Evaluation of a Pilot-Scale SHEFROL Unit Set Up for Rapid, Inexpensive and Clean-Green Treatment of Greywater

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1 Introduction

1.1 The SHEFROL® Technology

S. A. Abbasi and co-workers have patented and trademarked SHEFROL® bioreactor [1–3] wherein the acronym SHEFROL® denotes the unique sheet-flow-root-level hydrology of the reactor. As detailed elsewhere [3–11], SHEFROL® utilizes freely and abundantly available short-statured plants—which can be aquatic, amphibious, or terrestrial—in specially designed channels stocked with one or other species of these plants. Wastewater is made to flow through these channels in the form of a sheet thick enough to cover only the roots of the plants. The dimensions are optimized to ensure maximum contact between wastewater and plant roots. This facilitates natural agitation and oxygenation as the wastewater gets turbulent while passes though the plant roots in the SHEFROL® channels. Due to a variety of mechanisms, detailed in the references mentioned elsewhere [4–11], very strong secondary treatment, together with significant primary and tertiary treatment is achieved within a single process step [12, 13].

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1.2 The Present Work

The present work describes exploration of the efficacy of SHEFROL® at field scale in treating greywater discharged by three hostels of Pondicherry University. Of special focus was the assessment of the ability of the SHEFROL® to handle widely varying characteristics as well as quantities of inflows because water use in the hostels went by spurts of highs followed by the lows.

2 Installation of the SHEFROL® Unit

The pattern of wastewater generation during the morning, afternoon, and evening, at 10:30, 14:00, and 17:30 h, was studied for a continuous period of 10 days (Table 1). It is seen that the flows ranged from 8 L per minute (LPM) to 13 LPM, varying by 61%. The flows were expectedly the maximum in the morning and minimum in the afternoon. Based on these flow-rates, as also making allowance for monthly variations, the SHEFROL® unit was sized to handle upto 14,000 litres per day of greywater.

The system lay-out is as shown in Fig. 1. After it was commissioned and in operation, the unit had the appearance as in Fig. 2. It consisted of one primary collection tank (A) and four channels (B, C, D, E)—each of width 0.21 m, depth 0.3 m, and length 5.5 m. The channels B and C led to a collection tank (F) while the channels D and E fed the tank G. A polishing channel each (H, I) was attached to these tanks.

In order to demonstrate that the system can be efficient and robust even if installed with minimum use of materials, and even by persons not trained in civil construction, the reactor channels and tanks were created by measured digging the soil (Fig. 3).

Table 1 Pattern of wastewater inflows into SHEFROL-II®

Day	10:30 h	14:004	17:30 h	Average
Friday	10.0	9.0	10.0	9.6
Saturday	11.0	10.0	10.0	10.3
Sunday	12.0	8.0	10.0	10.0
Monday	13.0	9.0	10.0	10.6
Tuesday	9.0	8.0	8.0	8.3
Wednesday	11.0	9.0	10.0	10.0
Thursday	12.0	8.0	8.0	9.3
Friday	12.0	9.0	9.0	10.0
Saturday	11.0	9.0	9.0	9.6
Sunday	10.0	8.0	9.0	9.0

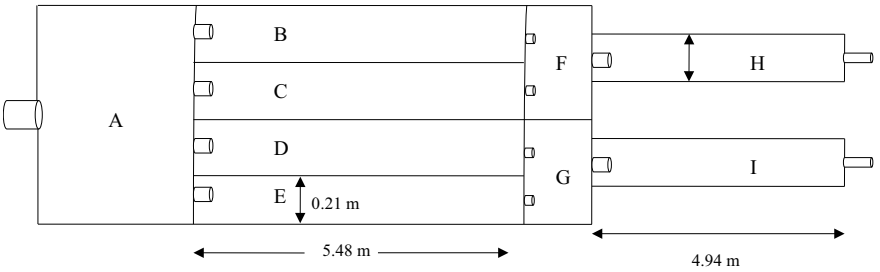

Fig. 1 Schematic of the SHEFROL-II® unit

The resultant shape was covered with high density polyethylene (HDPE) sheets to ensure bank stability as also to prevent percolation of water/wastewater.

The unit was started by allowing greywater to move through it while its channels B, C, D, and E were stocked with *M. quadrifolia, E. prostrata, A. sessilis*, and *M. quadrifolia,* respectively. The channels of the publishing component H and I were stocked with *E. crassipes* and *A. sessilis*, respectively (Fig. 2). The plants multiplied quickly and soon covered their respective tank/channel.

The system performance was monitored by drawing influent and effluent COD samples at 14.00 h every day and analysing them. This was done for a continuous period of 80 days. As already established earlier [4–11], COD serves as an all-round indicator of SHEFROL® performance and all other pollutants get attenuated in proportion as found in numerous cases earlier.

3 Results and Discussion

The results of continuous monitoring of the unit's performance over are summarized in Fig. 4.

As may be seen > 30% treatment occurred on the very first day which rose to > 55% by the tenth day. All channels came close to peak performance—as reflected in the extent of COD removal—in about 20 days and attained steady state in about 40 days. Thus the unit took very little time to start giving significant treatment and attained its peak by the 40th day. Both the *M. quadrifolia* channels achieved mean COD reduction of about 84% at the steady state. The steady state performance of *E. prostrata* and *A. sessilis* hovered around 75% (Fig. 4). The effluent of these channels was further treated in the polishing channels to CODs of 5–9 mg/L.

Even as the rate of inflow into the SHEFROL® varied over the days as well as across each day Fig. 5, showing zig-zag pattern, this variation did not effect the unit's performance or the reactor's stability. The system output remained steady. In other words, the system was able to handle the flow variations that occur daily as well as diurnally in greywater generation and could tolerate shock loads as well, without

Fig. 2 The SHEFROL® unit in operation

jeopardising the quality of the system output. These attributes reflect the sturdity and sustainability of the SHEFROL technology [14–17].

4 Pest Attack in SHEFROL® and Its Management

No pest attack was encountered during the period of about a year when SHEFROL®-II was in operation. In some SHEFROL® units established elsewhere, occasional pest

Fig. 3 Making of SHEFROL® channels and tanks excavating soil

attacks were encountered but they could always be easily controlled by (a) replacing damaged plants and (b) spraying of neem oil.

Since water is constantly moving in SHEFROL units, there is no mosquito breeding possible.

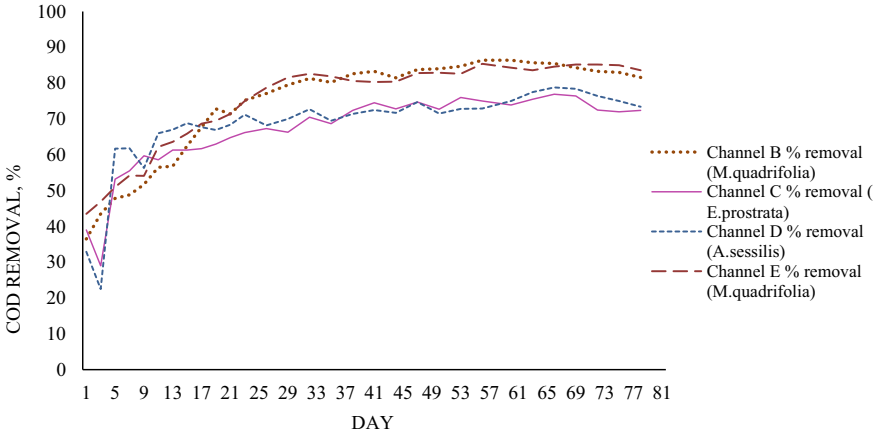

Fig. 4 Removal of COD (%) in the different channels of SHEFROL

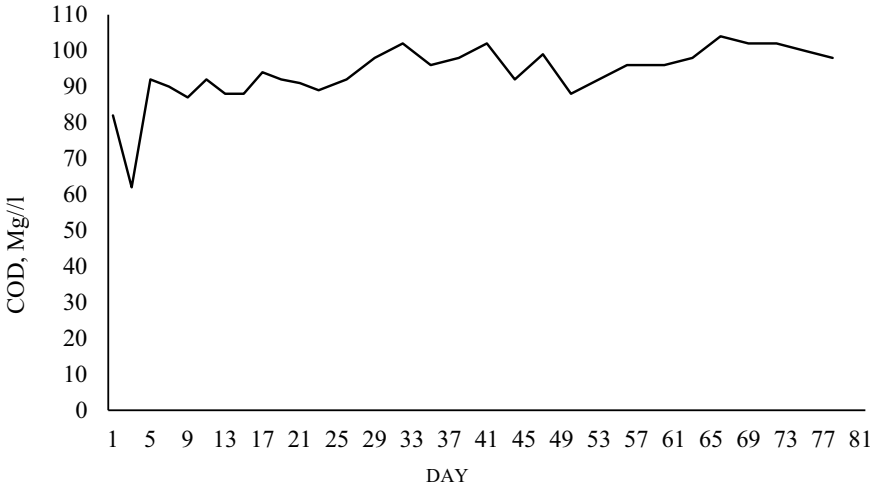

Fig. 5 COD of the greywater entering SHEFROL® unit

5 Summary and Conclusion

A 14,000 L per day pilot plant was set up on the basis of SHEFROL® technology recently patented and trademarked by S. A. Abbasi and co-workers. This paper demonstrates the ease and inexpensiveness associated with this technology as well as its efficiency and robustness. The system was quick to commission and start and soon began to provide COD removals of the order of 80 ± 5 mg/L. It was able to withstand fluctuations in the inflows on daily as well as diurnal basis.

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