Performance of different types of constructed wetlands for treating wastewater in short time horizon

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Abstract. Constructed wetland is one of the well-known cost-effective technologies for treating domestic sewage. This work is mainly focuses to study the performance of constructed wetland at initial stage of wetland. Three types of constructed wetland namely Vertical Flow Constructed Wetland (VFCW), Horizontal zigzag flow Constructed wetland (HFCW) and Upflow Constructed Wetland (UFCW) were made based upon the direction of water flow through porous medium. The primary treated sewage is passed through three wetlands and the water quality was tested before and after treatment. Wetland performance was analyzed continuously for one month after sapling stage. Water quality parameters such as pH, Temperature Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD), Nitrates (NO$_3^-$) and Phosphate (PO$_4^{3-}$) were tested. Removal of COD and Phosphates are uniformly increasing for this duration. The maximum removal of COD, TSS and Phosphates are 40%, 30%, 87% and 45% respectively. Nitrification is good from initial stage of constructed wetland. In one month experimental period, removal of solids is not stable. It was observed that, heavy fluctuation was occurred during experimental period. But increasing trend is observed in the removal of solids. Also it is recommended that more sampling is needed at initial stage of constructed wetlands.

Keywords: Domestic sewage, Constructed Wetlands, Water quality parameters, Treatment, Removal efficiency

1. Introduction
Due to water scarcity and increasing stringent regulations for the release of wastewater generated from industrial and domestic sources, proper treatment and safe disposal of wastewater has become one of the major concerns of wastewater discharge regulatory authorities [16]. However capital resources needed are high to implement conventional wastewater treatment system [27]. Conventional methods and other steps such as treatment by sewage treatment plants have been taken by the government to treat the sewage, could only treat 1/4 of the sewage produced, while 3/4 of untreated sewage is being released into the river, which affects water quality severely [18]. Due to continuous unsafe disposal of wastewater, the water bodies lose their self-purification capability [25].

Constructed Wetlands (CW) are a natural alternative to technical methods of wastewater treatment [23]. Constructed wetlands are engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation, soils, and their associated microbial assemblages to assist in treating wastewater [14]. They are much sustainable treatment alternative for treating municipal sewage and agricultural effluents [26]. The treatment processes in constructed wetlands are
sedimentation and filtration, precipitation, sorption, and microbial decomposition, nitrification and denitrification [24]. Table 1 shows different types of wetland with treatment efficiency.

**Table 1. Different types of constructed wetland with treatment efficiency**

| Type of plant | Substrate | Type of wetland | Efficiency (%) | References |
|---------------|-----------|-----------------|----------------|------------|
| *Phragmites* | Gravel    | HFCW            | BOD=61, COD=44, TSS=65, TC=92, FC=97 | [2]         |
| *Australis*  |           |                 |                |            |
| *Canna indica,* | Limestone | Artificially aerated VFCW and HFCW | BOD=52, TP=41.61, NH₄-N=58.41, COD=34.1, TSS=38.9, TN=31.05 | [13]        |
| *Acorus calamus* |           |                 |                |            |
| *Typha latifolia,* | Gravel    | Sub surface flow constructed wetland | BOD=90, PO₄=86, NO₃=76, TSS=65, TDS=78 | [18]        |
| *Phragmites australis,* | Red Ferralic soil and gravel layer | VFCW           | BOD=84.9, COD=89.8, TP=76.5, TKN=82.7, NH₄-N=82.2, TSS=98.1 | [17]        |
| *Colocasia esculenta,* |           |                 |                |            |
| *Polygonum hydropiper,* |           |                 |                |            |
| *Alternanthera sessilis and Pistiastratoites* |           |                 |                |            |
| *Cyperus Alterfolios* | Crushed rock and Sand | Saturated vertical flow Free drained Vertical Flow bed Horizontal flow bed | BOD=94.5, COD=84.4, P=65.4 | [10]        |
| *Phragmites Australis* | Limes stone | HFCW | BOD=94.4, NH₄-N=89.1, TN=86 | [15]        |
| *Palaris arundinacea* |           |                 |                |            |
| *Common reed* | Limes stone | HFCW | BOD=95, COD=95 | [20]        |
| *Canna* | Zeolite | HFCW | BOD=95, COD=95 | [20]        |
| *Silver sand* | VFCW |                 |                |            |
Generally, in constructed wetland studies, the samples are tested in long time horizon with occasional sampling. For instance [1] collected monthly two sampling for one year. [2] collected monthly one sample in HSSF. [21] collected monthly sample in subsurface flow constructed wetland for 18 months. It is very important to measure the efficiency of treatment unit at initial stage because that the majority of removal is taken place in sapling period of wetland. So here an attempt is made to identify the performance of constructed wetland in short time horizon of one month period with 27 sampling (after 45 days of seedling) with continuous monitoring at initial stage of constructed wetland. This is helpful for knowing initial condition of the system.

2. Materials and methods

In this work, three types of constructed wetland namely VFCW, HFCW and UFCW were made. Each constructed wetland having size of 2m x 1m x 1m. During construction of experimental tank, water proof cement was added with ordinary portland cement in order to prevent seepage during experimental period. The D_{90}, D_{30}, D_{10} for sand 1.30, 0.61, 0.33 and native soil are 0.7, 0.49, 0.25 respectively. Uniformity coefficient (C_u) for native soil and sand are 2.8 and 3.94 respectively. The gravel layer is laid at bottom at the thickness of 30cm, above the gravel layer, sand is laid at the thickness of 50cm. Above the sand layer, local soil is laid at the thickness of 10cm. Phragmites Australis is identified as one of the invasive plants in Koomapatti, Virudhunagar District. Phragmites rhizome is planted at every 0.2m distance. After sowing of 45 days, the efficiency of water quality was checked in three constructed wetlands. The primary treated domestic sewage is pumped from sewage treatment plant to three wetlands and the water quality was tested before and after treatment. Totally 27 samples were collected and tested within one-month period.

Various water quality parameters of the sewage are analyzed using standard methods as follows: TDS and TSS were analyzed by gravimetric method, pH was measured by pH electrode method, COD was measured by digestion method, Nitrates were determined by Brucine sulphate method and Orthophosphate was determined by Ammonium molybdate method.

3. Results and Discussions

Table 2 shows the overall efficiency of treatment wetland in the one-month period.

| Parameters | Influent values | VFCW | HFCW | UFCW |
|------------|-----------------|------|------|------|
| pH         | 6.6-6.9         | -    | -    | -    |
| TDS        | 860-1087        | 27   | 19   | 29   |
| TSS        | 165-406         | 83   | 82   | 87   |
Table 2 show the overall removal efficiency of different wetlands in month period. The pH value of wetland during the entire period ranges from 6.6-6.9. The optimum pH for Phragmites Australis is 3.7-8.0 [6]. Temperature is observed throughout the experimental period is 32ºC to 35ºC.

3.1.1. Removal of COD. COD removal is almost same in HFCW and VFCW and it is less than 10% than UFCW. In VFCW maximum COD removal is 21% wherein the case of HFCW, COD removal is 20%. In UFCW maximum COD removal is 31%. One third of removal of COD removal happens at initial stage itself. It is observed from Figure 1, within one-month experimental period, after fourteenth day the COD removal is increases.

3.2.2. Nitrification in Wetlands. Nitrification occurs properly in all types of constructed wetland. From Figure 2 it is observed that, Nitrification is more in VFCW. It is understood that aeration is going properly inside the system and microorganisms which consumes available oxygen to nitrify [3]. It is evident that with increase of time, plant height increases and the nitrification increases. The nitrate-N removal increased as the wetlands matured and the vegetation grew denser [22]. According to [9], better oxygenation can be achieved by using sand layer in constructed wetland. In our study 50 cm thickness of sand layer is also one of the primary reasons for nitrification. There was an increase in the level of Nitrate which suggest nitrification as the nitrifying bacteria converted ammonium nitrogen in the influent to nitrite and further to nitrate [5].

3.2.3. Phosphorous Removal. In this study, removal of phosphorous is steady but low (Figure 3). This was in agreement with a previous study by [9]. In HFCW, the maximum removal obtained is 46%. Almost part of the pollutants is removed at initial stage itself. While in other two types of constructed wetland such as VFCW and UFCW the removal is 29% and 31% respectively. Comparing to other two types of wetland, phosphorous removal is a little high in HFCW. According to [11], the removal of nutrients is usually low in constructed wetland and does not exceed 50% when dealing with municipal sewage. Substantial phosphorous removal achieved only HRT more than 15 days [19]. Phosphorous removal is mainly by adsorption on filter media, bind or precipitate the incoming phosphorous [4,8]. Gravel substrate is not suitable for phosphate removal. It is apparent when using gravel or crushed stone for filter media causes lower removal [12]. The proposed way of phosphorous removal is the use of special substrate material with high sorption capacity [11].

3.2.4. Solids Removal. Removal of TSS concentration in UFCW is 87%. In HFCW and VFCW, the maximum removal is 82 % and 83% respectively. It is observed form Figure 4, the fluctuation is occurred at three wetlands, consists of solid faeces, bacteria and sediments that are filtered from the wastewater in the wetland by incorporation into the substrate [8]. The most widely recognized process for contaminant removal is physical one which implicates filtration and sedimentation. Most of the suspended solids are filtered out and settled within the first few meters beyond the inlet zone [11]. From Figure 5, TDS also fluctuated in all types of wetland. Maximum TDS removal in VFCW, HFCW and UFCW are 27%, 30% and 31% respectively. TDS removal is comparatively same in three types of constructed wetland. It is observed that the TDS removal is not steady throughout the period. In some experimental results we found that the outlet values are higher than the inlet values. This may
be due to possible interaction between substrate and formed biofilm might have release of water soluble salts [3].

Figure 1. Removal of COD in three Wetlands

Nitrification

Figure 2. Nitrification Process in three wetlands
**Figure 3.** Phosphorous Removal in three wetlands

**Figure 4.** TSS Removal in three wetlands
4. Conclusions
The inference of the study is focused on the behaviour of constructed wetland in short period of time with continuous data. For this purpose, three types of constructed wetland were made based upon water flow. It is observed that almost 50% of removal is taken place at sapling stage. From the observed results more sampling and testing of results at initial stage is necessary because the sensitive changes occursmainly in growing stage. Hence it is recommended to do more sampling at initial stage in constructed wetland studies. This will helps us to understand the wetland in a better way. It is also suggested that long term studies are also required for further analysis of wetland in matured stage.

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