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PHYTO-REMEDIATION OF DAIRY-WASTE WATER USING CONSTRUCTED WETLAND

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ABSTRACT

The search for cost-effective and eco-friendly ways to control water pollution has led to renewed interest in constructed wetlands. The constructed wetland studied herewith consisted of a basin or channel with a barrier to prevent seepage and with beds filled with a suitable depth of porous media. The media also supports the root structure of vegetation. Thus a constructed wetland was made to mimic the function of a natural wetland, and allowed to mature naturally for 12 days, planted with Typha species to treat diary-wastewater. The treatment resulted in significant reduction of BOD (73%), solids (including suspended, dissolved & volatile solids (75-83%) and phosphorus (75.7%), with moderate improvement in COD and ammonical nitrogen (about 26% in each of these cases). The plants used for phyto-remediation are found to show significant growth with regard to height (71-100%), number of leaves per plant (80-100%) and root-length(57-65%). growth was also observed.

KEY WORDS: Constructed-Wetland, Diary-Wastewater, *Typha latifolia*, Phyto-remediation

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INTRODUCTION

India has the largest livestock population in the world. It has 57 percent of the world's buffalo population and 16 percent of the cattle population. The dairy industry is a well established industry and India is known for "Operation flood" also referred as "White Revolution". The generation of wastewater is due to washing of equipments, milk spillage, other milk products waste, wash-down of yard area containing urine and manure, detergents, spilled milk, and can have adverse effect on environment due to high BOD_5, COD, TSS and nutrients such as phosphorus and nitrogen, which cause eutrophication. For the treatment of dairy wastewater, conventional plants are normally used but they cause numerous problems which are tedious and not cost effective. In fact, during flood season the washout of the diary wastewater causes a sudden local drop in the dissolved oxygen level of the river water; consequently the river suffers from a great damage demonstrated normally by mass fish kill. The waste also has an adverse effect on the agricultural productivity of the adjacent land.[1,2]

For low cost wastewater treatment, constructed wetlands are beneficial. Constructed wetlands are engineered systems that have been designed to employ natural processes including vegetation, soil, and microbial activity to treat contaminated water.[3] Constructed wetlands are small artificial wastewater treatment systems consisting of one or more shallow treatment cells, with herbaceous vegetation that flourish in saturated or flooded cells. Because of inherent possession of the merits of low-cost. low-maintenance, eco-friendliness, and capability of removing various pollutants including heavy metals, nutrients, organic matters, and micro-pollutants. [4-6]

Recent studies of diary water management using constructed wetland showed promising success in Ontario and Ireland, with regard to organics and other nutriants. [7,8] The present study is to see the compatibility of the system in ambient condition for a tropical country like India. Besides the purpose for and maintenance of cattle in India varies widely so also the types of indigenous aquatic weeds. Because of high cattle population, agrarian nature, deep cultural linkage of cow to ethos and mindset of the population, the present work seem to be crucial, not only for India, also for other similar developing nations, with equatorial/tropical set up; which is likely to be different from colder regions.[9,10]

There are two basic types of constructed wetlands, Free Water Surface constructed wetlands (FWS) and Vegetated Submerged Bed constructed wetlands (VSB). FWS wetlands have a combination of open water areas with some floating vegetation as well as emergent plants rooted in the soil bottom.VSB constructed wetlands, also known as subsurface flow wetlands, consist of gravel and soil beds planted with wetland vegetation. These systems have many of the same features of the FWS but are distinguished by their subsurface hydraulic gradient.[11,12]

MATERIALS AND METHODS

(i) Study Area

This work is carried out in SRM University, located in SRM Nagar of Potheri village (12^0 9′ N to 12^0 49′ N and 80^0 2′ E to 80^0 3′ E), which is one of the villages of Kancheepuram district , Tamil Nadu, India. It is situated near NH 45, about 40 km away from Chennai city.

(ii) Collection and Characterization of dairy wastewater

The sample was taken from private Dairy firm, in Chennai, used in the study containing high COD, TSS and TDS. It was necessary to reduce the TDS before sending into the wetland unit to avoid clogging the soil pores and reduce the treatment efficiency. The wastewater was diluted to various proportion and based on the data obtained a regression was carried out to evaluate the requirement of dilution so as to bring to the BIS-standard (Table 1), so assess the optimum dilution for constructed wetland study. Based on this study, the minimum dilution required to bring any parameter to acceptable limit was taken to be the desired dilution, which was 1:10 (for pH).

Table 1
Characteristics of raw and diluted sample

Sl. No	Parameters	Raw sample	1:10 Dilution Sample	1:40 Dilution Sample	Standard values* (mg/l)	Reqd. Dilution (theoretical) for acceptance** (R^2)
1.	pH	10	9.54	8.32	**5.5 – 9**	**1:10 (1.00)**
2.	BOD	1028	95	54	**30**	**1:45 (0.66)**
3.	COD	421	365	305	**250**	**1:61 (0.95)**
4.	Total Solids	3811	583	474	**120**	**1:67 (0.57)**
5.	Total Suspended Solids	1880	261	156	**30**	**1:68 (0.67)**
6.	Total Dissolved Solids	1931	376	176	**120**	**1:44 (0.78)**
7.	Total Volatile Solids	2591	368	145	**90**	**1:44 (0.78)**
8.	Ammonical Nitrogen	94	76	64	**50**	**1:64 (0.89)**
9.	Phosphate	9.89	2.14	0.87	**0.4**	**1:52 (0.83)**

**** Bureau of Indian Standards (Environmental Protection Rules, 1989)***
***** Based on regression assuming exponential trend***

(iii) Construction of Constructed wetland pilot unit
Inlet zone :

The primary criterion for design of inlet structure was discharge which was expected to be uniform along the entire width in order to prevent short circuiting (Figure 1). A 25 liter container was used to provide a continuous flow of wastewater through the inlet.

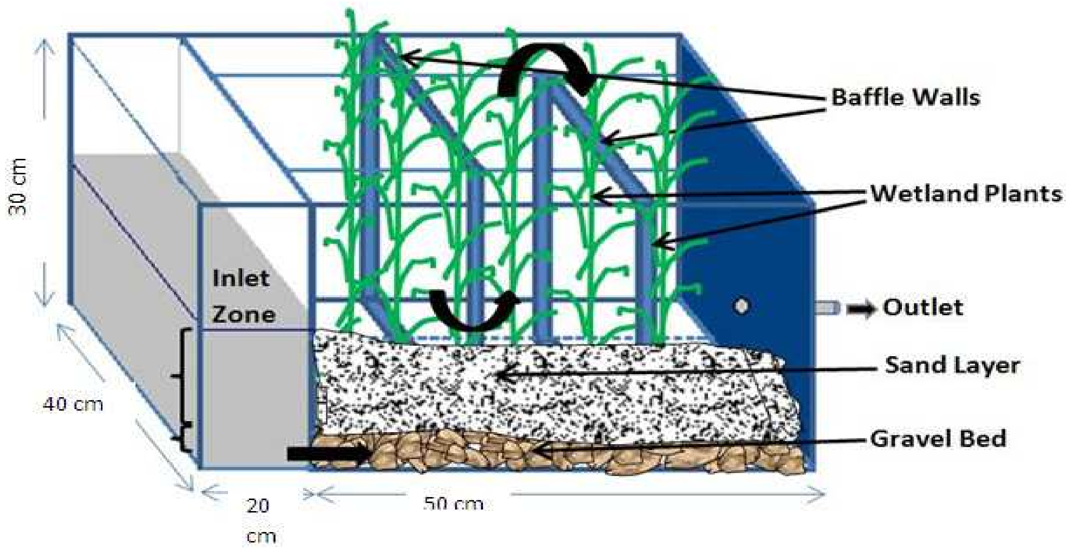

Figure 1
The Constructed Wetland used for the Study

Wetland cell :
The pilot wetland unit consisted of a PVC container of length, width and depth of 70 cm, 40 cm and 30 cm, respectively (Figure 1)

Wetland media :
The system was built with slight inclination of 1-2% between inlet and outlet zone. The media consist of a gravel bed underlain by an impermeable layer of filters.(Figure 1) Bed was filled to height of 7 cm with gravel of diameter 10-30 mm followed by a 7 cm thick top layer of sand (2 mm diameter). The portion of the wetland unit is filled with sandy clay soil to support vegetation. The media-characteristics are presented in Table 2

Table 2
Media characteristics

S.No.	Type	Effective Size (D_{10}) mm	Porosity (n) %	Hydraulic Conductivity (Ks $m^3/m^2/d$)
1.	Coarse sand	2	32	1000
2.	Medium gravel	32	40	10000
3.	Fine gravel	16	38	7500

Vegetation :
Typha latifolia, a local wetland species, was used in the study. The plants were collected from a nearby lake and planted in the wetland unit. They were used to increase the residence time of water by reducing velocity so as to increase sedimentation of the suspended particles as well as to add oxygen and provide a physical site for microbial bioremediation. The plants had been used to remove suspended solids, nutrients, heavy metals, toxic organic compounds and bacteria from acid mine drainage, agricultural landfill and urban storm water runoff.

Outlet zone :
Outlet zone is designed to allow variations in the level of water discharge.

RESULTS AND DISCUSSION

(i) Wastewater Remediation:

Constructed wetland was designed and the prototype model was constructed based on the standard design criteria of EPA and the same is modified according to Indian conditions. [13]

As per the APHA manual the samples were analyzed for pH , BOD, COD, Total Solids(TS), Total suspended solids(TSS), Total Dissolved solids (TDS) ,Total Volatile solids(TVS), Available Nitrogen(AN) and Phosphorous(p) were analyzed and the results were presented in Tables 1 and their remediation in Table 3..

Table 3
Variations of parameters with contact time

Days → Parameters	Day- 0	Day- 1	Day- 4	Day- 8	Day- 12
pH (% reduction)	9.54 (0.0)	9.3 (2.5)	8.2 (14)	7.6 (20.3)	7.4 (22.4)
BOD mg/l (% reduction)	95 (0.0)	46 (51.5)	34 (64.2)	29 (69.4)	25 (73.6)
COD mg/l (% reduction)	365 (0.0)	348 (4.65)	310 (15.06)	285 (21.9)	270 (26)
TS mg/l (% reduction)	583 (0.0)	172 (70.4)	148 (75.9)	136 (76.6)	113 (80.6)
TSS mg/l (% reduction)	261 (0.0)	67 (74.3)	60 (77)	51 (80.4)	42 (83.9)
TDS mg/l (% reduction)	376 (0.0)	120 (68.1)	114 (69.6)	105 (72)	94 (75)
TVS mg/l (% reduction)	368 (0.0)	182 (50.5)	118 (67.93)	98 (73.3)	89 (75.8)
AN mg/l (% reduction)	76 (0.0)	72 (5.26)	64 (15.7)	60 (21)	56 (26.3)
P mg/l (% reduction)	2.14 (0.0)	1.84 (14)	1.13 (47.2)	0.89 (58.4)	0.52 (75.7)

As presented in the Figure 2 to Figure 10 (& Table 3) we find there is distinct reduction of all the parameters considered. From the observation table and bar charts, it is very clear that the influent used is treated and results can be seen in the effluent after 1 day Contact Time (CT), the pH is found to reduce by 2.5%, BOD & COD is reduced by 51.5% and 4.65% respectively, which clearly implies that the constructed wetland is able to minimize the BOD & COD content from the dairy wastewater. In a similar manner the Total Solids (TS), Total Suspended Solids (TSS), Total Dissolved Solids (TDS) & Total Volatile Solids (TVS) are reduced by 70.4%, 74.3%, 68.1%, & 50.5% respectively which indicates that the lab scale prototype model of constructed wetland seems to be a very good setup for the removal of solid content from the dairy wastewater. The chemicals like Ammonical Nitrogen (AN) and Phosphorus (P) present in the dairy wastewater reduces considerably by 10% & 14% respectively.

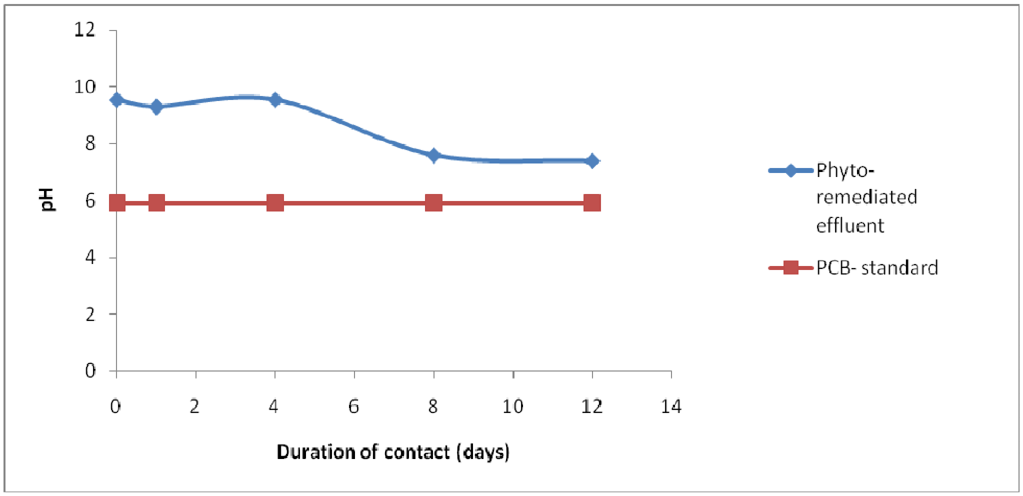

Figure 2
Change in pH due to Typha latifolia

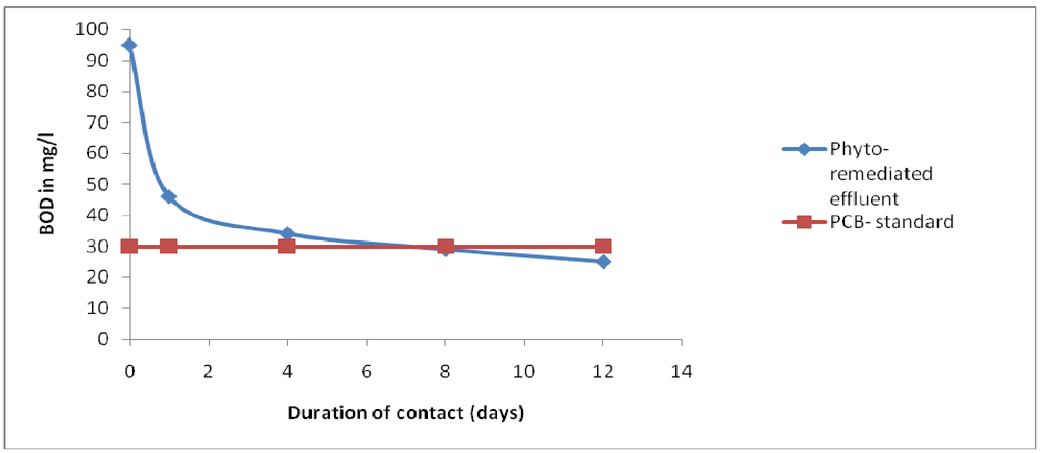

Figure 3
Change in BOD due to Typha latifolia

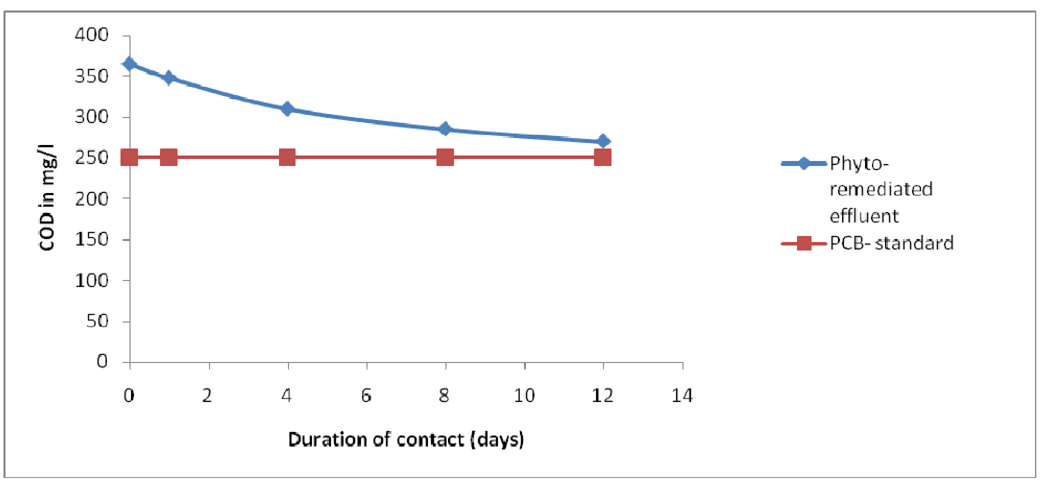

Figure 4
Change in COD due to Typha latifolia

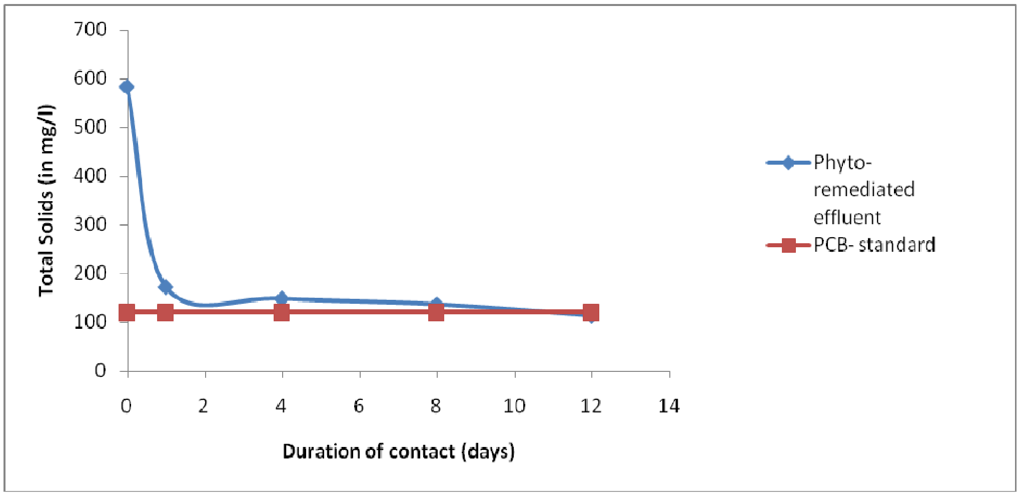

Figure 5
Change in Total Solids due to Typha latifolia

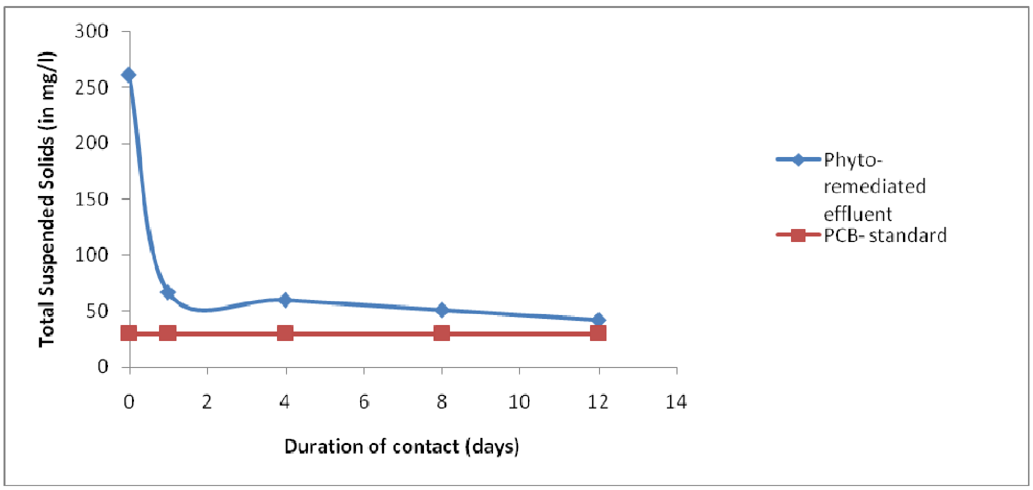

Figure 6
Change in Total Suspended Solids due to Typha latifolia

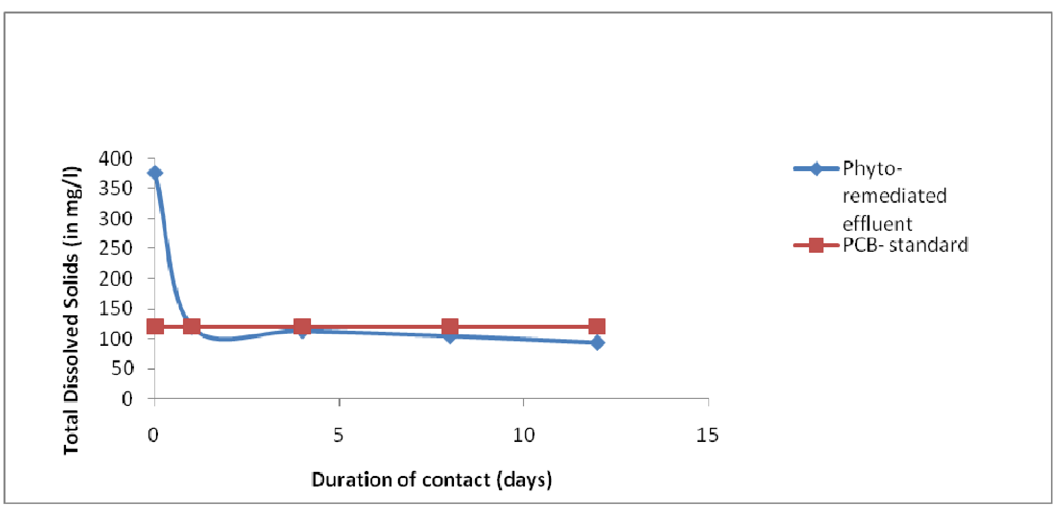

Figure 7
Change in Total Dissolved Solids due to Typha latifolia

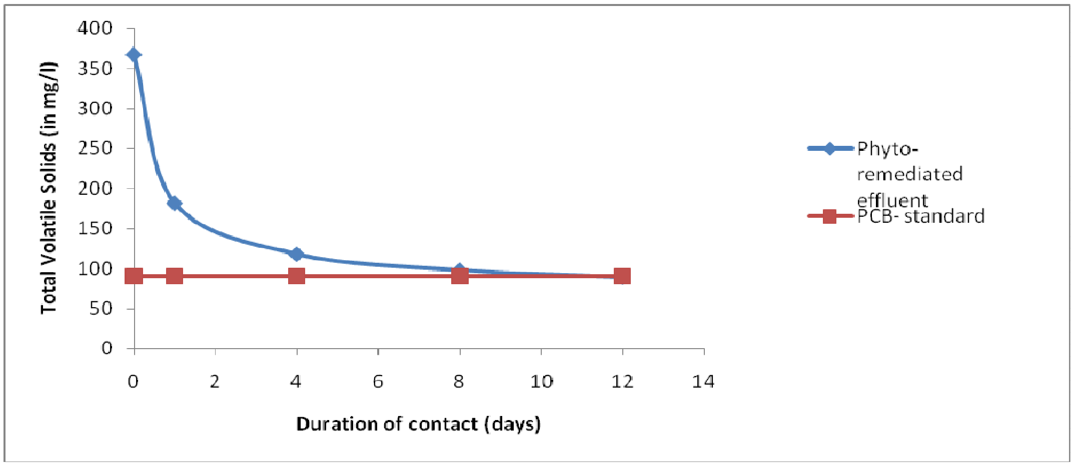

Figure 8
Change in Total Volatile Solids due to Typha latifolia

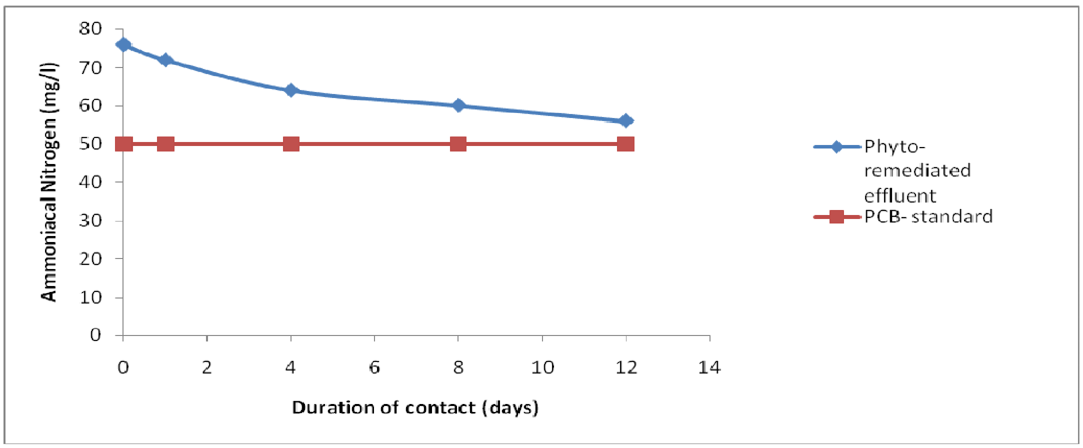

Figure 9
Change in Ammonical Nitrogen due to Typha latifolia

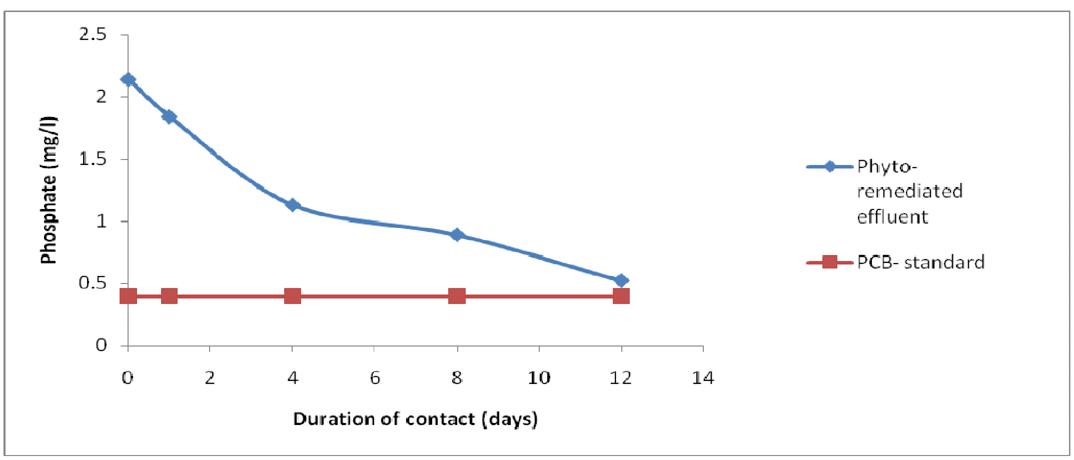

Figure 10
Change in Phosphate due to Typha latifolia

When the Contact Time (CT) is increased i.e. after 4 day CT, pH is found to have lowered, but the reduction in BOD & COD increases to 64.2% and 15.06%. TSS & TDS removal is increased to 77% & 69.6% respectively, and a good increase of 67.93% in the removal of TVS is found in the 4th day CT which is nearly 25% more than the removal in 1 day CT. The chemical removal of AN & P are also increased to 15.7% and 47.2%, which shows that in the 4 day CT, the mechanism of plant and soil uptake of chemicals is working more efficiently.

When the Contact Time (CT) is further increased to 12 days, the pH reduces by 22.4% and there is high reduction in all other parameters especially Total Suspended Solids showing 83.9% and BOD showing 73.6% reduction. The results clearly show that the reduction in chemical parameter of waste water is more obvious proving the efficiency of mechanism. It is also evident from the T-test that the results are extremely significant

(ii) Plant growth Studies :

The change in growth of the plants as a result of wastewater feed in the constructed wetland are presented in Table-4. Here, we see height and leaf number shows encouraging growth (70-100%),followed by root-length (57-65%) and finally, plant numbers (33%).

Table 4
Plant growth analysis

Growth Status → Treatment Status		No. of plants	Height of plant (cm)	Width of stem (cm)	Average No. of leaves/plant	Colour of leaf	Root length (cm)
STUDY ONE	Before treatment	12	5	0.5	3	Green	2
	After treatment	16	10	0.6	6	Light green	3.3
	Improve in yield (%)	33	100	20	100	---	65
STUDY TWO	Before treatment	12	7	0.6	5	Green	3
	After treatment	16	12	0.7	9	Light green	4.7
	Improve in yield (%)	33	71	16.6	80	---	57

The growth seems to be more preferred than reproduction. Since the vegetation in a wetland provides a substrate (roots, stems, and leaves) upon which a community of microorganisms (known as the periphyton) can grow as they break down organic materials. In fact, the periphyton and natural chemical processes are responsible for approximately 90 percent of pollutant removal and waste breakdown and the plant to about seven to ten percent of pollutants, which also act as a carbon source for the microbes when they decay.[14] Thus, the Phragmites was left to grow under favourable condition until it was stabilized in the set-up. It was only after achieving stable growth, the wastewater was allowed into the inlet of the proto type. The growth of the plant before and after treatment with waste water was monitored closely.[15]

It is evident from the study that dairy wastewater treatment using Constructed Wetlands enhances the growth of the plants ,along with simultaneous improvement in water quality. There is a slight colour change in the leaves after the treatment with dairy water, but still there has been continuous growth in the root, which may be due to growth of Phragmites. The overall growth of the plant in terms of its height is good even after the inlet of dairy waste water. It is found that the soil characteristics before and after treatment without the plant cultivation increases the nutrition content in soil. But after treatment with cultivated wetland, we are able to maintain the nutrition content within the standard levels. Such findings are also in accordance with similar studies elsewhere.[14]

CONCLUSION

Constructed wetlands have been used extensively to treat several types of waste water and runoff. The present study reveals the potential of treatment of dairy effluent (rich in BOD, COD, total solids, total dissolved solids, total suspended solids, nitrogen and phosphorus), using lab scale model of constructed wetlands (comprising of indigenous plant species). The reduction of organics are found to be more than 70% in 12 days, without any chemical treatment with plant growth more than 70%.The advantage of this system is that it can be used where land is available, and it blends with nature. Even a small-scale treatment system will be enough to prevent the contamination of the natural water sources. Studies need to be carried out with grasses which can be used to treat the diary wastewater and also used for the cattle-feed in turn.

REFERENCES

1. Raudiansky, S. The Covenant of the Wild. New York: William Morrow and Company, Inc, 1992, pp.10-50.
2. Khayat Maesoon N., Some problems associated with brewery and dairy water discharges, Environment International, 12(5): 563–569, (1986).
3. Zhang Honggang, Cui Baoshan, Hong Jianming and Zhang Kejiang, Synergism of natural and constructed wetlands in Beijing, China, Ecological Engineering, 37(2): 128-138, (2011).
4. Babatunde A.O., Zhao Y.Q., O'Neill M. and O'Sullivan B., Constructed wetlands for environmental pollution control: A review of developments, research and practice in Ireland, Environment International, 34(1) : 116-126 (2008).
5. Vymazal J., The use constructed wetlands with horizontal sub-surface flow for various types of wastewater, Ecological Engineering, 35(1): 1-17, (2009).
6. Yeh T.Y., Chou C.C. and Pan C.T. Heavy metal removal within pilot-scale constructed wetlands receiving river water contaminated by confined swine operations, Desalination, 249(1): 368-373, (2009).
7. Dunne E.J. , Culleton N., O'Donovan G., Harrington R and Olsen A.E., An integrated constructed wetland to treat contaminants and nutrients from dairy farmyard dirty water, Ecological Engineering, 24(3): 219-232, (2005).
8. Gottschall N, Boutin C. and Crolla A., Kinsley C. and Champagne P, The role of plants in the removal of nutrients at a constructed wetland treating agricultural (dairy) wastewater, Ontario, Canada Ecological Engineering, 29 (2): 154-163, (2007).
9. Kivaisi Amelia K, The potential for constructed wetlands for wastewater treatment and reuse in developing countries: a review; Ecological Engineering, 16(4): 545-560, (2001).
10. Muñoz Pete, Drizo Aleksandra and Hession W. Cully, Flow patterns of dairy wastewater constructed wetlands in a cold climate , Water Research, 40(17) : 3209-3218, (2006).
11. Yalcuk Arda and Ugurlu Aysenur, Comparison of horizontal and vertical constructed wetland systems for landfill leachate treatment, Bioresource Technology, 100(9): 2521-2526, (2009).
12. Buchberger Steven G. and Shaw George B., An approach toward rational design of constructed wetlands for wastewater treatment, Ecological Engineering, 4 (4) : 249-275, (1995).
13. EPA Design Manual – Constructed wetlands and aquatic plant system for Municipal Waste water Treatment.EPA 625/11-88/022, (1988).

14. Stottmeister U., Wießner A. ; Kuschk P., Kappelmeyer U., Ka¨stner M., Bederski O., Mu¨ller, R.A.and Moormann H.. Effects of plants and microorganisms in constructed wetlands for wastewater treatment; Biotechnology Advances 22(1-2): 93–117,(2003).

15. Vymazal Jan and Lenka Krőpfelová,, Growth of Phragmites australis and Phalaris arundinacea in constructed wetlands for wastewater treatment in the Czech Republic, Ecological Engineering, 25 (5) : 606-621, (2005).