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Performance Assessment of the Vertical Flow Constructed Wetlands Treating Effluent from the UASB Reactor – A Demonstration in a Tropical Climatic Region

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Abstract ***This paper presents the performance of the vertical flow constructed wetlands (VF-CWs) that has been investigated at a demonstration-scale level for the treatment of effluent from the anaerobic digestor (up-flow anaerobic sludge blanket) for municipal wastewater. The area of the bed is 480m^2 with a depth of 1.0m, having dual media. The macrophytes (vegetation) used in the VF-CWs is phragmites australis. The performance efficiency of the system was measured for different parameters like BOD, COD, TSS, TKN, and TC. The result indicates that the combination of UASB & VF-CWs offers a very promising way to deal with the municipal wastewater within cost-effective and sustainable approaches, particularly in the developing countries in a tropical climatic regions. The overall removal efficiency from UASB and VFCW for COD, BOD, TSS, TKN is 80.8%, 91%, 88.23% and 92.25% respectively. The total coliforms removal has been observed from 1E+06 to 1E+04 CFU/100ml***

Keywords: Municipal Wastewater, Vertical Flow Constructed wetlands, India, UASB, BOD

I. INTRODUCTION

Wastewater treatment is not a cheap option, especially in developing countries like India. It requires huge capital investment, recurring budget, technical know-how and a policy. Of the total Indian population, 69 per cent lives in the rural areas and the rest in the urban settlements. As per the estimates, India generates about 61754 MLD (million litres per day) of municipal wastewater, out of which the present treatment installed capacity is of about 22963 MLD [1]. This gap of 63% is one of the reasons for the pollution of water bodies, mainly rivers, lakes, and ponds.

Rural and urban sanitation in India should be seen differently due to diverse conditions prevailing [2] [3]. In the recent past and in particular with the launch of SWACH Bharat Mission, a national level program to address sanitation, efforts are being made to deal with wastewater management in rural areas as well.

The high-rate treatment systems like activated sludge process (ASP), sequencing batch reactor (SBR), anoxic-oxic process, moving bed bio-reactor (MBBR) etc. are energy-intensive and requires huge investment. In contrast, the natural treatment systems like constructed wetlands are cost-effective, simple to construct and O&M hassle-free [4]. The wetlands technology offer enormous potential to address pollution abatement in rural areas, townships, small towns, institutions, communities and other places.

This paper briefly discusses the findings of the demonstration-scale research that was aimed to treat municipal wastewater through the use of combination of UASB (up-flow anaerobic sludge blanket) followed by vertical flow constructed wetlands[5-8].

II. MATERIALS & METHODS

A. Study Site and Experimental Set-up

The study was carried out at a demonstration-scale unit which is located at Aligarh, about 130kms from the Indian capital city, Delhi, in the northern part of the country. This unit was one of the configurations that was designed, constructed and commissioned under the major collaborative Indo-Euro Water Technology Research Programme "SWINGS", supported by the Government of India and European Commission. This research project was started in 2013 and completed in 2016. Since then, the demonstration units are continuously under the monitoring of the Aligarh Muslim University (AMU), the lead Indian coordinator of the project.

The raw sewage of the AMU campus is conveyed to the existing sewage treatment plant (STP) which is owned and maintained by the institution. A stream of raw sewage is tapped at the inlet point of this adjoining STP for SWINGS wastewater treatment plant (WWTP). The raw sewage is firstly collected into a holding cum equalization tank. From this tank, the wastewater is pumped into a UASB reactor. After anaerobic digestion in the UASB reactor, the effluent is divided equally and goes to the two identical vertical flow constructed wetlands (VF-CWs). One of the VF-CWs is fed with the help of siphon that ensures pulse hydraulic loading and gravity flow to the bed. The bed has a depth of 1.0 m with a free board of 0.20m. The area of the bed is 480m2.

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It has a top layer of 0.80m coarse sand and bottom layer of 0.20mm coarse aggregate (20mm size). The combined porosity of the media matrix is about 40%. The beds have been vegetated with *phragmites australis*. This was planted with its native soil. The vegetation was fetched from the bank of river Yamuna which is about 50kms from Aligarh.

The flow diagram of the treatment scheme is shown in **Figure 1** whereas the pictures of the demonstration units at AMU Aligarh are given in **Figure 2 & 3**

Monitoring and Sampling

When the vegetation reached its maturity level, the sampling and analysis were started continuously for 4 months (November 2016 – February 2017). Various parameters at the inlet and outlet of the VF-CWs were measured. These include COD, BOD, TSS, TKN, and TC. Samples were collected two times on weekly basis, except BOD and TKN. These were tested once in a week only. All the samples were collected in 500 ml Nalgene laboratory-grade bottles. Sample analysis was completed within six hours of collection [9]. The samples were analyzed in the Indo-Euro Water Technology Lab, Department of Civil Engineering, AMU Aligarh as per Standard Methods for the Examination of Water and Wastewater [10]

III. RESULTS AND DISCUSSIONS

A.Influent and effluent wastewater UASB

The parameters COD, BOD, TSS, TKN and TC for influent and effluent to UASB and VFCW are presented in **Table 1.** The table 1 also shows the percent removal of COD, BOD, TSS, TKN and TC removal in UASB as well as in VFCW

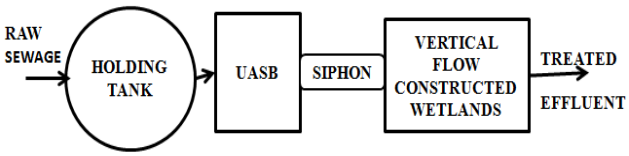

Figure 1: Flow Diagram of the SWINGS WWTP, AMU Aligarh

Figure 2: View of UASB Reactor at SWINGS WWTP, AMU Aligarh

Figure 3: View of Vertical Flow Constructed Wetlands at SWINGS WWTP, AMU, Aligarh

Table 1: Influent and effluent Characteristics after UASB and VFCW

Parameter	Units	Influent	After UASB	% Removal	After VFCW	% Removal
COD	**Mg/l**	230	126	45.21	44	65
BOD	**Mg/l**	134	70	47.76	12	82.85
TSS	**Mg/l**	215	110	48.8	25.3	77
TKN	**Mg/l**	40	37	7.5	3	91.89
TC	**CFU/100ml**	10^6- 10^7	10^5- 10^6	90	10^4- 10^5	90

B. Influent and Effluent loading on VFCW

The data discussed in this paper is only for one bed. This bed of VF-CWs receives pulse loading with the help of the siphon having a volume of ~ 10m3. Each day, 10 cycles of the siphon was maintained. The bed was operated under a surface loading rate (SLR) of 21 cm per day. The mean organic loading (OLR) to VFCW is 26.25 $g.m^{-2}/d$ for COD, 14.5 $g.m^{-2}/d$ for BOD, 22.9 $g.m^{-2}/d$ for TSS and 7.7 $g.m^{-2}/d$ for TKN and after treatment in VFCW (HRT=2.88 day) the various parameters reduced to 9.16 $g.m^{-2}/d$ for COD, 2.5 $g.m^{-2}/d$ for BOD, 5.20 $g.m^{-2}/d$ for TSS and 0.62 $g.m^{-2}/d$ for TKN. Thus the removal efficiency in VFCW is for COD, BOD, TSS, TKN are 65.00%, 82.85%, 77.00%, 91.89% respectively.

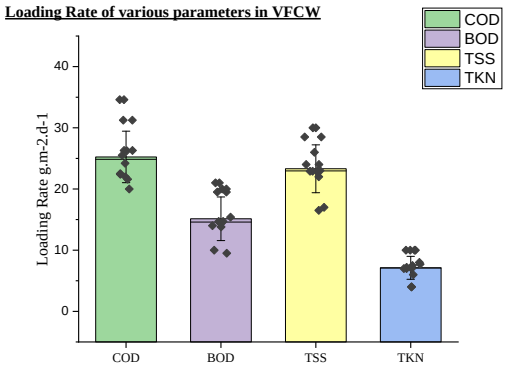

Fig 4 Loading rate of Various Parameters in VFCW

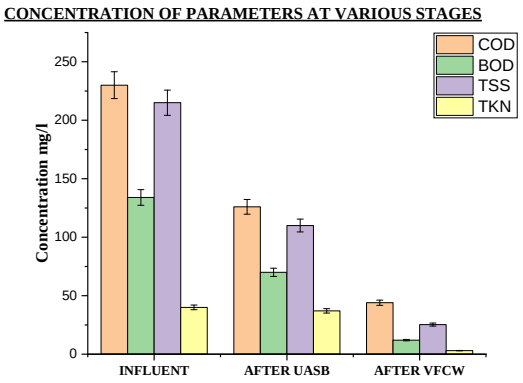

Figure 5: Concentration of various parameters at various stages.

IV. CONCLUSION

It is evident from plots and Table as above that UASB reactor has removed COD 45.21%, BOD 47.76, TSS 48.8% and TKN 7.5% whereas removal in the VF-CW is COD 65.0%, BOD 82.85.%, TSS 77.0% and TKN 91.890%. Hence the overall removal of COD, BOD, TSS and TKN in a combined system (UASB+ VF-CW) is 80.8%, 91.0%, 88.23% and 92.5% respectively. The total coliforms removal has been observed from 1E+06 to 1E+04 CFU/100ml (Table 1). Thus the combination of UASB followed by Vertical Flow Constructed wetland (VFCW) performs very effectively for municipal wastewater treatment with no process energy requirements and O&M hassle free.

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Kamal Kulshrestha obtained his Bachelors and Masters degree in Civil Engineering from Aligarh Muslim University. Presently he is pursuing Ph.D. from Department of Civil Engineering, Aligarh Muslim University, Aligarh.. He is working in the area of sustainable waste water treatment through constructed wetlands. He has more than 15 years of industrial and teaching experience in the field environmental engineering. He has published about 5 papers in the conference proceedings.

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