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Removal of COD from domestic wastewater at minimum retention using artificial aeration in vertical flow constructed wetlands.

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Abstract
A pilot scale study was carried out on vertical subsurface flow constructed wetland planted with *Phragmites australis* to remove COD from domestic wastewater generated from college campus in Ludhiana. Three identical models were constructed using same plants on the three. The first one is non-aerated type and its substrate is of fine clay. The rest two have substrate of alluvial soil that contains silt, one is only provided with aeration pipe for artificial aeration while the other is aerated using electric blower. The latter gives better COD removal in much less time even at high hydraulic loading than both of the former setups. With artificial aeration from top and bottom we can achieve about 82% removal efficiency with retention of just 15min. The efficiency of the system can further be enhanced by connecting another wetland cell in series.

Keywords: Aeration, COD, domestic wastewater, phragmites australis, constructed wetlands.

INTRODUCTION
Water is an essential and most important resource on the planet. Without water it is impossible to imagine life on the planet. But due to rapid increase in global population the stress over the freshwater resources increases and these resources are depleting day by day. The wastage of freshwater resources has also increases many folds. This untreated water is discharged mainly into water bodies mainly lakes and rivers or normally this water is openly discharged on soil. This leads to contamination of soil and other water bodies and these contaminants enters directly or indirectly to our food chain. So this wastewater needs to be treated before discharging to any water body or soil or further reuse [World Water Assessment Programme, 2009].
Constructed wetlands are economical systems which are widely used to treat various wastewaters. They require low maintenance as compared to conventional treatment plants. They are natural and sustainable and require negligible man power [Zhang et al., 2012]. It is defined as one of the green technology to treat wastewater of any type whether industrial or domestic. Constructed wetlands are the kidneys of our planet.
They are very simple to operate and no separate energy is required to carry out processes in CWs as compared to STPs [Chen et al., 2006].The purification capacity of CWs relies on various naturally occurring processes which are continuously running within the system and degrade various pollutants as a result of the synergetic actions of the system components, i.e., substrate

media, plant roots and microbial community [Stefanakis et al., 2014].In wetlands, the efficiency of the system depends upon the vegetation cover over it. Plants are able to absorb pollutant through: 1) absorption of pollutants in the roots of the plant; 2) the tissues present in the plants i.e. xylem and phloem might transfer the contaminants to the plant upwards; and 3) the tissues present in the plant species might bind the pollutant only in root tissue[Sigua et al., 2013]

Constructed wetlands not only treat water with organic impurities, they also have the tendency to remove metals with higher density from the wastewater. Now a day most of the industries set up their own wetlands treatment systems so as to treat their effluent which mainly consists of heavy metals [Hadad et al., 2006, Maine et al., 2006, Jayaweera et al., 2008]. The following are major types of constructed wetlands working effectively across the world.

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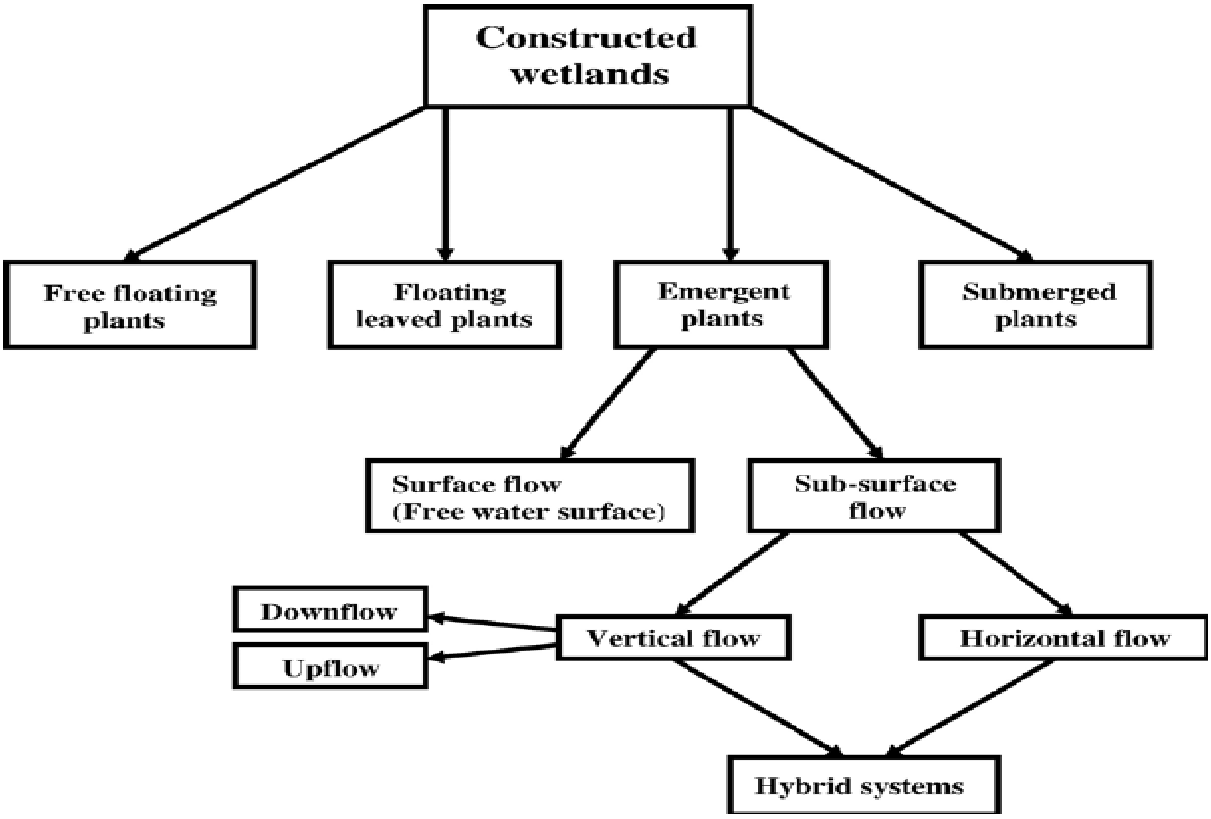

Fig- 1: The major types of constructed wetlands

Vertical sub-surface flow constructed wetlands (VFCWs) are intermittently fed from the top [Vymazal et al., 2016], wastewater percolates and oxygen enters the system from the atmosphere as wastewater is drained. Vertical sub-surface flow constructed wetlands are predominantly aerobic [Kadlec et al., 2009]. The beds of these systems are of porous substrate which means that it offers large surface areas to treat wastewater as compared to free flow wetlands. This means that we can treat the same amount of wastewater as in case of free water type in very small area in subsurface type using optimum design considerations.

In this study three pilot scale models of VFCWs were constructed and tested for the removal Chemical Oxygen Demand (COD) in domestic wastewater at low HRT using artificial aeration. Domestic wastewater is a combination of blackwater [Mulec et al., 2016] and greywater [Maimon et al., 2014] usually originates from bathrooms, kitchen, toilets and urinals. The COD is an important wastewater parameter which indicates the amount of organics in water [Yand et al., 2009]. If the water with high COD is directly discharged to the natural water body without treatment, it will reduce the dissolved oxygen in water thus becomes fatal for aquatic ecosystem. The study area is the Guru Nanak Dev Engineering College Ludhiana, from whose septic tank the samples of domestic wastewater were taken.

MATERIAL AND METHODS

A - Pilot scale CW design and description

Three identical glass containers of size 30cm×30cm×60cm [Dan A et al., 2017] each were used in the study. Bottom layer of 15cm consists of gravel of size between 40-60mm which have been previously washed and dried in order to remove dirt and other organic material from them. Above gravel layer, lied a 10cm layer of coarse aggregates of size ranging between 10-20mm. A gunny bag (Jute) of size 30cm×30cm was placed as a separator between sand and aggregate layer. Above jute bag, Sand was placed and size of the layer is 10cm. Sand is sieved through 450micron sieve and properly compacted. Uppermost layer is of local soil consist of fine alluvium contains silt in two models and fine clay in one model. Plantations were done on this layer. The model with fine clay does not have any artificial means of aeration. Whereas in other two models 2.5cm wide circular pipes are inserted from top to bottom. One of these setups works normally as natural air passes through the pipe to the bed of the wetland while other is operated on artificial aeration provided by electric blower in which aeration is both provided at top as well as to the bed.

B -Plantation cover

Phragmites australis was used as vegetation over both the vertical and horizontal wetlands which were uprooted from pond of Gill Village. They are specifically selected because Phragmites australis is locally available and they are adaptable to local environment. They are the power houses to take up pollutants.

C –Sampling and setting of flow.

Domestic wastewater taken in this study as sample was collected from the septic tank of the college in which the wastewater of whole college and hostels was collected. A 20litre container was used to collect domestic wastewater and coarsely screened to remove floating matter. This sample was transferred to a steel container of 15litre volume which is used as influent tank in the study.

The flow was adjusted using I.V. pump (intra venal for injecting glucose to body in hospitals). In case of 24hrs HRT (hydraulic retention time) the flow was 0.174ml/s. The hydraulic loading rate (HLR) was 0.16m^3/m^2/day. The flow for 3hrs HRT was1.39ml/s and HLR was 0.98m^3/m^2/day. The flow for 15minutes (min) HRT was 1.39ml/s and HLR was 1.31m^3/m^2/day.

The influent COD and the COD after treating the influent in these models were checked in laboratory using spectrophotometric method. The effluent was collected in glass bottles.

Fig-2: Complete working setup of VSCW with aerator.

RESULTS AND DISCUSSION

A - VSCW working without aeration

In the first setup, no aeration is provided, the substrate sucks only the atmospheric oxygen. The HRT was 24hrs and substrate is of fine clay. The flowing are the results drawn from the study conducted. The sample was taken daily and each reading shown in table 1 is the average of two taken on consecutive day

OBSERVATION TABLE – 1: COD removal rate at 24hrs HRT without aeration.

Sample	Inlet COD(mg/l)	Outlet COD(mg/l)	Rate of removal (%)
1	295.5	128.7	56.44
2	310.4	136.3	56.08
3	311.5	139.5	55.21
4	384.7	155.6	59.55
5	289.1	125.4	56.62
6	322.4	144.6	55.14
7	299.1	128.1	57.17
8	354.9	147.9	58.32
9	308.3	132.9	56.89
10	291.7	125.8	56.87
Mean removal in percentage			**56.83**

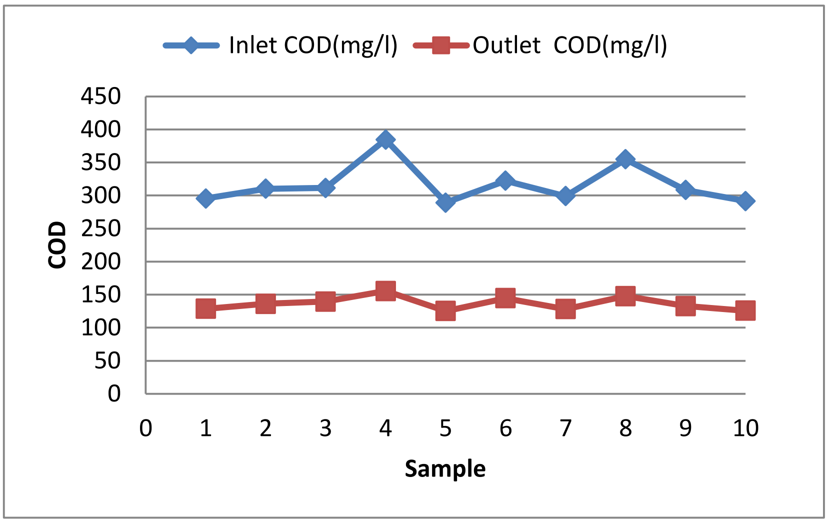

Fig-3: Inlet COD and outlet COD at 24hrs HRT

From the above results it was observed that the fine clay restricts the flow of water and also the system clogs if it is continuously fed without draining the previous water from substrate.

B **- VSCW provided with aeration pipe from top to bottom.**

Two samples for this setup are collected daily and each sample in the table 2 is the average of four samples.

OBSERVATION TABLE – 2: COD removal rate at 3hrs HRT with natural aeration through 2.5cm diameter pipe.

Sample	Inlet COD(mg/l)	Outlet COD(mg/l)	Rate of removal (%)
1	331.7	155.1	53.24
2	393.4	174.8	55.59
3	299.5	142.0	52.58
4	377.2	171.9	54.43
5	312.5	145.5	53.44
6	290.9	130.0	55.27
7	297.4	129.9	56.32
8	323.6	145.6	55.00
9	300.5	131.2	56.34
10	360.8	166.9	53.74
Mean removal in percentage			**54.60**

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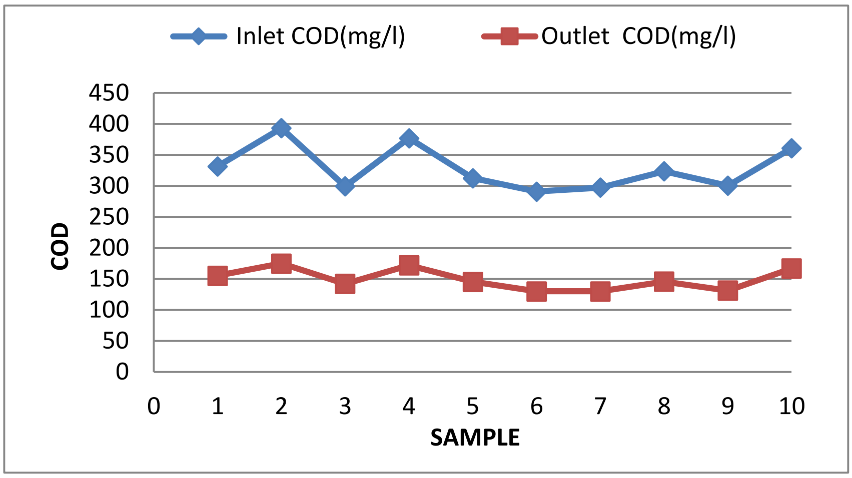

Fig-4: Inlet COD and outlet COD at 3hrs HRT

From the results it was observed that the removal efficiency was little bit lower than the efficiency at 24hrs HRT. This is so because the wastewater comes in contact with roots for about 3hrs. The natural aeration through pipe increases the permeability of the substrate and water seeps faster. The natural aeration has negligible influence on removal efficiency.

C – VSCW provided with artificial aeration on top as well as bottom using electric blower.

In this setup two samples are taken daily and each reading shown in table 3 indicates the average of four samples taken on two consecutive days.

OBSERVATION TABLE – 2: COD removal rate at 15min. HRT with artificial aeration through electric blower.

Sample	Inlet COD(mg/l)	Outlet COD(mg/l)	Rate of removal (%)
1	360.3	71.8	80.07
2	288.9	55.3	80.86
3	299.5	60.1	79.93
4	378.4	75.4	80.07
5	312.5	63.7	79.61
6	313.7	64.3	79.50
7	299.8	58.9	80.35
8	298.3	59.1	80.19
9	280.1	50.3	82.04
10	302.6	60.0	80.17
Mean removal in percentage			**80.28**

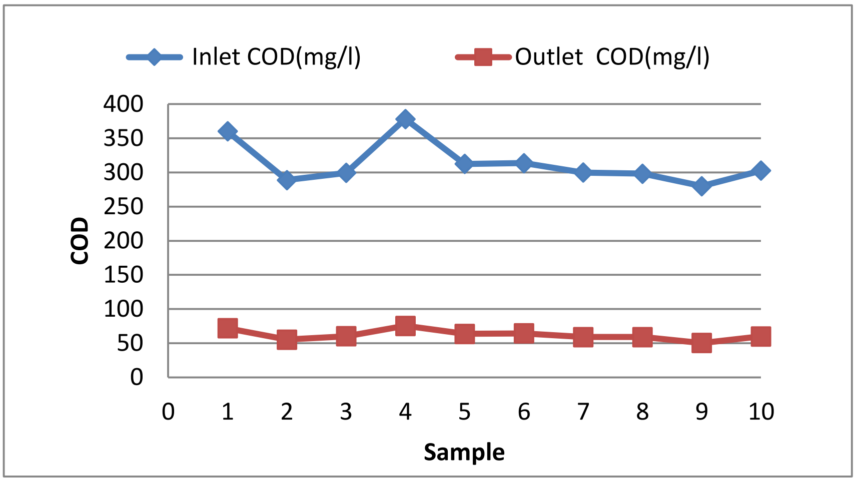

Fig-5: Inlet COD and outlet COD at 15min HRT.

From the results it was observed that the aeration provided at surface as well as to the bottom bed aerates the system to large extent and about 3/4th of the total COD is removed only at 15min HRT. Moreover the system becomes continuous fed type as the substrate takes necessary oxygen from the bottom and no chances of clogging is there.

CONCLUSIONS

From the above results it was clear that we can achieve high removal rate in wetlands through aeration. as in last case the aeration is provided both at substrate surface as well as the bottom of the bed, the setup removes 82.28% of the inlet COD in just 15min retention period while the setup with 3hrs HRT shows 54.60% removal and the one with 24hrs HRT gives 56.83% removal efficiency as shown in figure 6. Further in case of alluvial soil with silt the problem of clogging was not seen whereas the clay bed was clogged after some repetitions and is not suitable for subsurface wetland substrate.

The experiments were carried out in the month of April, 2017 and the average temperature in this month lies in the range of 38^{o}C – 43^{o}C. The observations shows that almost 39% of water is lost through evapotranspiration at 24hrs HRT and 10% at 3hrs HRT. While evapotranspiration losses are negligible in 15min HRT model, less than 3%. The evapotranspiration losses constitute both direct evaporation loss and the loss of water through plants.

Further the efficiency can be enhanced by connecting a horizontal wetland before treating in vertical because they are very effective in removing settleable solids without clogging.

The water obtained after treatment in wetlands is free from odor and color. So, it was estimated that other parameters are also reduced to great extent after aeration.

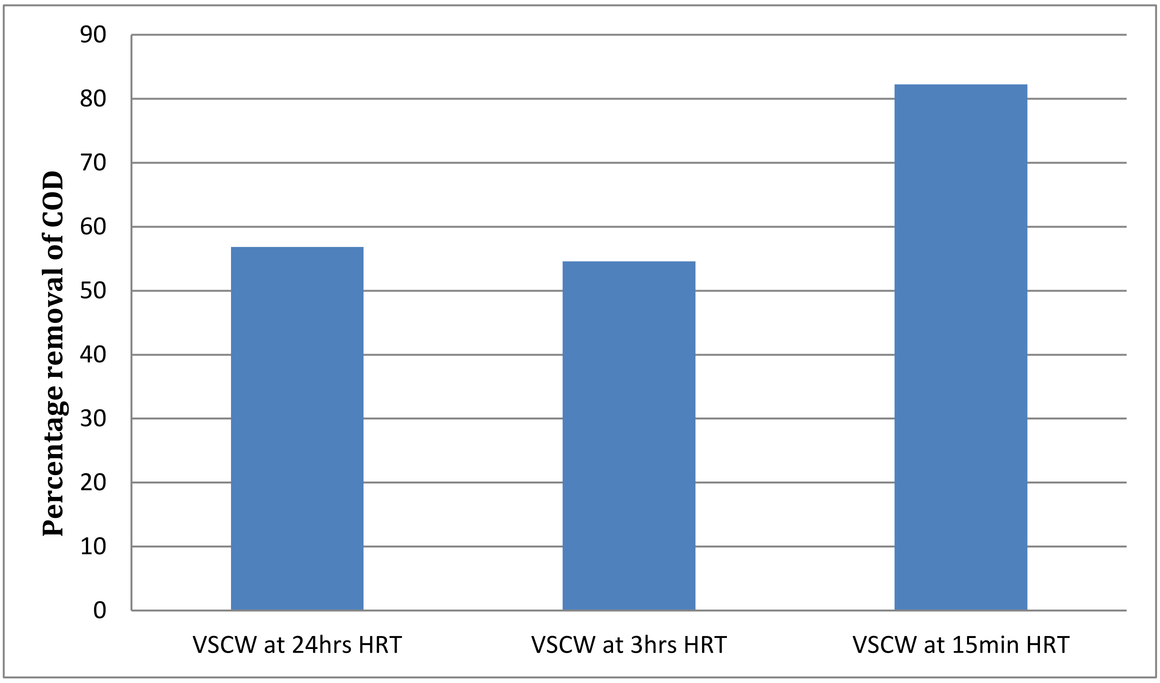

Fig-6: Percentage removal of COD with different HRT and aeration conditions.

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