Performance Analysis of Vertical Flow Constructed Wetland to Treat Domestic Wastewater using Two Different Filter Media and Canna as a Plant

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Abstract

Objectives: Investigation for low cost, small scale, decentralized waste water treatment system for small communities and suburbs was done in this study. Total passive system, artificially engineered to treat domestic wastewater by mimicking the natural water purifying processes of river, swamp and wetlands, gives us what is known as constructed wetland. Methods: In this paper, we carried out the design and installation of two laboratory scale vertical flow constructed wetland within the premises of Lovely Professional University sewage treatment Plant. Two separate systems of height 45 cm and average diameter 15 cm was created, one with gravel and sand as a media and other with gravel, sand and soil as a media. Both the wetland was planted with Canna sp as an excellent phytoremediating plant and was available easily in locality. This plant shows very high growth rate and has a large rhizome. The waste water was fed through the 1.5cm diameter pipe. Eight liter of pretreated wastewater from the university Sewage treatment plant was fed with a retention period of 2 days, feeding was done in such a way that the gravitation does all the work, as the feeding tank was placed higher above both the wetland. Feeding was control by the valve. Findings: Initial analysis of wastewater subjected to wetland shows dramatic reduction in the visible suspended solids and color. Dissolve oxygen was improved from 3.6±0.4mg/L to 5±2mg/L in both the wetland system. pH in effluent from both the CW was in between 6.5-8.5, pH of influent was in between 9±0.4. BOD₅ at 20°C of both the effluent form vertical flow CW was found to be below 30mg/L as against the 180-190mg/L of influent given to wetland, which was well within the range as per as Environment (protection) rules, 1986 of GOI for inland surface water discharge. Application/Improvement: Potable water is already a scare resource; even the water for irrigation is becoming scarce and not to forget the depleting ground water table. The findings of this study shows us a potential cheap method to treat wastewater generated, which can be used to met our agricultural water demand and can even be used to recharge ground water.

Keywords: Canna, Constructed Wetland, Phytoremediation, Vertical Flow, Wastewater Treatment

1. Introduction

The treatment of wastewater for reuse has been in a debate recently in large cities and small cities of India due to scarcity of water. The disposal of untreated waste water directly in a river or lake has an adverse effect on the water bodies. Eutrophication, water born disease is few names among many effects. The hurdle to treat municipal waste water comes from the unavailability of resources, skilled man power and not to forget the large
power needed to run conventional treatment plants. In such a scenario the constructed wetland not only serve purpose of treating waste water and saving water bodies from adverse effect but also provide habitat for different amphibian and reptiles therefore increasing overall utility. By integrating the wetland into treatment infrastructure, we are trying to unleash its potential without affecting its basic utility as an ecosystem. Ever since West Germany pioneered the early constructed wetland the idea have been floating around the world and have made huge difference in poor and developing countries where the resources to established conventional treatment units are very inadequate.

The process that are happening in a swamp, river and wetland, where water gets purifies naturally are engineered in a controlled manner to form a constructed wetland, to treated waste water, that may be domestic, municipal, industrial etc. The knowledge of comparative assessment by adding and subtracting different component in a constructed wetland, that may be by trying different plants, different media or by engineering the whole system differently may show the solution to a distinctive problem of wastewater treat-ment which would otherwise be neglected in a name of larger utility. It is clear that the natural chemical process like assimilation by plants is important mechanism by which the pollutant gets removed from the wastewater. Plants role is out most important as it provides, in its root, the site for bio film to develop. The rhizome size, the growth rate of plant all play major role while selecting the wetland plant Canna have high growth rate, have large rhizome and have found to be very adaptive in tropical places. The plant have been growing easily in and outside the university area, along the road side and in many swamp area in Jalandhar, Punjab (India).

The research tries to find out the treatment efficiency of constructed wetland when (1) the wetland is constructed with sand and gravel only (2) when the soil is used along with sand and gravel. In both the case the top layer is planted with Canna plant whose root system will extensively colonize layer.

2. Material and methods

In a two 0.0318m bucket whose average diameter was 15cm the laboratory scale vertical flow constructed wetland was established within the premise of university sewage treatment plant. The entire set up has been shown in Figure 1 and Figure 2. The media used in wetland was river gravel sand and soil. The detail is as follows.

![Figure 1](image1.jpg)

**Figure 1.** Day one after transplantation of plant (left) and after three month of plantation (right).
1. Set up of type 1, where only gravel and sand was used. Four layer of this wetland consist of larger size gravel of 40-45 mm in lower layer, which lies 10-20 mm followed by small pea size of less than 4mm and in the top lays sand. The height of bucket is 45cm.
2. Type 2 has all the common element of type 1 except the top layer is a soil instead of sand.

Each set up was planted with three healthy Canna plant, shown in Figure 2 (right) is the root of Canna. The root of which penetrates deep below when it grow. The average root length was 15cm The Canna plant which was planted was having large rhizome and was planted within an hour of bringing it from the nearby swamp. At the bottom of each set up the opening valve for effluent was made. Each set us place a brickwork which a slope of 1%. The 70 liter feeding tank was set up the two constructed wetland to allow the influent to gravitate itself. The 1.5cm diameter pipe was use to fed each constructed wetland from facing face of the feeding tank. The wastewater coming out from the grit chamber was fed to this feeding tank manually. The feeding valve in the feeding tank was made 10cm the base of feeding tank to make sure less suspended solids enters the constructed wetland. As we know that the pretreatment of wastewater is necessary before the wastewater flow into the constructed wetland.

The 8 liter per day of waste water was fed to each constructed wetland with a detention period of 2 days. After 2 days the effluent from each vertical flow of constructed wetland along with the influent from grit chamber was collected and tested for pH, COD, DO and Total Nitrogen (TN) in laboraotry of Civil Engineering and Agriculture Department.

The porous pipe of diameter 2.5cm was installed after a month of transplantation in each constructed wetland, this was done to incres the aeration process in order to facilitates the nitrification process. The porous pipe penetrates all the way to bottom of bucket. The Figure 2(left) shows the set up with porous pipe.

The effluent sample was tested for pH, suspended solids and DO in laboratory of Civil Enginnering Department of Lovely Professional University itself for Total Nitrogen the sample was sent to the Agriculture Department in university itslef.

3. Result and Discussion

The small flow of 8 liter pers day was fed to each vertical flow constructed wetland. The wastewater subjected to both the constructed wetland was having the characteristics as shown in the Table 1. The wastewater was
subjected to pretreatment to allow settleable solids to settle as wetland is poor in handling solids.

The relative good level of DO of waste water of the grit (influent) is attributed to the aeration process of wastewater in the sump well before pumping it into grit chamber. The wastewater of university have very high BOD as the wastewater comes directly from hostels and mess which have high organic content. The turbidity and color is very effectively removed by both the wetland. The result of which can be seen by naked eye too in the Figure 3.

The effluent pH was found well within the limit of 6.5 to 8.5 against the influents’ average value of above the 8.5. Figure 4 clearly shows that not much variation was seen in the value of pH in effluent of both the wetland.

The DO too shows not much variation for both the constructed wetland but value of DO was improved overall in both the constructed wetland well to the level above 4mg/l as against the effluent value of DO of less than 3.6±0.4. Figure 5 clearly shows the trend of DO concentration in influent and effluent of both the CW.

The turbidity level was found very well within the limit in both the influent water. The removal of suspended solids (SS) was mainly due to adsorption in media and in bioslim layer formed in media and roots which in turn, will be a food for plants. The Figure 6 shows the ability of CW to bring down the SS concentration of around 600mg/L in influent to less than 100mg/L in effluent of CW. The proper functioning of constructed wetland over a long run depend heavily on the solids in influent. Over a long run, suspended solids is seen contributing to the clogging of media layers, thereby affecting vital processes of wetland functioning. It is also true that the roots have some role to play in increasing porosity of the media. Figure 3(left) shows the visible reduction in the SS concentration in effluent of Constructed wetland.

The significant work of the installed vertical flow construction wetland is its role in lowering down the value of BOD, in effluent. Figure 7 shows that, how in five weeks BOD concentration varied in influent and effluent of CW. The influent was having very high value of BOD (180-190 mg/L). Both the constructed wetland was able to lower down this value to well below the limit of 30 mg/L which was well within the limit for inland surface water discharge as per as Environmental (protection) rules.

![Figure 3](image-url) Influent in the middle bottle and effluent are in the side bottles (left), Plants after six month of transplantation (right).
Table 1. Characteristics of Influent wastewater

| Parameter                        | Regulatory level (Environmental (protection) rules) 1986 for Inland surface waters. | Influent |
|----------------------------------|--------------------------------------------------------------------------------------|---------|
| pH                               | 5.5-9                                                                                | 9±0.4   |
| DO (mg/L)                        | 4-8                                                                                  | 3.6±0.4 |
| BOD (mg/L)                       | 30                                                                                   | 180-190 |
| Total suspended solids (TSS) (mg/L) | 100                                                                                 | 605±5   |
| Nitrogen (TN) (mg/L)             | 100                                                                                   | 105-110 |

Note for graph: The effluent 1 means the effluent from the Vertical flow construed wetland type1, where the soil instead of sand is used and the effluent 2 means effluent from vertical flow constructed wetland without the sand.

4. Removal of Nitrogen as TKN, NO2 and NO3

The removal of total nitrogen can greatly be attributed to presence of Canna indica plant and the aeration pipe which boosted the nitrification process by enhancing the aeration. The large stem, tubler root, large leaf area provided ample platform to take up nitrogen either in ammonical or nitrate form. The oxygen needed for nitrification is also released by the roots in its vicinity forming the oxidised zone. Intresting point to note down was that the percentage removal of nitrogen as ammonia was observed almost same for both the constructed wetland despite soil being a top layer media in one of the constructed wetland. The Figure 8 shows the trends of TN concentration in effluent of constructed wetland in five weeks as compare to TN concentration in influent.

The removal percentage of nitrogen is 48% as ammonia in vertical flow constructed wetland without soil is in good comparision to that of and the removal percentage of ammonia nitrogen 49.6% for the vertical flow constructed wetland with soil as the top media is in very good competition. This variation can also be attributed to the fact that the N can gets adsorb to sand and soil differently, the substrate of the sands can adsorb N to a certain degree.

Figure 4. The pH value for the 5 weeks.

Figure 5. Variation of DO over five week.

Figure 6. Variation of SS over a six week.

Figure 7. Variation of BOD over a five week.

Figure 8. Variation of TN over a five week.
5. Evaluation of Presence of Soil and Canna Plant

The presence of soil can affect the treatment efficiency but bring along with it few drawbacks too. The organic removal in form of BOD₅ was found out to be high in the wetland with soil initially but later as the porosity of media in wetland seems to decrease, as soil becomes less porous than sand due to entrapment of soils in soil voids this effects the treatment efficiencies in terms of BOD₅ removal. The sand and soil act as a desorbing media for N but the soil seems to desorb N over a time, as infer in the canna plant which have very high growth rate, larger stem, large leaf area and extensive root system seems to be very effective in removal of nutrient from wastewater[9,10]. The harvesting of plant once the flowering season (Figure 3 (right) shows canna plants bears flower after six month of transplantation) is over, will increase the nutrient uptake capacity of plant as the new plants start growing from the root rhizome[11].

6. Conclusion

It is clear now that both type of constructed wetland perform almost same over study period in term of treatment efficiencies. However the constructed wetland in which sand was replaced with soil shows high nutrient removal capacity initially. Overall short term performance is high in one with soil but in longer run it has additional problems in term of clogging. Effective constructed wetland should be made of very high porous media, like small pea size gravel; the treatment effectiveness can be increased by incorporating the porous pipe which increases the aeration in constructed wetland. The Canna is a good wetland plant when it comes to nutrient removal, also its appealing flowers enhance aesthetic of treatment units and will make this sort of treatment process easily accepted by people. The finding of this research gives us an idea that constructed wetland can be easily adopted to treat domestic wastewater from small communities and suburbs. Constructed wetland provides us a low cost, small scale, decentralized waste water treatment alternative to conventional wastewater treatment processes which is both chemical and energy extensive. Constructed wetland can also be build along the lake or river shores to act like a buffer, generally along the point where the wastewater from small communities gets into lakes and river. This will ease down the eutrophication to a large extend. The main advantage for adopting such infrastructure is that constructed wetland maintains its natural functionality to sustain life form and ecosystem. Research is further continuing to check treatment capacity for microorganism removal along with phosphorus removal by doing necessary modification in media.

7. References

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