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PRELIMINARY STUDY ON NUTRIENT REMOVAL OF DAIRY WASTEWATER BY PILOT SCALE SUBSURFACE HORIZONTAL FLOW CONSTRUCTED WETLAND PLANTED WITH *Schoenoplectus grossus*

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Abstract: **This study was conducted to examine the nutrient removal efficiency of pilot scale Constructed Wetland (CW) designed to treat dairy wastewater. Two pilot scale fiber glass wetland units were constructed to function as Subsurface Horizontal Flow (SSHF) CWs. A gravel based medium was layered for inlets and outlets of each unit. Constructed Wetland bed was filled with sand and the upper layer was filled with compost: top soil mixture (1:2). Both units were planted with *Schoenoplectus grossus* (Giant bulrush). After establishing plants for three months, the treatment unit was saturated with seven Biochemical Oxygen Demand (BOD) loads of diluted and neutralized dairy wastewater ranging from 5g/m^{2}d, 16g/m^{2}d, 20g/m^{2}d, 24g/m^{2}d, 33g/m^{2}d, 48g/m^{2}d and 186 g/m^{2}d. Seven days were maintained as effective retention time under each BOD load. Control unit was maintained without the addition of dairy wastewater. Samples were collected from the inlets and outlets of each unit and analyzed for BOD, Chemical Oxygen Demand (COD), Total Nitrogen (TN) and Total Phosphorous (TP). Removal efficiencies of BOD, COD, TN and TP were calculated. The results of this study showed BOD removal efficiencies in the range of 30%-100%, COD removal efficiencies in the range of 75%-92%, TN removal efficiencies in the range of 40%-100% and for TP in the range of 0%-100% with respect to studied loading rates. Based on these results this paper suggests that this type of pilot scale SSHF CWs planted with *Scheonoplectus grossus* is appropriate for removal of BOD, COD, TN and TP in dairy wastewater arising from small and medium sector dairy industries.**

Keywords: **Constructed Wetlands, Dairy wastewater, *Schoenoplectus grossus*, COD, BOD.**

I. INTRODUCTION

Constructed Wetlands, artificial wetlands designed to treat wastewater (CW) play a vital role in effectively removing pollutants from a wide range of wastewater sources such as domestic, industrial, agricultural wastewaters and food industry wastewater [1].Constructed Wetlands are of two types as Free Water Surface (FWS) and Sub Surface Flow (SSF) [2]. In SSF CWs, water level is maintained below the filter bed, Further they are divided into Horizontal Flow (HF) or Vertical Flow (VF) based on the water flow regime through the filter bed [3]. Subsurface Flow CWs occupy specific capacity to absorb and retain particulate matters, nutrients and other pollutants [4]. It has also been accepted that SFCW is often significant for developing countries with tropical climates where the zones are warm and humid weather in all years [5]. Furthermore compared to other conventional wastewater treatment methods, CW requires low cost for construction and operation. Similarly this technology is a robust treatment technology with ecological benefits [6]. Thus the interest in implementing CW especially for treatment of food processing wastewater including dairy industry is growing due to above additional advantages provided by CWs [7]. However in Sri Lanka CW is a freshly minted term thereby most of the research is at embryonic stage. Therefore it is vital to conduct this type of pilot scale research in view of applying the outcome of this research to treat dairy wastewater, a threatening issue for water. In Sri Lanka most of the dairy industries are small and medium sector industries which are not capable of implementing high cost wastewater treatment technologies. Therefore CW technology can be easily introduced to these industries. When considering the treatment performance of a CW, it can be affected by factors such as configuration, hydraulic and BOD loading rate, substrate type of vegetation up to some extent [8]. In this study particular consideration was given for subsurface horizontal flow type CW planted with *Scheonoplectus grossus*. *Scheonoplectus grossus* plants were selected based on previous literature while considering aesthetic value, ornamental value and especially the potential as an additional income source.

1.1 Objectives:

This study was primarily aimed at determining the nutrient removal efficiency of dairy wastewater by a pilot scale SSHF CW planted with *Schoenoplectus grossus* plants. Secondary objective included the comparison of aboveground and belowground biomass of vegetation of control and treatment units at the end of the experiment to determine the effect of dairy wastewater on plant growth.

2. METHODOLOGY

2.1 Study Site:

The present study was conducted in the premises of Industrial Technology Institute, latitude 06° 54' 17"N, longitude 079° 52' 14"W, Sri Lanka during April to August 2014 under monsoon climate.

2.2 Constructed Wetland units (Pilot Scale):

Two waterproof Constructed Wetland units were constructed using fiberglass. (Width x Length x Depth of each units were 1m x 5m x1m).These systems were designed to function as Subsurface Horizontal Flow Constructed Wetland (SSHF) units. The cross section of the wetland is schematically illustrated in the Figure 01. Inlets and outlet zones of each unit were filled with coarse gravel (5mm) up to 0.7m.The bottom of the filter beds were first layered with washed river sand up to 0.45m as illustrated in the Figure 01.Then a mixture of top soil: compost (2:1) was placed over the sand layer up to 0.3 m. The effective porosity of the media of each unit was 0.14.

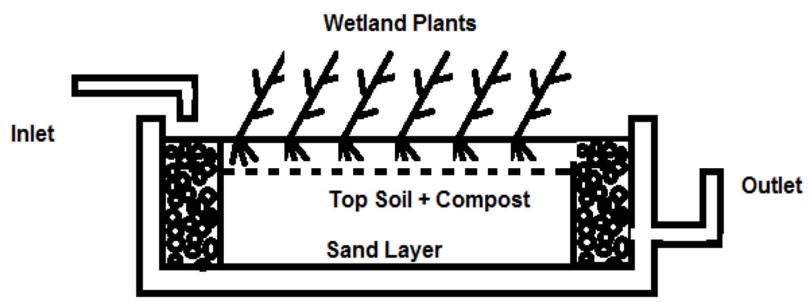

Figure 1: The Cross section of the Constructed Wetland

2.3 Planting:

Rhizomatous cuttings (approximately 15 cm height) of healthy and similar size *Schoenoplectus grossus* (Giant Bulrush) plants were collected in April 2014 from wild populations at "Gamagedara" the rush and reed conservation and diversification programme, Horana.Thirty three rhizomatous cuttings were planted in each unit maintaining 0.15m space between each plant on the filter bed. Planting density of each bed was 11m^{-2}. This vegetation was acclimatized until July 2014.

2.4 Wetland operation:

Dairy wastewater obtained from a nearby dairy industry was diluted and neutralized. Then fed to the wetland bed through a perforated pipes fixed at the influent inlets of the system. Seven hundred liters (700 L) of wastewater per one BOD load was fed in to the treatment unit and kept saturated for 7 days of effective retention time. Control unit was fed with 700L of tap water. Same procedure was followed for each respective BOD loads.

2.5 Sample Collection and Analysis:

Samples were collected from the inlet and outlet of each unit once a week (corresponding to the nominal HRT of 7days). All samples were collected into 500ml glass bottles and samples were analyzed for pH, DO, BOD, COD, TP and TN at the Environmental Technology laboratory and Chemical and Microbiology Laboratory of ITI. Test methods followed in analysis of wastewater quality parameters are outlined in the following table.

Table 1: Test methods used for analysis of wastewater

Parameter	Method
pH	Eco test pH meter
DO	Eco test DO meter
COD	APHA (21st Edition)
BOD	APHA (21st Edition)
TN	394 N, Total HR TNT stored test method (HACH/USA DR900 Colorimeter)
TP	542 P Total HR TNT stored test (HACH/USA DR900 Colorimeter)

2.6 Calculation of Removal efficiency:

The removal efficiency of each parameter was calculated using the equation 01

$$Removal\ Efficiency = \frac{\text{Ci}\ (\pm \text{A}) - \text{Co}}{\text{Ci}} * 100 \qquad \text{Equation 01}$$

Where: Ci and Co are influent and effluent concentrations of respective parameters of wastewater. A is the addition or subtraction of respective parameter over the filter bed.

The relationship between the BOD loading rate and the removal efficiency of each parameter was statistically analyzed using MINITAB 14 software package following Spearman's Rank Correlation Coefficient.

2.7 Comparison of Macrophyte Density and Growth:

2.7.1 Density

The number of plants and shoots per square meter was counted manually in each unit at the end of the experiment. In addition, above ground plant growth measurements such as plant height, diameter and number of shoots were recorded. Stat trek random number generator was used to select plants randomly from both control and treatment units. Accordingly 8 plants from control unit and 9 plants from treatment unit were selected with >10% likelihood.

2.7.2 Plant height

The distance from the ground to the top most internode of the shoot was taken as the height of the plant.

2.7.3 Diameter

Shoot diameter was recorded using a digital vernier caliper. Three diameters along each shoot were recorded and the average was calculated.

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2.7.4 Number of shoots

Number of shoots per plant was counted.

2.7.5 Dry weights of shoot and roots

Randomly selected plants were sampled and washed gently and separated from sand and other debris and dried well. Shoot and root dried weights were determined using a weighting balance after oven drying for 48 hours at 80 ^{o}C until reaching a constant weight.

ANOVA General Linear Model procedure was followed using MINITAB 14 software to compare the differences in means of respective growth parameters.

3. RESULTS

3.1 Nutrient removal efficiencies:

Table 2: Nutrient removal efficiencies under different BOD loading rates

BOD Load	Removal efficiency (%)			
	BOD	COD	TN	TP
5g/m^{2}d	100	81	100	34
16 g/ m^{2}d	62	74	62	*
20 g/m^{2}d	30	86	100	100
24 g/m^{2}d	62	82	40	75
33 g/m^{2}d	55	79.2	64	100
48 g/m^{2}d	100	78.3	43.3	82.1
186g/m^{2}d	100	92.1	19.54	100

*No removal efficiency

The respective nutrient removal efficiencies for BOD, COD, TN and TP are given in the Table 2. Accordingly removal efficiencies for BOD and COD indicate considerable values.

3.2 Spearman's correlation between BOD load and removal efficiency of respective parameters:

Table 3: Spearman correlation Load vs. Parameters

Parameter	Spearman's Correlation	P -Value	Significance
Loading rate Vs. BOD	0.448	0.314	ns
Loading rate Vs. COD	0.740	0.057	ns
Loading rate Vs. TN	-0.708	0.075	ns
Loading rate Vs. TP	0.447	0.315	ns

ns: not significant

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The correlation between the BOD load and the parameters are given in Table 03. Accordingly Table 03 implies no correlation between the loading rate and the removal efficiencies of respective parameters.

3.3 Macrophyte Density:

Table 4: Differences of plant growth in treatment and control units

	Control	Treatment
Initial -Number of plants/shoots	33	33
No of plants at the end of treatment	65	75
No of shoots at the end of treatment	166	215
No of plants/m^2	20	24
No of shoots/m^2	55	72

The Table 04 shows growth of number of plants and shoots over the time in both control and treatment units. Accordingly plant number and shoot number had increased in both units but treatment unit occupies the greatest number at the end of the experiment.

Table 5: Analysis of variance for differences in means of plant growth parameters between control and treatment unit

PARAMETER	SOURCES	DF	MS	F	P	
Number of Shoots	Treatment	1	1.38	0.12	0.732	ns
Height	Treatment	1	37589	7.66	0.007	ns
Diameter	Treatment	1	10.46	0.24	0.623	ns
Shoot Dry Biomass	Treatment	1	6.3	0.05	0.825	ns
Root dry Biomass	Treatment	1	1682.7	3.21	0.099	ns

DF: Degree of Freedom, MS: Means of Square, F: F value, P: P value, ns; not significant

3.4 Dry Biomass at the end of the experiment:

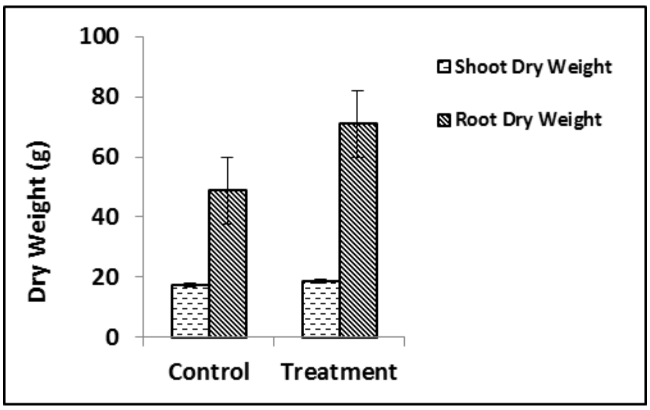

Figure 2: Dry biomass at the end of the experiment

4. DISCUSSION

Removal efficiencies calculated according to the equation (1) shows considerable removal efficiencies for BOD, COD and TN under BOD loads of $5g/m^2d$,$20g/m^2d$, $48g/m^2d$ and $186g/m^2d$. BOD removal efficiency has ranged from 30%-100% under applied BOD loading rates. A significant reduction of BOD removal efficiency has been obtained under $20g/m^2d$ BOD loading rate. This could be due to the way of application of wastewater [9]. According to the visual observations a slight mixing up of inlet and outlet's previously saturated wastewater was noticed during that loading. It was fixed for latter loadings. Further according to Table 03 there are no evidences to show a significant correlation between the BOD loads versus removal efficiencies of respective parameters. Accordingly there is no any pattern of removal efficiencies of respective parameters with the increment of BOD load under same Hydraulic Retention Time (HRT). Further Table 03 shows no significant correlation for BOD loading rate versus TP removal efficiencies and TN removal efficiencies. These variable trends in TP and TN removal efficiencies could be probably due to different removal mechanisms related to nitrogen and phosphorous cycles [10].

Macrophyte growth could also have implications for the removal of nutrient contaminants and uptake of nutrients [11]. Macrophytes provide the attachment sites for microbes to grow in and accumulating nutrients as biomass of plants [12]. Though similar number of plants / shoots was planted initially in both units it has remarkably increased in treatment unit than in the control. That may be possibly due to enhanced nutrient uptake by plants with the addition of dairy wastewater [13] and deficit of nitrogen in control unit [14]. On contrary to this observation, according to the analysis of variance of growth parameters there are no evidences to suggest that plant growth parameters in treatment are higher than that of the control group as depicted in the Table 05. Moreover the Figure 2 depicts that the above ground shoot biomass and below ground root biomass of both control and treatment unit at the end of the experiment. As per the Figure 02 the root dry weight of *Schoenoplectus grossus* is high in the treatment unit yet the above ground shoot biomass is more or less same in both units. This implies that the application of dairy wastewater has affected the increment of root biomass up to some extent. This might be due to nutrient supply with the application of dairy wastewater in to treatment group [15].

5. CONCLUSION

This type of pilot scale SSHF CWs planted with *Schoenoplectus grossus* showed to be effective in removal of BOD, COD, TN and TP in dairy wastewater under studied BOD loading rates. It was also observed that macrophyte density in the treatment unit has remarkably increased in the treatment unit indicating the uptake and accumulation of nutrients as biomass of plants. It can be concluded that *Schoenoplectus grossus* and its rhyzhosphere microbes has contributed up to some extend for the degradation of nutrients in dairy wastewater.

6. ACKNOWLEDGEMENT

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7. RECOMMENDATIONS

It should be strongly noted that this study had been conducted as a trial feasibility study in order to determine the applicability of SSHF CW for treatment of nutrients in dairy wastewater. It is stringently required to follow this methodology in a more scientific base during further studies.

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