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Performance Study On Inverted Anaerobic Sludge Blanket Reactor For High Fat Content Wastewater

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Abstract - *In dairy wastewater treatment, Fat, Oil and Grease (FOG) have been an ever-growing environmental concern. Because, FOG is considered hard to treat with current biological systems as having susceptibility to float, in due course solidifies and deposits on the ramparts of the pipeline, reactor and causes obstruction. Consequently, restricts the oxygen transfer in the conventional aerobic treatment. FOG is usually produced in food service establishments, discharge from slaughterhouse, palm oil mill effluents, dairy industry effluents, automobile workshop, etc. In our country, even though a many research works were carried out in treating a low strength to very high strength wastewater, considerable landmark is not achieved in FOG removal/ treatment. It is a well-recognized fact that anaerobic digestion is an energy recovery process, where the organic matters are converted into methane, a renewable energy which can be upgraded to bio-methane, removing CO2. This present study aimed to recover and enhance biogas production from wastewater rich in FOG, under anaerobic condition in a specially designed reactor named as Inverted Anaerobic Sludge Blanket (IASB) reactor exclusively for treating wastewater rich in FOG concentrations. The effects of varying organic loading rate (OLR) and hydraulic retention time (HRT) on the performance of the reactor treating fat rich dairy wastewater having chemical oxygen demand (COD) and fat content ranges between 1980 to 3320 mg/L and 50 to 140 mg/L, respectively were investigated in a bench scale reactor with an effective volume of 12 L operated at an ambient temperature 26 to 380C for 100 days including startup period of 52 days. After stabilization, the reactor was operated at different HRTs of 24, 18 and 12 h with OLRs 3.1, 4.3 and 6.2 Kg COD/ m3.d, respectively. A maximum COD removal of 92.4 % and corresponding fat removal of 92.1 % was achieved. Concurrently, the biogas generation of 11.6 L/d (331 L/ kg COD removal) was observed at 24 h HRT. The ratio VSS/TSS of the sludge increases gradually from 0.33 to 0.38 at the end of the study showing the growth of microbes. Morphological examination of sludge also confirms the presence of Escherichia coli, Bacillus.sp, Kelbsilla.sp, Enterococcus.sp and Streptococcus.sp. The quality of the effluent found to be agreeable for irrigation, aquaculture or industrial use as it is anticipated that recycling of water will play a major role in meeting upcoming water shortages.* **Keywords -** *dairy wastewater, fat, anaerobic, biogas, inverted*

I. INTRODUCTION

Dairy industry has grown in most countries of the world because the demand for milk and milk products has steadily risen. Simultaneously, the production of milk per head of cattle has also grown as a result of advancements in veterinary science [1]. Among nations, India is one of the largest, and is projected to become the largest producer of milk and dairy products in the world [2]. India is also by far the largest producer of dairy-based wastewaters of the world as well. Dairy industries release large quantities of wastewater often in the order of thousand cubic meters/day [3]. The dairy industry wastewaters 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 wastewaters 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 [4]. 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. 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 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. Furthermore, no requirement for aeration, low amount of excess sludge production and low area demand are additional advantages of anaerobic treatment processes [5]. Dairy wastewater containing mainly Fat, Oil and Grease (FOG). FOG hydrolysis results in the production of long chain fatty acids (LCFA) which have been extremely toxic to anaerobic treatment because they induce floatation of biomass disrupting conventional anaerobic treatment systems based on biomass sedimentation. Therefore, FOG is normally removed from wastewater prior to anaerobic treatment using e.g. dissolved air floatation [6]. Keeping this in mind, the experimental work here described was focused on the anaerobic treatment especially wastewater contains high Fat content under tropical conditions. The main objective of this work was to look into the performance of a lab scale IASB reactor inoculated with digested slurry, which was collected from an effluent treatment plant. The operational parameters such as HRT, OLR, COD, and Fat, total alkalinity, volatile fatty acids (VFA) concentration, total suspended solids (TSS), volatile suspended solids (VSS) and pH were investigated. In addition to that, biogas generation and
COD removal efficiency were also investigated. Ease of Use

II. MATERIALS AND METHODS *A.* Experimental set-up

IASB reactor was fabricated using transparent acrylic tube of 18cm diameter vertical cylindrical shape with a total volume of 14 L. The reactor essentially had an internal effective working volume of 12 L and the remaining volume of 2 L was kept for gas liquid solid (GLS) separation arrangement. A possible configuration of the IASB Reactor with submerged wall to create two compartments i.e. downer compartment is 14.5cm and riser compartment is 3.5 cm. The height of the reactor is 55cm. The reactor had one influent port at the top, one effluent port and five sampling ports (Figure. 1). The GLS separator attached at the top of the reactor was essentially facilitating effective biogas collection. The treated effluent collected by a pipe attached in the riser compartment. A peristaltic pump (Miclins PP 30) was used for feeding wastewater as uniformly as possible over the reactor top, passes through the sludge bed in the reactor. The reactor was operated at mesophilic temperature (24 - 35°C).

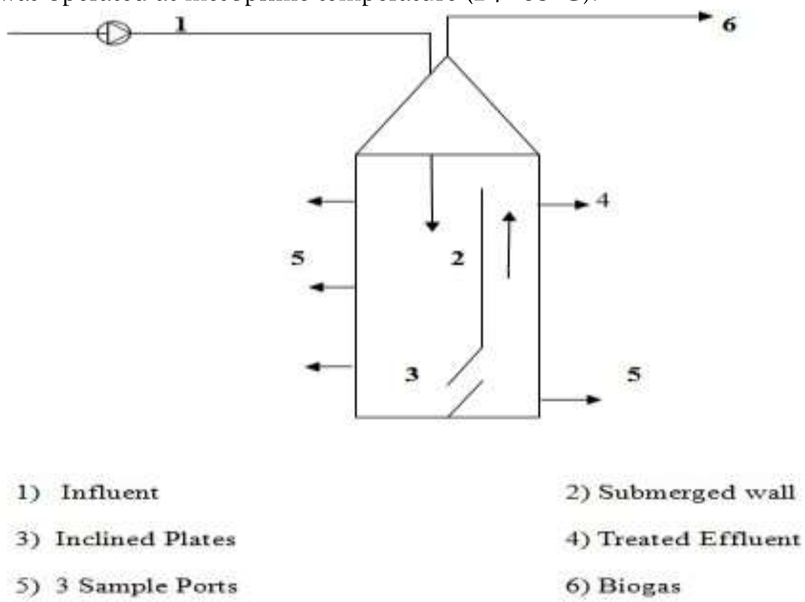

Figure 1. Schematic diagram of IASB reactor *B.* Synthetic wastewater preparation

In this study, synthetic wastewater was prepared, in which organic COD was provided by sucrose. About 1000 mg/L of COD contains 1000 mg of sucrose. The synthetic wastewater was then neutralized to a value of pH ~ 7.2 by using sodium hydroxide (NaOH). Urea and KH2 PO4 were added as sources of nitrogen and phosphorus respectively to maintain COD: N: P ratio. A ratio of 300:5:1 was maintained as COD: N: P during start-up period [7]. The pH in the feed tank was adjusted to a value ~ 7 after every 10 -12 hours. The fresh feed was prepared daily. Trace elements like ferric chloride, copper sulfate, magnesium chloride, calcium chloride were added appropriately.

***C.* Seed sludge**

Digested slurry was collected from an effluent treatment plant in dairy industry located at Thanjavur District, Tamilnadu. After analyzing the concentration of total suspended solids (TSS) and volatile suspended solids (VSS), this sludge was used as seed. Initially about 50% reactor volume was filled up with this active sludge.

***D.* Analysis**

During the operation of the reactor, temperature, sludge bed height and biogas production were monitored and recorded daily. Feed and treated effluent were taken for the analysis of COD, pH, FOG and VFA on daily basis. TSS and VSS were determined once in a week.

III. RESULTS AND DISCUSSION *A.* Wastewater Characterization

The results and analysis of dairy wastewater for various physico-chemical parameters, minimum, maximum, mean and standard deviation are shown in Table 1.

Parameters*	Minimum	Maximum	Mean	SD
pH	5.87	6.48	6.29	0.21
Temperature	26	28	27.14	0.74
Turbidity	128.7	156.7	145.60	10.04
EC	4.96	5.74	5.19	0.27
TS	5650	6200	5957.14	198.80
TDS	3000	3800	3203.57	270.96
TSS	2400	2950	2753.57	188.43
VSS	340	420	377.14	26.90
BOD_5	1080	1580	1342.85	194.74
COD	1980	3320	2617.14	473.48
TKN	78	88	84.12	3.71
TP	59	82	68.28	7.78
Fat	67.5s	162	112.57	33.17

The physico-chemical characteristics of dairy wastewater depending on local climate condition and treatment methods which will vary from industry to industry. At the same time designing a reactor for secondary biological treatment, fluctuations in the concentrations like BOD, COD, pH, TSS, Fat, TKN, and temperature, etc. of the wastewater were evaluated based on the Variance and Standard Deviation. The parameters like BOD, COD, TSS and Fat exceed the permissible limit prescribed by the Central Pollution Control Board for disposing the wastewater into surface water. Temporal variations exist in the concentration of most of the constituents of wastewater.

***B.* Characteristics of seed sludge and Inoculation**

[8] Revealed that in order to avoid excessive sludge washout, the amount of seed sludge must be small enough to maintain the sludge bed within the reactor upon increasing the space-loading rate, and large enough to prevent a needless delay of the reactor start up. The authors also suggested, when using thick digested slurry of relatively low specific methanogenic activity, 12 to 15 kg VSS/ m3d sludge can be used because expansion washout will be limited in that case. While, using sludge with higher specific activity, the amount of seed sludge should not exceed approximately 6 kg VSS/ m3d, because more seed sludge will be washed out due to the occurrence of sludge bed expansion. Initially, the seed sludge had a TSS content of about 75100 mg/L and VSS content of about 24900 mg/L. Hence, initially about 50% reactor volume were filled up with this active sludge having a VSS concentration of about 24900 mg/L.

Accordingly the VSS concentration in the entire reactor at the start-up was about 12450 mg/L (12.5 kg VSS/m3d).[9] recommended sludge with 40% reactor volume might be enough to accelerate start-up.

***C.* Reactor Start- Up**

The start-up period is considered as the period taken for stable operation to be achieved. This is a crucial step for the stable operation of the UASB and other anaerobic reactors, at a designed organic loading rate (OLR). In this work, the IASB reactor after seeding was operated at a temperature between 24^{0}C and 35^{0}C. This comes under the mesophilic range (20^{0}C to 45^{0}C). Fluctuations within this range were not enough to cause any real impact on performance and in terms of reaction kinetics [10].

To start with, the sludge has a VSS / TSS ratio of about 0.33. Poor generation of biogas at the initial stage of start-up shows that sludge activity was initially low. An inhibition of methanogenesis generally results in an increase of VFA concentration and a sudden drop in pH [11]. Accordingly, the OLR maintained during start-up phase is presented in Figure 2. The COD removal efficiency after five days was above 40% and correspondingly the VFA concentration is also decreased. On the 10th day, COD removal efficiency is above 60% and hence, the fat content to an amount of 140 mg/L was added gradually to the reactor. Due to the shock loading of fat, the COD removal efficiency suddenly decreased to 34% and VFA concentration increased to 892 mg/L. In this position, the reactor was again stabilized with the synthetic wastewater by stopping the addition of fat content. This amounted to higher OLR of more than 3.32 kg COD/m3d is presented in Figure 4.1. However, the operating parameter HRT was maintained at 24 h for stabilizing the reactor. At the 52nd day, the COD removal efficiency is 95.2 % with OLR of 3.32 kg COD/m3d is shown in Figure 2.

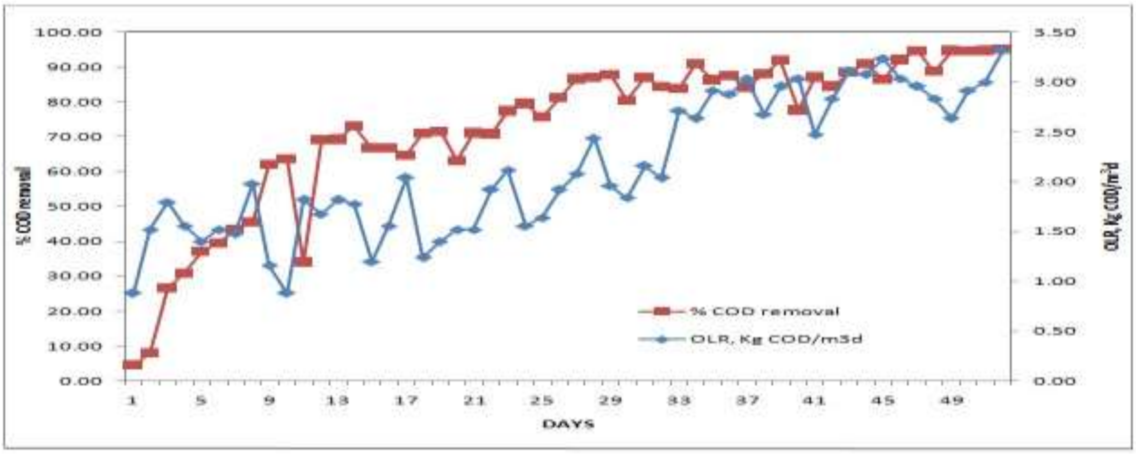

Figure 2. Organic loading rate and % COD removal during start-up period

Figure 3 shows the variations in pH of the influent and effluent. The value of pH slightly decreased during the initial days of operation, indicates the prevalence of acid fermentation over methanogens. However, after the initial drop, the pH of the treated effluent was in the range of 7.2 - 8.3. It indicates healthy anaerobic environment which is favorable for methanogenic organisms [12].

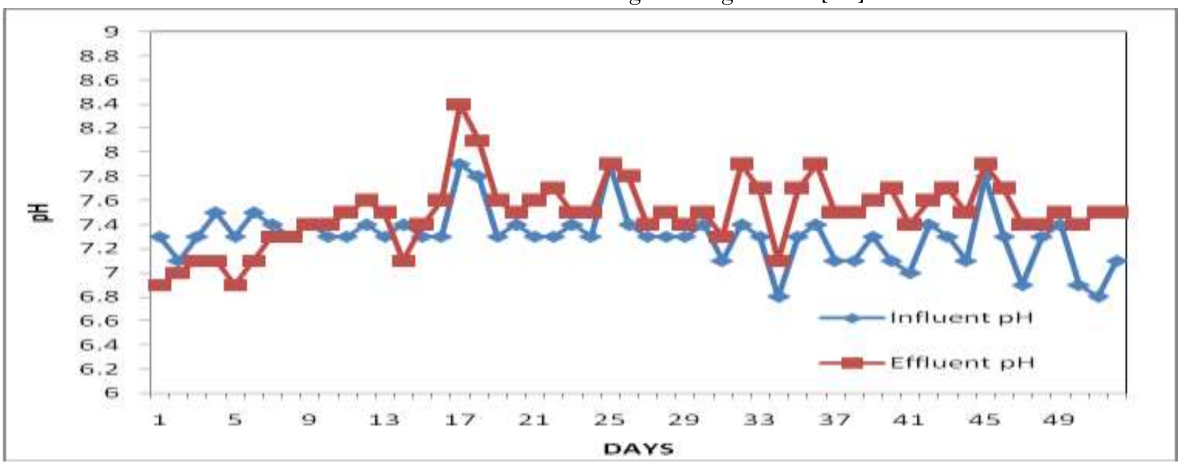

Figure 3. Feed and effluent pH during start-up period

The VFA concentration in the effluent during the first 30 days was in the range of 221-892 mg/L from that it dropped to 89 mg/L on day 40. Subsequently, the VFA in the effluent decreased gradually from 80 to 52 mg/L towards the end of start-up period. It indicates healthy anaerobic environment and satisfactory methanogenic activity. The overall performance of the reactor during the start-up was more than satisfactory. The selection of seed material plays a crucial role in minimizing time required for initial bioflim eshtablishment [13]. It was likely that the sludge collected from an active biogas plant and used as a seed had sufficient numbers of physiologically active microorganisms.

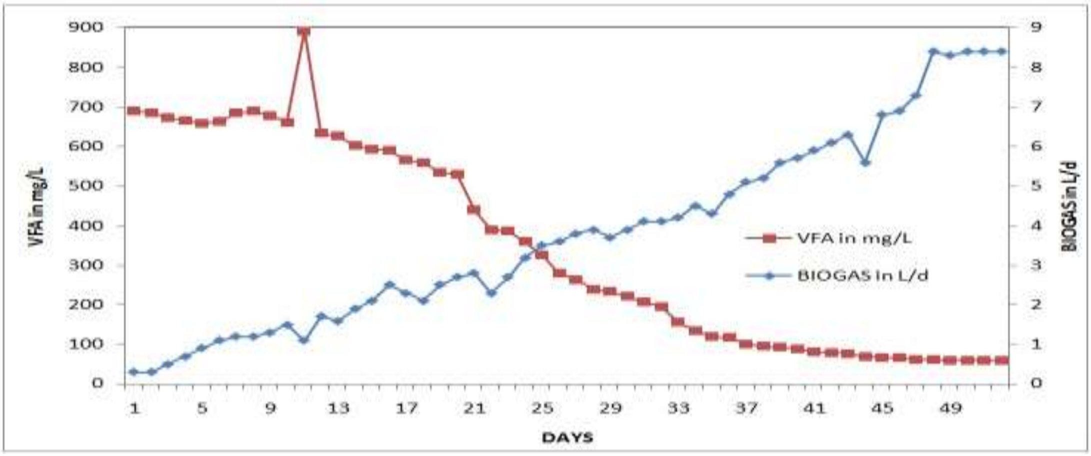

Figure 4. VFA concentration and biogas during start-up period

The biogas production for the first 20 days was very low, less than 2.7 L/d and VFA level raised up to 892 mg/L on 10th day because of shock loading with higher concentration of fat content (Figure 4). Beyond day 35, however, as soon as VFA concentration was controlled to less than 120 mg/L. The gas production as well as COD removal efficiencies started showing marked improvement. By day 52, the gas production rate reached a value of about 8.4 L/d (Figure 4) and the VFA in the effluent had reduced to less than 60 mg/L (Figure 4). This shows that the process of hydrolysis and acidification of the organic matter took place in proper condition. It was observed that the reactor took merely 52 days to reach a steady-state condition after inoculation. This has also been given in the Figure 2, which shows that the COD removal efficiency attains stability after 46th day. The start-up period for the reactor was completed in 52 days, as the VFA level in the effluent stabilized gradually. The pH value of the treated effluent was in the range of 7.3 to 7.9 and increased in COD removal efficiency (95.2%) indicates good start-up.

***D.* Reactor performance during steady state Effect of pH and Temperature**

The pH values of influent for 12, 18 and 24 h HRTs and corresponding temperature were in the range of 6.5 to 7.5 and 28 - 33°C, respectively. The pH values of treated effluent were in the range of 6.8 – 7.9. The temperature of effluent in this study could be considered to be in mesophilic range (20-40°C). The variation in temperature did not influence the performance of anaerobic bacteria [9].

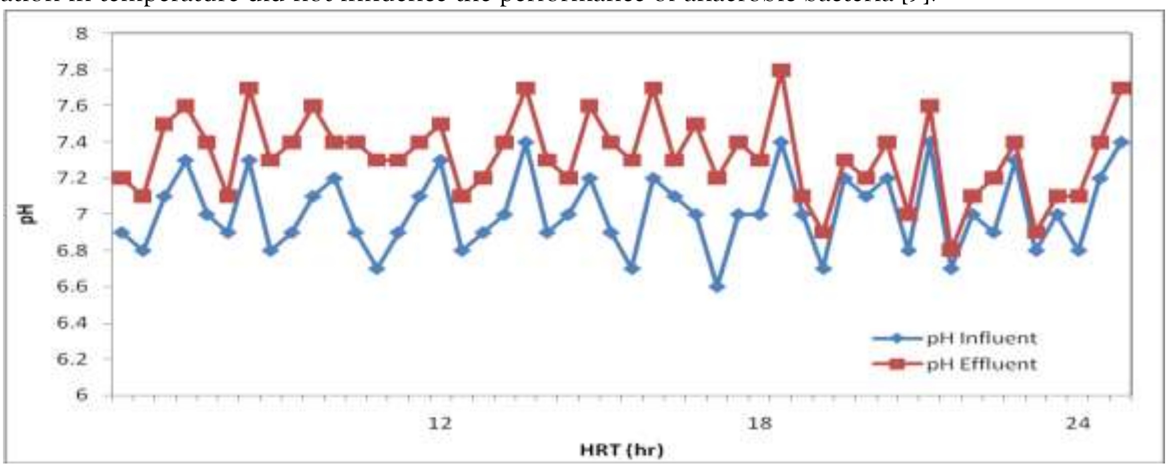

Figure 6. Influent and Effluent pH at various HRT *E.* COD Removal Efficiency COD Removal Efficiency with hydraulic retention time (HRT)

The COD removal for 12, 18, 24 h HRTs fluctuates between 88.0 and 92.4%. The COD removal efficiency was reduced with HRT in the order of 24, 18 and 12 h, respectively. Figure 7 shows the percentage of COD removal drastically dropped at 12 h HRT. [14] reported a COD removal efficiency of 89 % with the maximum OLR of 1.052 kg COD/m3d for the treatment of dairy wastewater using UASB reactor at 24 h HRT. [15] reported a COD removal efficiency of 96 % at 10 h HRT with the maximum OLR of 6.2 kgCOD /m3d for treatment of dairy wastewater with COD of 2050 mg/L by using 10.7 m3 UASB reactor.

The results of this present study show that whenever the HRT increases, more COD reduction, more fat removal and also increase in generation rate of biogas was observed.

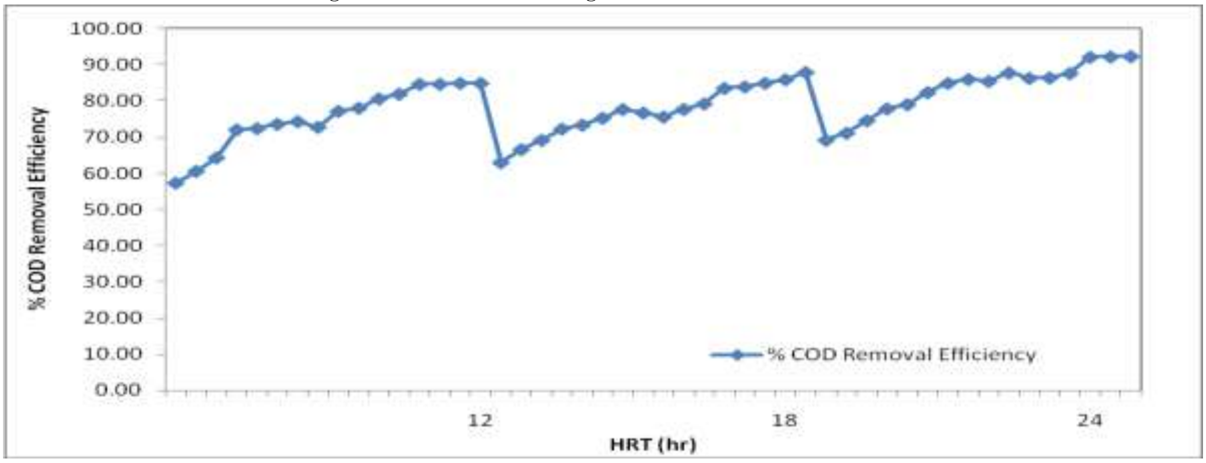

Figure 7. COD removal efficiency at various HRT COD removal efficiency with organic loading rate (OLR)

The COD removal efficiency decreased slightly with an increase in organic loading rate (OLR) from 3.15 to 4.91 kg COD/m3d with the percentage of 92.4 to 90.1. Whereas the removal efficiency of COD at the OLR of 6.23 kg COD/m3d decreased to 89%, as shown in Figure 8. [16] achieved the maximum COD removal efficiency 54.16% at lower organic loading rate of 1.0 kg COD/m3d in 72h HRT while treating dairy wastewater with an effective volume of 10 L anaerobic reactor. However, a minimum COD removal efficiency of 41.33% was observed at higher organic loading of 3.0 kgCOD/m3d in 72h HRT. The reason may be due to more acclimatization period taken by anaerobic bacteria at a higher organic load rate. [9]. The percentage COD reduction decreases with increase in organic loadings monotonically for different time.

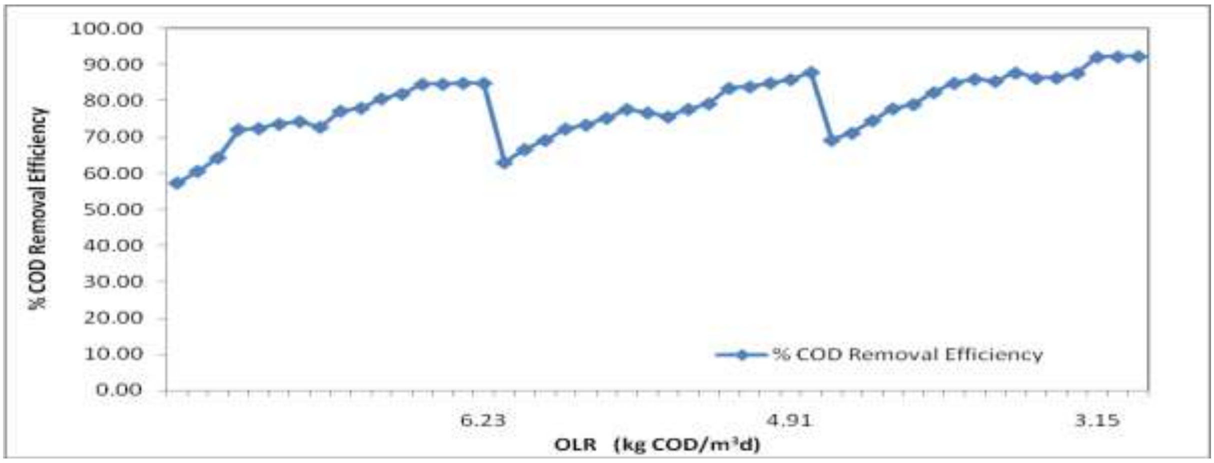

Figure 8. COD removal efficiency for each OLR

[17] indicated that COD removal efficiency of an anaerobic reactor is dependent on the organic loading loading rate. Thus, the removal efficiency of COD observed by various researchers as mentioned above was not different from this study. This is a common problem encountered with cheese, whey or dairy

wastewater, that when the substrate loading is increased, the acidogenic region extends into the methanogenic. This indicates that the COD removal is related to OLR.

***F.* Fat Removal Efficiency Fat removal efficiency versus hydraulic retention time (HRT)**

One of the main objectives of this present study is to enhance biogas production in an anaerobic reactor which contains fat and oil. Presence of fat and oil in the wastewater inhibits the performance of conventional reactors. Hence, the present study was carried out in an Inverted Anaerobic Sludge Blanket Reactor (IASBR). The effect of addition of fat and oil along with substrate was studied during start-up period. Its shock loading performance was also carefully monitored. By considering the problem during the operational period, fat and oil was gradually added from 40 to 140 mg/L at 12, 18, 24 h HRTs. Fat and oil removal efficiency at 24 h HRT was slightly higher than 18 h HRT and 18 h HRT was higher than 12 h HRT. From the Figure 9, it was observed that the percentage of fat and oil removal dropped at 12 h HRT. Maximum fat and oil removal efficiency at 24, 18 and 12 h HRT were 92, 84 and 78%, respectively.

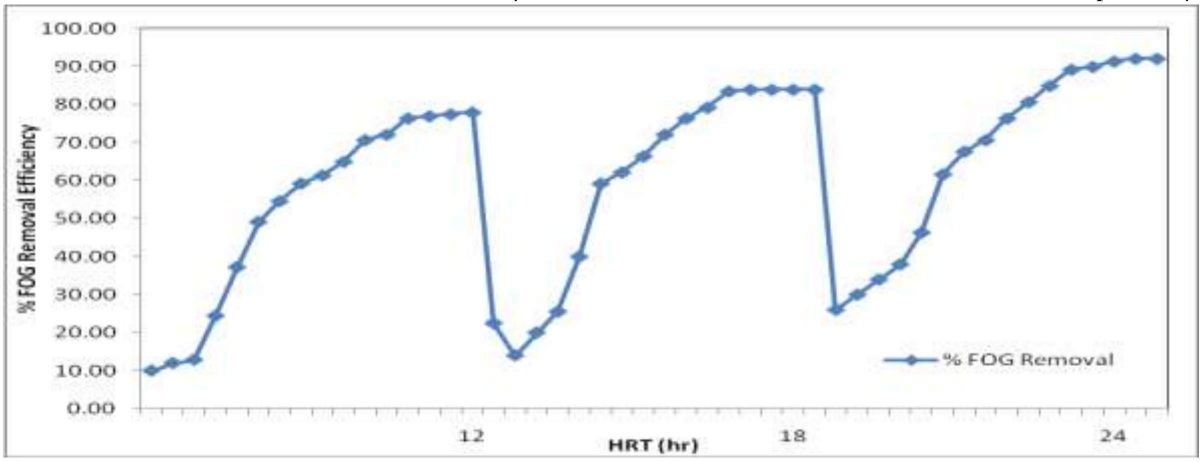

Figure 9. Removal efficiency of FOG at various HRT

This result indicates that HRT would affect the removal efficiency of fat for 12, 18 and 24 h HRT. However fat and oil content in the treated effluent ranges from 11 mg/L and to 69 mg/L. The maximum permissible limit for fat and oil in the treated effluent prescribed by authorities is 10 mg/L. [18] reported that 95.9 % of FOG removal efficiency was achieved by various bacterial strains isolated from vegetable grease and oilcontaminated industrial wastewater shows that anaerobic bio-film reactor system reduce oily wastewater. FOG content in the treated effluent was 16 mg/L. [19] reported that FOG removal efficiency was achieved 63 % at 12 h HRT corresponding to OLR 3.21 kgCOD/m3d. Fat removal efficiencies, higher than 85 % were achieved for organic loading rate between 10 and 16 kgCOD/m3d. Fat content in the treated effluent was 13 mg/L. Compared to the above studies, it is clearly indicated that whenever the HRT increases, more Fat removal and also increase in generation of biogas was observed. The present study indicates that the removal efficiency of fat and oil using inverted anaerobic sludge blanket reactor is effective.

***G.* Biogas Production Effect of HRTs on biogas production**

The daily biogas production was estimated by the water displacement method, analysed and represented in Figure 10. The maximum biogas production was 11.6 L/d (331L/kg COD) at 24 h HRT corresponding to an OLR of 3.2 kg COD/m3d. The biogas production at 12, 18 and 24 h HRT were 10.1, 10.8 and 11.6 L/d, respectively. [20] reported that 7.2 to 9.1 L/d gas production at 30 h and 40 h HRT using anaerobic reactor volume of 10 L. It shows that there is an increase in gas production to increase of HRT. [21] reported that when the hydraulic retention time was increased from 36 h to 48 h, the biogas production was 3.6 and 3.75 L/d, respectively with an effective volume of 5 L UASB reactor. Compared to present study it is clearly indicated that whenever the HRT increases, more generation of biogas was observed.

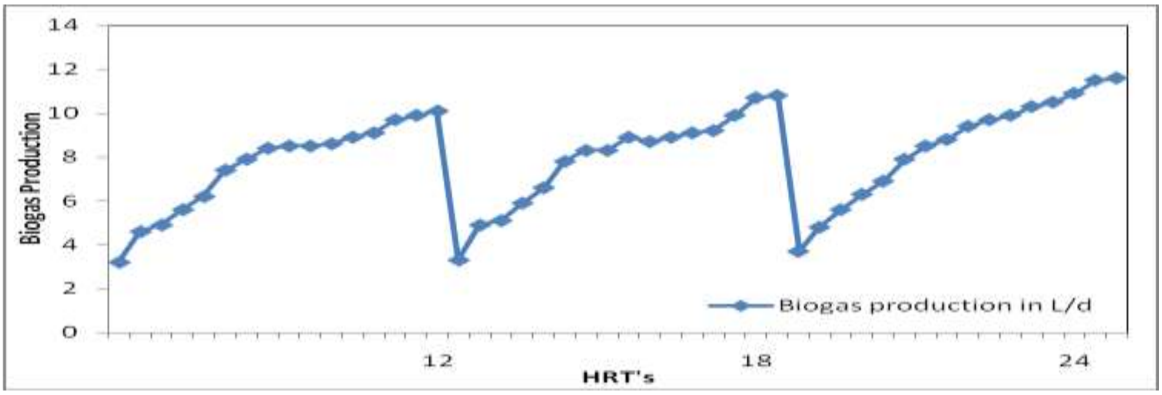

Figure 10. Biogas production at various HRT's

Effect of OLR on biogas production

The maximum biogas production was 11.6 L/d (331L/kg COD) at 24 h HRT corresponding to an OLR of 3.15 kg COD/m3d. It indicates that the increasing of OLR from 2.0 to 3.15 kgCOD/m3d, increase the rate of biogas production from 3.7 to 11.6 L/d. Increase of biogas also increases the suspension of the smaller size of sludge at the upper part of the reactor. [20] reported that when organic loading rate was increased from 3.7 to 4.5 kg COD/m3d, the biogas rate was increased from 3.6 to 3.8 L/d, respectively with an effective volume of 5 L UASB reactor. Compared to above researcher, it indicates that whenever the OLR increases, more generation of biogas was observed.

H. Characteristics of granular sludge

The microbial observation of microorganism was carried out by the scanning electron microscopy (SEM) photographs. The magnification scale was from 50 to 500, various kinds of bacteria were detected as shown in plate1.

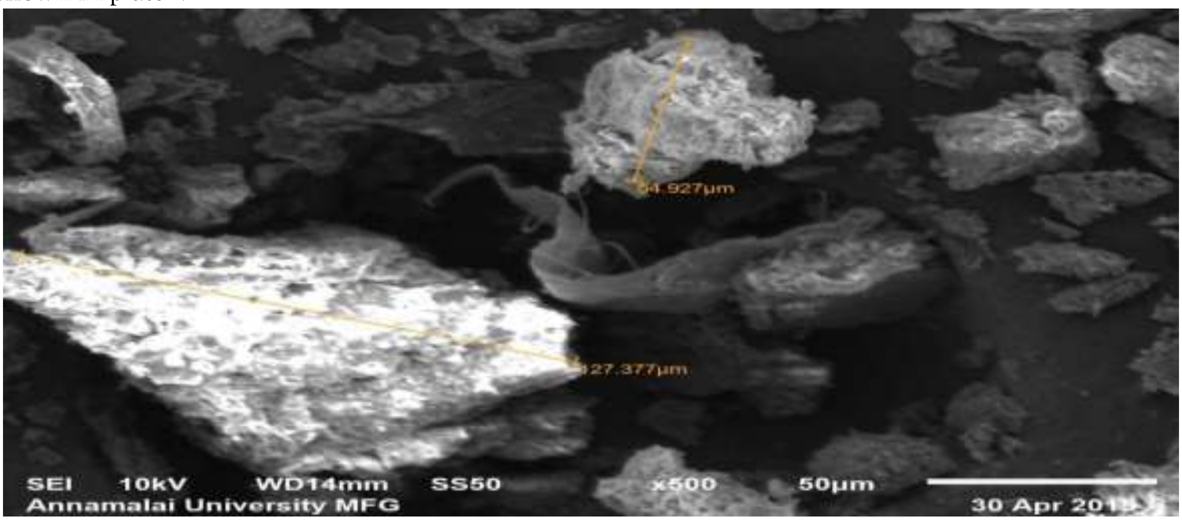

Plate 1: SEM analysis at 500 Magnification

To identify the potential microbes in degrading the fat, a biochemical characterisation was carried out for the sludge collected from the reactor on day 102 (APHA, 2005). The pure cultures were plated and visual observation states that the colonies are medium sized with a regular margin and convex elevation, this microbes not only ferments glucose to acid, it produce gas and unable to hydrolyze starch and does not produce amylase, this indicates that the presence of Escherichia coli and the colonies were larger and the margin is undulate with circular form and flat elevation, this microbe not ferments glucose and lactose, but hydrolyzes starch and produce amylase. This indicates that the presence of microbe Bacillus.sp (Plate 2)

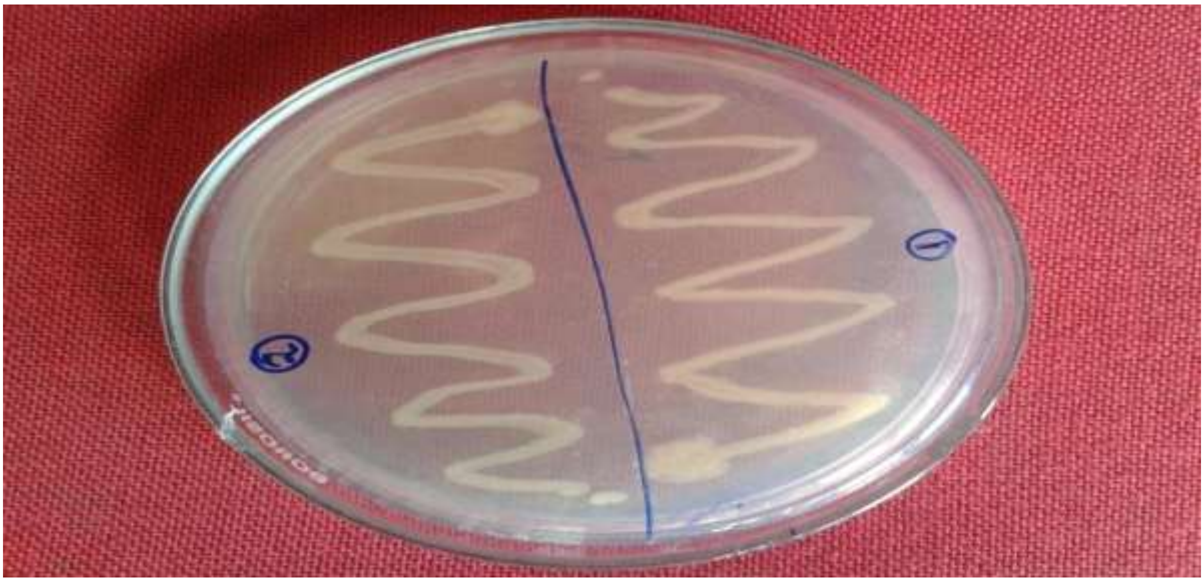

Plate 2: Microbial Streaking process

The colonies are slightly gummy wet looking colonies re convex with an entire margin, microbe not only ferments glucose to acid, it also produces gas and unable to hydrolyze starch does not produce amylase. This shows the presence of kelbsilla.sp with various sizes of 130.73, 162.98, 173.95µm (Plate 2). Similar findings were also observed by [18] using hybrid anaerobic baffled reactor for treating diary wastewater. Plate 3 shows the colonies of punctiform, convex with an entire margin, this microbes ferments glucose and lactose produce gas and unable to hydrolyze starch and does not produce amylase, this indicates that the presence of Enterococcus.sp with various size of 327.2 and 359.61 µm and the another colonies of coccoi shaped, circular, convex with an entire margin, this microbes ferments glucose and lactose produce gas and unable to hydrolyze starch and does not produce amylase, this shows the presence of Streptococcus.sp with various sizes of 54.9 and 127.37 µm. Similar findings were observed by [20] for biological treatment of dairy wastewater in an upflow anaerobic sludge-fixed film bioreactor.

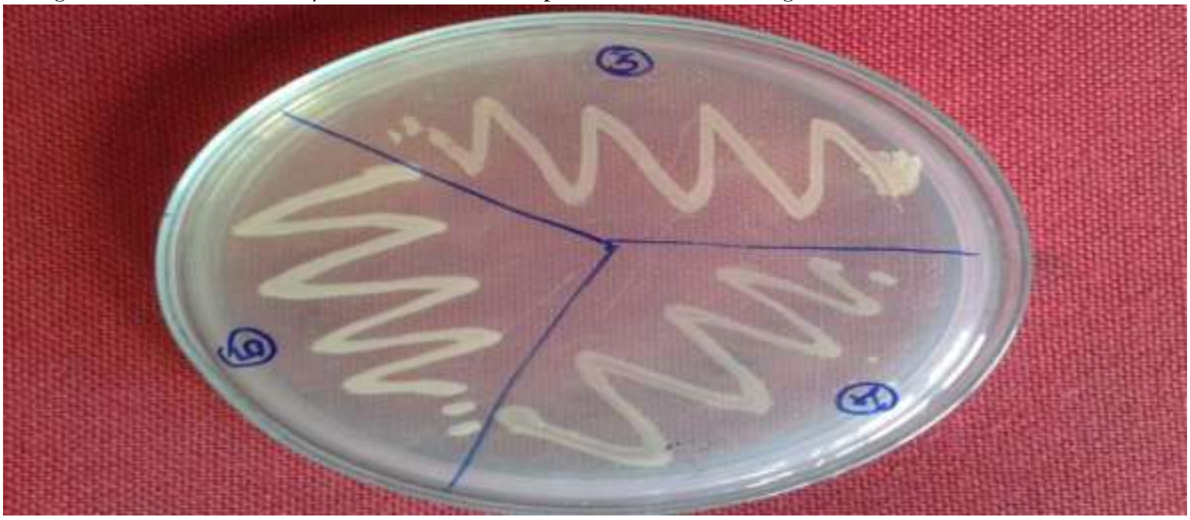

Plate 3: Microbial Streaking process

IV CONCLUSION

- The study was carried out to optimize the fat removal efficiency in an anaerobic condition using Inverted Anaerobic Sludge Blanket Reactor. The COD removal efficiency and biogas production are the other two parameters observed along with fat removal in this study.

- The reactor was operated at different HRTs of 24, 18 and 12 h with OLRs 3.1, 4.3 and 6.2 kg COD/ m3d, respectively. A maximum COD removal of 92.4 % and corresponding fat removal of 92.1 % was achieved.
- The biogas production at an optimized condition was found to be 11.6 L/d (331 L/ kg COD removal).
- Biochemical examination and SEM analysis of the reactor sludge confirm the presence of Escherichia coli, Bacillus.sp, Kelbsilla.sp, Enterococcus.sp and Streptococcus.sp., likely organisms.

V REFERENCE

1. Poompavai, S., "Treatment of different industry wastewaters", M Phil thesis, Pondicherry University, Pondicherry, p. 103, 2002.
2. Gupta, P.R., Dairy India, 5th ed., National Dairy Development Board, 1997.
3. Wheatley, A.D., Johnson, K.A., Winstanley, C.I., "The reliability of anaerobic digestion for the treatment of food processing effluent", In Proeedings of 5th Symposium on Anaerobic Digestion, Bolonga, pp. 135 – 146, 1991.
4. Vidal G, Carvalho A, Mendez R, Lema JM. "Influence of the content in fats and proteins on the anaerobic biodegradability of dairy wastewaters". Bioresource Technology, 74:231–9, 2000.
5. Demirel B, Yenigun O. and Onay, T.T. "anaerobic treatment of dairy wastewaters" a review, Process Biochemistry, 40: 2583 – 2595, 2005.
6. WO 2007058557 - Novel anaerobic reactor for the removal of long chain fatty acids from fat containing wastewater.(Alves M.M., Picavet, M.A., Pereira, M.A., Cavaleiro, A.J., Sousa, D.Z).
7. Aiyuk, S.E., Amoako, J., Raskin, L., Van Haandel, A. and Verstraete, W. Removal of carbon and nutrients from domestic sewage using a low-cost, integrated treatment concept. Water Res, 38(13), 3031–3042, 2004.
8. Lettinga, G. and Hulshoff, Pol, L.W. Advanced Reactor Design, operation and economy. Water Sci. Technol, 18(12), 99-108, 1986.
9. Venkatesh. K.R., Rajendran. M. & Murugappan. A.," Start-Up Of An Upflow Anaerobic Sludge Blanket Reactor Treating Low-Strength Wastewater Inoculated With Non-Granular Sludge" International Refereed Journal of Engineering and Science Volume 2, Issue 5, PP.46-53, May 2013.
10. Henze, M. and Harremoes, P. Anaerobic treatment of wastewater in fixed film reactor- A literature review .Water Sci.Technol, 15(1), 1-100, 1983.
11. Amit Kumar, Asheesh Kumar Yadav, Sreekrishnan, T.R., Santosh Satya and Kaushik, C.P. Treatment of low strength industrial cluster wastewater by anaerobic hybrid reactor. Bioresour. Tech., 99(8), 3123–3129, 2008.
12. Van Haandel, A.C. and Lettinga, G. Anaerobic Sewage Treatment: A Practical Guide for Regions with a Hot Climate. John Wiley and Sons, Chichester, UK.1994.
13. Bull, M. A., Sterritt, R. and Lester, J. N. Influence of COD, Hydraulic, temperature, and pH shocks on stability of an unheated fluidized bed reactor. J. Chem. Technol. Biotechnology, 33(4), 221-230, 1983.
14. Priyanka Pandya, Ashok K. Sharma, Sarita Sharma, Sanjay Verma , "Feasibility of Pilot Plant Upflow Anaerobic Sludge Blanket Reactor for Dairy Wastewater Treatment", http://www.eco-web.com/edi/110719.html, 2011.
15. Javed Iqbal Qazi, Muhammad Nadeem, Shagufta S. Baig, Shahjahan Baig and Quratulain Syed, "Anaerobic Fixed Film Biotreatment of Dairy Wastewater", vol. 8 (3), pp: 590-593, 2011
16. Abdulsalam Tawfeeq Dawood "Study on Anaerobic treatment of synthetic dairy wastewater under variable experimental condition", ISSN 2010-0264, International Journal of Environmental Science and Development, Vol. 2(1); Pg. 17-23, 2011.
17. Fang, H.P. B, "Treatment of wastewater from whey processing plant using activated sludge and anaerobic processes", J Dairy Sci. 74, pg no: 2015-2019, 1990.
18. Mahmoud Nasr, Ahmed Khalil, Amr Abdel-Kader, Walid Elbarki, Medhat Moustafa, "Comparative performance between conventional and hybrid anaerobic baffled reactors for treating dairy wastewater", International Journal of Chemical and Environmental Engineering, vol. 5 No.4,2014
19. Prasad M P and Manjunath K, " Comparative study on biodegradation of lipid rich wastewater using lipase producing bacterial species, vol. 10, pp; 121-124, 2011.
20. Najafpour.G.D, Hashemiyeh.B.A., Asadi. M and Ghasemi. M.B "Biological treatment of dairy wastewater in an up flow anaerobic sludge-fixed film bioreactor", American-Eurasian J. Agric. & Environ. Sci., 4 (2): 251-257, 2008.