomes. BOD removal efficiency was found to be higher, which may be due to the organic pollutants degradation by the microorganisms that adhere to the rhizosphere region of constructed wetlands. Ruchi Sharma *et al*. (2013) also revealed that the rhizosphere microbial communities will remediate the polluted systems through biotransformation of hazardous organic compounds in the root zone. Vyamazal Jan (2010) also found that by the physical and chemical processes in a network of aerobic, anoxic and anaerobic zones with aerobic zones being restricted to the areas adjacent to roots, where oxygen leaks to the substrate in the constructed wetlands for ease of the remediation mechanisms. Doughlas Gunnison and John W. Barko (1989) also reported that cat tail (Typha sp) plants have the structural and physiological mechanisms to acquire maximum available $0_2$ or able to respire anaerobically and tolerate organic by-products. The three-stage hybrid constructed wetland consisting of saturated vertical flow, free-drained vertical-flow and horizontal sub-surface flow wetlands, proved to be very effective in reducing organics, suspended solids and BOD removal amounted to 78.1% and 94.5%, respectively with outflow concentrations of 16 and 10 mg/l from municipal wastewater (Vyamazal Jan , 2013).

***COD removal***

Similar observation was recorded in the COD removal efficiency of the HCWS (Table 2). The COD removal efficiency increased in order of HRT of 5d > 3 d > 1 d. This may be due to the highly dense vegetative growth of *Brachiaria humidicola* and *Typha angustifolia* and the root system of these plants provides large surface area for attached microorganisms, thus increasing the potential of degradation of organic matter. Similar findings were reported by Sayadi *et al*. (2012). The growth of plants depends on the HRT and the media used in the constructed wetland systems. HRT of 3 days was found to be beneficial. This may be due to the maximum time provided for the plant surface for its reaction with wastewater. The results are in line with the findings of Suntud Sirianuntapiboon *et al*., (2006). Stottmeister *et al*. (2003) also stated that the growth rate of both *Typha sp* and aerobic bacteria increased with the increase of soil percentage in the media because the soil component provides good conditions for growth of both *Typha* sp. and aerobic bacteria. Generally the removal efficiency was higher in the summer season compared to winter. This may be due to the increased vegetative growth and microbial activity at high temperature during summer than winter. The combined effect of HF and VF in the HCWS proved to be significant in the pollutant removal efficiency. Florentina zurita and John R. white (2014) also reported that the hybrid ecological wastewater treatment systems were effective in treating the reclaimed water.

## Conclusion

The results revealed that HCWS could be beneficial in reducing the levels of BOD, COD of the sewage water. The native aquatic plants used in the system *viz*., *Brachiaria humidicola* and *Typha angustifolia* also proved to perform the best in the designed HCWS. The removal efficiencies of BOD, COD were higher with the hydraulic retention time (HRT) of 5 days compared to 1 and 3 day respectively. The combined effect of HF and VF in the removal of pollutants by using aquatic plants was found to be higher during the summer compared to the winter and autumn seasons.

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