SHORT COMMUNICATION

Floating Constructed Wetlands Efficiency in Removal of Total Hardness, Calcium and Magnesium from Secondary Treated Sewage Water

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Abstract

Floating Constructed wetlands (FCWs) also popular as Floating Treatment Wetlands (FTWs) were used *in situ* for suspended solids, heavy metals, biological oxygen demand (BOD), chemical oxygen demand (COD), faecal coliform bacteria, nutrients and heavy metals remediation from various types of wastewater. However, there was limited data available on total hardness (TH), calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions removal from secondary treated sewage water (STSW). This article focuses on TH, Ca^{2+} and Mg^{2+} ions removal efficiency of FCWs from STSW. Mesocosms include a control (without FCWs), FCWs planted with macrophyte plant species *Canna indica* var. *indica* L. (S1) and *Typha angustifolia* L. (S2) and one mixed culture with both *Typha* and *Canna* plants (S3). The changes in TH, Ca^{2+} and Mg^{2+} concentration in wastewater were recorded at a 7-day hydraulic retention time (HRT) for 7 batches. Mean percentage removal efficiency recorded was 9.8, 1.7, 4.9 and 11.2% for TH, -3.4, 7.6, 27.1 and 14.1% for $Ca^{2+}$and 29.5, 4.2, -0.6, and -0.6% for Mg^{2+}, in Control, S1, S2, S3 FCWs respectively. Results showed that S2 and S3 FCWs are effective in TH and Ca^{2+} removal but not for Mg^{2+} ions. Thus, FCWs can reduce TH and Ca^{2+} ions concentration along with nutrients from STSW.

Keywords: Percentage removal efficiency, *Canna indica, Typha angustifolia*.

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Introduction

Rapidly increasing urbanization has more demand for water. To reduce the demand for our drinking water supplies, we must use treated sewage water for some home and industrial purposes such as car washing, toilet flushing, garden irrigation, and crop irrigation on agricultural land. However, most traditional sewage treatment plants fail at the secondary and tertiary treatment phases. This resulted in the release of primary treated sewage water in our surface water resources or in nearby areas of cities. Many organic and inorganic contaminants in primary treated sewage effluent degrade surface water resources' quality. The use of this water also affects the health of aquatic life and humans. This primary treated water is sometimes used to cultivate vegetables and crops in the city areas from where the wastewater discharge channel passes. Consumption of such food will have a negative impact on human health. Therefore, there is a strong need to find a low-cost, sustainable and easy-to-maintain ecotechnology that will be effective in the treatment of primary or secondary treated sewage water (Kumari *et al*., 2021). Floating constructed wetlands (FCWs) were found effective in many studies in reducing nutrients, biological oxygen demand (BOD), chemical oxygen demand (COD) and heavy metal ions from secondary and tertiary treated sewage water.

FCWs also popular as floating treatment wetlands (FTWs) are the retrofits used in the past few years due to their cost-effectiveness, *in situ* installation feature (rather than surface flow and sub-surface flow constructed wetlands), eco-friendly nature, and esthetic values (Tanner *et al*., 2011). It is an innovative phyto-technology designed to grow macrophytes hydroponically on a buoyant raft of variable size, floating on the water surface, keeping macrophytes roots permanently in contact with water (Headley and Tanner, 2012). Macrophyte roots uptake nutrients from water and utilize them in macrophytes' growth and development. Along with sedimentation and entrapment of suspended particulate matter, roots also provide a large surface area for the growth of micro-organisms (Di Luca *et al*. 2019; Kumari *et al*., 2021).

Over last two decades, FCWs have been used to study their TSS, BOD (Billore *et al*., 2009), COD, Nitrate-N (Ghosh and Gopal, 2010; Golda *et al*., 2014), Ammoniacal -N, Total Kjeldahl nitrogen (White and Cousins, 2013a), Phosphorous, *E. coli* and *Faecal coliform* removal efficiency in various types of wastewater at microcosm, mesocosm, and pilot scale (Messer *et al*., 2022). But not much data was found related to the effect of FCWs installation on total hardness, calcium and magnesium ions removal from secondary treated sewage water (STSW), specifically in Haryana. This paper focuses on FCWs effectiveness in removal of total hardness, calcium and magnesium ions, from STSW. A mesocosm scale study was conducted on STSW for 7

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batches, with a Hydraulic Retention Time (HRT) period of 7 days in every batch.

The presence of dissolved salts of metal ions causes the hardness of water. Major salts are sulphates, bicarbonates and chlorides of Ca^{2+}, Mg^{2+}, Al^{3+}, Fe^{3+} and other heavy metal ions. Bicarbonate salts lead to temporary hardness of water while other salts result in permanent hardness. For domestic use hardness of water plays an important role since it is measured as the capacity of water to precipitate soap. Hard water makes a scummy precipitate with soap and consumes more soap.

Hardness is one of the important parameters of potable water. But it is also important to be reduced in treated sewage water. Since, treated sewage water is discharged in rivers, and also used in many parts of the country, for crop irrigation in agricultural land, plant nurseries, and gardens, for flushing toilets, washing cars, in industries, and for groundwater recharge (Kesari *et al*., 2021). Very hard water causes corrosion of metal pipes and chambers, increases the amount of salts in groundwater which affects their taste and quality, and increases the amount of salts in agricultural lands.

Materials and Methods

Experimental Site

The study was conducted at Nasiya Ji 24 MLD Sewage Treatment Plant (STP), Rewari (Haryana). This STP receives wastewater from city of Rewari, including domestic waste, runoff water and waste from the city market and small industries. STSW was used as an influent in mesocosm tanks for analyzing the impact of FCWs installation on TH, Ca^{2+} and Mg^{2+}ions.

FCWs and Construction of Floating Mat

A batch-loaded mesocosm study was conducted in 7 batches, each with a HRT of 7 Days. In the present study took four mesocosm tanks labeled as control, S1, S2 and S3. Each FCWs tank was 78 × 90 cm (height × diameter) and has 496 L capacity. The filling height of each tank was kept up to 67 cm, which has a 388 L water volume. The control tank was kept open without FCWs. It was smaller with 60 × 70 cm (height × diameter) dimensions and 230 L capacity, filled volume of the control tank was 219 L (Fig. 1). Each mesocosm tank was filled with STSW. After seven days HRT, the tanks were washed thoroughly and further supplied with STSW. The floating mats of dimensions 57 × 59 × 8 cm, made from poly styrofoam placed on the base made from bamboo shoots network, were connected with wires. The bamboo shoots help in holding the weight of growing macrophytes. Macrophytes of equal size (10 cm) were planted in perforated plastic cups and placed in FCWs at equally spaced holes. Pots in holes were also fixed using dried grass fibres and gunny bag. These holes allow macrophyte roots to hang in the water columns and shoots to grow above the water column (White and Cousins, 2013b; McAndrew *et al*., 2016). In mesocosm tanks S1 and S2, macrophyte plant species *Canna indica* var. *Indica* L. and *Typha angustifolia* L. were planted respectively as monoculture, in the S3 tank, both plant species with five saplings of each were planted as mixed culture, here *C. hybrida* was planted since *C. indica* growing comparatively slower with *Typha* in mixed culture (Fig. 1).

Selection of Plant Species

C. indica var. *indica* L. and *T. angustifolia* L. plant species were selected based on the following criteria developed by researchers for species selection 1. These should be native and non-invasive species. Some invasive species have higher nutrient removal efficiency but can negatively affect ecosystem integrity later. 2. Species should be perennial, terrestrial or emergent rooted hydrophytes 3. They have aerenchyma tissue 4. Preference to plants with aesthetic value should be given (Tanner *et al*., 2011; Wang *et al*., 2014). In S3 mesocosm, *C. indica* var. *indica* L. variety was not growing well with *Typha* then it was replaced with *C. hybrida,* which grew well with *Typha* in mixed culture.

Hydraulic Retention Time

The percentage removal efficiency of FCWs is dependent on HRT. This experimental variable reflects the contact period of macrophyte roots with treatment water. Studies showed that with increasing HRT, the removal efficiency of FCWs increases (Toet *et al*., 2005; Ghosh and Gopal, 2010; Tanner *et al*., 2011). In the present study, the performance of mesocosm FCWs was recorded at 7 days HRT.

Water Sampling and Analysis

Water samples were collected on day 0 (influent concentration) and day 7 (effluent concentration) from each mesocosm tank in pre-washed 300 mL sample collection water bottles from the outlet valve. Collected influent and effluent water samples were tested for physicochemical properties, i.e., total hardness, Ca^{2+} Mg^{2+} using 2340 C EDTA titrimetric method for TH, 3500 Ca-B EDTA for Ca^{2+}, and calculation method was used for Mg^{2+} as per guidelines of standard methods of APHA (Rodger B. Baird, Andrew D. Eaton, 2018).

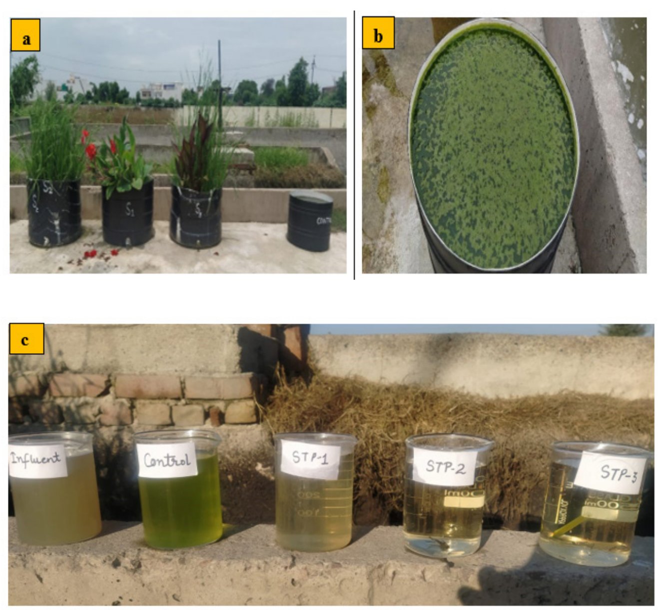

Fig. 1: (a) FCWs Mesocosms: Control, S1, S2 and S3 at the study site. (b) Control tank showing algal bloom after 7 days HRT (c) Comparative change in TSS, turbidity, color and transparency of influent and FCWs (HRT- 7 days).

Calculation

The percentage removal efficiency of FCWs was calculated using the equation:

%Removal Efficiency = ((Cin -Ceff))/Cin×100

Cin = Concentration of influent

Ceff = Concentration of effluent

Results and Discussion

Total Hardness Removal

In 7 batches, TH concentration of the influent was ranged from 420 to 600 mg/l. In this range the percentage removal efficiency of mesocosms was as follows- control 9.8, 1.7% *Canna* plant species, 4.9% *Typha* plants and 11.2% mixed FCWs (Table 1). Among all three FCWs S3 with Mixed plants was best performer (Fig. 2). However, control showed more removal efficiency than S1 and S2 (Fig. 3). Patel and Kanungo also get TH removal below 15% using *Lemna minor* L. from domestic wastewater (Patel and Kanungo, 2010).

Calcium Removal

Influent supplied in mesocosms has Calcium (Ca^{2+}) concentration range from 64 to 120 mg/l. The percentage Ca^{2+} removal efficiency of all three FCWs was found higher than the control with a maximum in S2 with *Typha* plants. Control showed -3.4% removal efficiency, while FCWs showed 7.6, 27.1 and 14.1 % removal efficiency of S1, S2 and S3 respectively (Table 2), (Fig. 3). Patel and Kanungo obtained Ca^{2+} removal less than 15%, here we got similar results with S1 and S3 but S2 showed better removal efficiency (Patel and Kanungo, 2010). The reason may be faster growth and emergence of more shoots from *Typha* rhizome which needs more calcium for growth and development than *Canna* since the mixed FCWs also had approximately double removal efficiency than S1. The concentration of Ca^{2+} in FCWs mesocosms was lower (Fig. 2). Also, the percentage removal efficiency of FCWs was significantly different from control.

Table 1: Mean concentration of TH in Influent loaded and effluent from control and FCWs mesocosms after a regular HRT of 7 days and percentage TH removal efficiency of mesocosm units.

Total Hardness (TH)	*Influent*	*Control*	*S1 (Canna)*	*S2 (Typha)*	*S3 (Mixed)*
Mean conc. (mg/l)	495.7 ± 115.4	447.1 ± 85.3	487.1 ± 89.7	471.43 ± 93	440 ± 95.5
Removal efficiency (%)		9.8	1.7	4.9	11.2

Table 2 : Mean conc. Of Ca^{2+} in Influent loaded and effluent from control and FCWs mesocosms after a regular HRT of 7 days and their percentage Ca^{2+} removal efficiency

Calcium	*Influent*	*Control*	*S1 (Canna)*	*S2 (Typha)*	*S3 (Mixed)*
Mean conc. (mg/l)	84 ± 20	86.6 ± 22.9	75.4 ± 25.8	59.7 ± 16.7	68.9 ± 21.0
Removal efficiency (%)		-3.4	7.6	27.1	14.1

Table 3 : Mean concentration of Mg^{2+} in Influent and effluent from control and FCWs mesocosms after a regular HRT of 7 days and percentage removal efficiency of FCWs for Mg^{2+}.

Magnesium	*Influent*	*Control*	*S1 (Canna)*	*S2 (Typha)*	*S3 (Mixed)*
Mean conc. (mg/l)	75.8 ± 26.6	53.4 ± 11.7	72.63 ± 11.9	76.2 ± 15.9	76.2 ± 15.6
Removal efficiency (%)		29.5	4.2	-0.6	-0.6

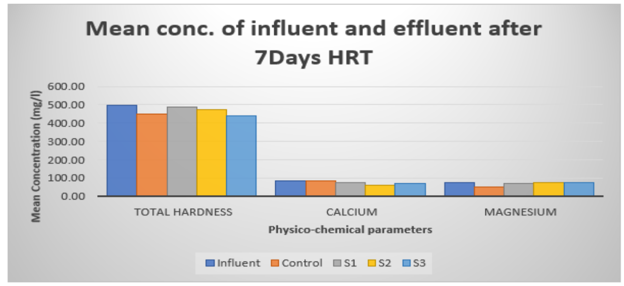

Fig. 2: Representing the change in mean conc. of Secondary Treated Sewage influent TH, Ca^{2+}, Mg^{2+} conc. in control and FCWs at 7 Days HRT.

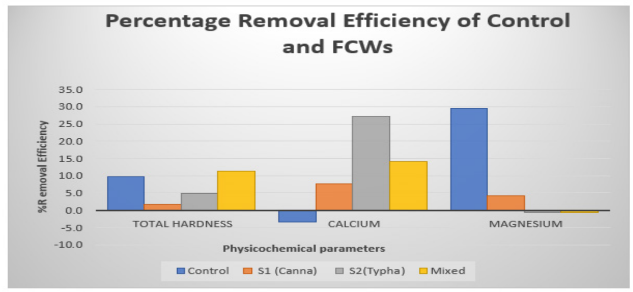

Fig. 3: Percentage TH, Ca^{2+} and Mg^{2+} removal efficiency of Control and FCWs.

Table 4: Statistical analysis of concentration reduction in effluent water parameters using single factor ANOVA with 95% significance level (α= 0.05)

Parameters	*Source of variation*	*SS*	*df*	*MS*	*F*	*p-value*	*F-crit*
TH	Between Groups	16554.29	4	4138.57	0.382	0.819	2.690
Ca^{2+}	Between Groups	3405.03	4	851.26	1.842	0.147	2.690
Mg^{2+}	Between Groups	2826.664	4	706.66	2.382	0.070	2.641

Note: *p-value* < 0.05

Magnesium Removal

In STSW Influent magnesium (Mg^{2+}) concentration varied from 38.4 to 112.8 mg/l. Magnesium concentration decreased significantly in control after 7d HRT period than in all mesocosms. The Mg^{2+} removal efficiency of all three FCWs was lower than Control (Fig. 3). Control showed 29.5% removal efficiency, while FCWs showed 4.2, -0.6 and -0.6% removal efficiency of S1, S2 and S3, respectively (Table 3). Similar results were obtained by Patel and Kanungo (2010).

Statistical analysis was performed using One Way ANOVA in 16. Results show no significant difference in concentration of all three parameters among FCWs and Control at 95% significance level (Table 4). The *p-value* was more than 0.05 among groups for all three parameters. For Mg^{2+}, *p-value* was near to 0.05 and Figs 2 and 3 shows this difference is shown by control instead of FCWs.

Conclusion

Percentage removal efficiency shows that FCWs can potentially reduce TH and Ca^{2+} concentration from STSW. For Mg^{2+}, FCWs did not show effective results. Further studies are required for that. Therefore, FCWs are eco-friendly and low-cost technology can be used for TH and Ca^{2+} reduction along with the reduction of nutrients (NO_3^- and NO_2^-), Sulfate, and heavy metal ions (Afzal *et al*., 2019), BOD, COD and TSS (Jawad *et al*., 2019) remediation from wastewater.

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Authors Contribution

Monika Kumari performed the manuscript's experimentation, data collection, and data analysis. Dr. Vinay Kumar guided and framed the manuscript. Dr. Bindu Sharma helped in editing the manuscript.

Conflict of Interest

None.

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