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Research Article

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High rate digestion of dairy industry effluent by upflow anaerobic fixed-bed reactor

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ABSTRACT

A laboratory scale upflow anaerobic fixed-bed reactor (UAF-B) packed with polypropylene pall rings as packing media was designed for treating effluent. UAF-B was used to treat dairy effluent at a hydraulic retention time (HRT) of 12 hours and at different organic loading rates (OLRs). It was observed that chemical oxygen demand (COD) removal efficiency and biogas production rates increased with increase in OLR and the average COD removal efficiency of 87% and maximum biogas production of 9.8 l/d was achieved. These results indicate the feasibility of UAF-B for dairy effluent treatment.

Keywords: UAF-B, OLR, Effluent, HRT, Dairy.

INTRODUCTION

A continuously increasing demand for milk and milk products has resulted in the growth in dairy industry in most of the countries of the world. Dairy industries discharge effluents containing high organic and inorganic contents. Vourch et al. [1] reported that a dairy industry generates about 0.2–10 liters of effluent per liter of processed milk. Effluents pose problems and challenges to the environmental engineers.

A number of biological treatment methods such as activated sludge system, aerated lagoons, trickling filters, anaerobic processes have been used for dairy effluent treatment [2]. Among these processes, anaerobic treatment has gained considerable interest as it converts organic content into a biogas, a source of energy with minimal quantity of sludge [3]; whereas the aerobic treatment process requires an additional energy input for aeration. The upflow anaerobic fixed-bed reactor (UAF-B) has been widely used as high rate anaerobic reactor for the treatment of high strength effluent. These reactors have several advantages over aerobic and conventional anaerobic reactors such as rapid start-up with minimum operational problems; ability to withstand shock loading without significant decrease in digestion efficiency; ability to adapt intermittent feeding and rapidity of restart after lengthy shut down periods; and lower hydraulic retention times.

Anaerobic filters are generally packed with various packing materials to retain the active biomass in voids and on surface of packing. Ideal packing media is that which maximizes the surface area as well as porosity. A large surface area of the media enhances the biomass attachment and increased porosity decreases the overall reactor volume, and also minimizes clogging of filter [4]. Anaerobic filters with packing media such as Stone rubbles [5], PVC tubing [6], Granite stones [7], PVC Raschig rings [8], RPF sheets [9], plastic tubes [10] and Pumice [11] are employed for the treatment of various effluents and reported the successful applicability of anaerobic filters for treating high strength industrial effluents.

In the present study, the performance of UAF-B reactor packed with polypropylene pall rings for the treatment of dairy effluent was investigated and analyzed.

EXPERIMENTAL SECTION

2. 1. EFFLUENT

The effluent for the present study was collected from the nearby dairy industry and preserved in the refrigerator at $4^{o}C$ in accordance with the standard methods for the examination of water and effluent. The effluent was characterised in terms of pH, color, total suspended solids (TSS), volatile suspended solids (VSS), chemical oxygen demand (COD) and biological oxygen demand (BOD) using standard methods, and are summarized in Table 1.

Table 1: Characteristics of dairy effluent

Parameter	**Range**
pH	7.2 -8.8
Color	White
Total Suspended Solids, mg/l	500 – 740
Volatile Suspended Solids, mg/l	400 – 610
Chemical Oxygen Demand (COD), mg/l	1900 – 2700
Bio-chemical Oxygen Demand (BOD), mg/l	1200 – 1800

2. 2. UPFLOW ANAEROBIC FIXED-BED REACTOR

An upflow anaerobic fixed-bed reactor was fabricated using PVC pipes and fittings. The dimensional sketch of the reactor is shown in Fig. 1. The internal diameter of the pipe is 10 cm and height 125 cm. A dispersion plate of 4 cm thick, 15 cm in diameter having 120 holes each of 0.6 cm diameters has been provided at the bottom of the reactor to support the packing media, as well as to ensure proper distribution of influent through the packing media. The reactor was packed with polypropylene pall rings as packing media. The inlet for the effluent is provided near the bottom of the reactor and the outlet near the top of the reactor. An outlet is also provided on the top of the reactor for collection of gas. The specifications of the reactor are summarized in Table 2.

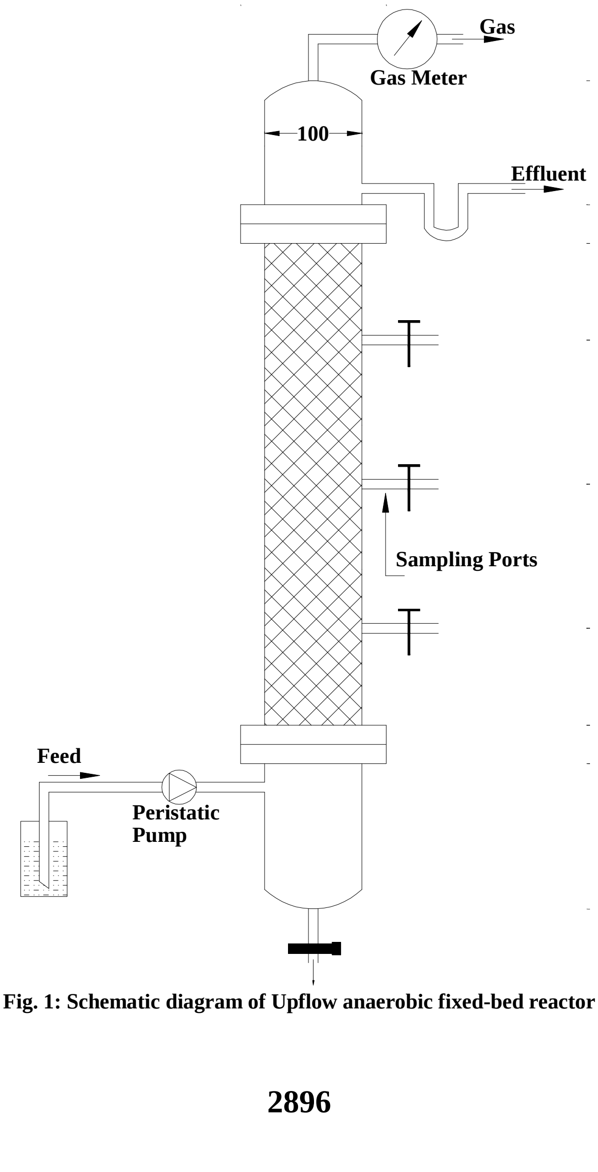

Fig. 1: Schematic diagram of Upflow anaerobic fixed-bed reactor

Table 2: Specifications of the Reactor

Internal Diameter, cm	10
Effective Height, cm	80
Total Height, cm	125
Effective Volume, litres	6.28
Volume of packing media, litres	3.91
Number of sampling ports	3

The reactor was tested for leakage if any with water. The reactor was then packed with pall rings up to the specified height and the end cap at the top was fixed. The reactor start-up was initiated by charging 3000 ml of digested slurry everyday using peristaltic pump at a HRT of 48 hours to develop methanogenic biomass in the reactor. It was followed by feeding the diluted dairy effluent of 1000 mg/l COD at same HRT of 48 hours. This rate of feeding corresponded to OLR of 0.50 kg COD/m^3/d. The reactor loadings were then increased step-wise by decreasing HRT by maintaining a constant feed concentration, 1000 mg/l COD. After the successful start-up of the reactor, the feed concentration was increased with an incremental of 500 mg COD/l at constant HRT of 12 hours until the target COD, 2700 mg/l (Refer Table 1). The operational parameters such as flow rate, pH of influent, effluent and amount of biogas generated were measured and recorded on daily basis. Biogas was analyzed for its methane content using ORSAT apparatus and COD of effluent from the reactor was also measured.

RESULTS AND DISCUSSION

The reactor was started with an initial OLR of 0.50 kg COD/m^3/d (i.e. feed concentration of 1000 mg COD/l) at a constant HRT of 48 hours. Then the reactor loadings were increased stepwise with a decrease in HRT. The loading pattern and the corresponding decrease in HRT is shown in Fig. 2. Fig. 3 shows the biogas production rate and the COD removal during the reactor start-up period. It was observed that a small quantity of biogas was produced on day 4 with 7.6% of COD removal. As days progressed, the biogas production increased with an increase in COD removal. From 40th day the reactor achieved steady state condition giving high COD reduction of 76% continuously for three days with a maximum biogas production of 3.8 l/d. The methane content of the biogas was 74% during these days. It was the clear indication of the formation of stable bio-film on the packing medium and production of very active biomass between voids.

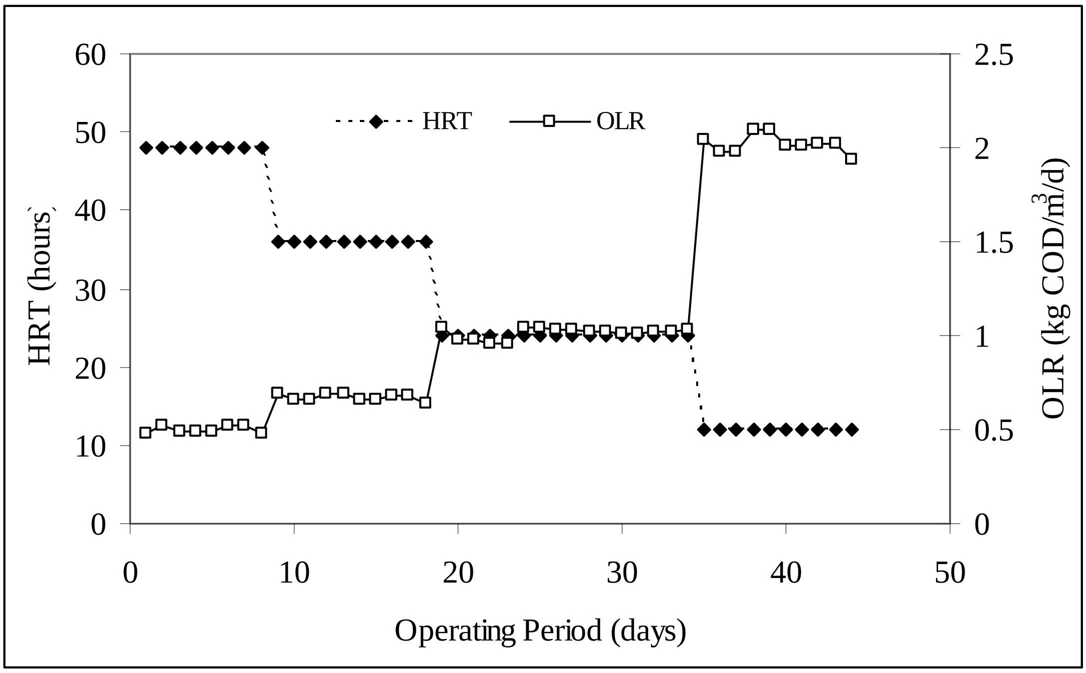

Fig. 2: Loading pattern of UAF-B during start-up

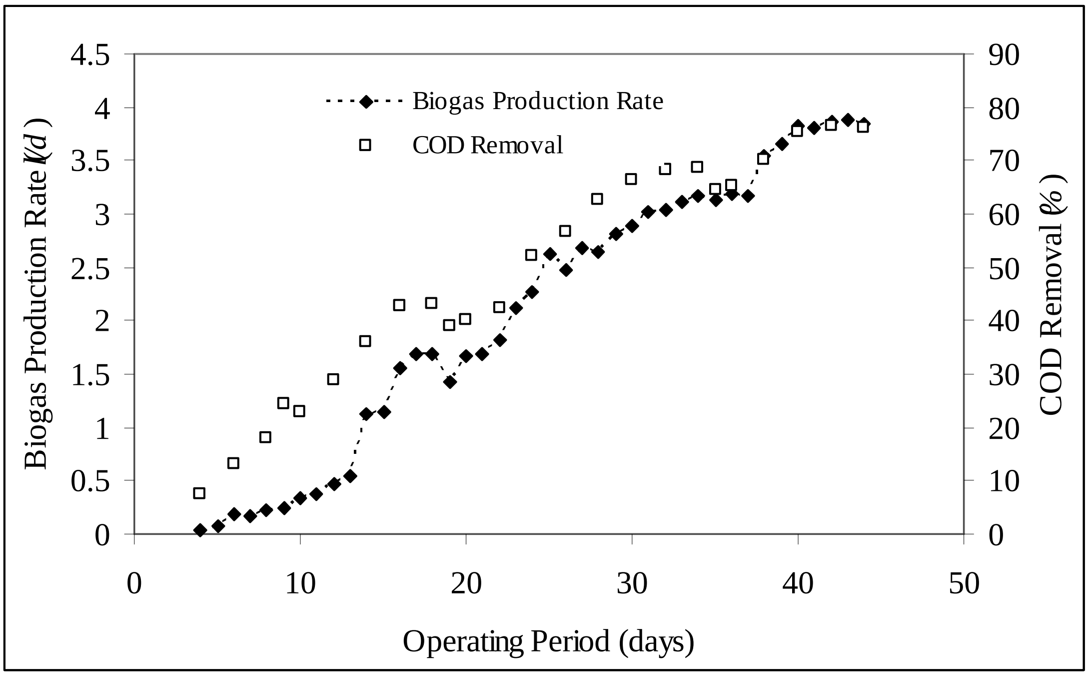

Fig. 3: Biogas production rate and COD removal during start-up

After the successful start-up of the reactor, the HRT was maintained at 12 hours and the reactor loadings were increased in steps to 3, 4, 5 and 5.4 kg COD/m^3/d. In order to achieve the desired loading rates in steps, the feed concentration was increased with an incremental of 500 mg/l till the target COD of 2700 mg/l. However, the last increment was only 200 mg/l to get the target concentration of 2700 mg/l. The biogas production rate and the COD removal after the start-up of the reactor is shown in Fig. 4. It can be seen that biogas production rate and COD removal efficiencies were increased with an increase in operating periods. It was observed that there was decrease in COD reduction whenever the OLRs were increased. It can be attributed to the fact that an increase in OLR is obtained by an increase in feed concentration, which inhibited the very sensitive methanogenic bacteria temporarily. However after few days the improvement in the performance was observed as expected. At the target concentration of 2700 mg COD/l high reduction of 86.60% was obtained indicating the feasibility of anaerobic filter for treatment of dairy effluents. Biogas production rates also increased along with operating days. It is mainly due to increased loading and increased activity of the biomass. However at each change of loading rates, marginal decrease in gas production rate was observed. Maximum biogas of 9.88 l/d was obtained at an OLR of 5.4 kg COD/m^3/d.

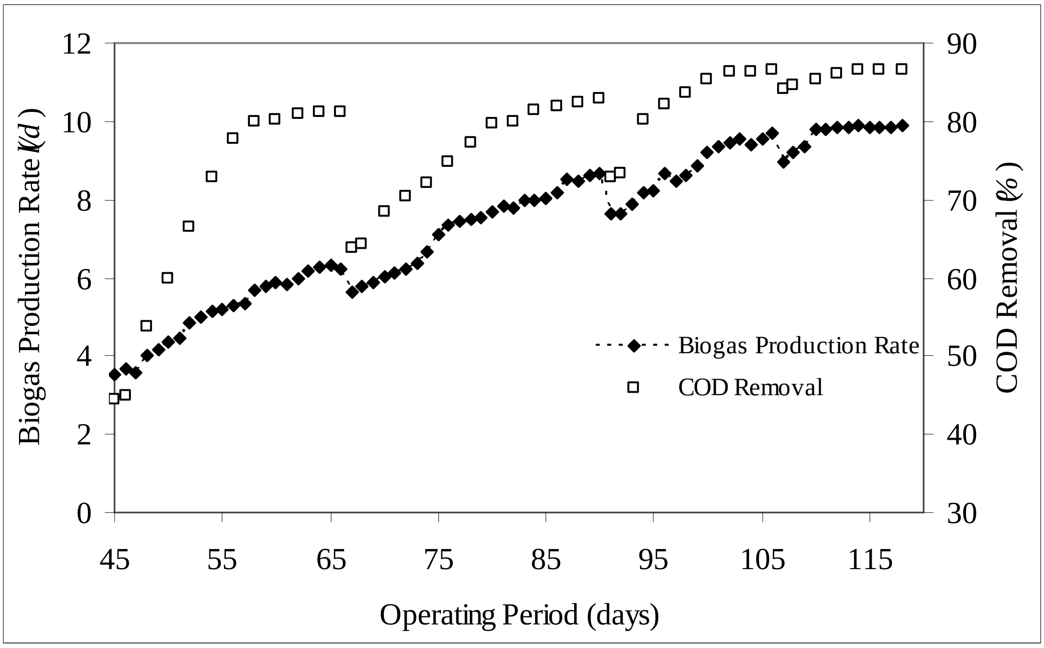

Fig. 4: Biogas production and COD removal after the start-up of UAF-B at HRT of 12 hours

CONCLUSION

A feasibility study using laboratory scale upflow anaerobic fixed-bed reactor was conducted for the treatment of dairy effluent. It was observed that the anaerobic filter with polypropylene pall rings as packing media can be effectively used for the treatment of dairy effluent at the lower HRT of 12 hours, at OLR of 5.4 kg COD/m^3/d with COD removal efficiency of 87%. The biogas production rate was 9.8 l/d. The biogas with high methane content (77%) produced due to the conversion of organics can be an alternative source of energy for the dairy industry itself.

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