Treatment of Dairy Wastewater Using Up flow Anaerobic Filter

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Abstract - The present study is related to the possibility of using Up flow Anaerobic Filter reactor (UAF) applied to the treatment of dairy wastewater and studies the effect of hydraulic retention time(HRT) (8,12,16 and 24 h) and different loading rates on the performance of the reactors. The dairy wastewater is characterized by high biological oxygen demand and chemical oxygen demand requiring systematic treatment prior to disposal.

Keywords — Up flow anaerobic filter, Hydraulic Retention time, Chemical Oxygen Demand, Biochemical Oxygen Demand, Total Solids.

I. INTRODUCTION

Ever increasing industrialization and rapid urbanization have considerably increased the rate of water pollution. The dwindling supplies of natural resources of water have made this a serious constrain for industrial growth and for a reasonable standard of urban living. The environmental protection agencies have imposed more stringent regulatory prohibitions and they have started more strict vigil along with some non-governmental organization to protect the environment. This has made the wastewater treatment more expensive and to comply with the discharge quality standard itself which is becoming a huge burden for the industries. Every industrial process is a potential source of pollution and requires a specific treatment for the wastes produced. The introduction of waste treatment increases the plant cost therefore any attempt to improve their efficiency is valuable. This applies to all kinds of industries but it is particularly important for low or medium added value industries with difficult wastes like food industries.

II. MATERIALS AND METHODS

A. Experimental Setup of Anaerobic Filters

Laboratory scale continuous Up flow Anaerobic Filter (UAF) reactor made of polyvinyl chloride (PVC) was used in the present study. The reactor had an internal diameter of 10 cm and height of 75 cm resulting in total volume of 5.890 litter and bed volume of 3.53liter. The top of the reactor was tightly closed to maintain the stringent anaerobic condition. A gas head space of 15 cm was provided on the top of the reactor. The configuration are depicted in table -1

Table -1 Construction Detail of Up flow Anaerobic Filter

S.NO.	PARAMETER	SPECIFICATION
1.	Reactor Type	Cylindrical
2.	Diameter	10 cm
3.	Total Height	75 cm
4.	Total Volume	5.890 L
5.	Bed Volume	3.53 L
6.	No. of. Sampling Ports	5

B. Components of UAF Reactor

- Feed tank
- Feed distribution system
- Packing media
- Gas collector
- Sampling ports

C. Feed Inlet and Outlet Arrangements

The reactor was fed with substrate from the feed tank to the inlet pipe provided at the bottom of the reactor. The diameter of the feed inlet pipe is 5mm provided upside down. The effluent pipe of diameter 5mm is provided along the side of the UAF reactor about 15cm from the top of the reactor. Constant flow rate in the range of 4 ml/min to12 ml/min were maintained with two adjustable stop rings.

D. Sampling Ports

Five sampling ports were installed in the UAF reactor for the purpose of

- Feed distribution
- Effluent collection
- Gas collection

Three sampling ports were installed along the length of the UAF reactor at 22 cm intervals, starting from a height of 10 cm above the reactor bottom. The sampling ports of 5mm internal diameter were made of brass nipples was used. The sampling ports were sealed into the wall of the filter with M.seal to give tightness. In UAF reactor out of three sampling ports one was below the packing media, one was at packing media and the other above the media fill. This was required to ascertain the role of packing material on reactor performance.

Table 2: Initial Characteristics of Dairy Wastewater from Avian.

S.No.	Characteristics	Values
1.	Ph	7.3
2.	Total solids (mg/L)	1120
3.	Total dissolved solids (mg/L)	712
4.	Total volatile solids (mg/L)	1123
5.	Total COD (mg/L)	1560
6.	BOD_5 (mg/L)	1020
7.	Volatile solids(mg/L)	1009
8.	Alkalinity (mg/l as Ca CO_3)	515

E. Support Material

The purpose of packing medium is to retain solids inside the reactor, either by the bio-film formed on the surface of the packing medium or by the retention of solids in the interstices of the medium or below it. The packing media used in the study were pebble stone and aggregate media of round shape which can retain more biomass on surfaces rather than plain surfaces. void if 90% and specific gravity less than 1. The packing media have been designed to occupy from the total depth of the UAF reactor to approximately 80% of the height of the reactor.

Table 3: Initial Characteristics of Synthetic Dairy Wastewater

S.No.	Characteristics	Values
1.	Ph	7.1-7.4
2.	Total solids (mg/L)	1359
3.	Total dissolved solids (mg/L)	720
4.	Total volatile solids (mg/L)	1040
5.	Total COD (mg/L)	1350
6.	BOD_5 (mg/L)	960
7	Volatile solids(mg/L)	988
8.	Alkalinity (mg/l as Ca CO_3)	710

F. Substrate

Dairy wastewater generated from AAVIN plant Perur Coimbatore Tamil Nadu was used as the substrate. Initially the reactor was fed with the wastewater collected from the dairy industry (AAVIN). From the third week onwards the feed was prepared by dilution of milk with tap water and addition of alkalinity and nutrients (H Naiads et.al 2005), dilution made with respect to the initial characteristics of the wastewater collected form AAVIN. Characteristics of the wastewater are summarized in Tables 2 and 3.

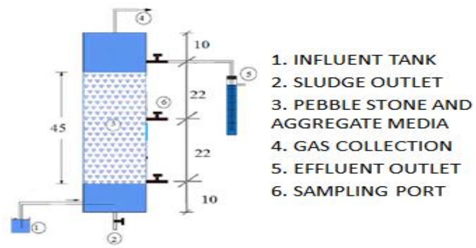

Figure 1: Schematic arrangement of up flow Anaerobic Filter reactor

G. Seeding

Effective microorganisms were used as seed and the reactor was seeded an aerobically with stale cow dunk.

H. Operating Conditions

The wastewater collected from aavinstored in a cold room at 40C to reduce degradation during storage. Room temperature is maintained as an optimum temperature for various operational conditions. Hence methanogenic population is maintained due to tropical and sub-tropical climate. The operating temperature of the reactors was in the mesospheric range (29-35 °C).The operating conditions maintained for the anaerobic filters were as follows:

- pH - 6.8 to 7.2
- Temperature -30 ºC
- HRTs -24, 16, 12 and 8.

I. Biogas Outlet

The biogas outlet was provided at the top of the reactor. A gas headspace of 15 cm was maintained. Biogas produced from the reactor was collected in a gas collection unit.

Figure 2 Gas Collection Jar

(Diameter 8cm, Height 25cm, total volume 1.256L)

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Figure 3: Laboratory Scale Setup of UAF Reactor

Figure 4: Packing Media Present In the UAF Reactor

Pebble stone(20mm) aggregate(20mm)

III. OPERATION OF UAF REACTOR

A. Start Up Phase

The purpose of the start-up of the high rate anaerobic process is to cultivate and to retain high concentration of active biomass in the reactor. The first start-up of an anaerobic process is considered critical as it may require long period of time and may result in the failure of the process. The start-up is affected by factors such as the seed sludge, the mode of process operation, waste water characteristics and environmental factors. This is a time consuming and delicate process, but in case of UAF reactor, startup period is not a time consuming process because of presence of the packing media and the effective microorganisms. This media enhances the growth of microbes and moreover, effective microorganisms have a synergetic effect with the microbes present in the cow dung and hence start-up process consumes less time. This period is considered as base pillar for the development of first macroscopic sludge granules which will shoot up the treatment efficiency of the substrate.

B. Inoculum and Feeding of the Reactor

The inoculums were prepared using cow dung. To begin with, the reactor was seeded with the inoculums- a mixture of cow dung slurry for one week at 24h hydraulic retention time (HRT). This HRT facilitated the build-up of microorganism on the packing medium and at the bottom. Then the reactor was fed with the substrate COD of 1350 mg/L until the steady state is observed for HRT of 36h. After the start-up period the bioreactor was fed with various OLR for different HRT.

C. Treatment Phase

In the operation phase the reactor was operated in continuous mode. UAF reactor was operated for varied HRT with respect to the corresponding OLR. During phase, the reactor was fed with an OLR of 1.35 kg COD/m^3.d and operated for an HRT of 24 h. Similarly during consecutive phases the reactor was operated for HRT 16, 12, 8 h. sampling was done only after steady state has been achieved for change in each HRT.

D. Phase 1

Initially the reactor was fed with OLR of 1.35 kg COD/m^3.d operated for an HRT of 24h with constant flow rate of 3.53 L/d and an inlet COD of 1350 mg/L with an up flow velocity of 0.60 m/s. The above operational condition was maintained in the reactor for four days after steady state has been reached. Samples were collected from the UAF reactor port 1 for the consecutive four days. The reactor attains steady state within 3 days from the start up of phase 1 operation. Further the OLR was increased with the increase in the inlet COD for HRT of 24h.

$$\text{Organic Loading Rate} = \frac{\text{COD (mg/L) x Flow rate (L/d)}}{\text{Volume (L) x 1000}}$$

$$\text{Flow Rate} = \frac{\text{Volume (L)}}{\text{HRT (d)}}$$

E. Phase 2

The reactor was fed with OLR of 2.04 kg COD/m^3.d operated for an HRT of 16h with constant flow rate of 5.348 L/d and an inlet COD of 1350 mg/L with an up flow velocity of 0.98 m/sate reactor attains steady state within 4 days from the start up of phase 2 operation. The above operational condition was maintained in the reactor for four days after steady state has been reached. Samples were collected from the UAF reactor port 1 for the consecutive four days.

F. Phase 3

The reactor was fed with OLR of 2.70 kg COD/m^3.d operated for an HRT of 12h with constant flow rate of 7.06 L/d and an inlet COD of 1350 mg/L with an up flow velocity of 1.20 m/s. The reactor attains steady state within 6 days from the start up of phase 3 operation. The above operational condition was maintained in the reactor for four days after steady state has been reached. Samples were collected from the UAF reactor port 1 for the consecutive four days.

G. Phase 4

The reactor was fed with OLR of 4.08 kg COD/m^3.d operated for an HRT of 8h with constant flow rate of 10.696 L/d and an inlet COD of 1350 mg/with an up flow velocity of 1.80 m/the reactor attains steady state within 9 days from the start up of phase 4 operation. The above operational condition was maintained in the reactor for four days after steady state has been reached. Samples were collected from the UAF reactor port 1 for the consecutive four days.

H. Monitoring of UAF Reactor

Performance of anaerobic filters were monitored by analyzing pH, Total Solids, Total Dissolved solid, Total Suspended Solid, Chemical Oxygen Demand (COD), five-day biochemical oxygen demand (BOD5), These parameters were tested with the effluent Collected from the UAF reactor during each phase.

I. Chemical Analysis

The determination of COD, BOD, Total Solid, Total Dissolved solid, Total Suspended Solid and pH were tested in accordance with the Standard Methods listed for water & wastewater.

IV. RESULTS AND DISCUSSION

A. Work Done

UAF reactor was operated for a period of 130 days. The experimental study was to investigate the performance of UAF reactor at different hydraulic retention times (HRTs). The UAF reactor was operated at a HRT of 24, 16, 12 and 8 hour for the corresponding Organic Loading Rate (OLR) of 1.35, 2.04, 2.70 and 4.08kg COD/m^3.d

B. Start Up Phase of the Reactor

The initial feeding rate was about 2.35 L/d, which corresponds to an HRT of 36h, this gave an initial OLR of 0.89 kg COD/m^3.d with an inlet COD of 1350 mg/L. The initial OLR of 0.89 kg COD/m^3.d was maintained for a period of 38 days in continuous mode to enhance the growth of microbes on the media. The experimental study was started after steady-state reached with chemical oxygen demand (COD) removal efficiency of ±4% variation for three consecutive days. The COD removal efficiency during the start up phase of the reactor maintained for a period of 38 days to achieve the steady state is shown in the table 4.

Table 4: COD Removal % During Start up Phase of UAF Reactor to Achieve Steady State (pebble stone media)

S.No.	**DAY**	**INLET COD (mg/L)**	**OUTLET COD (mg/L)**	**COD removal %**
1.	1	1350	1350	0
2.	2	1350	1132	1.33
3.	4	1350	1327	1.70
4.	10	1350	1028	23.85
5.	13	1350	942	30.22
6.	16	1350	885	34.44
7.	22	1350	742	45.03
8.	27	1350	457	66.14
9.	29	1350	457	66.14
10.	31	1350	314	76.74
11.	34	1350	285	78.88
12.	36	1350	285	78.88
13.	38	1350	285	78.88

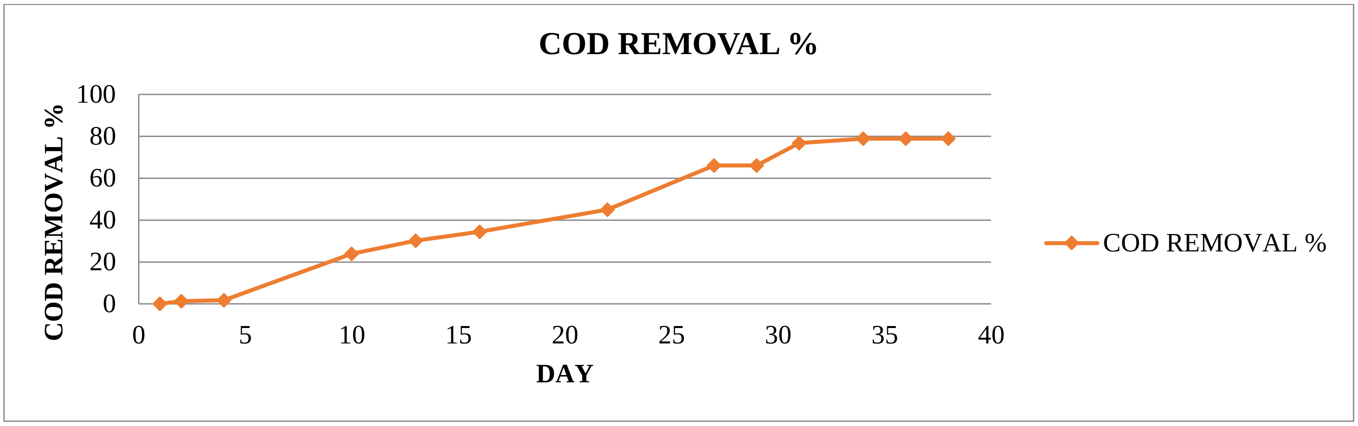


Figure 5: COD Removal% during Steady-State Phase to Achieve Steady-State

Table 5: COD Removal % During Start up Phase of UAF Reactor to Achieve Steady State (Aggregate media)

S.NO	**DAY**	**INLET COD (mg/L)**	**OUT LET COD (mg/L)**	**COD REMOVAL %**
1.	1	1350	1350	0
2.	3	1350	1285	4.81
3.	4	1350	1285	4.81
4.	7	1350	1228	9.03
5.	9	1350	1200	11.11
6.	11	1350	1028	23.85
7.	14	1350	857	36.51
8.	15	1350	657	51.33
9.	17	1350	457	66.14
10.	18	1350	342.85	74.60
11.	21	1350	285.71	78.60
12.	23	1350	285.71	78.60
13.	25	1350	228.57	83.11
14.	28	1350	200	85.18
15.	30	1350	142.85	89.48
16.	32	1350	114.28	91.55
17.	35	1350	114.28	91.55
18.	38	1350	114.28	91.55

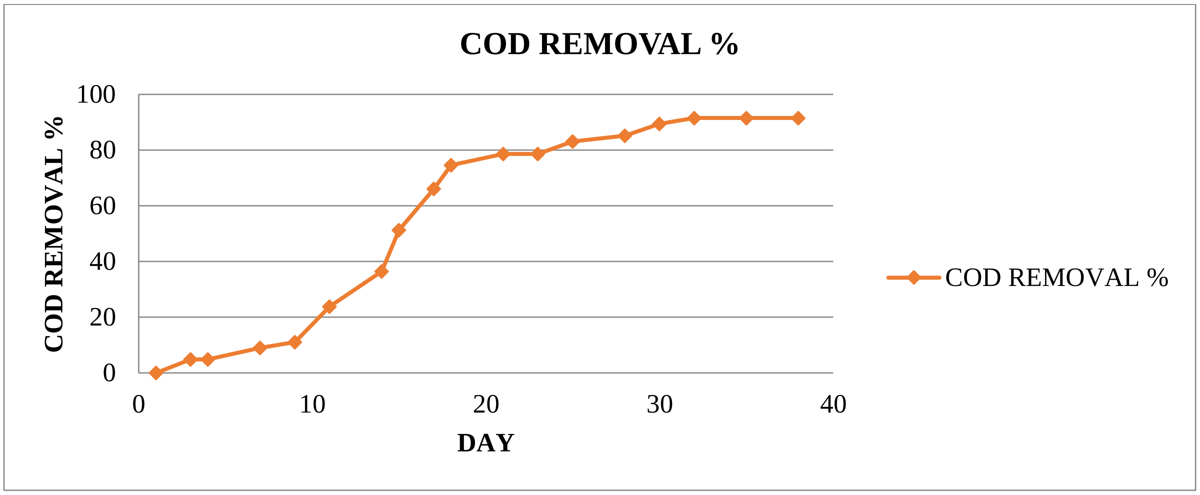


Figure 6: COD Removal% during Steady-State Phase to Achieve Steady-State

C. Ph

The pH is a very important variable in the UAF reactor process. When the pH in the reactor is too low (<6), the consumption of fatty acids gets strongly inhibited. If the pH is too high (>8.0), the bacteria are limited in their growth by the low concentrations of unionized fatty acids. The pH determines the growth of both methanogens and acidogens. So, the pH of the influent in the inlet was maintained between 7.1 and 7.4. The pH of the effluent after granulation was maintained between 5.90 and 6.90. Effluent pH of the UAFs reactor for varied HRT and OLR is shown in the table 6 & 7.

Table 6: Effluent Ph of the UAF Reactor for HRT Controlled At 24, 16, 12 And 8 Hour. (Pebble Stone Media)

S. No.	PARAMETER			EFFLUENT pH		
	SUBSTRATE COD (mg/L)	OLR (kg COD/m³.d)	HRT Hour	DAY 1	DAY 2	DAY3
1.	1350	1.35	24	5.90	6.60	6.30
2.	1350	2.04	16	6.10	6.24	6.10
3.	1350	2.70	12	6.30	6.40	6.45
4.	1350	4.08	8	6.90	6.82	6.52

Table 7: Effluent Ph of the UAF Reactor for HRT Controlled At 24, 16, 12 And 8 Hour. (Aggregate Media)

S.NO	PARAMETER			EFFLUENT Ph		
	SUBSTRATE COD (mg/L)	OLR (kg COD/m³.d)	HRT Hour	DAY 1	DAY 2	DAY 3
1	1350	1.35	24	5.90	6.60	6.30
2	1350	2.04	16	6.10	6.24	6.10
3	1350	2.70	12	6.30	6.40	6.45
4	1350	4.08	8	6.90	6.82	6.52

D. COD Removal Efficiency

The COD removal efficiency depends mainly on OLR and HRT. During the start up period the reactor was fed with an inlet COD of 1350 mg/L and poor removal efficiency of 23% (pebble stone media and aggregate media) was observed after 10 days of start of the reactor. This may be mainly due to the slow microbial growth in the reactor. The COD removal efficiency of 76% (pebble stone media) and 89.48% was reached after 31 days of start up period. Steady state has been achieved with ±4% variation of COD removal efficiency after38 days. This initial period was mentioned as “stabilization period” or “acclimatization period”. This period is considered as more essential for the better development of compact bio granules. The formation of concentrated biomass after start up period can with stand high organic loading. So, after the start up process the reactor was fed with various OLR for varying HRT. The COD removal efficiency for varying OLR and HRT is given below:

Table 8: Pirating Condition and Cod Removal Efficiency during Phase 1 of the Treatment for HRT 24h (Pebble Stone Media)

PARAMETER	**OLR of 1.35 kg COD/m^3.d for HRT of 24h**		
	DAY 1	**DAY2**	**DAY3**
Substrate COD (mg/L)	1350	1350	1350
Effluent COD (mg/L)	314.28	485.71	342.85
COD removal %	76.72	74.60	74.60

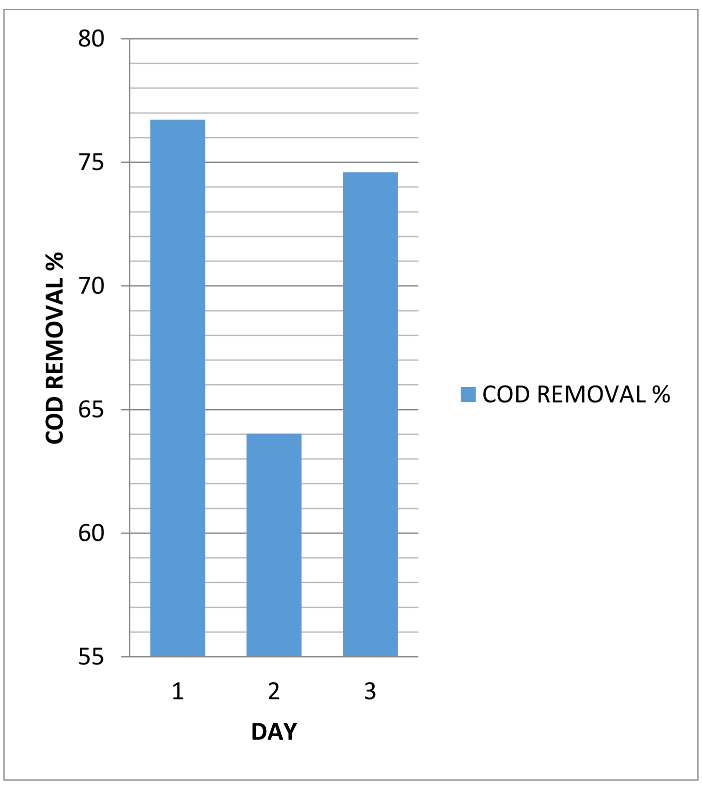
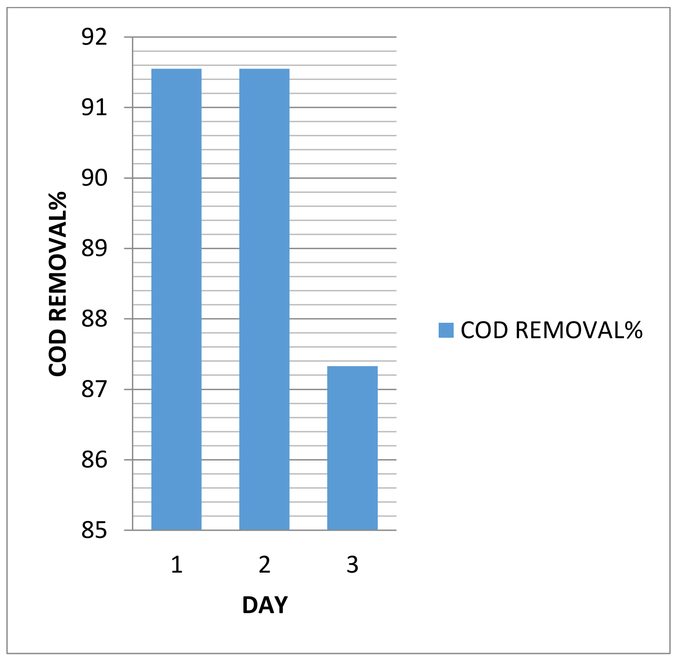


Figure 7: Cod Removal % for HRT 24h

Table 9: Operating Condition and Cod Removal Efficiency during Phase 1 of the Treatment for HRT 24h (Aggregate Media)

PARAMETER	**OLR of 1.35 kg COD/m^3.d for HRT of 24h**		
	DAY 1	**DAY2**	**DAY3**
Substrate COD (mg/L)	1350	1350	1350
Effluent COD (mg/L)	114.28	114.28	171.42
COD removal %	91.55	91.55	87.33



Figture 8: Cod Removal% For Hrt 24h

Maximum COD removal efficiency of 76.72% (PEBBLE STONE MEDIA) and 91.55% (AGGREGATE MEDIA) was achieved at an OLR of 1.35 kg COD/m^3.d for HRT of 24h.The removal efficiency for 8h HRT is about 45.03% and 78.88% due to the loss of biomass during wash out had reduced the COD removal efficiency. During the stepped increase of OLR, COD removal efficiencies were gradually increased. This was in general agreement with COD removal efficiencies were increased with time of operation.(Saravananan*et al.*, 2001). There is only 10% reduction in efficiency between HRT 16h and HRT 12h. The reason for the lower removal efficiency could be due to higher organic loading rate at shorter HRT.

E. BOD_5 Removal Efficiency

The BOD_5 concentration of the influent and the effluent and their removal efficiency operated for varying OLR and HRT is given in the table.

Table 10: Operating Condition and Bode Removal Efficiency during Phase 1 of the Treatment for HRT 24h (Pebble Stone Media)

PARAMETER	HRT of 24h		
	DAY 1	DAY2	DAY3
Substrate BOD (mg/L)	960	960	960
Effluent BOD (mg/L)	224.48	346.93	244.89
BOD removal %	76.61	63.86	74.49

Table 11: Operating Condition and Bode Removal Efficiency during Phase 1 of the Treatment for HRT 24h (Aggregate Media)

PARAMETER	HRT of 24h		
	DAY 1	DAY2	DAY3
Substrate BOD (mg/L)	960	960	960
Effluent BOD (mg/L)	81.62	81.62	122.44
BOD removal %	91.56	91.56	87.29

The maximum BOD removal efficiency of 76.61 % (Pebble Stone Media) and 91.56% (Aggregate Media) was achieved for 24HRT. The COD/BOD ratio was 1.4.

V. CONCLUSION

The result obtained from the present laboratory study reveals that the application of UAF reactor of hybrid type can successfully treat dairy wastewater at mesospheric temperature. From the performance evaluation of UAF reactor the following conclusions were drawn:

- A start-up period of 38 days was required to achieve the steady-state phase with an OLR of 0.89 kg COD/m³d at an HRT of 36h.
- The results show that the anaerobic filter performance at different HRTs in terms of BOD_5 and COD removal did not differ significantly.
- The UAF performed similarly at 24 hours and 16 hours fluctuating HRT in terms of the solids, COD and BOD_5 removal.
- Moreover, effluent quality achieved was very close to minimal standards for discharge of effluents from the dairy industry.
- UAF reactor with low up flow velocity has been feasible for treating dairy wastewaters in warmer climates resulting in lower energy requirements and less sludge production.
- From the result it can be concluded that the anaerobic filter is suited for treatment of high strength wastewaters.

It is evident that the UAF reactor can be effectively used for the treatment of dairy wastewater in developing countries like India, since the system can be designed with relatively short HRT.

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