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Research Article

SLAUGHTERHOUSE WASTEWATER TREATMENT BY ANAEROBIC FIXED FILM FIXED BED REACTOR PACKED WITH SPECIAL MEDIA

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ABSTRACT: Most of the slaughterhouses in Nagpur city do not have any proper effluent treatment facilities. Hence, a study was undertaken to assess the feasibility of anaerobic treatment of slaughterhouse wastewater in an anaerobic fixed film fixed bed reactor packed with specialized ultraviolet stabilized media matrix. This media matrix provides surface area of 400m^2/m^3 which is much more than the other conventional media. These anaerobic fixed film reactors are more favoured due to its capacity to withstand high organic loading and short retention time. Slaughterhouse wastewater was collected from a local medium scale slaughterhouse where a total of 300 bovines are slaughtered per day. Wastewater was collected on hourly basis for six hours (till slaughtering process was going on) and a combined and homogenised wastewater was prepared. This combined wastewater was settled for half an hour to remove suspended solids before feeding it to the anaerobic reactor. Study was evaluated to see the performance of the upflow fixed film fixed bed reactor at various organic loading rates varying between 0.8 – 3.2 kg COD/m^3/day at two different HRT's of one and two days. COD and BOD reductions varied between 85.4 – 91.8% and 87.4 – 93.2% respectively at one day HRT while it varied between 87.0 – 93.5% and 89.2 – 95.8% respectively at two days HRT. Corresponding biogas production varied between 0.196 – 0.295m^3/kg COD added and 0.263 – 0.332m^3/kg COD added for one day and two days HRT respectively. It is seen from the results that as the HRT increased, gas production also showed increased trend. Gas composition indicated methane content in the range of 65 – 67%.

Key words: Fixed film fixed bed, Anaerobic, Slaughterhouse, Biogas, Methane

INTRODUCTION

Slaughterhouse wastewater is considered to be very strong and polluting wastewater. This wastewater contains fats, proteins, fibres and blood which makes them highly polluting in nature and needs immediate treatment. It cannot be stored for longer period due to its fast putrefying nature leading to bad odour and fly, mosquito nuisance. This wastewater is highly amenable to biological treatment. Anaerobic processes have been proposed as a good treatment system for wastewaters with high to medium organic loads [1]. They are suitable for the treatment of effluent from slaughterhouses. Advantage of anaerobic process is its sustainable, cost effective and eco-friendly nature and is most suitable for slaughterhouse wastewater. Moreover, high calorific value fuel in the form of methane gas, a value added by-product is also derived.

There are several studies showing the viability of anaerobic process for the treatment of slaughterhouse wastewaters [2], [3], [4], [5]. However, anaerobic systems have not been extensively used on large scale inspite of high COD/BOD and suspended solid removals obtained in the process. The inadvertent mixing of blood, rumen content, paunch content, pieces of flesh etc in slaughterhouse wastewater increases its organic load and at this juncture it becomes essential to treat it by a biological method.

Lab scale studies have been reported on anaerobic filter using slaughterhouse wastewater [6]. Studies on fixed film reactors have been reported for slaughterhouse wastewater. [7], [8], [9]. Reports further say that good reductions in COD/BOD were obtained. Tritt [10] studied the treatment of slaughterhouse wastewater by anaerobic filter containing high COD and suspended solids. Del Pozo et al., [11] successfully used anaerobic filter packed with random support material for treating poultry slaughterhouse wastewater. Anaerobic fixed film upflow reactor packed with PVC pipe pieces as media matrix has been studied for the treatment of slaughterhouse wastewater. It has been further reported that a COD removal of 80% efficiency was achieved [13].

Earlier studies on upflow fixed film fixed bed reactors for slaughterhouse wastewater using conventional media like stone, pebbles, sand are reported. A new media matrix providing more surface area are slowly coming in to the market and one such media matrix is ultraviolet stabilized Biopac media which provides good surface area. So, in the present studies, treatment of slaughterhouse wastewater in an anaerobic upflow fixed film fixed bed reactor packed with ultraviolet stabilized Biopac media has been studied. Feasibility of this media matrix for the treatment of slaughterhouse wastewater has been studied in detail using different organic loading rates at two different hydraulic loadings.
This article discusses in detail the efficiency of the anaerobic reactor packed with special UV stabilized media matrix in the slaughterhouse wastewater treatment.

MATERIALS AND METHOD

A lab scale fixed film fixed bed reactor with a working volume of 700ml, fabricated from glass columns was used in the experiment. Reactor was packed with a special ultraviolet stabilized media called Biopac media. Experiments were carried out at ambient temperature. This special ultraviolet stabilized media provided a surface area of 400 m^2/m^3. Biopac media has been described as "an apartment with three rooms and a kitchen, where bacteria can live comfortably and stuck into hearty meals of water pollutants". A detail about the media is given in **Table 1**. **Fig 1** shows the schematics of the experimental setup.
Wastewater required for the experimental work was collected from a medium scale slaughterhouse run by the local municipal corporation. This slaughterhouse slaughters an average of 300 numbers of bovines per day. Wastewater was collected on hourly basis for six hours (till the slaughtering process continued) and then composited to get a properly homogenised wastewater. This wastewater was first settled for a period of half an hour before using it for the experiments. Both raw (as it is) and half an hour settled wastewaters were subjected to routine physico-chemical parameters. All the analysis was carried out as per the standard methods [12]. Results thus obtained are indicated in **Table 2**.

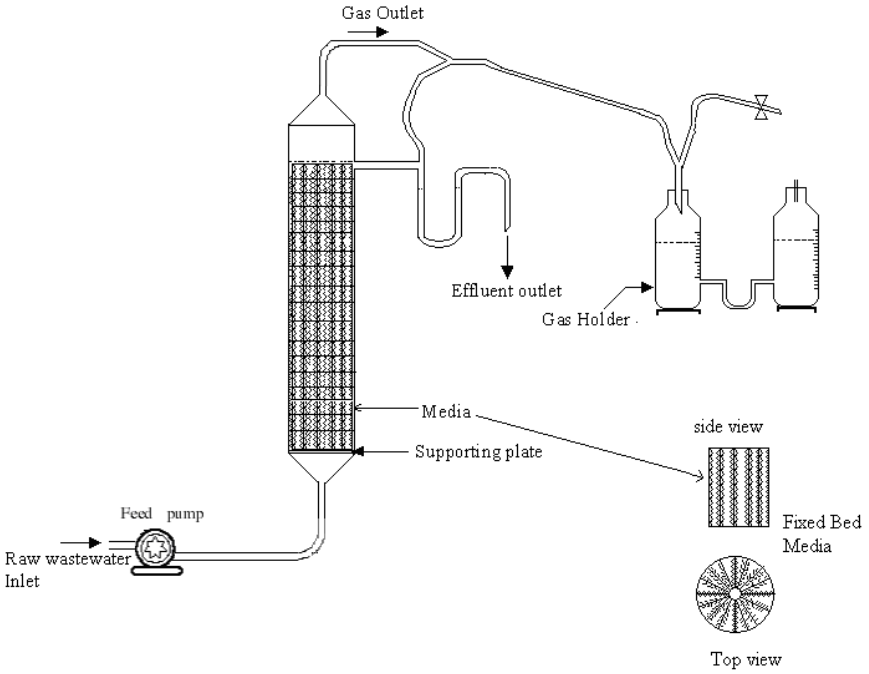

Fig. 1: Schematic of Upflow Anaerobic Fixed Film Fixed Bed Reactor

Table 1: Details of the Media

Sr. No.	Media	Surface Area (m^2/m^3)	Void Ratio (%)	Weight (gm/l)
1.	UV- stabilized Biopac media	350 - 450	80	78

Table 2: Physico-Chemical Characteristics of NMC Slaughterhouse Raw Waste water

S.No.	Parameters	Raw Wastewater	Raw Settled (30min) Wastewater
1.	pH	6.9 – 7.1	6.8 – 7.2
2.	Alkalinity as $CaCO_3$	3720	3626
3.	Total Solids	9200	7360
4.	Total Volatile Solids	5575	4582
5.	Total Suspended Solids	1484	326
6.	Chemical Oxygen Demand (COD)	27200	18680
7.	Biochemical Oxygen Demand (BOD)	14600	9490
8.	Sulphate as SO_4^-	82	74
9.	Phosphate as PO_4^-	62	56
10.	Chlorides as Cl^-	292	289
11.	Sodium as Na^+	286	284
12.	Potassium as K^+	333	326
13.	Total Ammonical Nitrogen as NH_3 N	248	232
14.	Volatile acids as CH_3COOH	580	544
15.	Total Kjeldhal Nitrogen as N	826	814
16.	Oil and Grease	236	224

*All the values except pH are expressed in mg/l

** All the values are the average of four sets of readings

Initially, the reactor was filled with a mixture of fresh domestic sewage and 2% solution of fresh dung and also fresh rumen content from the slaughterhouse. Reactor was then allowed to stand as it is for a period of 15 days. Then dilute slaughterhouse wastewater feeding was initiated to acclimatize the immobilised bacteria and to sustain the growth of biofilms on the media matrix. After a month of operation in this manner, it was observed that good attachment/growth of bacterial mass on the media matrix was observed visually through the glass column.

Once this situation was attained, minimum organic loading rate of 0.8 kg COD/m^3.day was initiated with a hydraulic loading of two days. On each organic load, reactor was continuously operated till steady state conditions were reached, which was seen from constant COD reduction and gas production. At this stage effluents were collected and subjected to important parameters of anaerobic treatment like pH, alkalinity, volatile acids, total ammonia nitrogen, COD, BOD, suspended solids, volatile solids etc. A total of four sets of analysis were carried out at each loading. A total of four organic loadings of 0.8, 1.6, 2.4 and 3.2 kg COD/m^3.day were studied. This organic loadings applied were increased stepwise in order to prevent shock loading leading to sloughing of the biofilm. In each loading, as the reactor reached steady state, effluent samples were collected and analysed. This same procedure was followed during one day HRT also.

RESULTS AND DISCUSSION

It is seen from the results that simple settling for half an hour has reduced COD and suspended solids to the tune of around 32% and 78% respectively. This amount of reduction is really very efficient considering simple settling. This results in less pressure on the fixed film reactor and also clogging and choking of the reactor is prevented. Settling of an hour increased the COD reduction marginally to 36% while there appeared no reduction in suspended solids. So, it is advisable to settle the wastewater for a minimum period of half an hour prior feeding it to the fixed film reactor.

From the results of treated effluent **(**Table 3 and 4**)** it can be seen that the pH remained more or less constant in the range between 6.8 and 7.6 at both the HRTs studied. This indicates good efficient working of the reactor system. Influent pH remained constant between 6.8 and 7.2, and this range was observed throughout the study period. Effluent pH was always marginally higher than the influent pH due to the formation of total ammonia nitrogen. Treated effluent showed enough alkalinity which controlled the working pH of the anaerobic system at congenial limit.

pH correction which is usually required in anaerobic processes was not needed at any stage of the experiment. Moreover, volatile acid to alkalinity ratio remained between 0.15 and 0.21 indicating very efficient performance at both the HRTs. There appeared no stress which sets in when the ratio touches 0.4. Even at the highest organic loading of 3.2 kg COD/m^3.day, the ratio was around 0.2 at both the hydraulic loadings. It is very clear from the results that even at higher organic loadings beyond 3.2 kg COD/m^3.day could be increased. But instead of running the reactor in a stress condition at higher loadings it is preferable to run it on lower loadings with good removals in terms of COD/BOD and suspended solids.

Table 3: Performance of Anaerobic Fixed Film Fixed Bed Reactor System at Various Organic Loadings HRT = 1.0 Day

S. No.	Parameters	Organic loading kg COD/m^3.d			
		0.8	**1.6**	**2.4**	**3.2**
1	pH	7.1 – 7.3	7.0 – 7.2	6.9 – 7.2	6.8 – 7.0
2	Alkalinity as $CaCO_3$	356	402	428	440
3	Volatile acids as CH_3COOH	55	76	88	96
4	Total Ammonia Nitrogen as NH_3N	132	146	166	178
5	Suspended solids	120	138	160	184
6	Suspended Volatile Solids	89	110	121	142
7	Total Nitrogen as N	21.56	22.54	23.8	24.32
8	Chemical Oxygen Demand (COD)	66	166	293	468
9	Biochemical Oxygen Demand (BOD)	28	72	127	206

*All the values are expressed in mg/l except pH
** All the values are the average of four sets of readings

Table 4: Performance of Anaerobic Fixed Film Fixed Bed Reactor System at Various Organic Loadings HRT = 2.0 Days

S. No.	Parameters	Organic loading kg COD/m^3.d			
		0.8	**1.6**	**2.4**	**3.2**
1	pH	7.3 – 7.6	7.2 – 7.5	7.1 – 7.3	7.0 – 7.2
2	Alkalinity as $CaCO_3$	398	426	458	472
3	Volatile acids as CH_3COOH	46	58	68	84
4	Total Ammonia Nitrogen as NH_3N	128	138	154	166
5	Suspended solids	110	124	142	160
6	Suspended Volatile Solids	78	96	110	125
7	Total Nitrogen as N	17.34	19.38	24.08	27.44
8	Chemical Oxygen Demand (COD)	104	270	528	832
9	Biochemical Oxygen Demand (BOD)	38	106	200	352

*All values are expressed in mg/l except pH
**All the values are the average of four sets of readings

COD/BOD reductions were more than 85% at highest loading and also at both hydraulic loadings. At lowest loading of 0.8KgCOD/m^3.day, COD reduction was 91.8% at one day and 93.5% at two days hydraulic loadings. If COD/BOD removals are concerned then, lowest loading can be applied but when reduction in volume of wastewater in shorter time interval is required then highest loadings can also be applied. It is very clear from the results that slaughterhouse wastewater can be easily treated by anaerobic system, where the wastewater stabilization to the tune of 80% and above can be achieved. Report shows that at lower HRT of 18 hours also resulted in 82-85% reduction in COD. [14].

Waste stabilization in anaerobic treatment is directly related to methane production. Hence regular monitoring of daily gas production was carried out. Gas production and corresponding COD/BOD reductions are shown in Table 5 and 6. The methane gas yield from anaerobic fixed film fixed bed in the present studies ranged between 0.196 – 0.295 m^3/kg COD added during one day HRT and 0.263 – 0.332 m^3/kg COD added in case of two days HRT.

It is very clear that high fuel value methane can be harvested from slaughterhouse wastewater by anaerobic process and will be a good source of energy and also disposal of the wastewater is achieved. This biogas can be used fruitfully in the slaughterhouse itself for hot water and for sterilization of equipments like knife and cutter etc. It is one of the most energy conserving system and also eco-friendly and sustainable in nature. Biogas produced was regularly analysed and the results showed methane content of 65 – 67% and carbon dioxide content of 33 – 35%.

Table 5: Gas Production for Different Organic and Hydraulic Loadings along with Corresponding COD and BOD Reductions
HRT = 1.0 day

Organic loading kg COD/m^3.d	% COD reduction	% BOD reduction	ml of gas per day	Gas m^3/kg COD added	Gas m^3/kg COD destroyed
0.8	91.8	93.2	1650	0.295	0.321
1.6	89.6	91.2	2960	0.264	0.294
2.4	87.8	89.6	3800	0.226	0.257
3.2	85.4	87.4	4410	0.196	0.229

Table 6: Gas Production for Different Organic and Hydraulic Loadings along with Corresponding COD and BOD Reductions
HRT = 2.0 Days

Organic loading kg COD/m^3.d	% COD reductions	% BOD reductions	ml of gas per day	Gas m^3/kg COD added	Gas m^3/kg COD destroyed
0.8	93.5	95.8	1860	0.332	0.355
1.6	91.56	93.5	3540	0.316	0.345
2.4	89.0	91.8	4870	0.290	0.326
3.2	87.0	89.2	5890	0.263	0.302

CONCLUSION

Studies have revealed that Slaughterhouse wastewater can easily be treated by fixed film fixed bed reactor system. Special Biopac media provided $400m^2/m^3$ surface area which was found to be efficient. Final treated effluent depicted no odour and no colour. There was no wide variation in COD and BOD reductions in case of both the hydraulic loadings i.e. 1.0 day and 2.0 days. Daily gas production varied between 0.196 - $0.332m^3$/kg COD added indicating good performance of the reactor. The gas production values are well comparable to the values reported in literature. The slaughterhouse wastewater can easily be treated by fixed film fixed bed reactor system in a shorter duration of time without storing it thus, preventing putrification and odour nuisance.

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