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Municipal Wastewater Treatment in Subsurface Vertical Flow Constructed Wetlands Using Conventional Media in Setup Phase

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ABSTRACT- Experimental investigation on municipal wastewater treatment through 6 pilot scale Subsurface Vertical Flow Constructed Wetlands (SSVF CWs) was studied utilizing two conventional materials as substrate used as 12 mm size gravel overlain by 2 mm size uniformly graded coarse sand at SWINGS site of Aligarh Muslim University, Aligarh, India. Among 6 CW beds first bed was kept unplanted and rest of the 5 beds were planted with Phragmites Karka, Canna Indica, Iris, Sagittaria and Phragmites Australis for conducting comparative study among macrophytes species used in context of contaminants removal. The primary emphasis of this study was the initial few months of the CWs running in setup phase. This phase encompasses improving phases in development of substrate permeability, microbial growth on substrate and rhizosphere, until the steady state for operation was achieved. The aims of this research paper are to assess duration requirement in setup phase for SSVF CWs through variations in removal efficiencies, and also to analyse the efficacy of conventional materials as substrate in the treatment of biological oxygen demand (BOD) and chemical oxygen demand (COD). The findings indicated that following a period of 174 days of running, the CWs had achieved a state of consistent permeability and commenced a stable removal process. The removal efficiencies for BOD and COD are found as Unplanted < Iris < Canna Indica < Sagittaria < Phragmites Karka < Phragmites Australis.

KEYWORDS- Subsurface Vertical Flow Constructed Wetlands (SSVF CWs), Substrate, biological oxygen demand (BOD) and chemical oxygen demand (COD).

I. INTRODUCTION

Researchers have shown that disposing of waste into surface water results in numerous additional environmental issues, wastewater treatment has become a global concern. In poor nations, traditional wastewater technology has frequently failed because of the intricate working materials and expensive maintenance procedures [1].

Because constructed wetlands are effective at removing a variety of contaminants, they are regarded as a technologically sound, financially feasible, and environmentally environmentally friendly choice for treating wastewater in small communities [2, 3].

In order to reduce contaminants exposure to humans, subsurface flow CWs are made to maintain the water level below the top surface of the substrate bed [4, 5]. Acid mine drainage, contaminated groundwater, industrial and agricultural wastes, and other contaminated waterways can all be efficiently treated by wetlands [6].

Substrate Bed in SSVF CWs offer locations for microbial colonies to develop on and an interface for wastewater to filter through. Microbes residing in gaps between the substrate particles consume contaminants items when wastewater flows through them, treating them from the water. Sustaining the existing plants in the wetlands is another way that the substrate works [7, 8]. Various kinds of substrate can be arranged in modified strata inside wetland beds. Conventionally, the most common media utilized in subsurface CWs are soil, sand and gravel [7].

In India, the amount of sewage from cities. remains a major problem, with barely 30% of wastewater in major cities receiving treatment without discarding. Hazards to the environment have resulted from this, including the discharge of more than 20% of the wastewater into Indore's water source [9]. The significant contribution of greenhouse gases from sewage treatment plants—estimated to be 7.3 Mt of CO_2 equivalent annually—further aggravate the issue [10]. A mere 60% of industrial wastewater is now treated, which is inadequate considering the opportunity for wastewater to be an important component of additional water demand [11]. The present study was carried out at SWINGS site of Aligarh Muslim University, Aligarh, India as 6 identical pilot scale SSVF CWs beds using 12 mm size gravel overlain by 2 mm size uniformly graded coarse sand as substrate for experimental investigation on removal efficiencies for BOD and COD. The goals of the present investigation are to: (i) examine the removal of BOD and COD using two conventional substrates—12 mm size gravel overlain by 2 mm size uniformly graded coarse sand—during the initial running phase of SSVF CWs to determine the transition from setup to steady running stages; and (ii) compare the macrophytes performance equivalent in percentage for chosen parameters in contaminant removal.

II. METHODOLOGY

A. Site Location and Experimental Investigation

The current experimental investigation was carried out at SWINGS site of Aligarh Muslim University, Aligarh, India. This SWINGS project site was developed with the joint venture of Indian Government (DST) with EU within FP7 Framework. A sub-tropical vicinity found in Aligarh city, positioned 130 km north-east of Delhi in north India. Aligarh is situated between 27°52' N to 27°56' N latitudes and 78°3' E to 78°6' E longitudes. 6 identical beds each of dimensions 160 cm × 60 cm × 105 cm, were filled with 12 mm size gravel filled up to 40 cm overlain by 2 mm size uniformly graded coarse sand filled up to 50 cm. These beds were connected in parallel and labelled as Bed 1, Bed 2, Bed 3, Bed 4, Bed 5 and Bed 6 respectively. Among 6 CW beds, Bed 1 was kept unplanted and rest of the 5 beds namely Bed 2, Bed 3, Bed 4, Bed 5 and Bed 6 were planted with Phragmites Karka, Canna Indica, Iris, Sagittaria and Phragmites Australis respectively. Each bed was fed through distribution tank of capacity was kept 800 litre capacity consisting of 2 tanks connected in series 400 litre each. For CWs treatment scheme, primary treatment is necessary for influent as it is susceptible to congestion more easily and risk their efficacy [12, 13]. Through collection tank, the distribution tank received the effluent of the UASBR of 50 m3 volume. Each Bed was having 4 outlets of ½ inches dia as sampling ports labelled as S1, S2, S3 and S4 and one inlet of 1½ inches dia. Each sample set was labelled the same way collected from the respective sampling ports as shown in the figure 1.

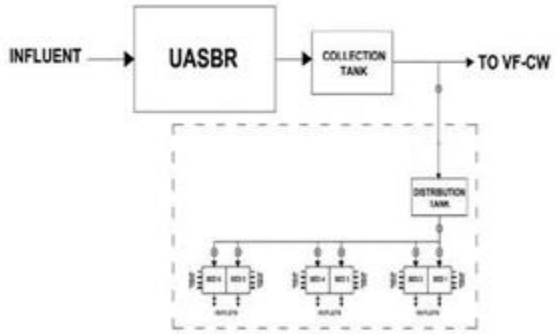

Figure 1: Typical pilot scale Set-up layout demarcated by dashed box

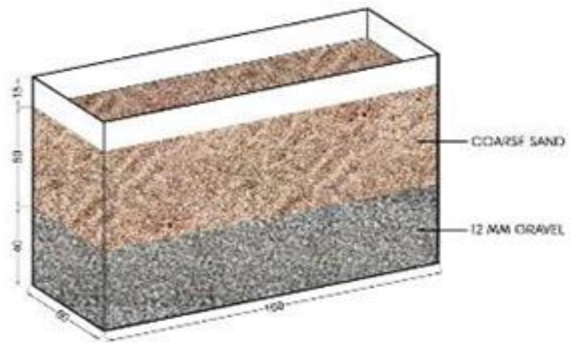

Figure 2: 3D cross Section of the SSVF CW Unplanted Bed

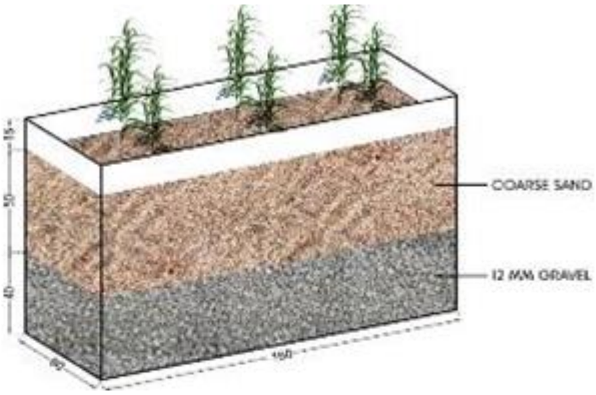

Figure 3: Figure 3: 3D cross Section of the SSVF CW Planted bed

B. Sampling and Data Analysis

From each bed every 6-day 4 water samples were collected manually as grab sampling in 500 ml in clean bottles; one from inlet and 4 from the sampling ports S1, S2, S3 and S4. Water samples were stored in ice tanks, sent to laboratory and examined for BOD and COD concentrations. 12 water samples (4 samples × 3 rounds) were collected from each bed making it a total of 72 samples during this work. To observe the active participation in removal and development of two major factors with time sampling was in progress from the 1st day of CWs running namely as thin microbial film attached to both the media surfaces and the newly grown planted reeds roots and stems.

Figure 4: Typical picture showing SSVF CWs Beds

C. Illustrations using Hydrodynamics

During the study period, the inlet flow and retention time were fixed. Every one of the six beds saw an average discharge of 16.67 l/d. The BOD concentration in the influent varied from 43 to 67 mg/l (0.7167–1.1167 g BOD/d). The following formulas were used to calculate the removal efficiency [14]:

$$RE = \left(1 - \frac{C_i}{C_0}\right) \times 100 \qquad (1)$$

where RE = removal efficiency in %, C_i = influent concentrations, mg/l; C_0 = effluent concentrations in mg/l.

III. METHODOLOGY

A. Calculating the setup phase duration and removal Efficiency

Figure 5 shows this data graphically for following 174 days of operation, it was observed that the removal efficiency values varied very little, which could indicate the conclusion of the setup period and the start of the removal's stable state. During the first ninety days of CW's operation, a gradual and noteworthy rise in removal efficiency was noted. This was attributed to the degradable small particles and suspended solids sedimentation, the growth of bacterial biofilm adhesion to the medium surface, and the establishment of reed roots. Over the course of the following 30 days of wetlands operation (days 60–110), a little increase in removal efficiency was noted as the medium pores gradually filled with fine solids that were free of degradable debris, and the connected biofilm layers and reed rhizomes both approached almost constant sizes. The removal efficiency improvement was negligible in all media during the ensuing period (days 110–366), and rising tendencies began to nearly flatten on day 174.

B. BOD and COD removal throughout setup phase

The efficacy of BOD and COD treatment throughout the initial 174 days of commencing operation for every CW Bed. It is evident that the remediation effectiveness of pollutants enhanced over the course of the operational phase.

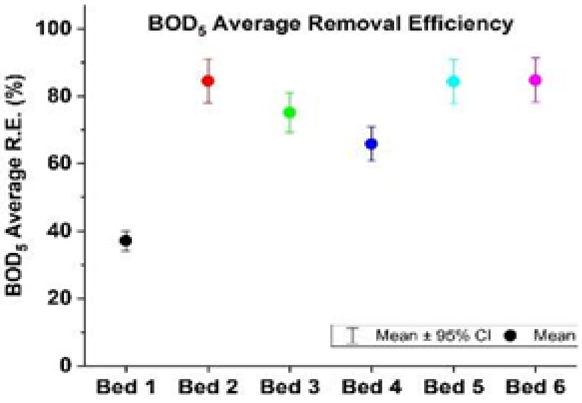

Figure 5: Average BOD_5 removal efficiencies in % with mean values

IV. CONCLUSION

A straightforward field approach is introduced for the periodic measurement and estimation of the removal efficiency of SSVF CW substrate. This is accomplished by measuring and comparing the removal efficiency with the initial removal efficiency. During the setup phase of CW Beds, there is an ongoing dynamic process of media permeability, bacterial biofilm formation, and growth of macrophyte roots until the operational steady state stage is reached. The improvement in removal efficiency for CW beds is associated with the growth of reed roots and the development of biofilm on the bed media surfaces, as well

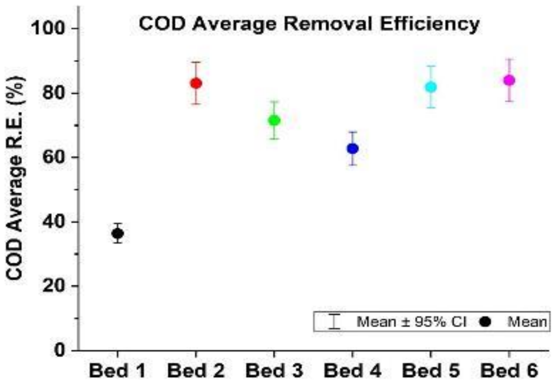

Figure 6: Average COD removal efficiencies in % with mean values

as the periodic accumulation of suspended matter. In this study, the porosity of the SSVF CW substrate reached a steady state after approximately 174 days from the start of operation for the wetland system. This suggests that the plastic and rubber media have a lower tendency to clog compared to gravel. At the end of the setup phase, the removal efficiency values were found to be in the following order: Unplanted < Iris < Canna Indica < Sagittaria < Phragmites Karka < Phragmites Australis. During the setup stage, the growth of planted reed roots and the increase in bacterial biofilm on the media surface and plant parts enhanced the accumulation, biodegradation, and treatment efficiency of pollutants. The removal efficiency for BOD5 and COD was found to be (22.5-42.8% and 21.5-41.8%) for Bed 1, (51.5-91.3% and 47.5-90.8%) for Bed 2, (43.2-82.8% and 35.5-78.9%) for Bed 3, (43.2-72.8% and 28.5-69.8%) for Bed 4, (52.2-91.8% and 46.2-89.8%) for Bed 5, and (53.2-92.8% and 48.5-91.8%) for Bed 6. Throughout the setup phase of the CWs, Bed 6 exhibited the highest removal efficiency for BOD and COD, followed by Bed 5, Bed 2, Bed 3, Bed 4, and Bed 1 respectively.

CONFLICTS OF INTEREST

The authors declare that none of the work reported in this study could have been influenced by any known competing financial interests or personal relationships. The design and execution of this study, all study analyses, the writing and editing of the research paper, and its finished contents are entirely the responsibility of the authors. Financial grant was given for this research study by University Grants Commission (UGC), Non-Net fellowship.

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