

Phytoremediation for Sewage Treatment by Varying Load Constructed Wetland under Hydroponic Condition Using Vetiver Grass

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ABSTRACT: Phytoremediation is an environmental pollutants clean-up technology using plants. To get higher efficiencies, the appropriate selection of the most efficient vegetation is very important for all phytoremediation applications. The main objectives of the study were to design, construct, and monitor the performance of a varying load constructed wetland and examine the pollutant removal efficiency in treating the domestic sewage. *Vetiveria zizanioides* commonly called Vetiver was used as the wetland vegetation under hydroponic condition over the period of 5 weeks. Being a hydroponic method the vegetation was fixed on a floating base to make the plants float while the roots remained completely immersed. The studies were done with the variation of the depth of media (wastewater) along with the development of the roots of the plants. The overall performance of the system was evaluated by analysing the parameters such as Biochemical Oxygen Demand (BOD₅), Chemical Oxygen Demand (COD), and nutrients (Nitrate-Nitrogen, Phosphate and Potassium) of both the influent and effluent for an interval of 5 days. From this experiment, it was observed that, the varying load constructed wetland proved to be highly efficient in the removal of BOD and COD in every 2 weeks as new roots are developed only in 2 weeks. Thus *Vetiveria zizanioides* was found to be a good species for phytoremediation of domestic sewage using varying load constructed wetland system.

KEYWORDS: Constructed wetland, *Vetiveria zizanioides*, Hydroponic, Subsurface flow, Domestic wastewater.

I. INTRODUCTION

Wastewater is defined as a combination of the liquid or water carried wastes removed from residence, institution, industrial & commercial establishments. Water pollution is a major global problem and it is leading worldwide cause of deaths and diseases. Increasing population, unplanned urbanization and industrialization are responsible for the water pollution. Wastewater treatment is a problem that has plagued man ever since he discovered that discharging his wastes into surface waters can lead to many additional environmental problems. Treatment of wastewater is required because it causes foul smell, bad odours, and demands for dissolved oxygen in the water bodies, adds nutrients (nitrate and phosphate) and increases suspended solids or sediments in streams.

Phytoremediation is one of the biological wastewater treatment methods using plants-based systems and microbiological processes for eliminating contaminants in nature. It is a clean-up technology for contaminated soils, groundwater, and wastewater with both low-tech and low-cost. The remediation technique involves specific planting arrangements, constructed wetlands (CW), floating-plant systems and numerous other configurations.

Wetlands are generally characterized by the presence of three basic parameters-soils; hydrology and vegetation. Constructed wetlands are artificial wastewater treatment systems consisting of shallow ponds or channels which have been planted with aquatic plants which rely upon natural microbial, biological, physical and chemical process to treat wastewater. Natural wetland systems have often been described as the "earth's kidneys" because they filter pollutants from water that flows through on its way to receiving lakes, streams and oceans. Constructed wetlands are treatment systems that use natural processes involving wetland vegetation, soils, and their associated microbial assemblages to improve water quality.

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II. RELATED WORK

Paul Truong et al (2001) conducted a study on Vetiver System for Waste Water Treatment at Queensland department of natural resources and mines. This study found in Australia and China shows that Vetiver System is a very effective method of treating polluted water, domestic effluent, industrial wastewater and landfill leachate. This study also verified vetiver's ability to treat landfill leachate and large-scale livestock and abattoir wastewater. Site-specific designs are being refined for vetiver grass planting expanse and medium, for wastewater system flows through the vetiver, and for monitoring total system effectiveness.

Boonsong et al (2008) conducted a study on Domestic Wastewater Treatment using Vetiver Grass Cultivated with Floating Platform Technique at Thailand. The study was divided into three phases of eight weeks each, using 7, 5 and 3 days of hydraulic retention time (HRT), respectively. The results indicated that the treatment efficiencies of different HRT and wastewater concentrations were significantly different. The 7-d HRT showed highest treatment efficiency. Thus, the overall results suggested that the optimal condition of this technique should be designed at 7-d HRT.

Samuel et al (2015) conducted a study on purification of industrial wastewater with vetiver grasses (*Vetiveria zizanioides*): the case of food and beverages wastewater in Ghana. The results indicated that vetiver grass grown in Biogas effluent experienced the best growth where all 5 tillers developed; followed by vetiver grown in Pinora effluent sample, where two tillers developed, and finally, the vetiver grown in Palm Oil Mill effluent experienced the worst growth. The physico-chemical analysis indicated that Biogas effluent experienced the highest removal rate of contaminants, followed by effluent from Pinora Ltd whereas effluent from Oil Palm industry experienced a low removal efficiency of contaminant.

From the papers mentioned above obtained that *Vetiveria zizanioides* is the best phytoremediation species for waste water treatment which shows better results. Also, the hydroponic method of vetiver grass is more effective than other on-site systems for the treatment of domestic sewage.

III. MATERIALS AND METHODS

Experimental Setup

The raw sewage collected from anaerobic filter unit was improved by passing through constructed wetland system. A pilot wetland system was constructed using glass sheet of 6mm thickness. The dimension of the tank was 0.7m X 0.35m X 0.5m (length x width x depth). The influent was supplied from a reservoir which was kept at the top to facilitate the vertical flow condition.



Fig. 1 Experimental Setup

The effluent was collected from the bottom end of the tank. The design of the units was done in such a way that it allows a full characterization of relevant model parameters and an easy monitoring of the system performance by sampling the inflow and outflow in regular time intervals during the whole period of the operation.

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Inlet and outlet arrangements

Domestic wastewater was allowed to flow into the wetland through a pipe in a controlled manner. The inlet unit was provided with a pipe along with a calibration knob. The calibration knob was adjusted such that it works for different loads. Once the tank is filled it is allowed to given retention time of about 5 days. The outlet was made at the same level as of inlet pipe using a plastic tap to collect the treated sample and was checked for different characteristics.

Varying Load Constructed Wetland



Fig. 2 Initial stage of varying load CW

The varying load constructed wetland can treat high load concentrations having higher depth. It is very efficient and economic technology for domestic waste water treatment. Since it is a varying load wetland with greater depth, deep rooted plants are mostly preferred. Being a hydroponic method, there were no ongoing fly, mosquito problems, bad smell and gas formation. In the initial stage 24 L of the raw sewage was given to the tank with an HRT of 5 days. After 5 days, the effluent is taken for the analysis of the physico-chemical parameters.

Wetland Vegetation

For the experiment, the dried leaves were separated and then washed. They were then transferred to aqueous hydroponic solution until adequate roots and shoot development were ready for the experiment. After one week, vetiver grass of the same size, by separating it into 10 clumps of equal weights (50g each) was taken and transferred to the tank containing hydroponic solution of raw sewage. Initially, the length of roots of plant was 10 cm and the shoots were cut back to approximately 30 cm height to reduce transpiration. Thermocol (2mm thickness) was used as the floating material to make the vetiver grass to float in the tank.

Design of the constructed wetland pond

To determine the performance of the wetland and to find out the polluting parameters, a bench scale study was done by constructing a wetland pond of following dimensions. The wetland pond was constructed of glass sheet of 3mm thickness. The design parameters are as follows;

$$\begin{aligned}\text{Total volume} &= L \times B \times D \\ &= 0.7 \times 0.35 \times 0.5 \\ &= 0.1225 \text{ m}^3\end{aligned}$$

The experiment was conducted for 5 weeks and in every week the load and depth of the wetland system was varied with the hydraulic retention time of 5 days. Batch type of operation was adopted to feed the raw sewage. The influent was applied for first week; the wastewater feed into the tank was about 24 litres and the effluent was collected after keeping a HRT of 5 days. In the second week, after removing all the treated water from the tank, the fresh wastewater of about 48liters was fed into the tank and retained for the same hydraulic retention time. Similarly, in the next 3 weeks wastewater of 72liters, 96liters and 120liters was fed to the tank with 5 day HRT.

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Untreated & Treated Samples

The raw sewage samples was collected from anaerobic channel and then transferred to the reservoir. The wastewater collected from the reservoir for treatment and the treated wastewater from the outlet of the tank is shown below:



Fig. 3 Untreated & Treated Samples

IV. EXPERIMENTAL RESULTS

The depth of the constructed wetland system was varying weekly with increasing the loading rates. A loading of 24L was given in the first week and the HRT of loading was 5 days. In the second week, a fresh loading was given into the tank was about 48 litres for same hydraulic retention time. Similarly, the next 3 weeks of 72liters, 96liters and 120liters of freshly taken wastewater was given for 5 days HRT.

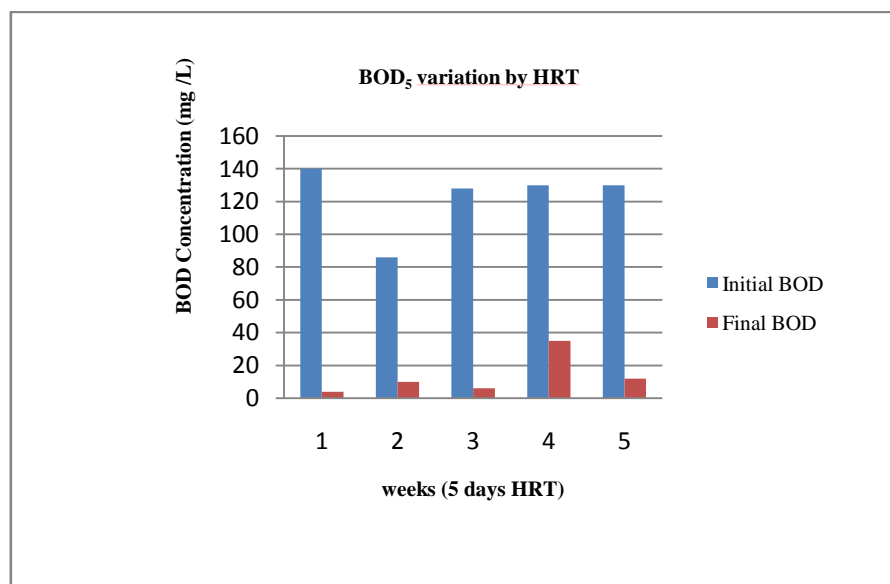


Chart.1 BOD₅ variation under varying loads by HRT

The performance of the wetland system was constantly watched and samples from the inlet and outlet were collected in every week and the parameters like pH, COD, BOD₅, Nitrates, Phosphates and Potassium were analysed.

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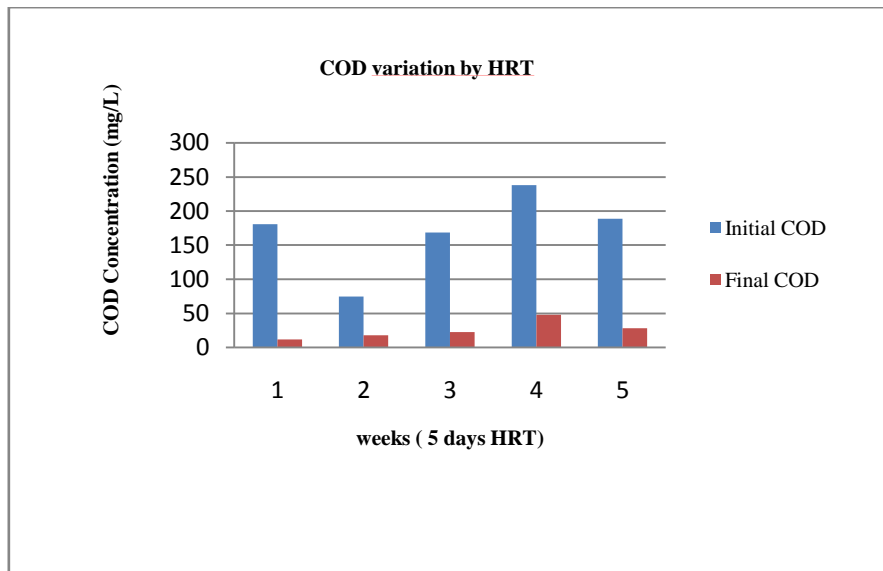


Chart. 2 COD variation under varying loads by HRT

The above results show that 90% to 95% of BOD and 85% to 90% of COD removal occurred in every 2 weeks. Hence the minimum HRT of 2 weeks is suggested for the maximum removal of BOD and COD using varying load constructed wetland system.

V. CONCLUSION

Phytoremediation is an interesting alternative to current environmental clean-up methods that are energy intensive and expensive. This term is given to the process of treating waste water through a hydroponic system which incorporates certain plant species as the filtration agent. The results illustrated that vetiver grass is an efficient biological means of primary filtration and can be used as a low-cost primary filter of water run-off in poorer areas where it is not treated and discharged into natural water courses. When hydroponic culture is applied for wastewater treatment, vetiver shoots and roots can be harvested easily to remove the pollutants. It can be used safely for bio energy production, compost or even as material for handicrafts.

Varying load constructed wetland can treat high load concentrations, very efficient and economic technology for domestic waste water treatment. Since it is a varying load constructed wetland with greater depth, deep rooted plants are mostly preferred. Being a hydroponic method, with floating base on the top of the wastewater, prevents the fly nuisance and mosquito breeding. The odour can be prevented and the gas produced can be effectively channelized outside. From this experiment, it was observed that, it is highly efficient in the removal of 90-95% of BOD and 85-90% of COD removal occurred in every 2 weeks because, the developments of new roots are occurred only in 2 weeks. Hence the minimum HRT of 2 weeks is suggested for the maximum removal of BOD and COD using this method.

From these results, it is clear that vetiver can tolerate domestic effluent and have an unusual ability to take up nutrients and other pollutants from treatment medium. So it can be concluded that the *Vetiveria zizanioides* is a good species for phytoremediation of domestic waste water using varying load constructed wetland technology even though the vetiver plants struggles in the stressful environment created by the effluent to establish their successful survival.

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