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Performance Evaluation of Different Soil Media by Batch-Operated Pilot-Scale Horizontal Subsurface Flow Constructed Wetlands for Wastewater Treatment

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ABSTRACT

Constructed wetland systems (CWs) are low-cost natural treatment systems for various types of influents. Although mainly the natural wetlands are soil-based, the constructed wetlands have been traditionally built using aggregate media. The performance of four types of available soils in Chhattisgarh was studied as the filter media in the horizontal subsurface flow-constructed wetland (HSFCW). Fourteen pilot-scale CW units with different soil types (entisol, vertisol, alfisol, inceptisol, and stone aggregate) and plant types (*Canna indica* and *Typha latifolia*) were used to treat domestic wastewater (WW). One set of each soil base reactor was planted with *Canna indica* and *Typha latifolia*, and one was kept blank (unplanted). All soils and plants are easily available.

The reactors received primary wastewater in batch loads with WW loading for six hours to maintain aerobic conditions. The residence time of WW was 48 hours, and the applied hydraulic loading rate (HLR) was based on soil and aggregate. According to the findings, the planted HSFCW was more effective than the unplanted system. The results show that the wetland constructed on the treatment efficiency of the soil base has excellent potential to treat WW, with both plants.

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INTRODUCTION

For domestic wastewater treatment, constructed wetlands have long been used (Nyer et al., 2022). Wetlands benefit local communities in a variety of ways, including economic, social, environmental, cultural and cost-effective, cleaner, and more sustainable (Kesarwani et al., 2023; Roebeling et al., 2016). Constructed wetland systems (CWs), mimicking natural wetlands, can be effective treatment for domestic and municipal wastewater (Swarnakar et al., 2022). Depending on flow conditions, CWs can be configured in different ways, such as horizontal flow constructed wetland systems (HFCWs), vertical flow constructed wetl and systems (VFCWs), and hybrid flow constructed wetland systems (HCWs) (Singh et al., 2022). The choice of substrates affects the performance of CWs. Generally, different types of aggregate, sand, soils, industrial waste, and agricultural waste can be used as substrate materials (Swarnakar et al., 2021). Pollutants can be eliminated from the soil by leaching and complexation by washing them with water or solutions containing specific complexes like Cl^- and K (Ramos et al.,

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2021). The potential for soil to absorb phosphorus from wastewater that has been treated is significant, and aerobic conditions appear to be helpful for long-term retention of phosphorus (Morvannou et al., 2022). Singh and Vaishyav 2022 have used soil as the top layer in both VFCW and HFCW for municipal wastewater treatment. Locally available soil substrate-based CWs provide an economical alternative (Jethwa et al., 2016). Soil-based constructed wetland systems (SBCWs) provide ample research opportunities due to different types of soil media, their location, infiltration capacity, clogging, and pollutant removal (Petitjean et al., 2015). In the filtration zone of HSFCWs, the use of finer materials allows a shorter percolation time and improves removal performance. Plants serve key functions in built wetlands (CWs): they manage temperature, reduce wind speed, prevent nutrient and sludge resuspension, provide surface for periphyton and bacteria, and provide conditions for diverse biological and physicochemical processes for effective wastewater treatment. The types of native or exotic plants, their tolerance to nutrient load, stage of development, number, density, and spacing, germination, growth, and harvesting seasons, oxygen delivery to roots, and microbial growth on the root surface affect the performance of CW (Jethwa et al., 2016). The efficiency of horizontal surface flow in treating of WW in CWs with and without plants differs significantly (Vymazal 2009, 2011). According to Laviranc and Mancini (2016), using small grain size and low water depth will greatly enhance system performance and removal efficiency for HSFCW. Soil substrates has much efficient filter media for wastewater treatment through CW.

One of the biggest ways that domestic wastewater pollutes India’s water sources is by going down the drain. Only about 38% of domestic wastewater in India is treated, and the rest, 62%, enters the water bodies without any treatment (CPCB, 2015). One reason for the slow expansion of treatment capacity is the high cost of treatment. CWs based on local soil media substrates provide an economical treatment alternative that is worth examining (Jethwa et al., 2016). Kadam et al. (2009) have observed a high degree of organic matter removal through laterite-based soil filters. This study is an attempt to investigate the performance of four locally available soil types as CW substrate media in the treatment of domestic wastewater.

In this study, we look at how different types of pilot-scale CWs work with different types of soil media. Second, we tested for the removal of clogging with proper inlet and outlet assemblies.

MATERIALS AND METHODS

Collection and characterization of wastewater

Domestic WW was collected from the staff quarters located on the NIT Raipur campus. The WW characterization was done according to the Standard Methods for the Examination of Water and Wastewater (APHA-AWWA-WEF-2017). The parameters evaluated (table 3) were pH, total alkalinity, total dissolved solids (TDS), total suspended solids (TSS), electrical conductivity (EC), dissolved oxygen (DO), biochemical oxygen demand (BOD_5), total kjheldal nitrogen (TKN), chemical oxygen demand (COD), and soluble reactive phosphorus (SRP).

Meteorological conditions for study area

The study location (21°15‘00’N and 81°36’15’E) was located in Raipur, the capital of Chhattisgarh state in India. The site location has a tropical wet and dry climate with an average ambient temperature of 35°C and average total rainfall of 1260 mm, with most of the rain occurring from June to October (https://weather-and-climate.com). The maximum temperature (from April to May) is 48°C (118°F). Winters last from November to January and are mild, although lows can drop to 14°C to 17°C, making it reasonably cold for a tropical climate.

Experimental set up

Fig. 1 depicts the experimental setup, which is divided into four parts: the sedimentation tank (part I), the distribution tank (part II), and HSFCW with outlet (parts III and IV). Fourteen

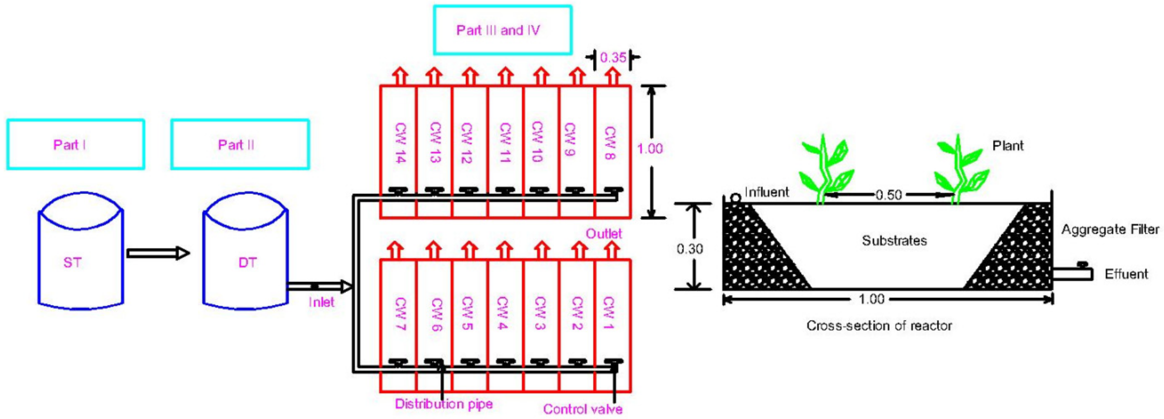


Fig. 1. Layout diagram of experimental setup of the soil base horizontal subsurface flow constructed wetland

Table 1. Design parameters of the HSFCW

Parameters	Unit	HSFCW				
		Entisols	Vertisols	Alfisols	Inceptisols	Aggregate
Substrates depth	m	0.17	0.17	0.17	0.17	0.17
Effective area	m^2	0.35	0.35	0.35	0.35	0.35
Effective volume	m^3	0.122	0.122	0.122	0.122	0.122
HRT	Day	2.00	2.00	2.00	2.00	2.00
SOR	m^3/m^2-D	0.0143	0.0153	0.0147	0.017	0.0125

Table 2. Combination of substrates and plants

Specification	CW1	CW2	Cw3	CW4	CW5	CW6	CW7
Name of Plant	Unplanted	*Canna indica*	*Typha Latifolia*	Unplanted	*Canna indica*	*Typha Latifolia*	*Canna indica*
Substrates	Entisols	Entisols	Entisols	Inceptisols	Inceptisols	Inceptisols	Aggregates with sand cover
Specification	CW8	CW9	CW10	CW11	CW12	CW13	CW14
Name of Plant	Unplanted	*Canna indica*	*Typha latifolia*	Unplanted	*Canna indica*	*Typha latifolia*	*Typha Latifolia*
Substrates	Alfisols	Alfisols	Alfisols	Vertisols	Vertisols	Vertisols	Aggregates with sand cover

laboratory-scale CWs, having dimensions (Lx Wx H) of 1.0m x 0.35m x 0.30m and an outward slope of 0.01 (1.0%), were manufactured with mild steel sheets of 2 mm thickness. Each unit was designed based on the recommendations of CPCB 2001 and EPA 1988 (Table 1). Of the 14 CWs, four CWs were used with the four different types of soil substrate but without any plant species, to serve as a blank. Two sets of CWs with only aggregates as substrate (40 mm, 20mm, 10mm, and sand) with plants were also used for comparison. The rest eight CWs were used with four different soil substrates, with one planted with *Canna indica* and the other, with *Typha latifolia* (Table 2). The onsite plants were sourced from the nearby natural wetlands. The fully developed constructed wetlands are shown in photo and initially on the right side in photo b, in Fig. 2.

Fig. 2. *Canna indica* and *Typha latifolia* in various soil and aggregate media-type CWs (a) experimental setup (b) starting with plant density two

Four types of soils available locally, were collected from different locations. Soil samples were taken 20 to 30 cm below the top surface. The soil and aggregates were air dried in the shade and filled in CW. To avoid the frequent chocking of the soil substrate in CW, an aggregate layer was provided as an inlet and outlet.

In Fig. 1, it is depicted how the HSFCW was used to treat domestic wastewater in a pilot-scale experimental investigation. The raw WW was settled in a PVC tank (250L capacity) for one hour, and the supernatant was transferred to two elevated PVC tanks for feeding to the CWs. Another tank was used to maintain the head and distribute WWs to the CWs. A PVC pipe with a control valve was used for WW distribution under gravity in CW. The settling time of one hour was derived from the Imhoff cone analysis. Angassa et al. (2018b) also used a sedimentation tank and a distribution tank for municipal WW treatment through HSFCW.

In HSFCW, two plants each of *Canna indica* and *Typha latifolia* (height 30 cm) were planted in the respective soil and aggregate base CW. Plant spacing was kept at 50cm. For a period of one month, tap water was fed into each unit until new shoots began to grow. Regular counts of plant shoots and stem height measurements were made throughout the study. The pants were acclimatized with WW dosing at dilutions of 25%, 50%, 75%, and 100% for 2 months (USEPA 2000). After the plants acclimated in two months, influent and effluent samples were collected for analysis.

Operation of soil base HFCWs

In soil-based CWs, clogging is the main problem. Pretreatment like screening and settling, are necessary to avoid clogging in pipes and media. Suspended and settleable solids may block the pore space (Nivala et al., 2019). To avoid this, solid particles such as tissue paper, toilet paper, large-size organic substances, and other rubbish were removed from the WW by screening, and the WW was settled for one hour before feeding the CWs. Aggregate filters (10mm) are used in the inlet and outlet to protect the choke. The trapezoidal shape (due to inlet and outlet filtration) of soil substrates reduces the problem of chocking. The combinations of pilot-scale CWs are summarized in Table 2.

The temperature of the study was 41^{O}C in the month of April 2022, due to which the HLR had to be gradually increased at different reactors. Due to the higher temperature, the evacuation rate has increased, which affects the HLR and removal efficiency of CWs (Dong et al., 2011).

Table 3. Influent characteristics and methods used in this study (average value ± standard deviation, n= 20)

S. No.	Parameter	Unit	Value	Method	Reference
1	pH @ 27°C	pH units	7.7±0.2	Potentiometric	APHA
2	Total suspended solids (TSS)	mg/L	68 ± 11	Gravimetric method	APHA
3	Total dissolved solids (TDS)	mg/L	580 ± 88	Potentiometric	APHA
4	Electrical Conductivity (EC)	µS/cm	1140 ± 212	Potentiometric	APHA
5	Alkalinity	mg/L $CaCO_3$	285 ± 20	Titrimetric	APHA
6	Dissolved Oxygen (DO)	mg/L	2.1 ± 0.5	Titrimetric	APHA
7	Total Kjheldal Nitrogen (TKN)	mg/L	17.5±3.6	Micro-Kjeldahl method	APHA
8	Biological Oxygen Demand (BOD_5)	mg/L	109±30.0	5 days incubation at 20 °C	APHA
9	Chemical Oxygen Demand (COD)	mg/L	276 ± 3.0	Close reflux	APHA
10	Soluble Reactive Phosphorus (SRP)	mg/L as PO_4^{-2}	14.1 ± 5.0	UV spectrophotometer	APHA

Since wetlands are shallow bodies of water that are exposed to the atmosphere, weather and climate have a big impact on them. Temperature fluctuations have an impact on the wetland system's ability to remediate pollutants by affecting both physical and biological activity (El-Refaie,2010).

System Monitoring

All of the transplanted plants did well in both soil and aggregate media, without showing any signs of toxicity or nutrient deficiency. Within two months of planting, the plants were fully established, and during the next twelve months of operation of the lab-scale CWs, the plants exhibited luxuriant growth. Over a period of twelve months, influents and effluents from fourteen different pilot-scale CWs were analyzed. The analysis was carried out in triplicate. The system has been monitored for clogging as well.

Estimation of Pollutant Reduction

The performance of the reactors with respect to the removal efficiency for different parameters was evaluated using the following equation:

$$\%\ \text{Removal Efficiency} = \frac{Cin_{-Cef}}{Cin}*100 \qquad (1)$$

here Cin and Cef are respectively the influent and effluent concentrations

Data Analysis

Microsoft Excel 2007 (Microsoft Windows 2007 Ultimate) and Minitab 16 (Minitab 2007) were used to conduct the statistical study. Variables were compared using ANOVA. p-value are shown wherever required.

RESULTS AND DISCUSSION

Physico-chemical parameters

Domestic wastewater from NIT campus staff quarters was collected from the inspection chamber, and the characteristic parameters of the samples were promptly analyzed. The characteristics of the influent samples and the analytical methods used in this study are shown in Table 3.

In WW, a high conductivity value denotes the existence of a high concentration of dissolved inorganic solids. The effluent of each reactor of the CWs was monitored through physico-chemical parameters after two days (HRT). Table 4 shows the removal (%) of the physicochemical parameters of wastewater treated with planted and unplanted CW.

POLLUTANT REMOVAL

Consequence of pH, EC

pH is a crucial treatment parameter. Before and after treatment, the samples showed significant pH differences (Fig. 4a). In general, the influent pH was 7.7, which decreased in the unplanted CWs and the further planted CWs. After treatment, the effluent of CW2, CW3, CW7, and CW14 shows a pH of 7.2 ($p < 0.05$). The influent EC is 1140 ± 212 µS/cm and in the effluents, there are variations in the planted and unplanted CW. Jamwal et al. (2021) reported minor changes in pH and EC in planted and unplanted HSSF-CW. Variations of EC are shown on the right side of Figure. 3c.

Extirpation of solids

The average rate of TSS removal in pilot-scale CWs that were either blank or had plants in them was nearly 99%. Total dissolved solids, also known as TDS, are another common indicator of water quality. Carbonate species, metals, organic matter, salts, and viruses are the constituents that make up dissolved solids (Nema et al., 2020). The RE of TDS in aggregate base CWs with canna indica is high among all CWs. For the all soil based CWs either planted or unplanted,

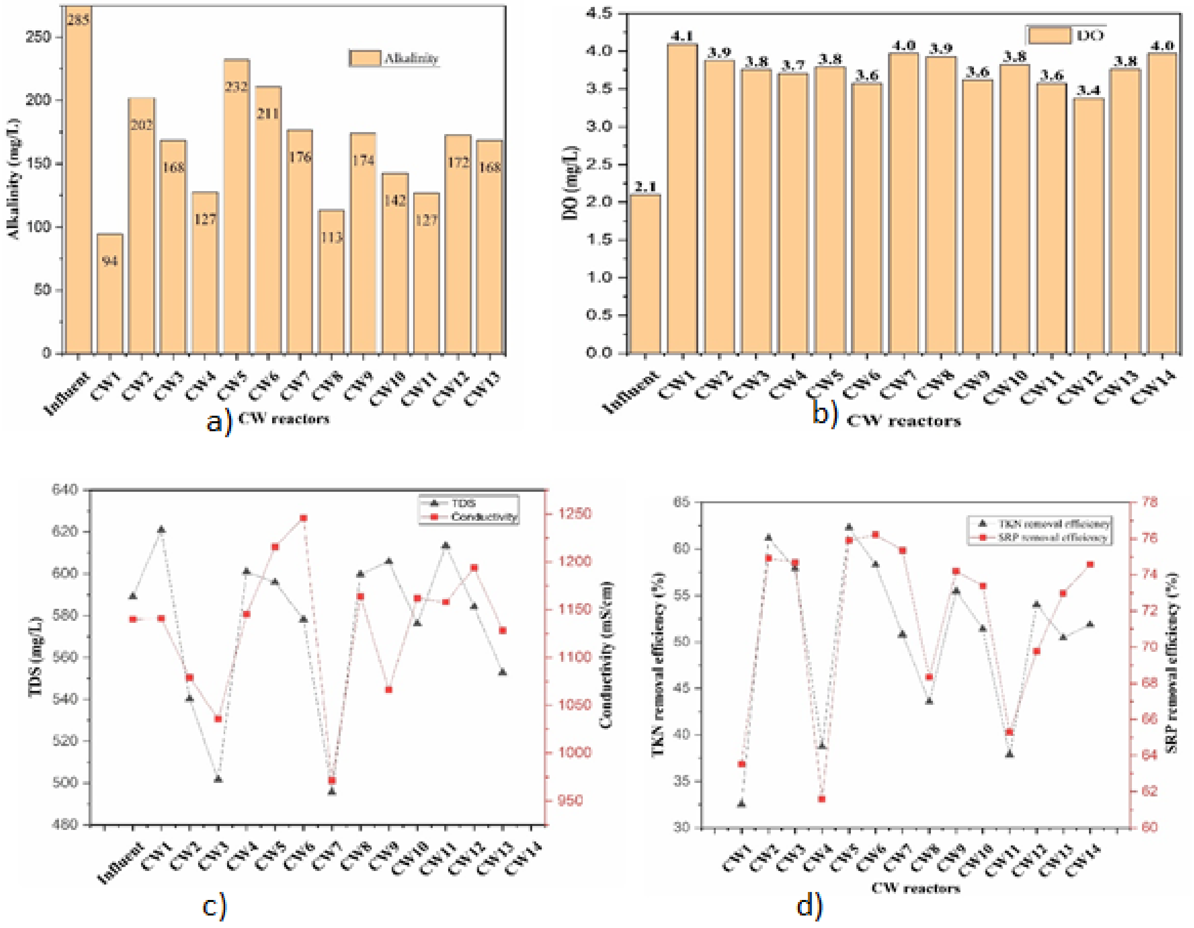


Fig. 3. Variation in a) alkalinity, b) DO, c) TDS and d) TKN of treated WW through various CWs

Table 4. Removal (%) of physico-chemical parameters of wastewater treated through planted and unplanted CW

Parameter (in mg/L unless specified)	CW1	CW2	CW3	CW4	CW5	CW6	CW7	CW8	CW9	CW10	CW11	CW12	CW13	CW14
TSS	98.2	99.5	99.3	98.7	99.4	99.6	99.4	98.1	99.3	99.4	98.5	99.1	99.3	99.6
TDS	-5.4	8.3	14.8	-2.0	-1.2	1.8	15.9	-1.8	-2.9	2.2	-4.1	0.8	6.2	12.4
EC (µS/cm)	-0.1	5.4	9.1	-0.5	-6.6	-9.3	14.8	-2.1	6.5	-2.0	-1.6	-4.7	1.0	11.4
Alkalinity	67.0	29.2	41.0	55.3	18.6	26.1	38.1	60.3	39.1	50.1	55.6	39.5	40.9	30.2
BOD_5	54.6	73.9	71.5	58.9	81.7	55.9	81.0	50.9	70.1	67.3	51.7	57.6	63.6	79.9
COD	46.3	68.3	67.6	50.4	73.6	64.0	72.1	42.0	63.4	61.0	46.8	59.8	59.2	72.4
TKN	32.5	61.2	57.9	38.8	62.3	58.3	50.8	43.6	55.5	51.4	37.9	54.0	50.8	51.8
SRP	63.5	74.9	74.7	61.6	75.9	76.2	75.3	68.3	74.2	73.4	65.3	69.8	73.0	74.6

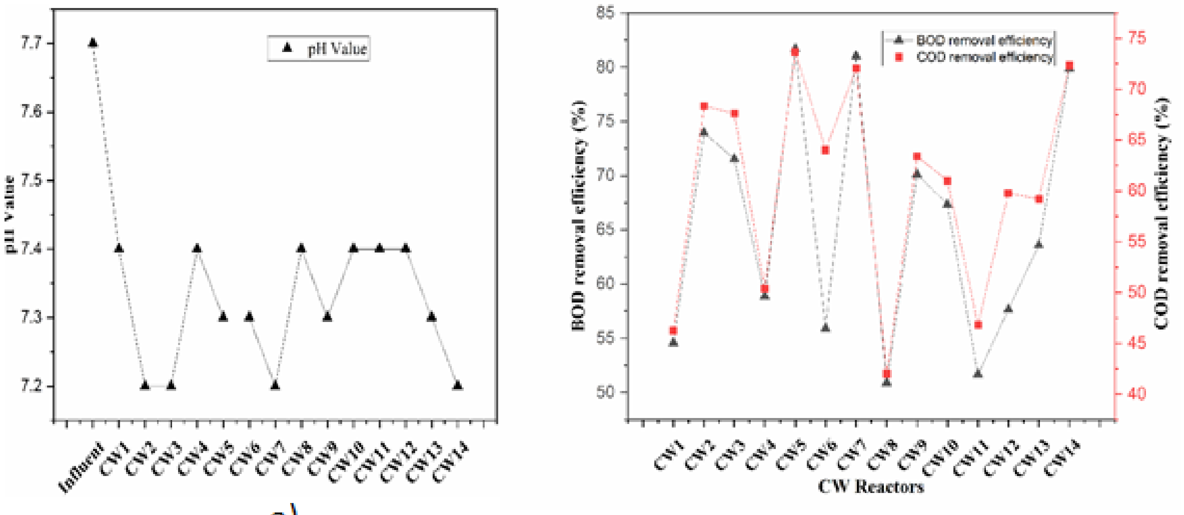
entisoles have batter then all. The percentage of removal efficiency is negative in all unplanted CWs and higher in aggregate base CWs. The authors observed that solids can be removed from influents through a settling tank and filter media (6-10 mm aggregate) at the inlet and outlet of CWs. In wetland systems, the use of coarse media will improve hydraulic conductivity and reduce the risk of system clogging, whereas fine media will effectively remove suspended particles and turbidity. This is also observed: due to the dilution of influents in rainwater, the amount of TSS has decreased after heavy rains and increased in the summer. The water coming out of the outlet was clear and transparent by visual observations, which qualitatively indicates a lower turbidity. The measured data show higher TDS for unplanted wetland compared to influent, indicating lower treatment efficiency for unplanted CW (figure 3c).

Alkalinity

The influence alkalinity was 285 mg/L, which is reduced by 67% in unplanted CW and by 55.6% in planted. The results show that the unplanted CWs have a high alkalinity reduction efficiency compared to planted CWs (figure 3a). Alkalinity affects nitrification and denitrification in the wetland bed. Alkalinity can be consumed during nitrification and is reduced during denitrification (Li et al., 2007). Mayes et al. (2009) studied the wetlands in terms of effective treatment efficiency for high-alkaline wastewater. In the laboratory test, *Typha latifolia* showed better performance compared to *Canna indica* on soil substrates. Plantations in soil-based CWs are recommended due to the fact that vegetation can serve as a carbon source for the crucial microbial communities involved in the high alkalinity removal processes. However, CW1 that contains lateritic soil reduces the alkalinity content the most compared to other CWs.

BOD_5 and COD

Organic removal efficiency was used to determine the removal rates of BOD_5 and COD. The concentration of pollutants in the inlet at both the pilot-scale HSFCW unit and the unplanted units is shown in table 3. The efficiency of BOD_5 and COD reduction was high in blank and planted-type CWs (figure 4b). In pilot-scale HSFCWs, the highest average COD removal efficiency was 46.3% in the entisole in unplanted CWs, while 73.6% was achieved in the inceptisole with planted *Canna indica.* The highest removal efficiency for BOD_5 was



a)

b)

Fig. 4. Variation in a) pH, b) BOD and COD of treated WW through various CWs

recorded for CW4 (54.6%) in unplanted CW and 81.7% inceptisole with planted *Canna indica*. The higher removal rate is likely the result of the higher rate of dissolved oxygen. The retention time of the wastewater was prolonged by the presence of plant roots in the CWs of the soil base, improving treatment effectiveness (Yadav et al. 2021). Throughout the trial, the composition changed significantly. The values of COD and BOD_5 varied between 192 and 368 mg/L and 58 and 168 mg/L, respectively. The WW used in this experiment was rated weak to medium strength due to its collection before the inspection chamber of the septic tank. According to the influent BOD/COD ratio, which ranged from 0.30 to 0.45, the raw wastewater is reasonably biodegradable and can be properly treated biologically. Fig. 4b shows that the wetlands were able to significantly lower BOD_5 and COD in the WW effluent. Each concentration of pollutant in the effluent was inversely proportional to the pollutant load. The curves show that the changes in influent and effluent concentrations for COD and BOD5, the courses of the parameters, were parallel to each other, indicating that the main determinant of capacity of the wetland units to treat the WW effluent is the strength of the WW.

The removal efficiency of BOD_5 and COD in Inceptisols is higher. The maximum removal efficiency for CW5 is 73.6%and the minimum is 42% in unplanted CW. The fact that the planted beds were better at getting rid of COD and BOD_5 than the ones that weren't planted suggests that the plants were able to add enough oxygen to the beds to help the WW's organic load break down aerobically. Also, as plants break down, microorganisms can grow on the roots, stems, and leaves of plants, which provide a food source (EPA). For aggregate-type CWs, the BOD_5 removal efficiency (CW7>CW14) was recorded (CW7>CW14) 81% in *Canna India.*

Total Kjeldal Nitrogen (TKN)

According to Seplveda-Mardones et al. (2017), nitrification and denitrification are the most efficient ways to remove nitrogen from CW. Nitrogen is essential for plant growth. Roots absorb nitrogen and transform it into biomass. Inceptisols shows the higher TKN removal efficiency and CW7 and CW13 are same for TKN removal. Figure 3d shows that the HSFCWs planted with *Canna indica* and then *Typha latifolia* are better at removing TKN than the CWs that were not planted. CW5 was the most effective at getting rid of TKN (62.3%), while CW7 and 13 were the least effective (50.8%). Nema et al. (2020) said that the effectiveness of TKN removal in this study was much higher than gravel-based CWs. However, Prochaska et al. (2007) found that TKN in municipal wastewater treated by vertical-flow CWs had a lower nitrogen reduction removal rate of 11%. In addition to some organic N molecules, plants mostly take in ammonium and nitrate, which together make up more than 90% of the nitrogen in soils (Sheng et al., 2013). This is their main advantage over the CW base aggregate.

SRP

During the experiments, the SRP value in the influent was 14.1 mg/L. The SRP values ranged from 6.7 mg/L to 11.9 mg/L in CW effluents. The maximum reduction efficiency observed in CW6 means Inceptisols (black), planted with *Typha latifoliya* SRP ($p<0.05$), with good performance achieved by the plant density of 17 plants/m^2. The minimum reduction efficiency was achieved in CW4. Inceptisols with *typha letifolia* shows the higher removal efficiency. In aggregate base CWs *typha letifolia* planted CWs is batter then *Canna indica*, for SRP removal. The higher SRP removal efficiency of planted *Canna indica* and *Typha latifolia* is higher than unplanted HSFCWs ($p<0.05$). All soils have calcium carbonates, which help remove phosphorus. SRP variations are shown in figure 3d. Calcium carbonate is an important parameter for the materials used as substrates. The presence of calcium carbonate improves the efficiency of phosphorus removal in the soil (Yanamadala, 2005).

DO

Throughout the study period, DO was observed ($p<0.05$) from 0.8 to 3.0 mg/L for influent, 3.4 to 3.9 mg/L in planted, and 3.6 to 4.1mg/L for unplanted CWs (figure 3b). Both aggregate types of CWs have DO value of 4.0 mg/L. The DO upgrade order is CW1> CW7 and CW14 > CW8 and CW2> CW3, CW5, CW10, CW13> CW4> CW6, CW9 and CW11>CW12. In the aerobic treatment process, the rate at which the medium takes in oxygen is determined by how well oxygen dissolves in the medium (Sawyer et al., 2003). Diffusion into planted beds and oxygen release from macrophyte roots bring the oxygen needed for aerobic degradation from the atmosphere (Kadlec et al., 2000; Vymazal, 2001; Hook and Stein, 2005; Kropfelova and Vymazal, 2006). Unplanted CWs are showing good results for increasing DO, and aggregate base CWs are also having high DO in effluents. Vertisol soil has better water retention properties (Wakode et al. 2013). Angassa et al. (2019a) have reported that the planted and unplanted HFCWS were significantly different, and plants can improve DO. CW7 and CW14 both release similar DO (4.0 mg/L). The authors have found that, along with temperature, the absorption capacity of the soil also affects the DO in CW.

Monitoring the plant growth

All plants were planted in May 2021. It is observed that the survival capacity of both plants at higher temperatures is better. During laboratory experiments, both plants survived effectively in soil and aggregate media. In April 2022, the temperature was close to about 42°C and 45°C, and it was observed that some of the leaves of the two plants had dried up. The plant growth of *Canna indica* are CW5>CW7>CW2>CW12>CW9 and for *typha letifolia* CW5>CW7>CW2>CW12>CW9. In May 2022 the plant density (number of plants) was CW2-37, CW3- 15, CW5 -38, CW6-16, CW7 -13, CW9-22, CW10-9, CW12-28, CW13-14 and CW14-22 numbers. The length of plants in July 2022 is maximum for *Canna indica* at 112 cm in CW5 and for *Typha latifolia* at 194 cm in CW6. Both aggregate bases reported by CW have also been observed at 85 cm in *Canna indica* and 166 cm in *Typha latifolia.* The necessary amounts of sodium, potassium, and calcium are the primary plant nutrients available in all substrate soil media. Phosphorous and nitrogen are significant contaminants in wastewater because they contribute to eutrophication and algal development in water bodies (Akhir et al. 2017). Algal blooms have been found in all planted CWs.

CONCLUSION

This batch-operated pilot-scale soil base study revealed the adequate performance of the unplanted and planned *Canna indica* and *Typha latifolia* to treat domestic WW for BOD_5, COD, TSS, TKN, SRP, and alkalinity at two days HRT at NIT Raipur. All soils used as substrates are easily available and cost-effective compared to aggregates. Based on the removal efficiency, treated water can be disposed of in any surface water body for irrigation purposes. The parameters examined fell below the standard allowed effluent limits set by the CPCB and WHO. SBCWs are cheaper than aggregate-based CWs. According to our findings, soil-based CWs with thinner biofilm formation provided more surface area for absorption and were more efficient than aggregate-based CWs in our experiments. The physical structure and various chemical compositions of the substrates have contributed to the variance in removal efficacy. Even after repeated lockdowns at the time of the COVID-19 pandemic, the plants did not dry up with roots and did not have to be replanted. The soil provides the primary plant nutrient for the initial stabilisation of the rector, saving time.

In general, the authors concluded that the potential of soil, as compared to the aggregate base CW, plays a leading role in the removal of the pollutant.

FUTURE SCOPE

There is work that has to be done to suggest ways to investigate the efficiency of heavy metal and microplastic removal. It could be done to increase the plant density in CWs. Effects on the climate could be observed. This study could be carried out on a field scale.

GRANT SUPPORT DETAILS

The present research did not receive any financial support.

CONFLICT OF INTEREST

The author declares no competing interests.

LIFE SCIENCE REPORTING

In this study, there was no use of a life science threat.

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