Effect of Media and Vegetation in Constructed Wetland for Domestic Wastewater Treatment

G. R. Munavalli[1], P. G. Sonavane[2], S. M. Wandare[4] G. V. Deshpande[3], and N.M. Aswale[5]

[1] Professor, Department of Civil Engg., Walchand College of Engineering, Sangli, Maharashtra, India
[2] Professor, Department of Civil Engg., Walchand College of Engineering, Sangli, Maharashtra, India
[3,4] Junior Research Fellow, Department of Civil Engg., Walchand College of Engineering, Sangli, Maharashtra, India
[5]Project Assistant, Department of Civil Engg., Walchand College of Engineering, Sangli, Maharashtra, India
*Corresponding author email: guru.munavalli@walchandsangli.ac.in

Abstract: Constructed wetland (CW) as physical and biological treatment has been used in decentralized domestic wastewater. The performance of CW is significantly affected by support media and type of vegetation. In this context, four laboratory scale treatment systems with different combination of media and vegetation were developed. The reactors of CW developed include CW system 1 (coconut shell, charcoal and grit vegetated with *Canna Indica*), CW system 2 (coconut shell, charcoal and pieces of ceramic pot vegetated with *Phragmities Karka*), CW system 3 (thermocol, charcoal and grit vegetated with *Canna India* and *Phragmities Karka*), and CW system 4 (mixed media of coconut shell, charcoal and grit vegetated with *Canna India* and *Phragmities Karka*). The CW systems were operated in batch and fill-drain-idle-fill modes for Hydraulic Retention Time (HRT) of 3 to 24 h and idle time of 1to 2 h. The feed used for system was settled wastewater (greywater and blackwater) from hostel in the college (Walchand College of Engg., Sangli) premises. The performance of system was evaluated for organic matter (measured in terms COD) removal. The performance of CW systems 3 and 4 was found to be better. The contribution by vegetation/s is more significant than type of media used.

1. INTRODUCTION

Domestic wastewater generation and its indiscriminate disposal are concerns of society. The present systems of sewerage and treatment are inadequate to address safe disposal of wastewater. There is a large gap between domestic wastewater generated and treated (CPCB, 2015). National Sample Survey (NSS) shows that in 2012 nearly 49.9 percent of rural households and 12.5 percent of urban households of India had no drainage arrangement (Swachhta Status Report, 2016). Septic tank in combination with soakage pits is more common to treat black water with no treatment for greywater in isolated households. This has caused lot of pollution problems on the sources of surface water and groundwater, degradation of aquatic ecosystem and impairment of water quality for drinking. On-site wastewater treatment system can address these issues and provide an opportunity for public to share the responsibility of waste management. These systems are cost effective, less energy intensive, and concepts of natural purification can be induced in the treatment system. Low volumes of wastewater generated from individual or groups of households can be effectively treated by such systems.

Constructed Wetland (CW) based on-site treatment technology with a combination of anaerobic and aerobic process is more potential option in Indian context. CW system is natural, affordable, eco-friendly and sustainable for treating domestic wastewater. The major components of CW include support medium and vegetation. The studies conducted with mono-species and mono-medium on CW include [1 to 9]. In this context, the present study focuses on the use of multi-media and multi-species to treat domestic wastewater.

2 MATERIAL AND METHODS

2.1 Source of wastewater

The wastewater was collected from a disposal location within the campus of Walchand College of Engineering, Sangli (Maharashtra). The water for non-potable use is supplied with groundwater. The wastewater at disposal location 1 is contributed from from residential bungalows, ladies and boys' hostel, and mess. The typical usage of water from these buildings includes bathing, washing (cloth and utensils), and septic tank effluent. The hostels are provided with septic tanks and effluent from septic tank flows into sewer. The greywater (from bathroom and washings) flows directly into sewers. The collected wastewater was settled for 2 hours before it is used for study in CW systems.

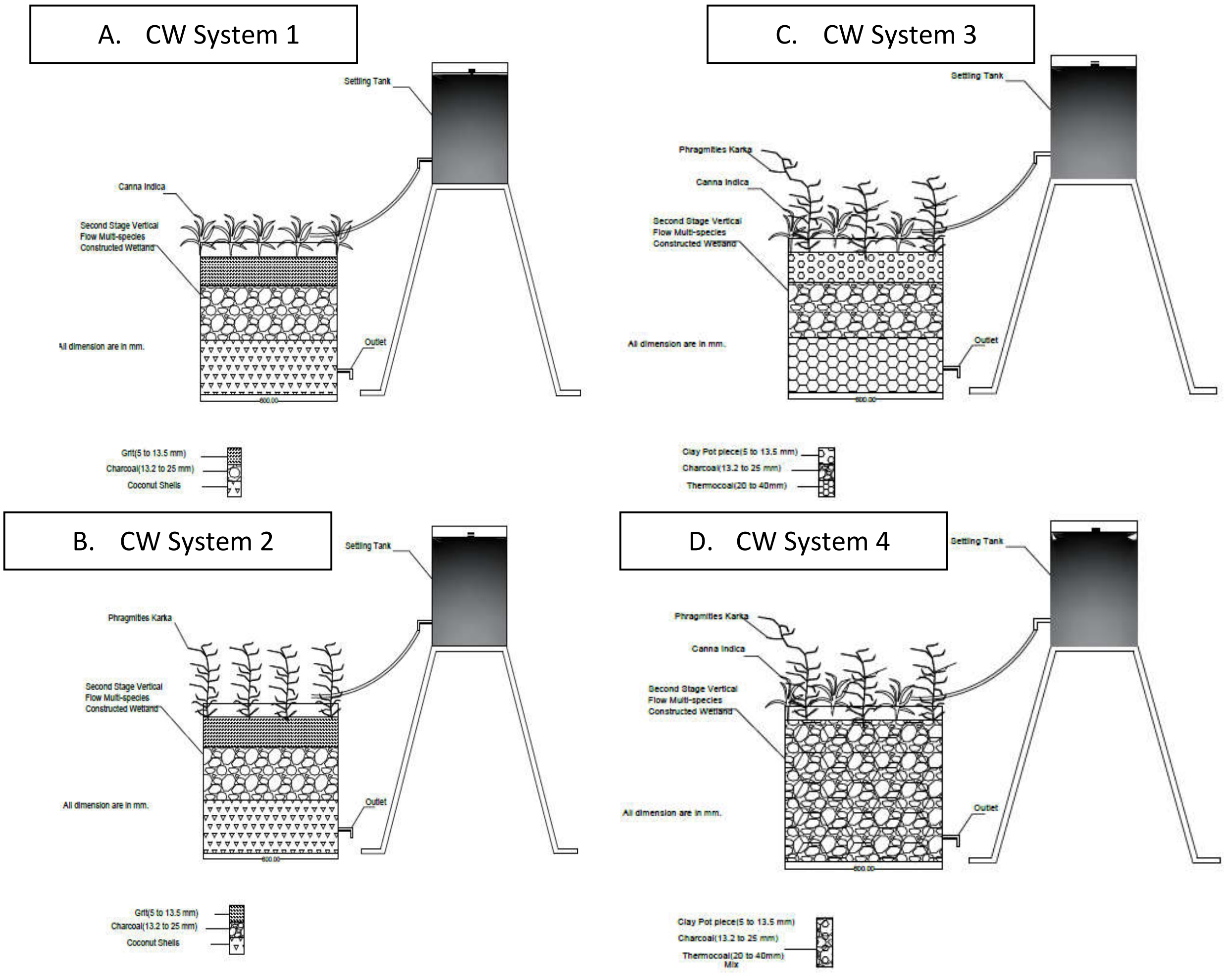

Fig. 1: Schematic Sketch of laboratory scale experimental set-up

2.1 Laboratory scale experimental set-up

Four CW systems made up of circular plastic tanks having diameter and depth of 60 cm were developed. The details of medium and vegetation used in each of these systems are given in Table 1. Fig. 1 shows schematic sketch of all four CW systems. The substrate/support medium used includes grit, charcoal, coconut shell, pieces of ceramic pot and thermocol. Coconut shell and thermocol were used in bottom layer in respective systems. Charcoal forms the middle and grit/ceramic pot pieces constitute top layer.

The charcoal is used due to its adsorptive nature. Finer to coarser gradation from top to bottom of each system is maintained. The flow distributors made up of perforated flexible pipes were provided to uniformly spread the wastewater. AN outlet is provided at the bottom to drain out the contents of the CW systems.

Table 1: Details of CW systems

<table>
<tr><td>Medium</td><td colspan="2">CW System 1 with Canna Indica</td><td colspan="2">CW System 2 with Phragmities Karka</td><td colspan="2">CW System 3 with Canna Indica and Phragmities Karka</td><td colspan="2">CW System 4 Canna Indica and Phragmities Karka</td></tr>
<tr><td></td><td>Size (mm)</td><td>Depth (cm)</td><td>Size (mm)</td><td>Depth (cm)</td><td>Size (mm)</td><td>Depth (cm)</td><td>Size (mm)</td><td>Depth (cm)</td></tr>
<tr><td>Grit (top)</td><td>5-10</td><td>10</td><td>-</td><td>-</td><td>5-10</td><td>10</td><td rowspan="5">5-30</td><td rowspan="5">Mixed media</td></tr>
<tr><td>Charcoal (Middle)</td><td>10-30</td><td>20</td><td>10-30</td><td>20</td><td>10-30</td><td>20</td></tr>
<tr><td>Coconut shell (Bottom)</td><td>20-30</td><td>20</td><td>20-30</td><td>20</td><td>-</td><td>-</td></tr>
<tr><td>Ceramic pot pieces (Top)</td><td>-</td><td>-</td><td>20-30</td><td>10</td><td>-</td><td>-</td></tr>
<tr><td>Thermocol (Bottom)</td><td>-</td><td>-</td><td>-</td><td>-</td><td>30-40</td><td>20</td></tr>
<tr><td colspan="9">Overall porosity 40% for all CW systems</td></tr>
</table>

Canna indica and *Phragmites karka* were used as vegetation for both the reactors. The vegetation was chosen considering their local availability, tolerance to organic load, and potential of developing good root matrix together. *Phragmites karka* has fibrous roots system with horizontally crawling rhizomes and *Canna indica* with relatively shallow roots.

2.3 Planning and Operation of system

Experiments were planned to conduct performance evaluation of four CW systems to remove Chemical Oxygen Demand (COD). The methods of analysis were referred to [10]. The system was assessed for COD removal when operated in batch and fill-drain-idle modes. A typical operation consisted of:

Fill-Drain-Fill (FDF) mode

i. The settling tank was filled with 30 L raw wastewater, and settled for 2 h.

ii. CW reactor was filled with settled wastewater and retained for desired HRT (3 to 24 h).

iii. CW system was drained. Fill-Drain-Idle-Fill (FDIF) mode

i. CW system was filled with settled wastewater and retained for desired HRT.

ii. CW system was drained and kept idle without filling with wastewater.

iii. After the desired idle time another batch was run. CW systems were applied with and assessed for HRTs of 3 h, 6 h, 18 h and 24 h. In FDIF mode of operation, the idle time used was 1 h and 2 h. Further, the variability of effluent quality (COD) for each HRT was also assessed.

3 RESULTS AND DISCUSSION

3.1 Wastewater Characterization:

The summary of wastewater characteristics during the period of study is given in Table 2. The organic strength of wastewater is low (evident in values of COD and BOD) and hence it is a medium strength wastewater. The ratio of BOD/COD is more than 0.5 indicating amenability of this wastewater for biological treatment.

The higher value of TDS indicates relatively higher proportion of groundwater being used for non-potable purpose than surface water. TSS and TKN are also observed to be significant in quantity. The wastewater with these characteristics is not disposable either for land disposal or onto water bodies. The characterization also indicates that settling is required before feeding this wastewater to CW.

Table 2: Wastewater Characteristics

Parameter	pH	TDS	TSS	TKN	COD	BOD_3
Value	7.60±0.40	1260±150	175±15	130±15	250±25	135±20
All values are in mg/L except pH						

3.2 Effect of HRT on performance of CW Systems

Fig. 2 shows the effect of HRT on COD removal in four CW systems operated in FDF mode. The results show that COD removal increases with increase in HRT. However, increase in HRT beyond 6 h does not contribute significantly to COD removal. Charcoal forms major area of contact for roots of wetland vegetation in all CW systems. The effect of multi-species is evident in the results of CW systems 3 and 4. COD removal rate in CW system 2 is relatively higher than CW system 1. It is due to the deeper and denser roots of *Phragmites karka* when compared to *Canna indica*. These results indicate that vegetation plays significant role in CW systems for COD removal. Majority of COD removal in CW is attributed to aerobic attached growth bacterial action. The surface for bacterial attachment is provided by roots, and support medium. The use of multi-species (*Canna indica* and *Phragmites karka)* provided a dense matrix of shallow and deep roots. The oxygen liberated at root surface and simultaneous filling/draining action maintained aerobic conditions within the wetland. This has significantly contributed to higher COD removal. Further, the use of coal as a support medium provided adsorptive surface for COD removal.

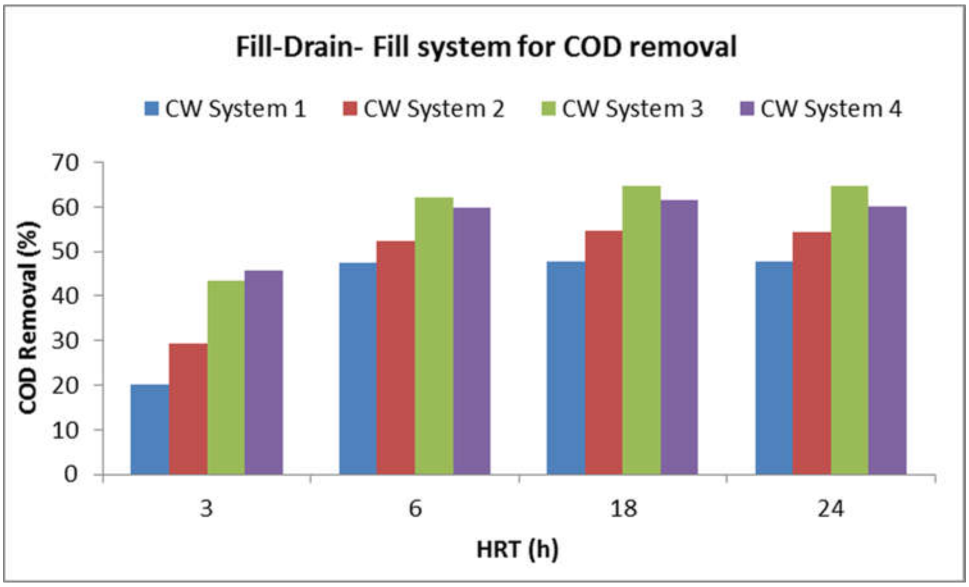

Fig. 2: Effect of HRT in FDF mode of system operation on COD removal

3.2 Assessment of Fill-Drain-Idle-Fill (FDIF) operation in CW systems:

The study was conducted to assess the effect of idle time (empty bed condition) in CW systems in COD removal. Fig. 3 shows COD removal for batches of 3 h and 24 h HRT with idle times of 1 h and 2 h. It can be seen that idle time affects COD removal. The increase in idle time has enhanced the COD removal by 5% to 10% when compared to no gap between batches. The better oxygenation conditions prevail within CW system for higher idle times thereby enhancing the performance.

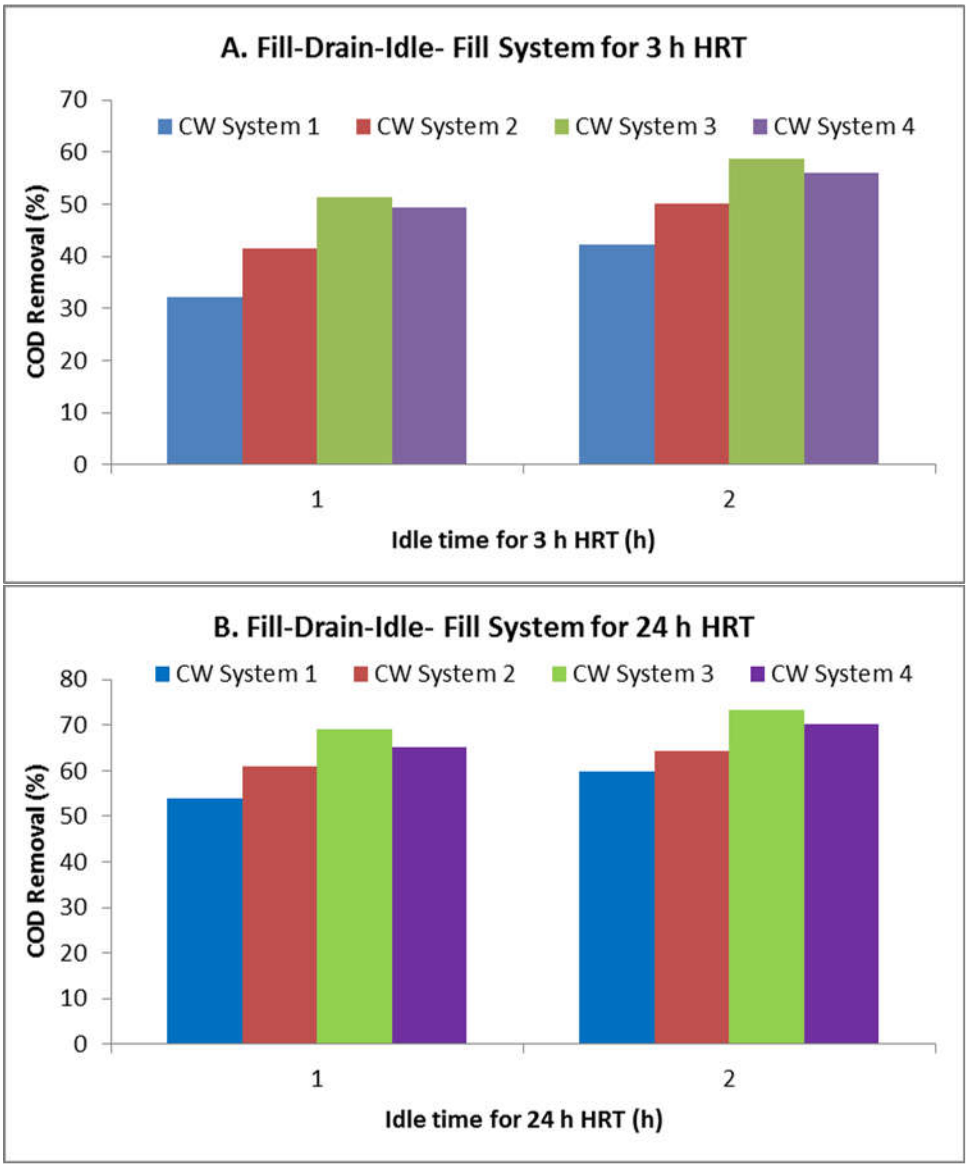

Fig. 4: Effect of idle time on COD removal for A) 3 h HRT and B) 24 h HRT in FDIF system

4 CONCLUSIONS

The effect of medium and vegetation was assessed in CW on COD removal under FDF and FDIF modes of operation. Based on the study the conclusions drawn include:

1. Increase in HRT beyond 6 h does not contribute significantly to COD removal.
2. Vegetation plays significant role compared to medium in CW systems for COD removal.
3. FDIF mode of operation enhances COD removal.

5 ACKNOWLEDGEMENTS

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