Dairy Industrial Wastewater Treatment Using (UASB) Reactor

Farhikhteh Samadi, Seyed Ahmad Mirbagheri, Seyed Mohammadjavd Falsafi

Abstract— This study was carried out for examination of a pilot scale UASB reactor, to optimize organic loading rate (OLR) and hydraulic retention time (HRT) for the treatment of dairy wastewater. The total volume of the reactor was 4000 liter with a surface area 1.0 m^2 and height of 4.0 m. The reactor was used to treat dairy wastewater with the flow rate 20000 to 25000 liter/day, with chemical oxygen demand (COD) of 3000 to 3500 mg/L and biological oxygen demand (BOD_5) of 1600-1900 mg/L. The treatment plant was equipped under anaerobic condition. This study was carried out in four stages in a 130 days period increasing flow rate from 133 to 1100 L/d with no additional nutrients added to the system. Results show that the maximum inflow rate to the reactor was 10000 l/d with COD removal efficiency about 80% and the organic loading rate between 7.5-7.67 kg⁄(m^3.d) and hydraulic retention time of 9.6 hour and upflow velocity equal to 0.42 m/h. The efficiency of this study indicated that the UASB process could be used effectively for the treatment of dairy wastewater.

Keywords— Biogas, BOD, COD, Dairy Wastewater, Methane gas, Organic loading, UASB,

1 Introduction

In some cases, domestic and industrial wastewater such as dairy sewage are discharged into collector systems and as a result high values of nutrients must be treated in wastewater treatment plants which causes increase in COD of the influent.

Biological treatment methods are of interest due to their cost effectiveness, diverse metabolic pathways and versatility of microorganisms [1],[2],[3],[4],[5]. Anaerobic technology is a mature and well-established process for biological wastewater treatment [6].

One of the anaerobic treatment methods is upflow anaerobic sludge blanket (UASB) that developed by Lettinga et al, in 1979 [7] in Netherlands and has been widely used to treat variety of industrial and domestic wastewaters all over the world [8]. A full scale UASB reactor was studied for treatment of pig and cattle slaughterhouse wastewater in which a physicochemical system was used. The COD removal of this system was 70-92% with maximum organic loading 1.46-2.43 (KgCOD)/(m^3.d) [9],[10]. Some other studies were done at temperatures between 14-37 °C with OLR rating from 0.5 to 16 (KgCOD)/(m^3.d) for treating different types of wastewater such as Grey water [11], fruit wastewater [12] and sugar industry wastewater [13]. They had COD removal efficiencies of 31-41, 70 and 89.4% respectively.

UASB process was developed as an anaerobic treatment system with a high degree of efficiency based on the immobilization of biomass in the form of sludge granules with good settling ability [14], [15]. The UASB reactor has four major components: 1. sludge bed, 2. sludge blanket, 3. gas–solids separator (GSS) and 4. settlement compartment [7], [8].

The sludge bed is a layer of biomass settled at the bottom of the reactor. The sludge blanket is a suspension of sludge particles mixed with gases produced in the process. A gas/solid separator prevents biomass washout from the reactor and maintains a large sludge mass in the UASB reactor [16]. Many factors have been found to affect the efficiency of UASB reactors such as: temperature, wastewater composition, mixing, pH, organic loading rate and toxicity [7]. Anaerobic processes in contrast with aerobic processes have some advantages such as: much less biomass production from the same amount of COD removal [17], capability of high organic loading, surviving anaerobic micro-organisms without feeding for a long period [18], low cost, reduction of greenhouse gas emissions and energy gains [19], [20]. They also have some disadvantages, for instance the organic removal efficiency in anaerobic processes does not fit environmental standards, they need a long time to achieve a stable situation at the beginning and anaerobic processes need higher temperature to reach more efficiency [21]. Mahmoud N (2008) [22] investigated a UASB reactor with HRT of 10h. in their study the achieved removal efficiencies were 54 and 32% in hot and cold weather respectively.

Whereas a myriad of possible factors have been reported that affect the efficiency of a UASB reactor in treating different types of industrial wastewater, there is no study on the effect of various flow rates on the treatability of dairy sewage using a UASB system.

The present study offers an attempt to obtain maximum applicable flow rate in removal efficiency of the contaminant present in the mentioned dairy wastewater by UASB reactor and determining optimum domain, to reach the maximum BOD and COD removal efficiency which are the contaminant parameters of the dairy sewage and finally measuring the volume of the produced biogases in different stages as removing 1 gram of COD or BOD in dairy industries.

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2 Materials and Methods

2.1 UASB reactor set-up

The pilot scale UASB reactor used in this study was designed with the following characteristics. Volume of reactor was 4000 liters. Height of the reactor was 4.0 m and it had a cylindrical section with 1.13 m diameter and a cone, to have a uniform wastewater distribution on the bottom of the reactor. Moreover, at the top of the reactor a settling unit was embeded to decrease the velocity to its half value. A cone for trapping gases, collected the produced gases and stored them in the collection tank and an outgoing valve was used to measure biogas using a gauge. The pilot was made of black iron C-S with an epoxy veneer to prevent corrosion. Various sampling valves were imbedded on the tank to measure amount of volatile suspended solids (VSS) along the tank's height. The distance between valves was 1.0 m and the first valve was located 0.5 m above the bottom of the reactor. To control the flow rate, a pump with power of 0.55Kw and a closed loop with two valves were used as shown in Fig 1. Further, to control the influent COD, a 1000 liters tank was used that was replaced with a 10000 liter after the third month. The wastewater entered three tanks from upstream with retention time about 3 hours in each, changing COD from 4500-5000mg/L to 3000-3500 mg/L in order to remove grease through the gravity method. In the reactor a pipe and an inlet valve for washing and returning flow, also a pipe and a valve for outflow were used.

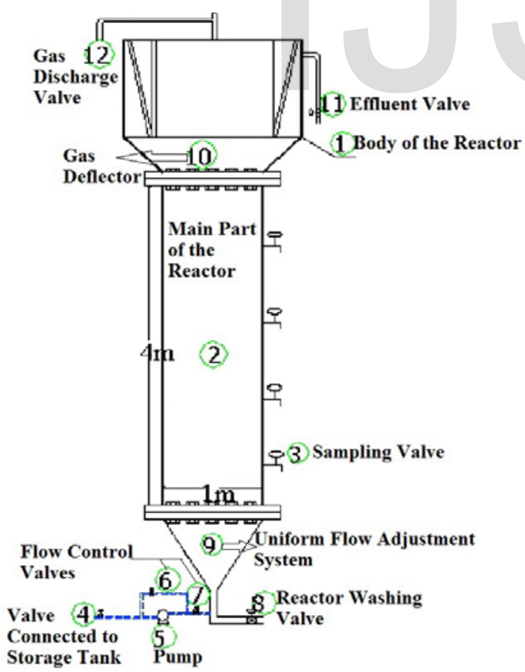

Fig. 1. Schematic diagram of UASB reactor

2.2 Site description and Wastewater characteristics

The wastewater plant produces 20000 to 25000 liters per day (L/d) of wastewater. Since its sewage has no whey, it is not salty and has the following characteristics as shown in table 1:

TABLE 1
THE CHARACTERISTICS OF THE INFLUENT WASTEWATER

Parameters	Concentration
Oil and grease (mg/L)	400 -600
BOD (mg/L)	1600 -1900
COD (mg/L)	3000 -3500
Total suspended solids (mg/L)	800 -850
Phosphorous (mg/L)	20 -30
Total Kjeldahl nitrogen (mg/L)	100 -120
pH	6.5 -7.5

2000 liters sludge and 2000 liters of water was poured to a 4000 liter reactor, operating with 133 L/d flow rate and 28°C temperature. When launching the system, upflow velocity, hydraulic retention time and organic loading rate (OLR) were 0.133 m/d, 30 days and 0.1 kg/(m^3.d) respectively knowing that the surface area of the reactor was 1.0 m^2 and its COD was 3000mg/L.

According to table 2, and considering the experiments done on the dairy industrial sewages using UASB reactors, industrial wastewater treatment usually has more than 80% COD removal efficiency. However, since the wastewater used in this research had a COD value more than 3000mg/L which is not in the range of aerobic treatment (COD <1000 mg/L) , the UASB reactor was used in a large volume in comparison with other industrial dairy wastewater experiments.

TABLE 2
SPECIFIED PARAMETERS IN DAIRY SEWAGE TREATMENT BY UASB REACTOR (OMIL ET AL, 2003) [3]

Reactor	Volume (L)	T (°C)	COD (mg/L)	Efficiency (%)	HRT (hours)	OLR (gCOD/L.d)
UASB	1.2	30	4100	78	6.5	15
UASB	4	35	2940	97.5	48	14.7
UASB	1	35	2800	91.1	2.9	23.8
UASB	4	35	2300	96	5.3	10.4
UASB	8	30	1800	87	5	8.5
UASB	4x(10^6)	35	4400	63	192	0.55

3 Results and Discussion

The project had various parts each of which contained several subgroups that according to each step and its conditions the running periods were different.

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The reactor began operation with upflow velocity 0.133 m/d, hydraulic retention time 30 days and increasing organic loading rate about 0.1 kg/(m^3.d) untill the 47th day. In each stage the flow rate was increased until getting to a steady state condition. At the end of the 63th day, high efficiency was achieved in each stage with upflow velocity of 4.0 m/d and retention time of 1.0 day. Afterwards, in order to reach the maximum flow rate, the COD depletion percentage was controlled and flow rate growth was kept steady to get to the COD removal efficiency more than 80%. The procedure was the same until the 96th day. From the 97th day the influent wastewater flow rate was raised up to 11000 m/d. It was observed that COD removal efficiency was decreasing and pH of wastewater was going down to even less than 6, therefore, the influent flow rate was instantly decreased. Reactor reached its maximum efficiency at the flow rate equal to 10000 L/d and COD removal efficiency was 80% with OLR 7.67 kg/(m^3.d) and retention time 9.6 hour.

At the beginning of system operation, Q for the system was 0.133 m/d and it stayed constant until reaching the steady state in the reactor. This process was done for different organic loadings according to table 2. By increasing each OLR, inflow and outflow PH, inflow and outflow COD, OLR and produced gas flow rate tests were continuously performed until reaching the steady state. COD removal efficiency, retention time and upflow velocity were measured and presented in table 3. Results of VSS experiments obtained from UASB reactor sampling valves and system inflow and outflow BOD_5 tests are shown in table 4.

TABLE 3
LOADING PROCEDURE IN DIFFERENT DAYS WITH RETENTION TIME AND FLOW VELOCITY

TIMED	OLR (KG/M^3.D)	HRT D	VUP M/H	W.W. L/D
1-3	0.1	30.08	0.006	133
4-8	0.2	15.04	0.011	266
9-15	0.3	10.00	0.017	400
16-24	0.4	7.27	0.023	550
25-29	0.6	5.00	0.033	800
30-33	0.9	3.33	0.050	1200
34-40	1.1	2.67	0.063	1500
41-47	1.5	2.00	0.083	2000
48-56	2.3	1.33	0.125	3000
57-63	3.0	1.00	0.167	4000
64-71	4.2	0.73	0.229	5500
72-82	5.3	0.57	0.291	7000
83-96	6.8	0.44	0.375	9000
97-104	8.3	0.36	0.458	11000
105-130	7.6	0.4	0.420	10000

TABLE 4
MEASURED PARAMETERS DURING THE UASB SYSTEM OPERATING

TIME D	BOD_{IN} MG/L	BOD_{OUT} MG/L	VSS1 MG/L	VSS2 MG/L	VSS3 MG/L	VSS4 MG/L	BOD RED. %	COD RED. %
1	1830	104	15900	12700	12920	8340	94	91
8	1795	115	12300	12420	10140	9735	94	88.6
16	1890	186	13820	12190	9340	8030	90	86.2
26	1798	256	13050	11570	8060	6120	86	79.9
34	1780	212	14030	10340	7090	5410	88	82.2
42	1790	269	13700	10210	7180	4112	85	78.2
58	1812	290	12120	9700	6720	3900	84	80.5
66	1790	312	11200	7150	4060	2730	83	74.8
74	1795	406	10840	7230	3950	2520	77	71.3
82	1783	218	10900	6880	3985	1266	88	82.2
94	1735	409	10985	7340	4015	985	76	71.5
100	1736	436	11175	8900	4190	816	75	64.3
108	1744	345	9320	7140	5280	1935	80	68.1
116	1776	253	9860	7295	6385	1145	86	72.6
124	1776	112	10130	8330	5580	936	94	76. 3
130	1795	116	10865	8842	5116	842	94	78.6

In Fig 2. flow velocity is plotted versus OLR in which X-axis is the amount of organic loading rate in terms of kg/(m^3.d) and Y-axis is the upflow velocity in trems of m/h. As indicated in the figure, the maximum upflow velocity in the optimum loading OLR = 7.6 kg/(m^3.d) is 0.42 m/h, which is in the recommended range 0.1 – 1 m/h [8].

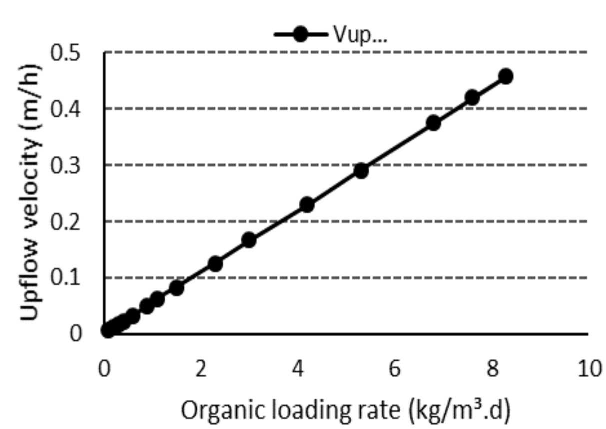

Fig. 2. Upflow velocity during operation at different ORL values

Fig 3. illustrates the volume of produced biogas and organic loading rate during the system operation. It can be seen that, as organic loading increases, the amount of produced biogas increases as well. It reveals the proper operation of the system. In 97th day because the system was not compatible with the growth of OLR (=8.3 kg/(m³.d)), rate of gas production decreased and in the 105th day by decreasing organic loading rate (OLR=7.68 kg/(m³.d)), it improved to 329 L/d.

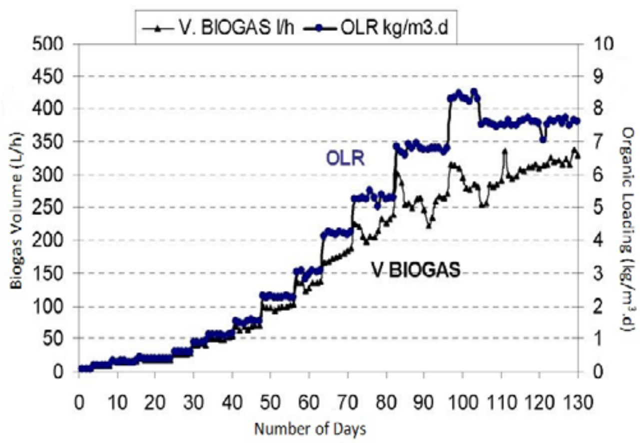

Fig. 3. Volume of produced biogas and organic loading during UASB performance

Fig 4. indicates the amount of biogas in contrast with 1-gram COD removal. X-axis shows the amount of COD removal in one day and Y-axis shows the amount of produced biogas in one day. After plotting regression line, produced biogas is 0.3144 as 1-gram COD removal which is less than previous studies (0.38 to 0.53) [23] ,[24], and it may be because of the defference in the method of biogas measurement.

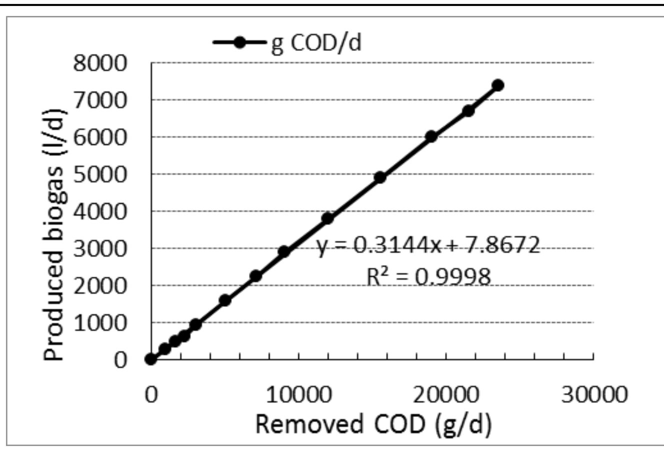

Fig. 4. Graph of produced biogas volume as 1-gram COD removal during operating the UASB system

Fig 5. indicates amount of biogas in contrast with 1-gram BOD removal. X-axis shows the amount of BOD removal in one day and Y-axis shows the amount of produced biogas in one day. After plotting regression line, produced biogas is 0.4315 as 1 gram BOD removal.

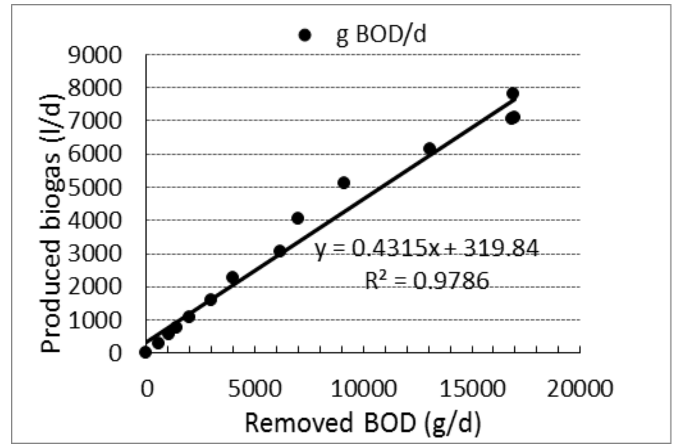

Fig. 5. Graph of produced biogas volume as 1-gram BOD removal during operating the UASB system

4 Conclusion

The present work was successfully conducted to reach a maximum applicable flow rate in a dairy wastewater using the UASB bioreactor as an anaerobic bioreactor. The main conclusions drawn from this study are:

UASB design is feasible to treat dairy industry wastewater efficiently up to an optimum OLR of 7.6 kg/(m³.d) with the average COD equal to 3000 mg/L. In this case the maximum COD removal efficiency was 80%; maximum flow rate obtained in the reactor was 10000 L/d and maximum BOD_5 removal in OLR=7.6 kg/(m³.d) was 90%. Maximum velocity in pilot at its optimum loading was 0.42 m/h with retention time of 9.6 h. If the loading rate is more than UASB reactor capacity, both pH and COD removal efficiency will decrease. Biogas production as 1 gCOD/d removal is 0.3144 and as 1 gBOD/d removal is 0.4315 which was less than previous studies.

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