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Original Research Paper

Comparative Study of Performance Evaluation of UASB Reactor for Treating Synthetic Dairy Effluent at Psychrophilic and Mesophilic Temperatures

R. Sivakumar*† and V. Sekaran**
*Department of Civil Engineering, As-Salam College of Engineering & Technology, Thirumangalakudi, Tamilnadu, India
**Pavai Engineering College, Namakkal, Tamilnadu, India
†Corresponding author: R. Sivakumar

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ABSTRACT

Dairy industry contributes to the pollution of the environment, both in quality and quantity. It generates about 0.2 to 10 L of effluent per liter of milk processed. Up-flow anaerobic sludge blanket is most suitable for biodegradable wastes, hence the present study evaluated the performance of UASBR through a laboratory model (25 liters of volume) for treating the dairy effluent with maintained psychrophilic temperature (15-20ºC) at phase I and mesophilic temperature (30-40ºC) at phase II. This model was studied for its treatment efficiency in terms of COD reduction. In the phase I, the average varying influent COD applied over the model are 1684, 2693, 3160, 3637, and 4059 mg/L with flow rates for each average influent COD as 4.80, 9.60, 14.40, 19.20 and 24.00 L/d. It was found that, successful COD removal of 91.42% was for the operating conditions of OLR at 0.039 kg COD/kg VSS day, VLR at 0.70 kg COD/m^3 day and HRT at 5.21 days. In the phase II the average varying influent COD of 2316, 2827, 3329, 3908 and 4522 mg/L were applied with same flow rates. The experimental work on UASBR model was found successful with 94.70% COD removal under the operating conditions of OLR at 0.037 kg COD/kg VSS day, VLR at 0.630 kg COD/m^3day and HRT at 5.21 days. The reactor achieved BOD, TSS, TDS, N and P removal efficiency, observed in phase I and II, as 91%, 82%, 89%, 42% and 46% and 96.4%, 86%, 91%, 41% and 50% respectively.

INTRODUCTION

Industrialization has become a matter of major concern due to its deteriorating activity on the environment (Tiwari 1994). The discharge of the polluted water from industries is a serious concern. Dairy industry is one such industry which is considered to be the largest source of food processing wastewater in many countries. Generally, in most of the dairy industries, water has been a key processing medium and used for cleaning, heating, cooling and floor washing, which directly implies the requirement of more water. It generates about 0.2-10 L of effluent per liter of processed milk and estimated that about 2% of the total milk processed is wasted into drains (Munavalli & Saler 2009, Vourch et al. 2008). The dairy wastewaters contain high biochemical oxygen demand (BOD) normally in the range of 0.8 to 2.5 kg per ton of milk, chemical oxygen demand (COD) normally about 1.5 times of BOD and TSS as 100 to 1000 mg/L (Kavitha et al. 2013). Biological treatments either by anaerobic or aerobic is the natural choice for biodegradable wastes. Anaerobic treatment technology is the most attractive practice in which there is a pollution reduction and energy recovery. Hence, in the recent years, the anaerobic treatment process has increased considerably due to energy considerations and environmental concerns.

Dairy wastewaters are generally treated using biological methods such as activated sludge process, aerated lagoons, trickling filters, sequencing batch reactor (SBR), anaerobic sludge blanket (UASB) reactor, anaerobic filters, etc. (Demirel et al. 2005). Among which, the high rate anaerobic treatment system such as “up flow anaerobic sludge blanket reactor” (UASBR) is a logical alternative to treat the wastewater. The UASB reactor process has been investigated since 1971 (Lettinga 1984) . Anaerobic treatment converts the wastewater organic pollutants into a small amount of sludge and large amount of energy as gas (Ayati & Ganjidoust 2006). The up flow anaerobic sludge blanket (UASB) reactor is by far the most widely used high rate anaerobic treatment system for variety of wastewaters (Van Haandel & Lettinga 1994). The wide application of the UASB reactor is due to its high efficiency in organic material removal, its low construction cost and land requirement and its extremely simple operation. Also, the suspended growth systems have sludge, that is considered to be granular sludge, coexist in the reactor. Temperature plays an important role in the anaerobic process in UASB technology, to enhance the microorganisms’ ability to produce biogas from digestion. The temperature and upward velocity affect the sludge granulation substantially as investigated during the formation of sludge granulation at ambient temperature (19-28°C) and upward velocity of 0.478 m/h (Barbosa & Sant 1989). The rate of degradation of organics is enhanced at elevated temperature of mesophilic condition and UASB reactor displays better efficiency at a lower rate (Abdullah Yasar & Amtul Bari Tabinda 2010). Around 78% decrease in the gas production rate can be obtained when the temperature is lowered from 27 to 10°C (Agrawal et al. 1997). There is an increase in methane production with a gradual increase in temperature (Van Lier & Lettinga 1990). The suitable temperature provides the microorganisms with less viscosity and good degradation (Kaviyarasan 2014). The rate of degradation of organics is enhanced at mesophilic temperature (30-40°C) and a decline in UASB efficiency at low temperature (psicrophilic) can be explained due to decreases in microbial activity (Mrunalini et al. 2013). The main objective of the study was to evaluate the performance of reactor with respect to various parameters like COD, BOD, pH, TDS, TSS, P and N in psychrophilic temperature (15-25°C) and mesophilic temperature (30-40°C) ranges.

MATERIALS AND METHODS

Sample collection and characterization: The real time wastewater was collected for both the phases from TAMIL PAL dairy Kurichi, Tamilnadu. It was characterized as: COD, 3456.6mg/L; BOD, 1860mg/L; pH, 6.6; TSS, 580mg/L; TDS 2350mg/L; nitrogen (as N), 17mg/L; and phosphorus (as P), 16mg/L. Present research study was conducted for the period of 8 months for both phase I and phase II. The performance of reactor was evaluated and the quality of reclaimed waste was compared to disposal standards.

Fig.1: Laboratory model of the UASB reactor.

Table 1: Chemical composition of the synthetic dairy wastewater.

Milk powder	Varied
NH_4Cl	Varied
$MgSO_4.7H_2O$	50 mg/L
$FeCl_3.6H_2O$	3 mg/L
$CaCl_2.H_2O$	0.4 mg/L
KCl	60 mg/L
$(NH_4)_2PO_4$	Varied

Experimental setup: A laboratory model of the up flow anaerobic sludge blanket reactor with necessary mixing cum equalization tank, having capacity of 25 liters was fabricated with 5mm thick acrylic sheet of 200 mm internal diameter and effective height of 600 mm was used for this study (Fig. 1). The reactor was provided with an inlet at the bottom and gas outlet at the top and another at a distance of 40mm from the top of the reactor, as the outlet for the treated effluent, at the same level a gas liquid solid separator (GLSS) was provided. Baffle arrangement was also made to guide the gas bubbles into the separator to capture the evolved gas. As per the guidelines given by Lettinga & Hulshoff Pol (1991), three phase separator was also provided with 3 sampling ports at a distance of 300mm c/c along the reactor. A check valve was fixed at the bottom for sludge withdrawal. Miclins peristaltic pump of model PP 20 was used to maintain the flow rate and upward velocity of the feed.

The initial start up and process stabilization of the reactor model was seeded with domestic wastewater of COD (250-370mg/L), BOD (180-260mg/L), pH (6.6), TSS (110mg/L), TDS (560mg/L) and stabilized sludge for a period of 60 days continuous runs, and the observations were noted for the COD removal. It is started with 46.8% and it rises up to a maximum of 84.2% (Fig. 2) and process stabilization was observed after 60 days with average removal of 80% to 85%. The synthetic wastewater, which simulates the typical characteristics of real time dairy wastewater was prepared with necessary chemicals and nutrients (Table 1), and a feed with an initial COD of 2000 mg/L and HRT of 48 hrs (Mehrdad Farhadian et al. 2007, Punal

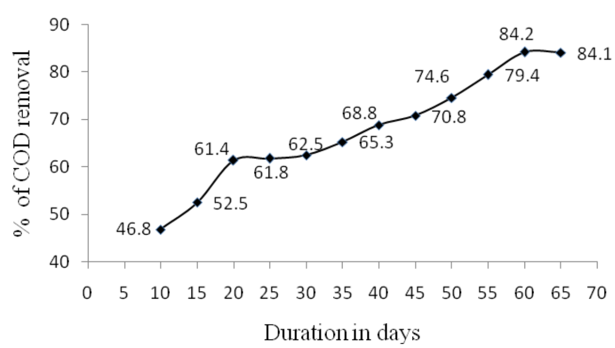

Fig. 2: Startup and process stabilization of reactor.

Table 2: Performance of the model for varying average COD of dairy effluent under varying flow rates at psychrophilic range.

Average Influent CODmg/L	Flow Rate m^3/day	HRT days	VLR kg COD /m^3·day	OLR kg COD/ kg VSS.day	Conc. of VSS in blanket zone mg/L	Effluent COD mg/L	% of COD removal mg/L	Gas conversion m^3/kg COD removal
1684	0.0048	5.21	0.331	0.020	46400	442.12	84.42	0.25
2693	0.0048	5.21	0.521	0.029	46420	649.15	86.12	0.25
3160	0.0048	5.21	0.88	0.044	52720	1073.71	89.72	0.27
3637	0.0048	5.21	0.70	0.039	48240	316.40	91.42	0.26
4059	0.0048	5.21	0.77	0.040	51150	915.55	88.34	0.27

Table 3: Performance of the model for varying average COD mg/L of dairy effluent under varying flow rates at mesophilic range.

Average Influent CODmg/L	Flow Rate m^3/day	HRT days	VLR kg COD /m^3·day	OLR kg COD/ kg VSS.day	Conc. of VSS in blanket zone mg/L	Effluent COD mg/L	% of COD removal mg/L	Gas conversion m^3/kg COD removal
2316	0.0048	5.21	0.427	0.025	48510	274	87.70	0.22
2827	0.0048	5.21	0.54	0.032	46810	240	91.5	0.23
3329	0.0048	5.21	0.63	0.037	48880	176	94.70	0.25
3908	0.0048	5.21	0.74	0.042	49630	293	92.4	0.26
4522	0.0048	5.21	0.85	0.047	51120	512	88.4	0.27

Table 4: Influent and effluent characteristics at maximum COD removal.

Parameters	Psicrophilic range			Mesophilic range		
	Influent	Effluent	% Removal	Influent	Effluent	% Removal
pH	7.68	6.14	-	7.89	6.23	-
BOD, mg/L	1540	139	91	1620	58.3	96.4
TSS, mg/L	340	61.2	82	350	49	86
TDS, mg/L	2100	231	89	1900	171	91
N, mg/L	19.3	11.2	42	21.1	12.5	41
P, mg/L	4.80	2.6	46	5.2	2.6	50

2007) was selected in order to allow the sludge acclimatize itself to the environment. Then the performance of UASBR could be found out with different average COD with different OLR, VLR and HRT at both the temperature ranges.

The optimum operating condition for UASBR in treating dairy effluent was identified by different operating conditions viz., varying influent flow rate (L/day), OLR and HLR. And also, the observations were made for VSS and biogas generation. The laboratory analysis of the wastewater and treated effluent were carried out by the standard methods and standard analytical procedures for water analysis (1999).

RESULTS AND DISCUSSION

The varying average COD of synthetic dairy influent applied over the model during phase I are 1684, 2693, 3160, 3637 and 4059 mg/L, and during phase II are 2316, 2827, 3329, 3908 and 4522 mg/L. The varying influent flow rate applied over the model for each concentration of average influent COD on both the phases are 4.80, 9.60, 14.40, 19.20 and 24.00 L/d with a resulted upward velocity in the reactor varying from 0.0064 to 0.031 m/hr and hydraulic retention time (HRT) was 5.21, 2.6, 1.74, 1.3 and 1.04 days.

The graphs were plotted from the observed readings for the various operating conditions and finally the optimum condition for the maximum COD removal efficiency was identified. Figs. 3 and 4 show the performance of the model as % COD removal and varying organic loading rates OLR, 0.020 to 0.242 kg COD/kg VSS per day and identified that the maximum COD reduction at 0.039 kg COD/kg VSS per day at phase I and OLR, 0.025 to 0.283 kg COD/kg VSS per day, and identified that the maximum COD reduction at 0.037 kg COD/kg VSS per day at phase II. The Figs. 5 and 6 were drawn for % COD removal under varying volumetric

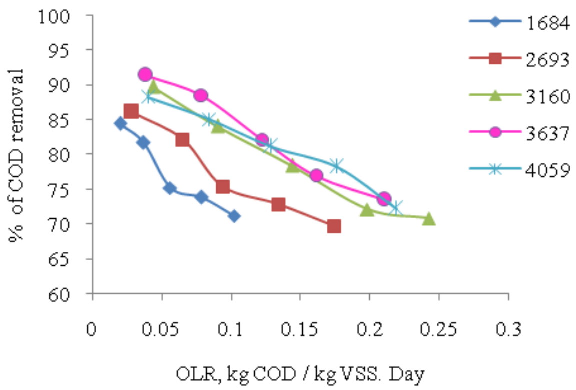

Fig. 3: Organic loading rate (OLR) vs COD removal under psychrophilic condition.

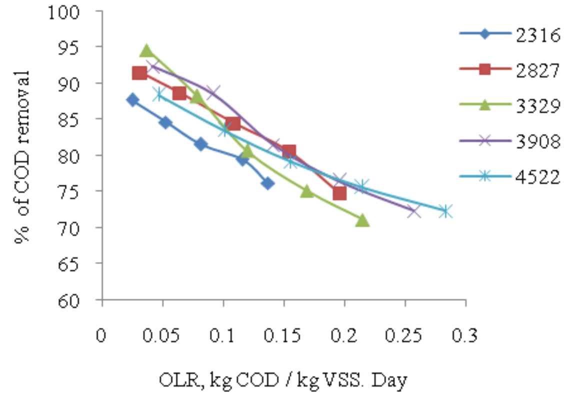

Fig. 4: Organic loading rate (OLR) vs COD removal under mesophilic condition.

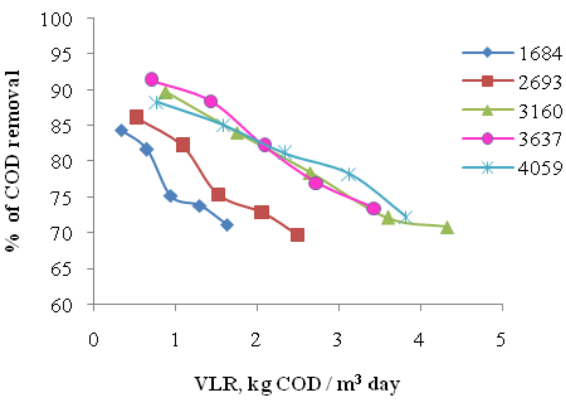

Fig. 5: Volumetric loading rate (OLR) vs COD removal under psychrophilic condition.

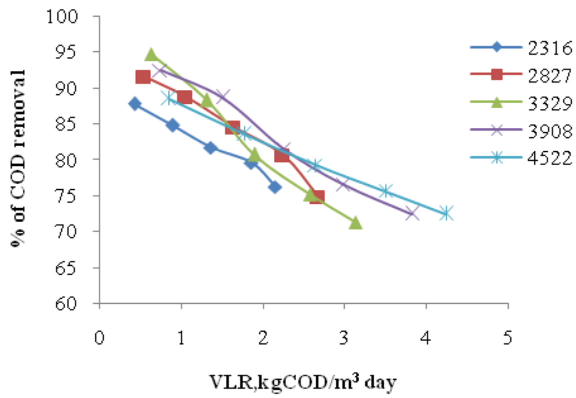

Fig. 6: Volumetric loading rate (OLR) vs COD removal under mesophilic condition.

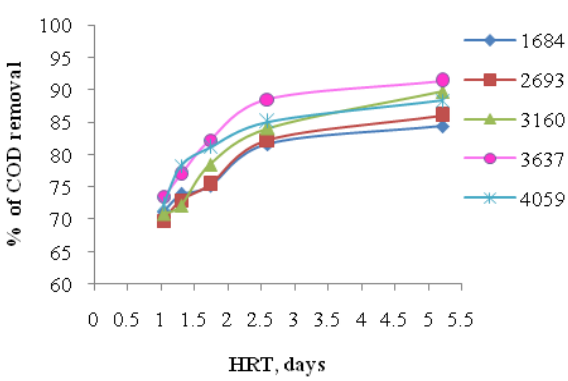

Fig. 7: Hydraulic retention time (HRT) vs COD removal under psychrophilic condition.

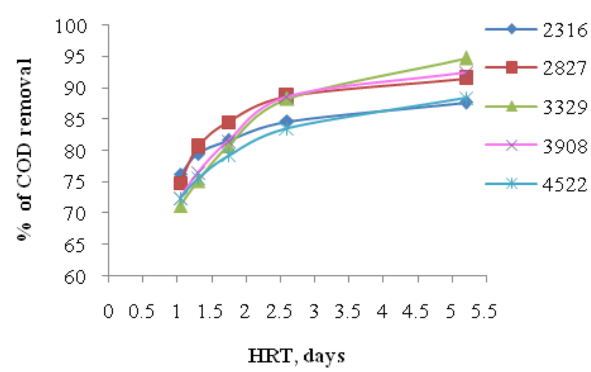

Fig. 8: Hydraulic retention time (HRT) vs COD removal under mesophilic condition.

loading rates VLR, 0.331 to 4.33 kg COD/m^3day and the maximum was found at 0.63 kg COD/m^3day at phase I, and VLR 0.427 to 4.24 kg COD/m^3day and the maximum was found at 0.63 kg COD/m^3day at phase II. The Figs. 7 and 8 were drawn on the performance of the model in terms of % COD removal under varying hydraulic retention time HRT, 5.21, 2.6, 1.74, 1.3 and 1.04 days, and the maximum was found at 5.21 days in both the phases.

The optimum condition for higher % COD removal of each average influent COD was identified from the results and given in Tables 2 and 3. The biogas generation, maximum efficiency of COD reduction, maximum concentration of VSS in sludge blanket and maximum gas conversion ratio were 0.21 to 0.27 and 0.20 to 0.31 m^3/kg COD removal, 91.42 and 94.70%, 52750 and 51120 mg/L and 0.28 and 0.31m^3 respectively. The influent and effluent characteristics at maximum COD removal are presented in Table 4.

CONCLUSIONS

a. The startup of a UASB reactor can be achieved within 60 days with domestic waste and stabilized sludge and the model was run with a synthetic dairy industry wastewater as substrate.

b. During psychrophilic temperature, the reactor achieved a COD removal efficiency of 91.42% at OLR of 0.039 kg COD/kg VSS per day, VLR of 0.70kg COD/m^3day and HRT of 5.21 days and the removal efficiency of BOD, TSS, TDS, P and N as 91%, 82%, 89%, 42% and 46% respectively.

c. During mesophilic temperature, the reactor achieved a COD removal efficiency of 94.7% at OLR of 0.037kg COD/kg VSS per day, VLR of 0.63 kg COD/m^3day and HRT of 5.21 days and the removal efficiency of BOD, TSS, TDS, P and N are 96.4%, 86%, 91%, 41% and 50% respectively.

d. Biogas can be produced at a rate of 0.30m^3/kg of COD removal. The model was observed to retain a concentration of biomass as VSS as high as 52720mg/L (psichrophilic range) and 51120mg/L (mesophilic range) in the sludge blanket zone. To meet the standards for disposal of treated effluent, UASBR required the downstream aerobic system to reduce COD further.

e. The UASB process is seen as one of the most cost effective, efficient anaerobic and energy recovery treatment for industrial wastes.

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