Study on suitability of single and hybrid constructed wetland for treating sewage for a small community

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Abstract. In this study an attempt is made to study the comparison of effectiveness of single constructed wetland and hybrid constructed wetland for treating wastewater. Single constructed wetland is made with Phragmites Australis. The flow of water is vertical. Hybrid constructed wetland is made with vertical flow constructed wetland allied with water hyacinth based free floating wetland system. Primary treated sewage is allowed to the wetland. Water quality parameters namely Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS) are measured before and after treatment. Two case studies have been in this study. In first study the water is allowed for one day contact time in single constructed wetland. In second case study, the treated water from one wetland is immediately transferred to other wetland. It is evident that, a hybrid constructed wetland gives better result in removing BOD and COD in wastewater. It is observed that there is no significant difference is observed in removing TSS removal. The water is allowed to different type of plants may increase the removal efficiency. The maximum BOD removal is obtained for hybrid wetland is 86% at one day detention time. The COD removal is obtained at one day is 48%.

Key words: Single wetland, Hybrid wetland, Detention time, Water Quality Parameters, Texting, Removal Efficiency

1. Introduction
Due to drastic increase in population, generation of wastewater is inevitable from rural as well as urban communities. Constructed Wetlands (CW) can be implemented at low cost, ease in maintenance and have a strong potential for application in developing countries, particularly in small rural communities [4,10]. The pollutant removal in constructed wetland includes physical, chemical and biological processes [11,19]. The water quality is improved in CW by adopting different operational parameters such as, the change of plants in wetland, change of filter media, selection of appropriate type of wetland, change in hydraulic retention time and change in hydraulic flow rate [20]. Table 1 shows the different methodologies which were adopted by various researchers for the treatment of wastewater. For instance, [9] adopted hybrid approach of “Horizontal Flow Constructed Wetland (HFCW) and Vertical Flow Constructed Wetland (VFCW)” for the removal of pollutants. [3] found that the combination of Horizontal Subsurface Flow Constructed Wetland (HSSF), Surface Flow wetland (SF) and Free Floating Wetland System (FWS) are effective in treating water.
In this study the enhancement water quality is analyzed by two ways. (i) In first case study, the effect of contact time on treatment of wastewater using single wetland named VFCW is taken into consideration (ii) In next case study, a comparison is made between single wetland (VFCW) and Hybrid wetland (VFCW and water hyacinth) on treatment of wastewater.

| S.No | Method                                                                 | Plants                                                                 | Contact time | Author |
|------|------------------------------------------------------------------------|------------------------------------------------------------------------|--------------|--------|
| 1    | Combined system composed of VFCW Horizontal Flow Constructed Wetland (HFCW) | Phragmites, Typha                                                       | -            | [9]    |
| 2    | 21 treatment wetland                                                   | Cell 1- Scirpus or Sagittaria Cell 2- Ornamental plants                | -            | [16]   |
| 3    | Recycled vertical flow constructed wetland (RVFCW)                     | Cyperushaspan Hydrocotyleleucocephala                                   | 8-12 hr      | [8]    |
| 4    | HFCW                                                                   | Typha latifolia Phragmites Australis                                    | 1.5 day      | [17]   |
| 5    | 18 wetland with emergent and submerged vegetation                      | Emergent- P. australis, G.maxima and Phalarisarundinacea Submerged-E.canadensis Myriophyllumalterniflorum and Ceratophyllumdemersum | 1 day 3 day  | [6]    |
| 6    | Saturated VF bed Free drained VF bed Horizontal flow bed               | P.Australis P.Australis Phalarisarundinacea                             | -            | [22]   |
| 7    | Subsurface flow constructed Wetland (SSFCW)                            | P.Australis T.latifolia C.esculenta                                    | 0 hr, 12 hr, 24 hr, 36 hr after 2,4 and 6 months of establishment. | [15]   |
| 8    | Aerated Vertical Flow Constructed Wetland(AVCW) and HFCW              | Acorus calamus Canna indica                                             | AVCW -11.3 hr HFCW-18.7 hr | [13]   |
| 9    | HSSF SF FWS                                                            | Cyperus with substrate 4 FWS with Lemna minor                           | 2,4,6,8,10,12 days | [3]    |

2. Materials and methods

2.1. Experimental Setup
Different types of constructed wetland are available based upon direction of flow path. VFCW are selected in this study because of effectiveness in treating wastewater due to better aerobic condition [21,4]. In study two case studies have been made. In first case study, mainly focuses to identify the
single constructed wetland for treating sewage where as in second case study focuses the effect of hybrid constructed wetland on removal of pollutants.

2.2. Case study 1: Effect of single wetland for removal of pollutants in VFCW
In case study 1, Constructed wetland cell is made with the size of 2mx1mx1m. The bottom of wetland gravel is filled at the thickness of 30 cm. Sand is laid at the thickness of 60 cm above gravel layer. Common reed (Phragmites australis) rhizome is collected near Koomapatti village, Virudhunagar district and it is grown on soil layer for two months. Primary treated sewage from sewage treatment plant is pumped into VFCW. The perforated pipes are adopted for distribution of sewage vertically. Figure 1 shows the experimental setup for case study 1. The treated water is immediately collected from outlet of VFCW and tested in first trail. In next trail, the water is allowed for a contact period of 16 hours and then testing of water quality is done. In third trail, the water is allowed for a contact period of 24 hour in the wetland and the water quality is tested.

![Figure 1. Experimental Set up of VFCW (Case study 1)](image)

2.3. Case study 2: Combined effect of VFCW with water hyacinth based free floating macrophytes for water treatment
In Case study 2, hybrid constructed wetland is developed for doing experiments. VFCW and Hyacinth based free floating macrophyte treatment method have been used for developing hybrid constructed wetland. Initially the primary treated sewage is passed through VFCW, and the treated water from VFCW is fed into hyacinth based wetland. Among the free floating macrophytes, hyacinth is the better choice for treating wastewater because of its rapid biomass growth and presence of extensive root system [14], availability in nearby areas. Figure 2 shows the experimental setup of hybrid constructed wetland.
2.4 Testing of water quality
In this study, water quality parameters namely Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD$_5$), Chemical Oxygen Demand (COD) are tested before and after treatment. TSS are measured by gravimetric method, BOD$_5$ is measured by incubation method, COD is measured by digestion method.

3. Results and Discussions

3.1 Removal of BOD$_5$
The wastewater characteristics before and after treatment in VFCW (case study 1) are shown in Table 2. It is observed from Table 3; the removal of BOD at immediate filtration, sixteen hour contact time and 24 hours detention time is 35%, 41% and 79% respectively. It is found that detention time increases, removal of BOD$_5$ also increases. The maximum removal (79%) is obtained at 24 hours. It is revealed that detention time play a major role in treatment. [12] found the detention time play a role in pollutant removal in constructed wetland. [7] found higher HRT of 4 days not only helped maximum removal of all the pollutants but also maintained the stability of the treatment efficiency throughout the monitoring period. [18] found longest detention highest removal is obtained. These results support our research findings. The detention time helps bacteria to consume the organic matter and convert into simple substances thereby BOD$_5$ removal happens.

In Case study 2, the treated water from VFCW is passed to hyacinth based wetland and it is allowed for 24 hours. The removal in hybrid wetland at 24 hours detention time is 86% (Table 4 and 5). It is observed that, the water is present in the same VFCW at 24 hours; the percentage removal is 79% where as it is allowed into two different wetland with the same contact time of 24 hours, but the removal increases to almost 10%. It is understood that the water is introduced into diverse vegetation, the removal occur in a faster way than normal single wetland.
### Table 2. Effect of Detention Time in VFCW (Case study 1)

| Parameter | Primary treated sewage (mg/l) | Outlet from VFCW (mg/l) |
|-----------|--------------------------------|-------------------------|
|           | Outlet from VFCW (mg/l)       | Immediate filtration    | 16 hour contact time | 24 hr contact time |
| BOD       | 190                           | 124                     | 112                 | 40                 |
| COD       | 560                           | 473                     | 448                 | 375                 |
| TSS       | 956                           | 518                     | 474                 | 446                 |

### Table 3. Percentage of Pollutant Removal in VFCW (Case study 1)

| S.No | Contact time                  | Removal of Pollutants (%) |
|------|-------------------------------|---------------------------|
|      |                               | BOD | COD | TSS |
| 1    | No detention time (immediate filtration) | 35  | 16  | 46  |
| 2    | 16 hour detention time        | 41  | 20  | 50  |
| 3    | 24 hr detention time          | 79  | 33  | 53  |

### 3.2. Removal of COD

The removal of COD at immediate filtration, sixteen hour contact time and 24 hour contact time in VFCW are 16%, 20% and 33% respectively. It is revealed that the detention time play a role in COD removal. The COD removal in single wetland and hybrid wetland are 33% and 48% for 24 hour detention time. It is observed that almost 15% more removal is obtained in hybrid wetland than single wetland. [5] found COD is high in human derived wastewater because of presence of recalcitrant such as lignin, vegetable fibre and tannins. In this study, the removal of COD is very less when compared to BOD because of presence of complex organic substance will cause delay in removal and also bacteria cannot degrade the complex organic substance present in wastewater. The removal is happens by various chemical processes like oxidation, reduction and the thereby COD value decreases.

### Table 4. Pollutant removal in Hybrid Constructed Wetland

| S.No | Parameters | Inlet sewage (mg/l) | Outlet from VFCW (mg/l) | Outlet from FFCW (mg/l) |
|------|------------|---------------------|-------------------------|-------------------------|
| 1    | BOD        | 190                 | 124.5                   | 26.5                    |
| 2    | COD        | 560                 | 473                     | 292                     |
| 3    | TSS        | 956                 | 518                     | 441                     |

### Table 5: Pollutant removal in Hybrid Constructed Wetland

| S.No | Parameters | Outlet from VFCW (%) | Outlet from FFCW (%) |
|------|------------|----------------------|----------------------|
| 1    | BOD        | 35                   | 86                   |
| 2    | COD        | 16                   | 48                   |
| 3    | TSS        | 46                   | 54                   |

### 3.3. Removal of TSS

The TSS removal in single wetland is 46%, 51% and 54% for immediate filtration, sixteen hour contact time and one day detention time respectively. It is found that there is very marginal improvement is observed with increase in contact time in TSS removal. Similarly from Table 3 and Table 5 it is observed that the significant removal is not observed between single wetland and hybrid wetland at 24 hour detention time. It is found that the removal is not increases significantly in terms of detention time and use of diverse wetlands. The removal in hybrid wetland is almost same as that of single constructed wetland used. It is revealed that the TSS removal is not shown a significant difference between two approaches. Figure 3 shows the comparison of single wetland and hybrid...
wetland for a contact time of 24 hours. It is observed that the pollutant removal is higher in hybrid wetland than single wetland for BOD$_5$ and COD removal. It may be due to some parameters is not removed in one macrophytes can be taken by another plant. The VFCW is acting like secondary treatment like trickling filter, whereas water hyacinth wetland is acting as polishing treatment. [1] observed that the performance of a single HFCW was probably not sufficient to achieve a suitable water quality for reuse of effluents and the hybrid CWs are more efficient and feasible systems for this purpose.

![Figure 3. Comparison of pollutant removal in single wetland and hybrid wetland in treating wastewater](image)

4. Conclusion
The following conclusions arrived
1. There is no significant difference is observed between increase of detention time for TSS removal, whereas the BOD and COD removal detention time play a major role.
2. It is recommended to use hybrid constructed wetland for pollutant removal than single wetland because it behaves like secondary treatment as well as polishing treatment.
3. The significant difference is observed between single constructed wetland and hybrid constructed wetland in BOD and COD removal.
4. The maximum pollutant removal is observed in BOD whereas the COD, the removal is low.
5. There is no significant difference is observed between single constructed wetland and hybrid constructed wetland in TSS removal.

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