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Evaluation of Bio Gas Generation in Biomass with the Influencing of Hydraulic Retention Time for the Treatment of Anaerobic Fixed Film Reactor

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Abstract: Sustainable development must be the foundation for economic growth in the twenty-first century. It is necessary redirect the efforts toward bioenergy production from renewable material, especially industrial wastewater. This effort will not only alleviate environmental pollution, but also reduce energy insecurity and demand for declining natural resources. The most cost-effective and sustainable approach is to employ a biotechnology option. Anaerobic treatment is a technology that generates renewable bioenergy to replace the energy requirements around the world through the production of methane. The attached growth microbial reactor was continuously fed with real time dairy wastewater with an influent flow rate of 0.18, 0.36, 0.54, 0.72, 0.90 l/day with varying Hydraulic Retention Time of 3.0, 1.50, 1.00, 0.75, 0.60 days. The maximum biogas of 0.048m^3/kg COD removed was achieved at an influent flow rate of 0.18 l/days at 3.0 days Hydraulic Retention Time with an influent COD concentration of 4500 mg/l. In addition, a substantial gas evolved constituting 64% methane incorporating 36% CO_2 with the expense of 0.048m^3 /Kg of COD, for fixed-film reactor. These results provide a suitable biotreatment process for high conversion of organic fraction to combustible methane gas.

Key words: Biofilm reactor · Biogas · Hydraulic retention time · Chemical Oxidation Demand · Sustainable energy

INTRODUCTION

There is a growing interest in alternate energy sources as a result of increased demand for energy coupled with a rise in the cost of available fuels. Rapid industrialization has resulted in the generation of a large quantity of effluents with high organic contents, which if treated suitably, can result in a perpetual source of energy. In spite of the fact that there is a negative environmental impact associated with industrialization, the effect can be minimized and energy can be tapped by means of anaerobic digestion of the wastewater. In recent years, considerable attention has been paid towards the development of reactors for anaerobic treatment of wastes leading to the conversion of organic molecules into biogas.

Most of the wastewater generated in rural areas all over the country is not disposed or treated in an environmentally acceptable manner. India is a large producer of milk and dairy products in the world with annual milk production crossing 85 million tones in the year 2002 and growing at the rate of 2.8% per annum [1]. The dairy industry wastewater are generated primarily from the cleaning and washing operations in the milk processing plants and are estimated to be 2.5 times the volume of the milk processed. Thus, some 200 million tons of wastewater are generated annually from the Indian dairy industry. Dairy waste effluents consist of carbohydrates, proteins and fats originating from the milk. Moreover, the dairy industry produces different products, such as milk, butter, yoghurt, ice-cream, various types of desserts and cheese, thus, the characteristics of these effluents also vary greatly, depending on the type of system and the methods of operation used [2].

Since, dairy waste streams contain high concentrations of organic matter; these effluents may cause serious problems, in terms of organic load on the local municipal sewage treatment systems.

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The treatment techniques may include physico-chemical and biological treatment methods. But, the biological processes are generally preferred due to high chemical costs and the poor soluble COD removability in physical–chemical treatment processes. Among the various biological treatment technologies available, anaerobic treatment process is generally employed as this treatment can easily handle the varying organic loads and the temperature ranges encountered. The variable COD concentrations, warm and strong dairy effluents are ideal for anaerobic treatment. Stability in biological waste treatment systems has been linked to increased biodiversity of the microbial community [3] and to an increased ability of the community to use alternative removal pathways for the same substrate [4].

Biogas, an important renewable energy source, is produced through the process of anaerobic digestion of biodegradable substances. It is primarily comprised of methane (CH_4) and carbon dioxide (CO_2). Use of biomass from waste sources can influence the economics of plant operations in a positive manner and at the same time provide a means of assisting with the environmental problems posed by the disposal of wastes in the developed world [5]. Biogas is a source of green energy [6] produced through biotechnological processes by which organic matter, such as organic waste, wastewater, or a renewable resource, e.g., purposely grown energy crops are degraded in the absence of oxygen [7]. Biogas can be used for electricity and/or heat generation. However, with a large portion of CO_2, the utilization of biogas is limited due to its low calorific value.

Therefore, the removal of CO_2 from raw biogas is essential. After the proper purification, drying and pressurization, the biogas can be even directly injected into existing natural gas pipelines or used as fuel for vehicles [8]. This further widens the range of biogas application and increases the overall energy utilization efficiency. A. Hilkiah Igoni, *et al.,* [9] recommended that anaerobic digestion systems be increasingly employed in order to harness the source of ''waste'' energy and simultaneously protect the environment. Generally, the applied external biogas purification and upgrading technologies, such as water scrubbing, pressure swing adsorption, cryogenic separation and membrane separation, combined with gas compression to inject biomethane into the gas grid, all consume high amounts of energy [10]; therefore, economical feasibility is always a big concern. In pressurized anaerobic digestion, the pressure of the biogas is gradually built up during fermentation. Liquid-to-gas mass transfer in anaerobic processes was investigated theoretically and experimentally [11].

Fixed film reactors offer the advantages of simplicity of construction, elimination of mechanical mixing, better stability at higher loading rates and capability to withstand large toxic shock loads [12] and organic shock loads [13]. The reactors can recover very quickly after a period of starvation [12]. Another constraint is clogging of the reactor due to increase in biofilm thickness and/or high suspended solids concentration in the wastewater. The main objective and purpose of this research work is to assess and investigate the feasibility and applicability of the anaerobic fixed film bio-reactor process to treat dairy wastewater at different hydraulic retention time.

MATERIALS AND METHODS

System Design: The laborotary model digester design having a working volume of 13.00 liters consists of a tank filled with media namely Fugino spirals on which a consortia of bacteria attach and grow as a slime layer or biofilm hence the name fixed-film digester. The reactor was made up of clear acrylic Plexiglas which was sealed to avoid any air entrapment. The media were of 19mm outer diameter, 1mm thickness and 15mm height, which were randomly packed. And they were light, durable inexpensive and easy to install and their high porosity to prevent any clogging by the increased bio mass. The media is packed in the reactor at a height of 50 cm. Javed Iqbal Qazi, [14] concluded that the material used for packing provided a large surface/volume ratio that permitted tremendous growth of microorganisms in the interstices; the amount of biofilm was great and the system operated at short HRT in the bioreactor. Schematic of the experimental set up is shown in Fig.1.1.

Influent and Seed Sludge: The initial inoculums of the seed culture were the mixture of influent and sludge obtained from the bed of an anaerobic treatment unit facilities at Annamalai University. The Dairy wastewater were collected from M/S. Aavin Chilling Plant Ltd., Villupuram, Tamil Nadu. The real time dairy wastewater was fed from the bottom of the reactor through a peristaltic pump by gradual addition with domestic sewage such as 20%, 40%,60%,80% and 100%. After allowing the dairy wastewater at 100% concentration, the COD removal was monitored to achieve a stabilized removal of COD.The reactor was operated under ambient room temperature during the study period between 27°C to 36°C. The HRT was maintained constant throughout the start up period. The system was operated and monitored for 90 days to allow them to reach steady state conditions.

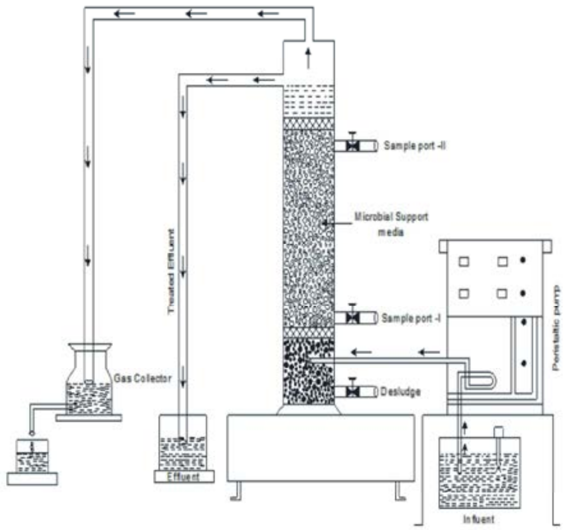

Fig. 1.1: Schematics of laboratory model of an anaerobic bio-film reactor

Table 1.1: Characteristics of Dairy Effluent.

SI. No.	Parameters	Concentrations		
		Sample I	Sample II	Sample III
1	pH	6.62	6.75	6.68
2	Total Suspended Solids, mg/1	560	590	575
3	Total Dissolved Solids, mg/1	2380	2560	2470
4	Total Volatile Solids, mg/1	2310	2160	2235
5	Total Fixed Solids, mg/1	850	910	880
6	Total Solids, mg/l	2940	3150	3045
7	BOD_5@20°C, mg/l	2180	1950	2065
8	COD, mg/l	3150	3360	3255
9	Nitrogen, [as N] mg/l	17	17.60	17.30
10	Phosphorus[as P] mg/l	15	14.30	14.65

Reactor Operation: After the start-up period, when the reactor reaches stable effluent characteristics, which was considered as the “steady state” operation, the reactor was operated continuously to investigate the process performance of inflow wastewater characteristics. The required flow rate is adjusted manually. The system was being continuously operated under constant flow condition. The wastewater flow was passed through the media-filled reactor in upflow mode. The attached anaerobic biomass converts both soluble and particulate organic matter in the wastewater to biogas, a mixture of mostly methane and carbon dioxide. The biogas produced was collected by the method of water displacement. The reactor was operated in successive five cycles with HRT of 3.00,1.50,1.00,0.75,0.60 days for effluent withdrawal. Average influents of COD concentrations such as 3620, 4060, 4300, 4570,5200 mg/l were made for this study.

Analytical Methods: The samples were analyzed and the characteristics of the parameters and their concentrations are presented in Table 1.1 [15]. The biogas produced was quantified regularly by water displacement method and its composition was measured by Gas Chromatograph.

RESULT AND DISCUSSIONS

The real time dairy effluent was used during the experimental study period. The bio film reactor run with five ranges of flow rates such as 0.18, 0.36, 0.54, 0.72, 0.90 l/day was pumped continuously through peristaltic pump. The dairy effluent with five ranges of COD concentrations was supplied to the model such as 3620, 4060, 4300, 4570 and 5200 mg/l with an Organic Loading Rates of 0.049 to 0.3655 kg COD/m^3/day. The performance of an anaerobic biofilm reactor was calculated in terms of %COD reduction and Bio gas generation during the experimental study period.

The attached growth microbial reactor was continuously fed with real time dairy wastewater with an influent flow rate of 0.18, 0.36, 0.54, 0.72, 0.90 l/day with varying Hydraulic Retention Time of 3.0, 1.50, 1.00, 0.75, 0.60 days. It increased the flow rate from 0.18 l/days to 0.90 l/days at an average COD concentration of 3620, 4060, 4300, 4570, 5200 mg/l and attained the %COD removal efficiency of 66% to 84%. It was concluded finally that the COD reduction was largely affected by HRT as shown in Figure 1.3. Priti patel, *et al*.,(1985) concluded that the charcoal fixed film reactor showed the best performance when operated at 2 d hydraulic retention times (HRT), achieving maximum COD removal of 81%.

Hydraulic retention time (HRT) is functional parameter to influence the production of biogas. The maximum biogas yield of 0.048m^3/kg COD removed was achieved at an influent flow rate of 0.18 l/days at 3.0 days of Hydraulic Retention Time with an influent COD concentration of 4500 mg/l. as shown in Figure 1.2.

However, the treatment efficiencies of the reactors are sensitive to parameters like wastewater composition, especially the concentration of various ions [Zhang Zhenya, Takaaki Maekawa. (1996), Mudrak K, Kunst S(1986)] and presence of toxic compounds such as phenol

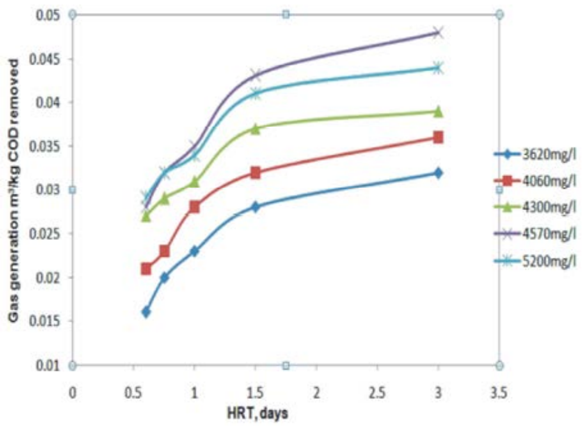

Fig. 1.2: HRT, days Vs Gas generation m^3/kg COD removed for dairy effluent

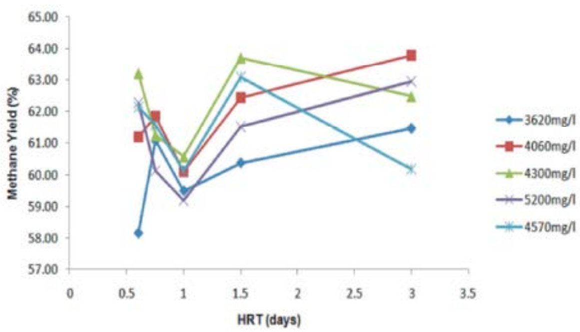

Fig. 1.3: HRT, days Vs Gas generation m^3/kg COD removed for dairy effluent

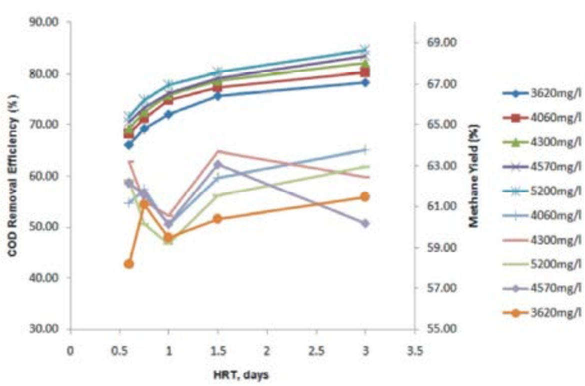

Fig. 1.4: HRT, days Vs COD removal efficiency (%) and Methane gas generation (%) for dairy effluent

[Fang HP, Chan O(1997)]. The temperature and pH are also known to affect the performance of the reactor by affecting the degree of acidification of the effluent and the product formation [Dinopoulou G, Rudd T, Lester JN(1998)].

Immobilization of the bacteria as a biofilm prevents washout of slower growing cells and provides biomass retention independent of HRT. Since the bacteria are not continuously washed out along with the effluent, a substantial microbial biomass develops within the reactor. Similar work was carried out by Asha.B,2015 with increasing OLR from 0.031 kg COD/m^3/day to0.288 kg COD/m^3/day by decreasing the HRT and the COD removal efficiency increases from 65% to 86% with corresponding OLR of 0.1772 kg COD/m^3/day to0.0548 kg COD/m^3/day.

The VFA concentration was increased with increase the Hydraulic Retention Time (HRT)(Sivakumar M.S and Asha.B,(2012)). Rantala and Vaananen (1985) reported that the organic volumetric loading rate is the major factor affecting the necessary volume of reactors. A substantial gas evolved constituting 64% methane incorporating 36% CO_2 with the expense of 0.048m^3/kg COD (Figure 1.3).

CONCLUSION

The fixed film fixed bed bioreactor was found to be a successful biological treatment system, achieving a maximum yield of biogas generation for the treatment of dairy wastewater. The results are summarized as follows:

- It was concluded that the hybrid system is much faster than the conventional digester.
- During the start-up process COD removal efficiency attained at a steady state after a period of about 90 days.
- The optimum yield of biogas production 0.048m^3/kg COD was achieved at an influent COD 4500mg/l with an average OLR of 0.0623kg COD/m^3/day
- The maximum %COD removal efficiency of 86% for the sugar wastewater at 3.0 days Hydraulic Retention Time, with an influent COD concentration of 3960 mg/l, was observed.
- The findings of this study revealed that the anaerobic biofilm reactor could be a feasible, eco-friendly and sustainable treatment system for dairy, sugar and sago effluents.
- Fixed-film digesters are ideally suited for treating large volumes of dilute,high-strength wastewater such as those generated by dairy operations, because large numbers of bacteria can be concentrated inside smaller digesters operating at shorter HRTs than would be needed to achieve the same degree of treatment with conventional suspended-growth anaerobic reactors.
- This process produced less non-hazardous organic sludge than the conventional physico-chemical treatment system that required further treatment and safe disposal of hazardous sludge produced.

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