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RESEARCH ARTICLE

EFFECT OF INCREASING FEED CONCENTRATION AND DECREASING HRT ON PERFORMANCE OF UASB REACTOR TREATING DAIRY WASTEWATER

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ABSTRACT

A continuously increase in demand for milk and milk products has led to increase in dairy industries. Subsequently, the wastewater generated also increased which cause environmental problems when discharged to surface water or land. Wastewater generated in dairy contains mostly organic constituents which can be treated with biological treatment methods. This research was carried out to treat dairy wastewater of different strength by using UASB reactor at different HRT. After steady state condition in batch mode, the UASB reactor was run in continuous mode. In continuous mode, the study was divided into three phases, based on increasing wastewater strength and decreasing HRT. The 50% diluted dairy effluent was fed into reactor in phase I, whereas, 100% dairy effluent was fed in phase II and III. The HRT was progressively decreased during study i. e. HRT was 20 hours, 14 hours and 10 hours in phase I, II and III, respectively. The pH of the reactor was in the range of 7.12 to 7.72 throughout the study. The COD reduction efficiency was observed 94.7%, 86.8% and 80.9% in phase I, II and III, respectively. With increase in strength and decrease in HRT, a decrease in COD reduction was observed during the study period. The VFA alkalinity ratio varied from 6.71 to 0.07, 5.68 to 0.07 and 4.17 to 0.15 in phase I, II and III respectively. The optimum pH and VFA alkalinity ratio indicate that the reactor was working properly leading to higher COD reduction rate.

INTRODUCTION

A steady rise in the demand for milk and milk products in many countries has led to advancements in veterinary science, which has subsequently result in steady growth in the production of milk per cattle (Poompavai, 2002). Among nations, India is one of the largest producer of milk and dairy products in the world, with annual milk production grossing 121.8 million tonnes in the year 2010-2011 and anticipated to be 127.9 million tonnes in the year 2011-2012 (NDDB, 2012). The amount of wastewater generated from these industries has also been increased with increase in milk production. In dairy industry wastewater is produced from bottle, can, tanker, machinery, floor washing, manufacturing process, utilities and service section. The dairy industry on an average generate 6-10 liters of wastewater per liter of the milk processed (Kolhe and Pawar, 2011). Dairy wastewaters generally contain large quantities of milk constituents such as casein, lactose, fat, and inorganic salts besides detergents and sanitizers used for washing (Kolhe *et al.*, 2009). Due to the high pollution load of dairy wastewater, the milk processing industries discharging untreated or partially treated wastewater cause serious environmental problems (Montuelle *et al.*, 1992). Among biological treatment anaerobic processes has gained considerable interest as it converts organic content into a biogas, a source of energy with minimal quantity of sludge. Whereas the aerobic treatment process requires an additional energy input for aeration (Deshannavar *et al.*, 2012). Wheatly, 1990 has reported that dairy effluent has high organic content and are warm, enabling them to be ideal for anaerobic treatment. Up flow Anaerobic Sludge Blanket (UASB) reactors have been widely used for the dairy wastewater treatment (Gavala *et al.*, 1999). The present research was carried out to study the effect of increasing feed strength of dairy waste water and decreasing HRT on performance of UASB reactor.

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MATERIALS AND METHODS

Dairy wastewater sample was collected and persevered at 4^oC in laboratory. The dairy effluents were analyzed using standard methods of analysis of water and wastewater for physico – chemical characteristics (APHA, 2005). The UASB reactor used for the study was cylindrical type made up of borosilicate glass having working volume of 2.5 L with length and diameter 31cm and 11 cm, respectively. The reactor was setup by using 500 ml filtrate of biogas plant sludge, 500 ml raw dairy wastewater and the remaining volume was filled with distilled water. The reactor was kept in steady state conditions for 15 days and after that it was fed with 500 ml raw dairy wastewater weakly. After proper acclimatization and steady state condition i.e. 92% COD reduction, the reactor was run in continuous mode. Continuous mode study was divided into three phases i.e. phase I, II and III based on decreasing HRT and increasing strength of wastewater. In first phase, the reactor was fed with 50% dairy wastewater at 20 hours HRT. Whereas in phase II and III, the reactor was fed with 100% dairy wastewater at HRT of 14 hours and 10 hours, respectively. The treated wastewater was analyzed for pH, alkalinity, VFA, VSS, TSS, sulphate, phosphate, TKN and COD.

RESULT AND DISCUSSION

The raw dairy effluents used in present study were pale white in color having pH 6.8 with high COD 3200 mg/L (Table 1). After UASB treatment, the effluents were analyzed, and results are shown in Table 2. The pH of the UASB reactor in phase I, II and III varied from 7.12 to 7.54, 7.21 to 7.65 and 7.29 to 7.72, respectively. The optimum pH range for anerobic degradation was 6.5 to 8 reported by (Shefali, 2000). The pH range from 7 to 8 is favorable for the methonogenic bacteria (Benson *et al*., 2007). It shows that the reactor was working properly and pH favours the methanogenesis. Sulphate varied from 159 mg/L to 45 mg/L in phase I (71.7 % reduction), 161 mg/L to 62 mg/L in phase II (61.4 % reduction) and 178 mg/L to 72 mg/L in phase III (59.5 % reduction), respectively. Sulphate concentration decreases with time during the study period in all the phases. Sulphate concentration was increases with increase in feed concentration and decrease in HRT. Higher concentration of sulphide can cause toxicity to the methanogens and inhibit the conversion of VFA into methane leading to decreased performance of reactor (Gupta *et al*., 2007). Bal *et al*. (2001) reported that sulphide concentration of more than 1000 mg/L is toxic for the acetate and H_2 utilizing methanogens. The TKN varied from 201.6 mg/L to 140.0 mg/L in phase I, 221.4 mg/L to 179.2 mg/L in phase II and 229.6 mg/L to 187.6 mg/L in phase III. The highest removal of TKN observed was 30.5% in phase I. The results show that there was a decrease in TKN concentration with time during the study period. But TKN concentration was increased with increase feed concentration and decrease in HRT i.e. from phase I to III. The lower removal rate of TKN may be due to non conversion of nitrite and nitrate nitrogen to nitrogen gas. The concentration of phosphate varied from 3.76 mg/L to 1.44 mg/L in phase I, 3.22 mg/L to 1.58 mg/L in phase II and 3.44 mg/L to 1.7 mg/L in phase III. The phosphate reduction observed during the study was 61.7 %, 50.9 % and 50.5%, in phase I, II and III, respectively. The results shows that phosphate removal decrease with increase in feed concentration and decrease in HRT i.e. from phase I to II, but further decrease in HRT has negligible effect on phosphate removal i.e. phase II to III. This may be due to increase in phosphate content with increase in fed concentration.

The volatile suspended solid and total dissolved solid ratio shows the sludge profile of UASB reactor. The maximum and minimum VSS TSS ratio observed during study period was 6 and 1; 2 and 1 and 1 and 0.5 in phases I, II and III, respectively. An initial increase in the VSS TSS ratio indicates the active biomass growth in the reactors. More than 90% of VSS contents are due to active biomass, and remaining 10% are attributed to non-biodegradable volatile solids and dead cell debris (Metcalf and Eddy, 2003). The VSS/TSS decreased

Table 1. Characteristics of Dairy wastewater

S. N.	Parameter of wastewater analyzed	Range mg/L)
1	Color	Pale white
2	pH	6.8
3	Alkalinity as calcium carbonate ($CaCO_3$)	850
4	COD	3200
5	Total Suspended Solid (TSS)	150
6	Volatile Suspended Solid (VSS)	100
7	Volatile Fatty Acids (VFA)	4937
8	Sulphate	115
9	Phosphate	2.43
10	Total Kjeldahl Nitrogen (TKN)	210

Note: All the parameters are in mg/L except pH and Color.

with time during study period in all phases. Results also shows that VSS TSS ratio decrease with increase in feed concentration and decrease in HRT. This may be due to high rate of degradation of biodegradable organic compounds and increase in non-biodegradable volatile solids and dead cell debris. The VFA Alkalinity ratio is shown in Figure 2. It varied from 6.71 mg/L to 0.07 mg/L, 5.68 mg/L to 0.07 mg/L and 4.17 mg/L to 0.15 mg/L in phase I, II and III, respectively. Initially the VFA alkalinity ratio was high but after a period of time it approaches to optimum condition of anaerobic treatment i.e. less than 0.4 (Grady and Lim 1980). The ratio of VFA Alkalinity more than 0.8 cause unbalanced conditions in the reactor (Vlissidis and Zauboulis, 1993). The VFA alkalinity ratio was lower than 0.4 in all phases. It indicate that UASB reactor was working properly and efficiently and methanogenic activities were smooth. An overall decrease in COD with time was observed during the study period in all the phases. The COD in mg/L varied from 1520 to 80, 1820 to 240 and 1680 to 320 in phase I, II and III, respectively (table 2). The maximum COD reduction was 94.7 %, 86.8% and 80.9% in phase I, II and III, respectively (Figure 1). The results show that when the fed concentration was increased and HRT was decreased, a decrease in COD reduction observed. Similar trend was observed by Yan (1990) and Nadais *et al*. (2005). The optimum pH, nutrients,VSS/TSS and VFA Alk ratio shows better performance of the UASB reactor which is indicated by higher COD removal . Results also shows that increasing feed concentration and decreasing HRT adversely affect the performance of the reactor as COD reduction down from 94.7% to 80.9 % from phase I to III.

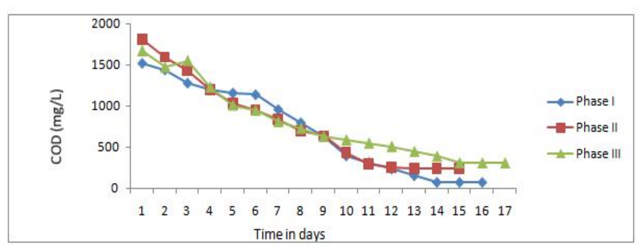

Fig. 1. COD removal during study period

It is essential that the reactor contents provide enough buffering capacity to neutralize any eventual VFA accumulation and thus prevent build-up of localized acid zones in the digester (Kanat *et al*., 2009). The degradation of proteins in the waste water by anaerobic treatment results in generation of alkalinity due to the reaction of ammonia with carbon

Table 2: Performance of Uasb reactor during study period

Days	Phase I									Phase II									Phase III								
	pH	Alk.	VFA	VSS	TSS	SO_4^{-2}	TKN	PO_4^{-3}	COD	pH	Alk.	VFA	VSS	TSS	SO_4^{-2}	TKN	PO_4^{-3}	COD	pH	Alk.	VFA	VSS	TSS	SO_4^{-2}	TKN	PO_4^{-3}	COD
1	7.19	950	4646	250	125	144	196.0	3.32	1520	7.40	700	3977	300	200	161	221.4	3.22	1820	7.40	1000	4165	250	250	178	229.6	3.37	1680
2	7.21	800	4235	300	125	159	201.6	3.67	1440	7.30	750	3255	275	175	130	218.4	3.01	1600	7.30	1100	3857	250	250	165	224.0	3.44	1480
3	7.26	700	4697	200	100	140	193.2	3.76	1280	7.21	800	2865	250	150	121	212.8	2.83	1440	7.40	1200	3291	200	275	153	215.6	3.21	1560
4	7.18	750	3343	200	100	127	193.2	3.28	1200	7.34	850	2317	200	150	116	204.4	2.63	1200	7.36	1250	2674	225	250	147	112.8	3.1	1240
5	7.20	800	3206	150	75	115	182.0	3.09	1160	7.40	900	2160	175	175	110	196.0	2.63	1040	7.33	1200	2434	200	225	138	207.2	2.94	1020
6	7.30	900	2674	150	50	111	179.2	3.04	1140	7.45	1000	1851	150	150	102	193.2	2.54	960	7.36	1300	2571	175	225	140	201.6	2.83	960
7	7.12	1000	2143	150	25	98	173.6	2.98	960	7.50	1200	1765	150	150	94	190.4	2.57	840	7.35	1400	2057	150	250	130	201.6	2.69	820
8	7.25	1100	1550	100	25	83	159.6	2.59	800	7.47	1250	1420	175	100	90	187.6	2.44	700	7.58	1500	1800	175	200	125	198.8	2.71	740
9	7.40	1150	1026	100	25	72	156.8	2.45	640	7.45	1350	1260	150	100	95	184.8	2.31	640	7.58	1550	1200	150	200	117	198.8	2.66	640
10	7.50	1150	725	150	25	69	148.4	2.4	400	7.40	1500	1026	150	100	97	182.2	2.1	440	7.72	1450	857	150	200	104	193.2	2.3	600
11	7.40	1100	406	100	25	61	142.8	2.22	320	7.50	1600	726	125	75	83	182.2	1.83	300	7.60	1300	514	150	175	98	198.2	2.21	560
12	7.54	1000	305	50	50	56	142.8	2.1	240	7.65	1550	408	100	75	88	179.2	1.68	260	7.42	1200	428	125	175	91	198.8	2.1	520
13	7.46	900	205	50	25	52	140.0	1.98	160	7.61	1400	305	100	50	74	179.2	1.69	240	7.36	1100	205	100	150	89	190.4	2.22	460
14	7.50	800	85.7	25	25	48	140.0	1.75	80	7.62	1300	85	50	50	69	179.2	1.58	240	7.29	900	171	100	125	85	190.4	2	400
15	7.46	700	51.4	25	25	47	142.8	1.44	80	7.60	1200	85	50	50	62	179.2	1.58	240	7.30	750	102	50	100	78	187.6	1.9	320
16	7.50	600	68.6	25	25	45	140.0	1.59	80										7.30	600	120	50	100	72	187.6	1.8	320
17																			7.29	550	85	50	100	75	187.6	1.7	320

Note: All the parameters are in mg/L except pH dioxide and water (Gohil *et al.*, 2006). It provides buffering of the accumulated VFA and optimize the pH.

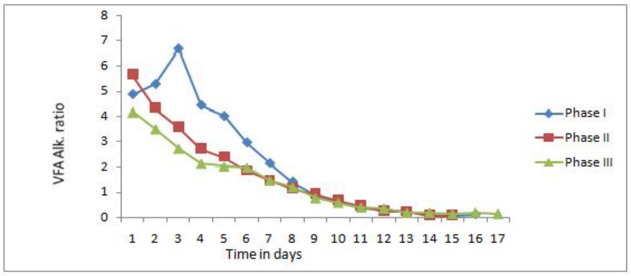

Fig. 2: VFA Alkalinity ratio during study period

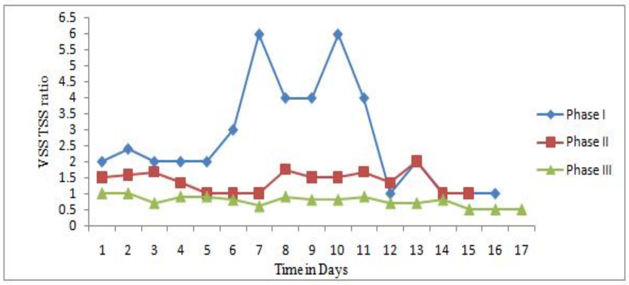

Fig. 3: VSS TSS ratio during study period

Conclusions

The optimum pH and VFA/Alk ratio and higher COD reduction shows that the reactor was performing well. However, a decrease in COD removal was observed when feed concentration was increased and HRT was decreased. In overall the reactor was treating dairy wastewater effectively. Even at higher feed concentration 100% and lower HRT of 10 hours, the COD reduction was 80.9%. Thus, it can be concluded that anaerobic treatment of dairy wastewater in UASB reactor is viable and better option. The UASB reactors are very efficient in treatment of dairy wastewater even at higher feed concentration and lower HRT but efficiency increase with decrease in feed concentration and increase in HRT.

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