# Optimization of Biogas Production from Dairy Wastewater using Upflow Anaerobic Filter (UAF) Reactor

**S. Prithiviraj, C. Jodhi**

***Abstract:*** *The present study explores the feasibility of biogas production from dairy wastewater in the UAF reactor with simultaneous wastewater treatment. The study was carried out at different hydraulic retention times (8h, 12h, 16h, 24h). Two different media such as pebble stone media and aggregate media were used as the packed media. The maximum COD removal efficiency of 91.55 % is achieved at the hydraulic retention time of 24 Hours with an organic loading rate of 1.35 kg/m$^3$/d for aggregate media, whereas for pebble stone media a maximum COD removal efficiency of 76.32 % is achieved. Before the start of the experiments, the COD/BOD ratio is fixed to 1.4 with initial COD and BOD of 1350 mg/L and 960 mg/L. So, from the results it is concluded that the Upflow Anaerobic Filter (UAF) Reactor can be used as a one of the best treatment methods for the diary wastewater treatment.*

***Keywords:*** *Biochemical oxygen demand, Chemical Oxygen demand, Dairy Wastewater, Packed media, UAF Reactor.*

## I. INTRODUCTION

Water pollution is an emerging problem in the modern world due to the rapid use of water in industries for manufacturing and other purposes [1]. These pollutions are causing serious issues to the environment and in turn, affect the surface water and groundwater. Even a very less quantity of pollutants say 1 mg/L will also result in degradation of aquatic life in the ecosystem [2]. If these pollutants are not treated properly it will cause adverse effects to the environment and to our ecosystem. Even though the government is taking many initiatives to treat the wastewater, but the present treatment technologies can't completely treat the wastewater generation from industries. Treatment methods are generally classified as physical-chemical and biological methods [3]. Of these different treatment methods, biological methods are having many advantages than physical and chemical methods [4-5]. Since biological methods are cost-effective and by-products can be obtained at the end of the treatment and it will be additional revenue for the treatment and will result in a reduction of cost for the treatment process. Biogas production is one of the best by-products that can be obtained from the wastewater in the anaerobic digestion tank at optimum hydraulic retention time and organic loading rate [6-7]. So nowadays all the treatment is enhanced with the anaerobic digestion tank for the sludge treatment and from these sludges, biogas is produced in a larger amount. Recently from the biogas, it possible to generate electricity also. So, this anaerobic digestion tank will be the economical treatment method for sludge and wastewater treatment. Of the different industries, the dairy industry is one of the fastest emerging industries in all countries due to the dairy products that are used in day to day activities.to meet the demand of the dairy products advancements has been evolved in veterinary science for the milk production Of all the nations, India is one among the top milk producers and dairy products are produced in huge quantity This has created a serious issue to the environment due to the generation of huge quantity of wastewater. It is also estimated that approximately 0.2 to 10 liters of wastewater are generated per liter of milk is processed the primary source for the generation of wastewater is from cleaning and washing of processing plants Dairy industry wastewater are classified into two groups. The first is concerned with high flowrates and second is dealing with small milk transformation units. Due to this highly polluted wastewater, industries are not having the capacity to treat the wastewater and result in a direct discharge into the environment. Biogas can be produced by dark fermentation of the photo fermentation process [8-9]. But biogas production is maximum at thermophilic conditions. [10]. The current investigation deals with the treatment of dairy wastewater in an up-flow anaerobic filter reactor for the biogas production using different media as a packing material.

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## II. MATERILAS AND METHODS

### A. Upflow Anaerobic Filter

Upflow 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 a height of 75 cm resulting in a total volume of 5.890 liters and a bed volume of 3.53 liter. A gas headspace of 15 cm was provided on the top of the reactor. Pebble stone and aggregated stone are used as a media.

A schematic view of the upflow anaerobic filter reactor is shown in Fig. 1.

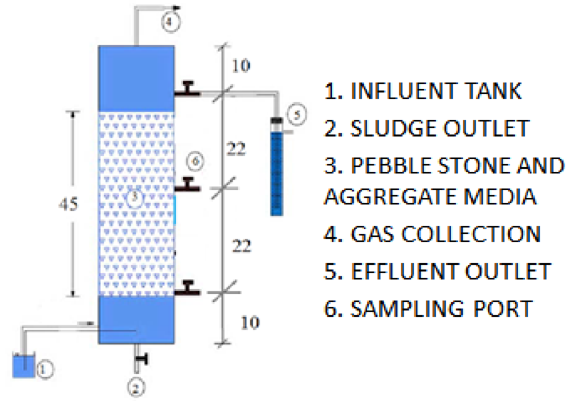


**Figure 1: Schematic arrangement of Upflow Anaerobic Filter (UAF) reactor**

### B. 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 the addition of alkalinity and nutrients dilution made with respect to the initial characteristics of the wastewater collected from AAVIN. Characteristics of the wastewater are summarized in Table1.

**Table 1: Initial Characteristics of. Dairy Wastewater from Aavin and Synthetic Dairy Wastewater**

| S.No. | Characteristics | Dairy Wastewater from Aavin | Synthetic Dairy Wastewater |
|---|---|---|---|
| 1. | pH | 7.1-7.4 | 1120 |
| 2. | Total solids (mg/L) | 1359 | 712 |
| 3. | Total dissolved solids (mg/L) | 720 | 1123 |
| 4. | Total volatile solids (mg/L) | 1040 | 1560 |
| 5. | Total COD (mg/L) | 1350 | 1020 |
| 6. | $BOD_5$ (mg/L) | 960 | 1009 |
| 7 | Volatile solids(mg/L) | 988 | 515 |
| 8. | Alkalinity (mg/l as $CaCO_3$) | 710 | 650 |

### C. Seeding And Operating Conditions

Effective microorganisms were used as seed and the reactor was seeded anaerobically with stale cow dunk. The wastewater collected from aavin stored in a cold room at $40^0$C to reduce degradation during storage. Room temperature is maintained as an optimum temperature for various operational conditions. Hence the methanogenic population is maintained due to tropical and sub-tropical climate. The operating temperature of the reactors was in the mesophilic range (29-35 °C). The operating conditions maintained for the anaerobic filters were as follows, pH of 6.8 to 7.2, Temperature of 30 °C and HRTs at 24 h, 16 h, 12 h, and 8 h.

### D. Biogas Outlet

The biogas outlet was provided at the top of the reactor (Fig. 2). 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**

### E. Operation Of Uaf Reactor

**Phase 1**

Initially, the reactor was fed with OLR of 1.35 kg COD/m$^3$/d operated for an HRT of 24h with a 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 the steady-state has been reached. Samples were collected from the UAF reactor port 1 for the consecutive four days. The reactor attains a steady-state within 3 days from the start-up of phase 1 operation. Further, the OLR was increased with an increase in the inlet COD for HRT of 24h.

**Phase 2**

The reactor was fed with OLR of 2.04 kg COD/m$^3$/d operated for an HRT of 16h with a 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/s. The reactor attains a 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 the steady-state has been reached. Samples were collected from the UAF reactor port 1 for the consecutive four days.

**Phase 3**

The reactor was fed with OLR of 2.70 kg COD/m$^3$/d operated for an HRT of 12h with a 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 a 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 the steady-state has been reached. Samples were collected from the UAF reactor port 1 for the consecutive four days.

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### Phase 4

The reactor was fed with OLR of 4.08 kg COD/m$^3$/d operated for an HRT of 8h with a constant flow rate of 10.696 L/d and an inlet COD of 1350 mg/L with an up-flow velocity of 1.80 m/s. The reactor attains a 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 the steady-state has been reached. Samples were collected from the UAF reactor port 1 for the consecutive four days. 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.

## III. RESULTS AND DISCUSSION

### A. Cod Removal Efficiency

Maximum COD removal efficiency of 76.72% for pebble stone media and 91.55% for aggregate 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 washout had reduced the COD removal efficiency (Fig. 3 and 4). 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. There is only a 10% reduction in efficiency between HRT 16h and HRT 12h. The reason for the lower removal efficiency could be due to the higher organic loading rate at shorter HRT.

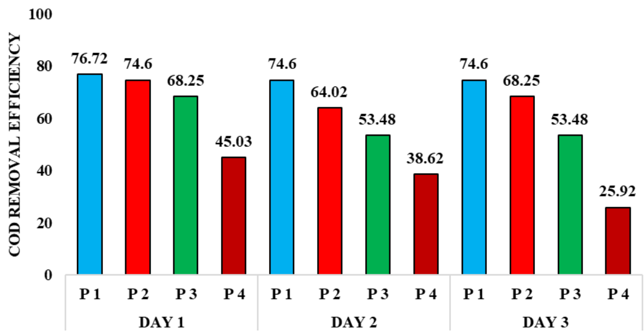


**Figure 3: COD removal efficiency for pebble stone as a packing media.**

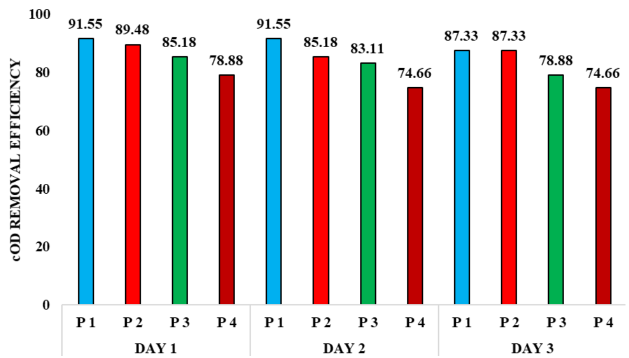


**Figure 4: COD removal efficiency for aggregate stone as a packing media.**

### B. Bod5 Removal Efficiency

The maximum BOD removal efficiency of 76.61 % for Pebble Stone Media and 91.56% for aggregate media was achieved for 24 HRT (Fig. 5 and 6). The COD/BOD ratio was fixed to 1.4. when the HRT is reduced to 8 H, the removal efficiency of only 44.72 % is achieved. The decrease in HRT results in a decrease in removal efficiency. From the batch study, it is concluded that there is not much difference with respect to the HRT of 24 hours and 16 hours.

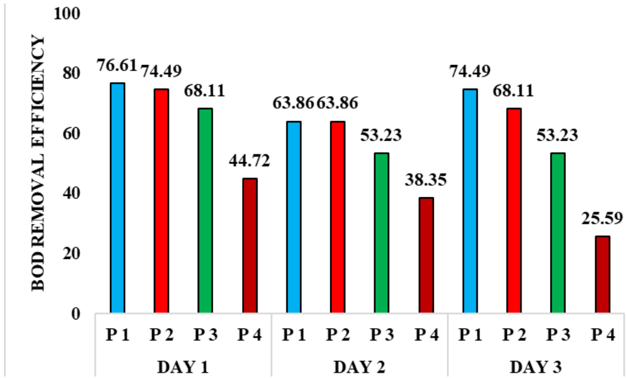


**Figure 5: BOD removal efficiency for pebble stone as a packing media.**

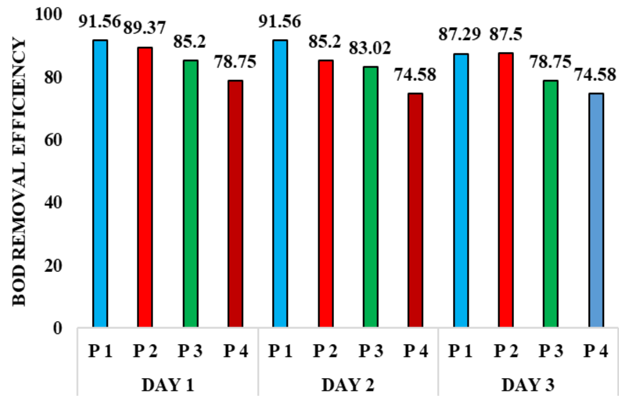


**Figure 6: BOD removal efficiency for aggregate stone as a packing media.**

### C. Total Solids Removal

Anaerobic bacteria are slower growing microorganisms compared with the aerobic bacteria. Moreover, methanogenic bacteria are slower growing bacteria compared with the acid-forming bacteria. Therefore, HRT of more than 1 day was applied during the initial start-up of UAFs for about 38 days to facilitate methanogenic bacteria to form a biofilm.
Solids removal efficiency can be affected by temperature, organic loading rate (OLR), hydraulic retention time (HRT) and flow velocity. Under 24 HRT, the effluent TS concentrations ranged from 176 to 232 mg/L and the effluent SS concentrations ranged from 137.6 to 187.2 mg/L. The SS concentration was very low during 24h HRT but during 12h and 8h HRT higher concentration was observed. The reasons for this could be higher hydraulic loading rate would have sloughed off the attached biofilm and higher organic loading would have increased the suspended biomass concentration. The maximum removal of solids was observed during 24h HRT. The concentration of solids in the treated effluent for varied OLR kg COD/m$^3$/d is given in table 2.

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**Table 2: Solids concentration in the effluent for varied OLR at HRT 24, 16, 12 and 8h respectively.**

| Phases | Parameter | Day | | |
|---|---|---|---|---|
| | | Day1 | Day2 | Day3 |
| PHASE 1 (HRT 24h) | TS mg/L | 205.2 | 49.2 | 156 |
| | TDS mg/L | 232 | 44.8 | 187.2 |
| | TSS mg/L | 176 | 38.4 | 137.6 |
| PHASE 2 (HRT 16h) | TS mg/L | 212.8 | 33.2 | 179.6 |
| | TDS mg/L | 234.8 | 109.2 | 125.6 |
| | TSS mg/L | 366.4 | 16 | 350 |
| PHASE 3 (HRT 12h) | TS mg/L | 459.6 | 107.6 | 352 |
| | TDS mg/L | 216.4 | 52.8 | 163.6 |
| | TSS mg/L | 226.4 | 102.4 | 124 |
| PHASE 4 (HRT 8h) | TS mg/L | 216.4 | 61.2 | 155.2 |
| | TDS mg/L | 184 | 62.8 | 121.2 |
| | TSS mg/L | 384 | 48 | 336 |

## IV. CONCLUSION

The result obtained from the present study concludes that the application of the UAF reactor of hybrid type can successfully treat dairy wastewater at mesophilic temperatures. 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, the effluent quality achieved was very close to minimal standards for the discharge of effluents from the dairy industry.
- UAF reactor with low flow velocity has been feasible for treating dairy wastewaters in warmer climates resulting in lower energy requirements and less sludge production.

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