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Food Industry Effluent Treatment: An Advance Anaerobic Method

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Abstract: In present study a food industry effluent was studied to find out its pollutants concentrations and to suggest a modified anaerobic treatment method which has a low cost technology for treatment of effluent. The performance of this modified method was compared with conventional anaerobic treatment method. Various experiments have been performed to find out suitability of this modified technology which was named as Up flow anaerobic sludge filter reactor (UFASFR). It was found that removal efficiency of pollutants was higher with UFASFR as compared with Conventional anaerobic reactor (CAR). It was also envisaged that hydraulic retention time (HRT) of 12 hrs was best suited for the treatment of food industry effluent by UFASFR treatment method.

Key words: Anaerobic treatment, slime, inoculums, food industry effluent, up flow reactor.

Introduction

Anaerobic treatment of wastewater is very well suited for industries discharging highly concentrated (over app. 1500 mg COD/L) wastewater. The food and food processing industry discharges wastewater of this type. Food industry wastewater can be characterized with pollutant parameters like BOD, COD, fats, oil and grease and SS. Most of them are composed of easily biodegradable compounds as carbohydrates, proteins and lipids (Clark, 2003).

Different types of anaerobic treatment methods have been discovered for wastewater treatment e.g., fixed bed loop, and anaerobic method for the treatment of highly organically polluted wastewater. COD removal rates of 80-160 kg (m^3 per day) have been obtained in lab and pilot scale reactors (Vasso and Winfried, 2006). Food wastewater treatment with anaerobic bioreactor with the volumetric loading rate 4.5 kg/m^3 d, COD removal rate was in the range of 81–94% and the gas yield stabilized at 0.136 m^3/kg COD (Yiliang et al., 2005). The high organic loading rate 5–6 kg COD/m^3 d, when treated with Anaerobic filter, rather than COD removal is higher than 90% (Omil et al., 2003).

In India, a variety of anaerobic reactors including anaerobic lagoon (Rao, 1980), conventional digester (Pathe et al., 1995), anaerobic filter (Gadre and Godbole, 1998), and biomass based biogas plants (Chanakya et al., 2004) have been studied. However very few studies have been made to evaluate the efficiency and usefulness of anaerobic fixed bed reactor for treating food (biscuit) industry wastewater. Hence in present study Upflow anaerobic sludge filter reactor (UFASFR), which is a modified anaerobic treatment method, has been suggested for treatment of this food industry effluent. In this study it was envisaged to develop a low cost treatment method for the removal of pollutants from Britannia Food Industry effluent.

The water requirement in this industry is around 215 KLD, including process and domestic requirements. The wastewater generation is only about 73 KLD from industry because most of the water used in the process is lost due to evaporation in baking. Keeping the above

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points in consideration, the present study was undertaken with following objectives:

- Increase the BOD, COD, and oil and grease removal efficiency by adjusting HRT values.
- Recovery of by-product in terms of methane gas after treatment of effluent with modified reactor and biogas quantification.

Materials and Methods

Experimental Site for Sample Collection

Wastewater samples were collected from Britannia Food Industry, SIDCUL, Pantnagar. This industry is around 12 km from main university campus of Pantnagar in south-west direction. After grab sampling, the effluent samples were brought to laboratory for further physico-chemical analysis and experimental setup.

Inoculum

Inoculum used for anaerobic treatment was collected from digested slurry of biogas plant. This digested slurry was filtered with muslin cloth and active bacterial suspension was brought to laboratory and used as seeding material.

Experimental Setup

A schematic diagram of experimental set up is shown in Figure 1. An Iron cylinder was used for designing laboratory scale UFASFR. Its volume is 20 L with 35 cm height and 27.5 cm diameter. Inlet is at 5 cm from the bottom, for up-flow of effluent, and an outlet at the height of 28 cm from bottom for discharge of treated effluent. For release of biogas from the reactor another outlet was provided on the top of the digester.

Figure 1: Designed Upflow anaerobic sludge filter reactor (UFASFR).

Packing Materials

Two types of packing materials were used in designed UFASFR. In A-type UFASFR, stones of very small size of 0.5 to 5 cm diameter and in B-type UFASFR, tin caps of glass cold drink bottles were used as packing materials. Packing material was used up to half of the reactor height. Conventional anaerobic reactor was used without any packing material for comparison of pollutant removal efficiency of different reactors.

Experimental Methodology

After packing of reactors, 30% seed culture was used with effluent and volumes made up 10 L. The reactor openings were sealed with M-seal for anaerobic conditions in reactor. Gas outlet is at the top of reactor and it was connected with plastic pipes to water-filled bottles for water displacement in other bottles. This was done for quantification of gas produced by anaerobic process.

After substrate stabilization for 30 days (from 16th April to 15th May, 2006) in ambient environmental conditions, optimization of hydraulic retention time HRT for all type of reactors were carried out. For calculation of HRT, two litres fresh effluent (without seeding) was fed in reactor at different HRT intervals and subsequently amount equivalent to feeding i.e. 2 L was withdrawn from outlet for making same effluent level in reactors. Different hydraulic retention time of 4, 8, 12 and 24 hr were given to effluent in each reactor up to a period of three days. Performance evaluation was done by comparing the pollutants removal efficiency of modified reactor (UFASFR) at a different hydraulic retention time in comparison with conventional anaerobic reactor.

Experimental Analysis

Methane gas was estimated by Nucon Make 5700 series gas chromatography with TCD detector (Thermal Conductivity detector). Oven temperature was 160^{o}C, H_2 gas used as carrier gas. All other analysis of pollution parameters such as COD, BOD, and oil and grease were determined according to standard methods (APHA, 1995).

Results and Discussion

In last few years extensive anaerobic treatment methods were used for food industry wastewater and an increase in number of its full scale applications have demonstrated the high rate potential for removal of pollutants (Guerrero et al., 1999; Yiliang et al., 2005).

The analytical results of effluent sample collected from effluent drain shows higher pollutant concentration such

as COD (8650 mg/L), BOD (4800 mg/L), TDS (3650 mg/L), and oil and grease (2200 mg/L). These values are quite higher than the permissible limits of industrial effluent discharge as given for BOD (30 mg/L), COD (250 mg/L), TSS (100 mg/L) and oil and grease (10 mg/L).

Optimum Hydraulic Retention Time for Better Performance of Reactors

Performances of all three types of anaerobic reactors were determined in terms of pollutants reduction efficiency of reactors. At first, stabilization of reactors was done for 30 days. Further, experiment was conducted to determine percentage reduction of pollutants concentration with 2 L of effluents, at different HRT of 4, 8, 12 and 24 hr.

Physico-chemical characteristics of effluent were analyzed on 1st, 2nd and 3rd day at all hydraulic retention time upto three days period and removal of pollutants concentration was compared with initial concentration of pollutants.

Results are given in Tables 1 to 4. From these tables we can conclude that performance of A-type UFASFR gave better results at 12 hr HRT as compared to 4, 8 and 24 hr HRT with highest pollutant reduction efficiency. Whereas in B-type UFASFR, reduction pollution parameters are again best at 12 hrs of HRT. At 24 hr HRT the reduction efficiency was found almost similar to that at 12 hr HRT for both types of reactors. Both UFASFR performed better than conventional reactor.

Figure 2 shows maximum 55% of methane at 24 hrs HRT with A-type UFASFR. The minimum concentration of methane was observed 35.4% at 4 hr HRT in conventional anaerobic reactors (control).

The results for fixing HRT experiment reveal that 12 hrs HRT is best suited for this effluent treatment. But generally a HRT of 22-24 hours is given for the wastewater of high COD of 7000 mg/L to 10,000 mg/L (Sutton and Corrdo, 1982). In A type UFASFR, microorganisms form firm layer of slime due to rough surface area of packing material as compared to packing media of B type UFASFR which has more smooth surface. However, non-attached biomass also contributed to the treatment activity in up flow fixed bed reactors (Pohland, 1992). Digested slurry from biogas plant is best source of inoculum which enhanced the microbial activities for substrate utilization and gas production (Boopathy, 1987).

Table 1: Removal of pollutant concentration at 4 hr HRT

Pollutant parameter	*Initial pollutant concentration in effluent (before treatment)*	*Concentration of pollutant after treatment in reactors*					
		A type UFASFR		*B type UFASFR*		*Conventional anaerobic reactor (Control)*	
		Mean of 3 days	*% Reduction*	*Mean of 3 days*	*% Reduction*	*Mean of 3 days*	*% Reduction*
COD (mg/L)	8650	3380	60.9	3683.33	57.36	4233.33	50.76
BOD (mg/L)	4800	1900	60.4	1995	58.3	2286	52.33
TDS (mg/L)	3650	1724	52.73	2299.66	37.06	2812.33	22.93
Oil & grease (mg/L)	2200	870	60.46	1026.33	53.33	1095	50.2

Table 2: Removal of pollutant concentration at 8 hr HRT

Pollutant parameter	*Initial pollutant concentration in effluent (before treatment)*	*Concentration of pollutant after treatment in reactors*					
		A type UFASFR		*B type UFASFR*		*Conventional anaerobic reactor (Control)*	
		Mean of 3 days	*% Reduction*	*Mean of 3 days*	*% Reduction*	*Mean of 3 days*	*% Reduction*
COD (mg/L)	8650	2858.66	66.9	3438.33	60.2	4081.66	52.8
BOD (mg/L)	4800	1420	70.33	1621.66	66.7	1723.33	64.13
TDS (mg/L)	3650	1424.33	60.93	1988.33	45.46	2615	28.33
Oil & grease (mg/L)	2200	786.66	64.26	876	60.16	1055	52

Table 3: Removal of pollutant concentration at 12 hr HRT

Pollutant parameter	*Initial pollutant concentration in effluent (before treatment)*	*Concentration of pollutant after treatment in reactors*					
		A type UFASFR		*B type UFASFR*		*Conventional anaerobic reactor (Control)*	
		Mean of 3 days	*% Reduction*	*Mean of 3 days*	*% Reduction*	*Mean of 3 days*	*% Reduction*
COD (mg/L)	8650	1410	83.66	2430	71.86	3735	56.76
BOD (mg/L)	4800	656.66	86.3	861.66	82.5	1213.33	74.73
TDS (mg/L)	3650	1266.67	65.26	1968.33	46.03	2446.66	32.53
Oil & grease (mg/L)	2200	638	71.06	786	64.26	1024	53.4

Table 4: Removal of pollutant concentration at 24 hr HRT

Pollutant parameter	*Initial pollutant concentration in effluent (before treatment)*	*Concentration of pollutant after treatment in reactors*					
		A type UFASFR		*B type UFASFR*		*Conventional anaerobic reactor (Control)*	
		Mean of 3 days	*% Reduction*	*Mean of 3 days*	*% Reduction*	*Mean of 3 days*	*% Reduction*
COD (mg/L)	8650	1338.33	84.46	2355	72.7	3693.33	57.33
BOD (mg/L)	4800	634.66	86.73	863.33	82.43	1196.66	75.06
TDS (mg/L)	3650	1255	65.63	1952.66	46.56	2371.66	35
Oil & grease (mg/L)	2200	628.33	71.46	768.66	65.06	1006	54.2

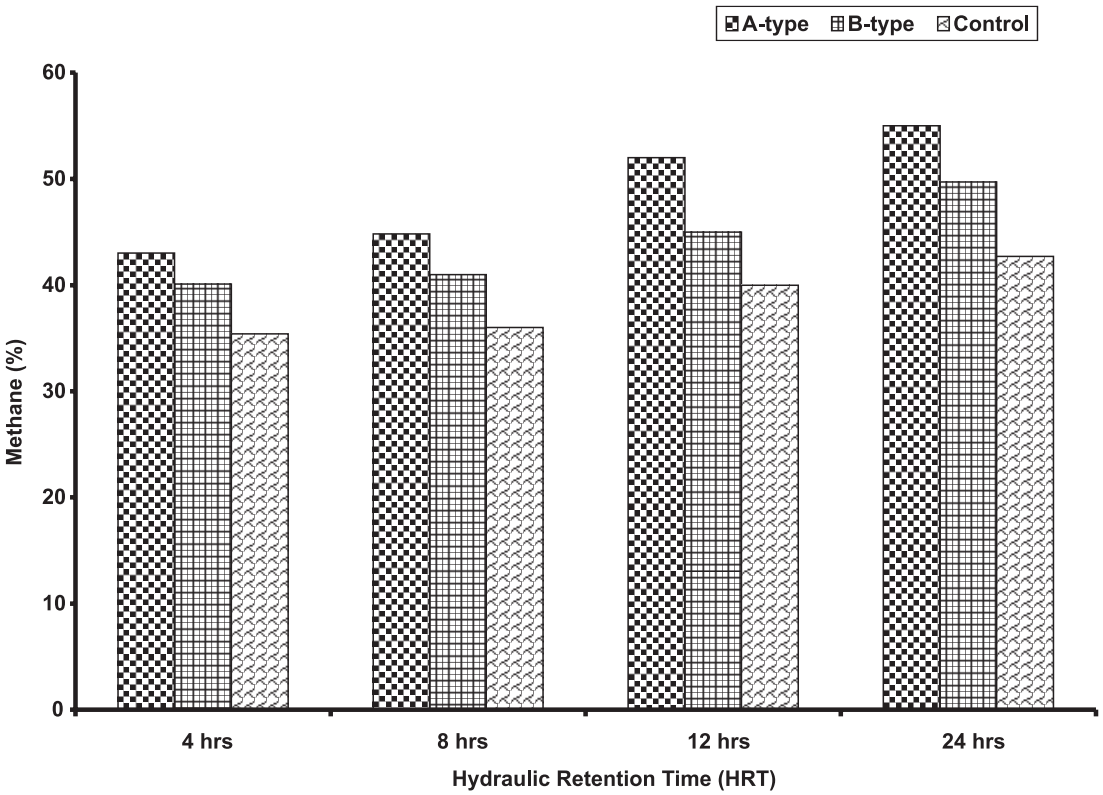

Figure 2: Average methane concentration (%) in biogas at different hydraulic retention time.

In the experiment, COD values were reduced from 8650 mg/L to 1350 mg/L at a hydraulic retention time of 12 hrs. Moreover it is reported that 1 kg of COD reduction produces 330 litres of methane (McCarty, 1964; Sennitt, 2005). Thus the reduction of 605.5 kg COD will produce the amount of methane equivalent to 199.8 KL. The calorific value of methane is 33.2-39.6 J/cm^3. So with pollutants removal we get energy also (Chawla, 1986; Ditaranto et al., 2004). Generally 1.1 Kwh of electric power is consumed for the removal of 1 kg COD by aerobic treatment method (Speece, 1996). Therefore, for 605.5 kg COD reduction the electric power requirement will be 666 Kwh and this energy can be saved by using A type Up flow anaerobic sludge filter reactor (UFASFR).

Conclusions

The results demonstrate that the pollutants removal efficiency in A type UFASFR were very satisfactory in ambient environmental conditions at 12 hr HRT. It gives maximum methane concentration in comparison to other reactors. This packing media used in reactors are easily available. Both the A and B type of reactors give better pollutants removal efficiency as compared to conventional anaerobic reactor in same existing ambient environmental conditions. Moreover this treatment method required almost nil energy and produce energy from effluent which can be termed as wealth from waste.

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Calendar of Events

Future Models for Energy and Water Management
20 to 22 July 2009
Brisbane, Queensland, Australia
Website: http://www.amsi.org.au/energy.php
Contact name: Parvin Ahadi
Organized by: Australian Mathematical Sciences Institute

3rd International Conference on Sustainable Energy & Environmental Protection
12 to 15 August 2009
Dublin, Ireland
Website: http://www.dcu.ie/conferences/seep/index.shtml
Contact name: Conference Coordinator
Organized by: Dublin City University

3rd International Conference Environmentally Sustainable Development ESDev 2009
16 to 18 August 2009
Abbottabad, NWFP, Pakistan
Website: http://www.ciit-atd.edu.pk/ESDev
Contact name: Dr. Iftikhar A. Raja
Organized by: Department of Environmental Sciences, COMSATS Institute of Information Technology

World Water Week
16 to 22 August 2009
Stockholm, Sweden
Website: http://www.worldwaterweek.org/
Contact name: Michael McWilliams
Organized by: Stockholm International Water Institute

CEST2009 - 11th International Conference on Environmental Science and Technology
3 to 5 September 2009
Chania, Crete, Greece
Website: http://www.gnest.org/cest
Contact name: Prof. T.D. Lekkas
Organized by: Global Network for Environmental Science and Technology and University of the Aegean

H209 : A Water Forum
9 to 10 September 2009
New York City, Netherlands
Website: http://www.henryhudson400.com/hh400_project.php?id=21
Contact name: Renee Cho
Organized by: Henry Hudson 400 Foundation

Water in Mining 2009
15 to 17 September 2009
Perth, Western Australia, Australia
Website: http://www.ausimm.com.au/wim2009
Contact name: Stephanie Finlay
Organized by: The AusIMM

Environmental Health Risk 2009
21 to 23 September 2009
New Forest, United Kingdom
Website: http://www.wessex.ac.uk/conferences/2009/ehr09/index.html
Contact name: Alice Jones
Organized by: Wessex Institute of Technology

International Riversymposium
21 to 24 September 2009
Brisbane, Queensland, Australia
Website: http://www.riversymposium.com/
Contact name: Carla Mathisen