Poll Res. 40 (1) : 111-116 (2021)

ISSN 0257–8050

REMOVAL OF NUTRIENTS FROM DOMESTIC WASTEWATER IN A HYBRID SUBSURFACE FLOW CONSTRUCTED WETLAND

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(Received 30 March, 2020; accepted 10 July, 2020)

ABSTRACT

Domestic wastewater has largest percentage of all wastewater generated from urban and rural areas hence it is major contributor to water pollution. Presence of nutrients in domestic wastewater contributes to eutrophication. It is therefore essential to reduce the concentration of these nutrients present in domestic wastewater to avoid any further adverse implication in water bodies. In this context, present study focused on the removal of nitrogen and phosphate from the domestic wastewater using two stage hybrid subsurface flow constructed wetland planted with *Arundo donax*. System consisting of vertical and horizontal subsurface flow wetland was operated for a period of 11 months. pH and temperature values during the study period were in the range of 7-8.5 and 11.1 to 37.5^{o}C respectively. Removal efficiency of Total Kjeldahl Nitrogen was observed 95.7%, 93.49% and 89% and for phosphate 55.54%, 41.64% and 20.43% respectively during summer, post monsoon and winter season in planted hybrid constructed wetland at a flow rate of 65 L/day. Since the removal of phosphate was not good enough so adsorbent prepared from eggshell was applied within the system that helped in improving the phosphate removal in hybrid constructed wetland.

KEY WORDS : Domestic Wastewater, Hybrid Constructed Wetland, Nutrients, Phosphate, TKN, *Arundo donax*

INTRODUCTION

Domestic wastewater contains organic and inorganic matter, microorganisms, suspended solids and nutrients such as phosphate and nitrogen. Nitrogen is a compound that exists in organic and inorganic form and has a complex biogeochemical cycle. Ammonia and Nitrate Nitrogen are mainly utilized by plants and algae to form plant proteins whereas phosphorous plays an important role in photosynthesis, cell division, respiration, energy storage and transfer, which is important for the growth of the plants. Nitrogen and phosphorous, both are of great importance in the food chain but when discharged in the excess amount in water bodies, they leads to eutrophication (Banu *et al.*, 2008). Use of conventional method for removal of nutrient may demands high energy, frequent maintenance and produce huge amount of sludge.

During the recent research on natural treatment methods such as constructed wetlands have gain popularity among all developed and developing countries since 1980's (Reed *et al.*, 1995). As the success rate of constructed wetlands is increasing, these are being used for the treatment of different wastewater such as industrial and agricultural wastewaters, landfill leachate, and stormwater runoff etc. (Vymazal, 2005). In the years of research it has been found that removal of organic matter, TSS and Nutrients is satisfactory in constructed wetland (Robins *et al.*, 2000; Sun, 2005), however studies also reveal that removal of nitrogen cannot be obtained in a single wetland system as it mainly depends on nitrification or denitrification (Stottmeister *et al.*, 2003). Nitrification occurs successfully in vertical subsurface flow wetland (VSSFW) where as horizontal subsurface flow wetland (HSSFW) provides suitable conditions for denitrification. Nutrients removal in wetland has been found due to sedimentation, adsorption on the soil layer, uptake by the plant biomass and due to nitrification and denitrification (Kadlec, 1997;

Robins *et al.*, 2000). For these reasons, combination of VSSF and HSSF wetland as a hybrid subsurface flow constructed wetland (HSSFCW) was constructed to conduct the research experiments for a period of 11 months. Also, the hybrid wetland was planted with *Arundo donax*, a alternate fast growing emergent macrophyte. A very little work has been done on the use of selected macrophyte in HSSFCW for removal of nutrients from domestic wastewater. Therefore this study aim to assess use of hybrid subsurface flow constructed wetland planted with *Arundo donax* for removal of nutrients from domestic wastewater. The performance of system was regularly monitored to collect the data for removal efficiency of Total Kjeldhal Nitrogen (TKN) and phosphate.

MATERIALS AND METHODS

The hybrid subsurface flow wetland in duplicate was constructed near sewage treatment plant, GGSIP University campus, Dwarka, Delhi. Plastic tanks were used for creating horizontal and vertical wetland bed. Wastewater from the sedimentation tank was passed through gravity in VSSFW and HSSFW through PVC pipe. Each tank was filled with large size gravels (35-40 mm) at the base followed by small size gravels (10-20 mm), coarse sand and organic soil as top layer. System was planted with *Arundo donax*. Similarly one unplanted hybrid subsurface flow wetland was operated as a control (Figure 1).

Domestic wastewater from the pumping station was supplied to the system with continuous flow. Wastewater was run throughout the HSSFCW system at a flow rate of 65 L/day. Flow of the water was adjusted with the control flow knob at every point provided before supply to VSSF tank. Influent and effluent samples were collected in the clean and washed polyethylene bottles over a period of 11 months from May 2018 to May 2019 with exception of rainy season (July 2018-August 2018). On spot measurements were taken for pH and temperature using Multi-Parameter PCSTestr™35. Further samples were analyzed for Dissolve Oxygen (DO), phosphate and Total Kjeldahl Nitrogen (TKN) in laboratory as per the standards methods for examination of water and wastewater (APHA, 2005). The flow rate was monitored regularly during the study period.

Percent removal of parameters was calculated as per the equation given below:

$$\% \text{ Removal} = \frac{(C_I \times Q_I) - (C_E \times Q_E)}{C_I \times Q_I} \times 100$$

Where, C_I is the influent concentration in mg/L
C_E the effluent concentration in mg/L
Q_I the volume of Influent in L/day
Q_E the volume of effluent in L/day

RESULTS AND DISCUSSION

The removal of all essential parameters such as organic matter, nutrients and heavy metals critically depends upon the wetland macrophytes, microbes and different environmental and operational factors like temperature, pH, oxygen, loading and retention time (Tanner, 1996; Saeed and Sun, 2013). In wetland, macrophytes play an important role in supply of oxygen near rhizosphere, provide optimum conditions and surface area for the growth

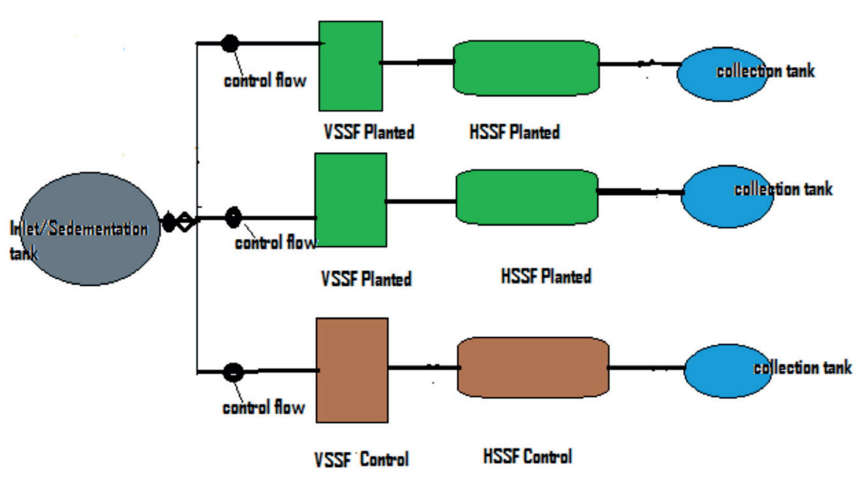

Fig. 1. Schematic diagram of HSSFCW (VSSF-HSSF)

of microorganism and also help to stabilize the hydraulic movement of wastewater (Brix, 1997). Therefore pH, temperature and dissolved oxygen were regularly monitored the influent and effluent of the planted and control (unplanted) system to analyze the impacts of different environment factors on removal of nutrients.

The samples collected from the influent of HSSFCW showed pH in the range of 7-7.8 which was very close to neutral. There was a slight change in pH from neutral to alkaline after treatment through HSSFCW. pH were found in the range of 7.2-8.4 and 7.2 to 8.5 with mean and standard deviation of 7.7±0.3 and 7.8±0.3 (Table 1) in effluent samples of planted and control HSSFCW which is quite considerable for nitrification and denitrification. Idris *et al.*, 2012 also observed slight increase in pH in unplanted wetland than the planted (*Arundo donax*) system. pH between 6.5-8.5 is suitable for nitrification and denitrification (Kaseva, 2004; Zenorina, 2008).

Temperature measurements were done regularly during the study period and results show that it was in the range of 14.8-36.4 °C with average of 26±5.4 °C in influent samples of HSSFCW. Temperature from influent to effluent slightly decreased and was measured in the range of 12.1-33.9 °C and 11.1-37.5 °C with an average of 24±6.8 and 24.5±6.9 °C in effluent of planted and control HSSFCW respectively. Variation in temperature and pH may be due to sampling at different season and also due to the influence of macrophytes and sediment layer in constructed wetland that prevent direct sunlight in the wastewater. It has found that temperature in the range of 25-35 °C and pH 6.5-7.5 is suitable for the growth and microbial activity in constructed wetland (Prescot *et al.*, 1996). The results are shown in Table 1.

Dissolve oxygen (DO) in influent samples was found nil in all the season during the experimental period. DO is one of an important parameter in water quality assessment. It is interrelated with nitrification, denitrification and decomposition of organic matter existing in wastewater (Sehar *et al.*, 2015). The concentration of DO improved in effluent collected from both planted and control system. In HSSFCW (planted) DO increased with an average of 7.0±2.6. Increase in DO may be due to the presence of aerenchyma cells that help in transfer of oxygen from shoot to root (Woolhouse, 1979) and simultaneously in the root zone area through diffusion or by convection (Bezbaruah *et al.*, 2005). Similarly DO in control HSSFCW were observed 7.4±3.3 which is slightly more than the planted system. Increase in DO in control HSSFCW may be due to algal growth and its involvement in photosynthetic activity in the tank. Increase in DO in both planted and control system supports decomposition of organic matter and nitrification.

Removal of phosphate in HSSFCW planted and control system

The process of phosphate removal includes adsorption, precipitation within the substrate or the soil media, biological decomposition and uptake by plant (Kadlec and Knight, 1996). Phosphate is considered to be one of the major nutrients for the growth of the plants. Present study observed influent phosphate concentrations in the range of 1.11 to 5.92 mg/L. Mean phosphate value in effluent reduced to 2.7±0.8 in planted and 3.3±0.9 in control HSSFCW respectively. Figure 2 shows that there was gradual decrease in concentration of phosphate in planted than the control HSSFCW. However, the removal was not good enough therefore adsorbent prepared from eggshell was added within wetland

Table 1. Measurement of pH, Temperature, DO, Phosphate and TKN in the influent and effluent samples of hybrid subsurface flow constructed wetland (HSSFCW)

Sr. No	Parameter	Units	HSSFCW Influent		HSSFCW Effluent (planted)		HSSFCW Control	
			Range	Average ±Std Dev.	Range	Average± Std. Dev	Range	Average ±Std. Dev
1	pH	-	7-7.8	7.5±0.2	7.4-8.4	7.7±0.3	7.2-8.5	7.8±0.3
2	Temperature	%C	14.8-36.4	26.8±5.6	12.1-33.9	24±6.8	11.1-37.5	24.5±6.9
3	DO	mg/L	0	0	3.6-13.8	7.0±2.6	4.8-16.1	7.4±3.3
4	Phosphate	mg/L	1.11-5.92	3.5±0.8	0.47-4.07	2.7±0.8	0.47-4.79	3.1±0.9
5	TKN	mg/L	37.8-69	50.3±9.6	1.4-11.4	5.6±3.0	5.6-39.2	16.2±10.5

Mean ± standard deviation

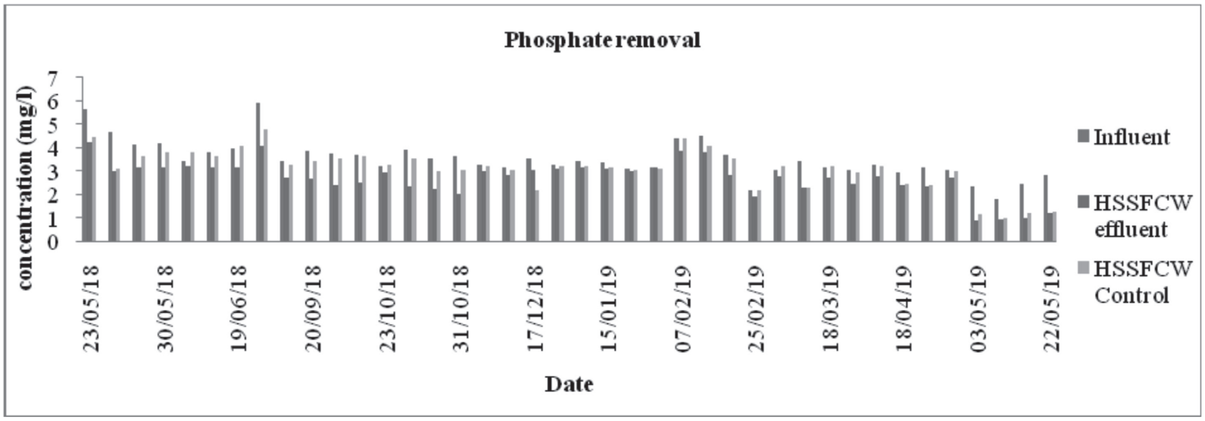

Fig. 2. Phosphate concentrations observed during study period in Influent and effluent of planted and control HSSFCW System.

system in the late April 2019 to improve the removal efficiency of phosphate. Adsorption is a cost effective and efficient technology to produces permiscible quality water (Loganathan *et al.*, 2014). Batch study of eggshell powder was also found effective as an adsorbent for the removal of phosphate by the surface reaction on the solid surface (Rani *et al.* 2019). Hence, analyzes the removal efficiency of phosphate by eggshell powder as an adsorbent in the constructed system. The result obtained in the month of May 2019 clearly indicates that the phosphate concentrations reduced sufficiently from the wastewater after addition of eggshell powder in the system. Figure 3 a shows the preparation of holes within wetland system and 3b presents the filling of eggshell powder in system.

Fig. 3. (3a) digging of holes in wetland system and (3b) holes filled with eggshell powder

Removal of Total Kjeldahl nitrogen (TKN) in HSSFCW planted and control system

TKN represents summation of organic nitrogen, ammonia and ammonium in the wastewater. Nitrogen removal in constructed wetland includes uptake by macrophytes and microbes, nitrification, ammonification, denitrification, ammonia volatilization and cation exchange for ammonium (Vymazal, 2007). Average TKN in influent samples was 50.3 mg/L. It was observed that under the influence of *Arundo donax* TKN reduced to 5.6 mg/L in planted and 16.2 mg/L in unplanted HSSFCW system.

Impact of seasonal variation on removal of nutrients

Percentage removal of nutrient in HSSFCW planted and control during different seasons is presented in

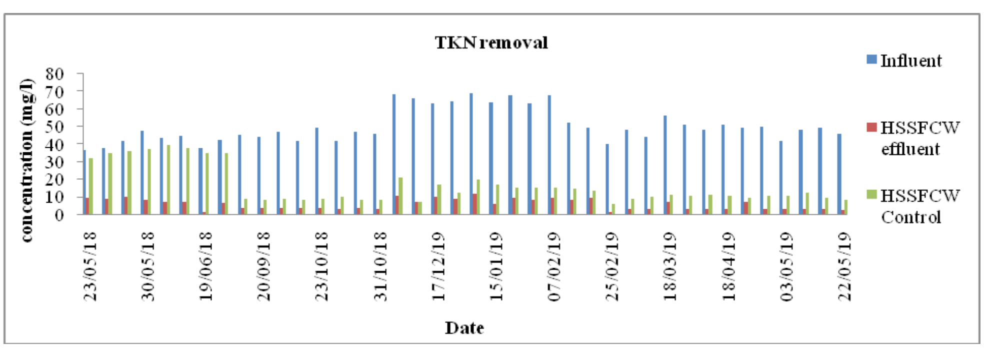

Fig. 4. TKN concentration during study period in Influent and effluent of planted and control HSSFCW System

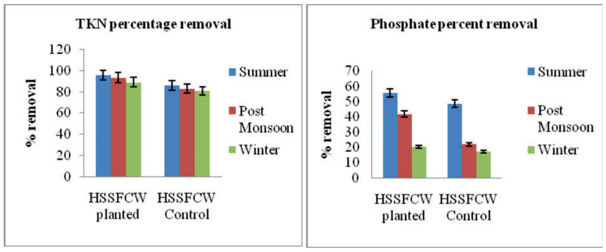

Fig. 5. Percent removal of Phosphate and TKN in planted and control HSSFCW during different seasons

Figure 5. The removal of TKN and phosphate during study period was found more in the order of summer>post monsoon>winter. Since during summers the temperature is suitable for growth of microbes therefore more nutrient removal could be observed during summers. Hijosa-Valsero *et al.*, 2012 observed the similar seasonal effect on removal of nitrogen and Tao *et al.*, 2010 reported the same trend for significant removal of phosphate. In effluent from planted HSSFCW, TKN removal was 95.7%, 93.49% and 89% respectively during summer, post monsoon and winter season. Similarly in control HSSFCW percentage removal of TKN was 86%, 83.07% and 80.9% in summer, post monsoon and winter season respectively. The experimental results show that seasons play an important role in removal of nitrogen. Also, directly and indirectly macrophytes plays an important factor in the removal of Nitrogen. Roots of the macrophytes provide space and aerobic condition in the root zone area thus influences nitrification, denitrification and increases organic removal (Wang *et al.*, 2012)

Similar trends were observed for the removal of phosphate during different seasons. In case of planted HSSFCW percentage removal of phosphate was observed to be 55.54%, 41.64% and 20.43% during summer, post monsoon and winter season respectively. On the contrary in control HSSFCW 48.51%, 22.01% and 17.12% of phosphate removal was found during summer, post monsoon and winter season respectively. Hence results obtained from the study shows that percentage removal of nutrients in hybrid subsurface flow constructed wetland depends on temperature.

CONCLUSIONS

From the study it has been found that HSSFCW planted with *Arundo donax* helps in reducing the nitrogen and phosphate concentration in treated domestic wastewater successfully. The use of eggshell powder as an adsorbent in the wetland system also played a very important role in improving removal of phosphate. Selected macrophyte supported the growth of microorganisms, provided sufficient oxygen supply and maintained temperature for proper functioning of HSSFCW system thus enhancing the TKN and Phosphate removal efficiency. Results also showed that removal of nutrient was more in summer than the post monsoon and winter season. Further study may be carried out on the use of different adsorbents within a wetland system to improve its efficiency of nutrient removal from the wastewater.

ACKNOWLEDGMENT

Authors are extremely grateful to Guru Gobind Singh Indraprastha University, Dwarka, Delhi for providing financial and other support in completion of the research work

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