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Research article

TREATMENT OF PARBOILED RICE MANUFACTURING WASTEWATER USING ANAEROBIC FIXED FILM FIXED BED REACTOR PACKED WITH SPECIAL MEDIA

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ABSTRACT: Studies on bench scale reactors packed with two different media matrix – Biopac media and Fugino spirals were undertaken to determine the performance at various organic loading rate (OLR) and on one day hydraulic retention time (HRT). Parboiled rice mill wastewater depicted a COD/BOD ratio of 1.6 indicating good degradable nature of the wastewater. Four different organic loadings of 0.8, 1.6, 2.4 and 3.2 kg COD/m^3/day were studied in detail. The results indicated BOD and COD removals in the range of 83.0-92.7% and 80.2-89.0% respectively with respect to Biopac media while it ranged between 79.4–90.6% and 76.7–86.1% respectively in case of Fugino spiral media. It is very clear from the results that, Biopac media packed fixed film reactor gave efficient removals compared to Fugino spiral media packed reactor. Volatile acid concentration was well within the congenial range in both the reactors and volatile acid to alkalinity ratio remained well below 0.8 indicating good performance of the reactors. pH of the treated effluent was in the range of 7.1–7.3 indicating good buffering in the system. Daily gas production was measured. This paper discusses in detail the feasibility of upflow anaerobic fixed film fixed bed reactors packed with special media matrix in treating the parboiled rice manufacturing wastewater. Comparative performance of two special media matrix i.e. Fugino Spirals and Special Ultraviolet Stabilized Biopac media in the treatment of parboiled rice manufacturing wastewater has been studied in detail.

Key words: Fixed film reactor; Fugino spiral media; Biopac media; parboiled rice wastewater; Biogas

INTRODUCTION

Environmental degradation mainly due to rapid industrialization has emerged as a major challenge world over. In recent years, it is necessary to increase awareness of the fact that clean environment is necessary for smooth living and better health of human beings [1]. The anaerobic treatment of organic effluents has the twin advantages of pollution control and production of energy as biogas [2]. Rice is one of the leading food crops of the world and is second only to wheat in terms of annual production for food use. It is the staple food of over half of the world's population [3]. It is estimated that, the 80% of the world population uses rice as major source of calories. Primary milling of rice is the most important activity in food grains. It has emerged as major industrial activity in small and medium sector to cater to the needs of increasing population. Parboiling is a hydrothermal treatment applied to raw paddy [4]. The three steps of parboiling – soaking, steaming and drying are generally achieved by soaking paddy in cold water for typically 24–48 hours until the kernels are saturated. The soaked paddy is then boiled at 100^0C for typically one hour [5]. Soaking paddy in water until it attains moisture content of 30–35% by weight is the key unit operation in parboiled rice processing [6]. Parboiled rice production requires large amount of water for soaking of the paddy. Wastewater coming from rice mill operations contains high concentration of organic and inorganic substances cause significant polluting phenomenon. Wastewater exiting the soaking tanks of the rice mills generally depicts COD of 4500 mg/l, which is well above the permitted discharge level of COD (<250mg/l) for wastewater discharge into surface waters [6]. This water, if not properly treated could result in water pollution and odor nuisance. Very scanty literature is available on the treatment of parboiled rice mill effluent. Studies have been carried out on the treatment of rice mill effluent by electro coagulation using aluminum electrodes which showed a maximum COD removal of about 96% between pH of 6 and 7. Oil and grease, total suspended solids and turbidity showed removal of 98%, 96% and 97% respectively [1].

Studies have shown that PHC (Paddy Husk Charcoal) could successfully remove COD, pH, odor, color and total dissolved solids in rice mill effluents [7]. Paddy Husk Charcoal (PHC) adsorption unit showed a COD reduction from 4500 mg/l to 500 mg/l in an adsorption column of 1.4 m diameter and 3.6 m height operated at a superficial velocity of 5 mm/min for 3 consecutive days from parboiled rice processing wastewater [8]. A study has been conducted to isolate and characterize micro-organisms capable of growing on Sella-rice effluent and to optimize conditions for its rapid bioremediation. These bacterial isolates reduced the amount of starch (80.10%), BOD (64.24%) and COD (75.0%) of Sella-rice mill effluent after 15 days of incubation [9]. Biodegradation of rice mill effluent by using free and immobilized cells of *Pseudomonas sp.* in a packed bed system have been studied [10]. Two stage biomethanation process using Upflow Anaerobic Sludge Blanket (UASB) bioreactors were studied for the treatment of rice mill wastewater. The overall BOD and COD reductions were 89% and 78% respectively at organic loading rate of 3 kg COD/m^3/day and HRT of 30 hours [11]. Investigations on the performance of two stage UASB bioreactor system for the treatment of low strength effluent like parboiled rice mill wastewater has been reported. The main objective of the study were to develop acid forming and methane forming microbial cultures for the UASB bioreactors and evaluate the treatment efficiency of the system in terms of COD reduction and methane production from parboiled rice mill wastewater. Treatment of parboiled rice mill effluent in a hybrid bioreactor was reported wherein different organic and hydraulic loading rates have been tried and the results were good [2]. Literature on the treatment of parboiled rice mill effluent using anaerobic fixed film fixed bed reactor is very scanty. In the present study, feasibility of fixed film fixed bed reactor for the treatment of parboiled rice mill effluent has been studied in detail. Moreover, two different media matrix and their efficiency are discussed in this article.

MATERIALS AND METHODS

The required wastewater sample was collected from a parboiled rice manufacturing unit situated in the outskirts of the city. The samples were collected on hourly basis for 12 hours and then composited. This combined wastewater was subjected to routine important parameters needed for an anaerobic reactor system. All the physico-chemical and heavy metals analysis were carried out as per Standard method [12].

Two fixed film bioreactors were fabricated in the institute’s workshop. The bioreactors were fabricated out of PVC tubes. The working volume of the bioreactors was maintained at 3 liters each. Flow to the fixed film fixed bed reactor was controlled at a required flow rate using a flow meter and the system worked on an upflow mode. One fixed film bioreactor was packed with UV-stabilized Biopac media as media matrix while the other bioreactor was packed with Fugino spiral media. The details about the media are given in the Table 1 and shown in Fig. 1 and 2.

Table 1: Details of the Media

S.No.	Media	Surface Area (m^2/m^3)	Void Ratio (%)	Weight (gm/l)
1.	UV- stabilized Biopac media	350 - 450	80	78
2.	Fugino spiral media	350	92	110

Fig. 1: Biopac Media

Fig. 2: Fugino Spiral Media

The bioreactors were provided with arrangements for feeding, collection of biogas and collection of treated effluent. The experimental setup is shown in Fig. 3. Different organic loadings of 0.8, 1.6, 2.4 and 3.2 kg COD/m^3/day were studied at 1 day's HRT. The treated effluent from different loadings were also collected and analyzed as per the Standard method [12]. Studies were carried out for a period of six months. Half an hour settled wastewater was used for the experimental studies. During the study period the reactor worked very efficiently. Regular gas monitoring was also carried out and analyzed.

RESULTS AND DISCUSSION

The results of physico-chemical characteristics of influent wastewater depict a COD/BOD ratio of 1.6 indicating that it is highly amenable to biodegradation. The results are presented in Table 2.

In case of treated effluents from Fugino spiral media, the pH varied between 7.0–7.18 indicating efficient working of the reactor. As the loading increased from 0.8 kg COD/m^3/d to 3.2 kg COD/m^3/d, the pH of the treated effluent remained more or less constant indicating that there is no imbalance in the working system. Alkalinity varied between 234–348 mg/l as $CaCO_3$ corresponding volatile acids ranged between 66–96 mg/l. Volatile acid to alkalinity ratio remained well below 0.8 indicating no toxicity due to volatile acids. Total ammonia nitrogen was between 126–157 mg/l. This indicates good buffering in the system. All other parameters were well within the range. COD reductions ranged between 76.7-86.1 % with corresponding BOD reduction in the range of 79.4-90.6 %. Even at the highest loading of 3.2 kg COD/m^3/d, COD and BOD reductions were more than 75 %. Heavy metals were well within the range in the treated effluent (Table 3).

Table 2: Physico-chemical Characteristics of Parboiled Rice Manufacturing Waste water

Sr. No.	Parameters	Raw Wastewater	Raw Settled (30 min) Wastewater
1.	pH	4.67- 4.90	4.62 - 4.82
2.	Color (Visual)	Faint Yellow	Faint Yellow
3.	Total Acidity /Alkalinity as $CaCO_3$	744	732
4.	Turbidity	68.6 NTU	12.2
5.	Suspended Solids	4187 - 5134	1480 - 1794
6.	Total Dissolved Solids	1386 - 2340	1380 - 2338
7.	Total solids	5574 - 7474	2860 - 4132
8.	Chemical Oxygen Demand (COD)	6400 – 7200	4900 - 5700
9.	Biochemical Oxygen Demand (BOD)	3968 - 4464	3032 - 3304
10.	Sodium as Na	52 - 64	50 - 64
11.	Potassium as K	29 - 34	28 - 33
12.	Sulphate as SO_4^{--}	47- 53	46 – 50
13.	Total Phosphate as PO_4^{---}	44 - 59	42 – 56
14.	Total Ammonical Nitrogen as NH_3-N	35 - 44	30 - 40
15.	Total Kjeldhal Nitrogen as N	27 – 36	22 - 32
16.	Oil and Grease	316 - 352	301 - 340
17.	**Heavy Metals**		
	Zinc (Zn)	1.467-1.469	1.446-1.449
	Lead (Pb)	BDL	BDL
	Cadmium (Cd)	BDL	BDL
	Nickel (Ni)	0.167-0.169	0.156-0.158
	Cobalt (Co)	0.005-0.006	0.004-0.005
	Manganese (Mn)	1.250-1.252	1.239-1.240
	Iron (Fe)	5.982-5.984	5.969-5.971
	Chromium (Cr)	BDL	BDL
	Copper (Cu)	0.447-0.449	0.434-0.436

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

**BDL = Below Detectable Limit

Table 3: Physico-chemical Characteristics of Treated Parboiled Rice Manufacturing Wastewater at 1 Day HRT (Fugino Spiral Media)

Sr. No.	Parameters	Organic Loading Rate (kg COD/m^3/d)			
		0.8	**1.6**	**2.4**	**3.2**
1.	pH	7.18	7.12	7.09	7.02
2.	Alkalinity as $CaCO_3$	234	276	312	348
3.	Turbidity (NTU)	5.2	7.7	8.8	9.2
4.	Suspended Solids	4	10	16	22
5.	Chemical Oxygen Demand (COD)	112	260	490	747
6.	% COD reduction	86.1	83.8	79.6	76.7
7.	Biochemical Oxygen Demand (BOD)	47	132	255	410
8.	% BOD reduction	90.6	86.4	82.6	79.4
9.	Sulphate as SO_4^{--}	28	30	35	40
10.	Total Phosphate as PO_4^{---}	25	28	33	35
11	Sodium as Na	16	18	20	23
12.	Potassium as K	2.0	2.15	2.24	2.36
13.	Total Ammonical Nitrogen as NH_3-N	126	136	147	157
14.	Total Kjeldhal Nitrogen as N	43	46	55	69
15.	Volatile acids as CH_3COOH	66	81	92	96
16.	ml of gas/day	672	1190	1642	1996
17.	m^3 gas/kg COD added	0.280	0.248	0.228	0.208
18.	**Heavy Metals**				
	Zinc (Zn)	0.086	0.092	1.012	1.026
	Lead (Pb)	BDL	BDL	BDL	BDL
	Cadmium (Cd)	BDL	BDL	BDL	BDL
	Nickel (Ni)	BDL	BDL	BDL	BDL
	Cobalt (Co)	BDL	BDL	BDL	BDL
	Manganese (Mn)	0.098	0.112	0.129	0.140
	Iron (Fe)	1.657	1.672	1.704	1.724
	Chromium (Cr)	BDL	BDL	BDL	BDL
	Copper (Cu)	0.110	0.126	0.139	0.149

*All the values are expressed in mg/l except pH, turbidity, percentage reduction, ml of gas/day and m^3 gas/kg COD added
**All the readings are an average of six sets
***BDL = Below Detectable Limit

While Biopac media gave marginally better efficiency compared to Fugino spiral media. The pH of the treated effluents was well within the limits and ranged between 7.1–7.3. Volatile acid to alkalinity ratio was well below 0.8 indicating that the system is working very efficiently. COD reductions were around 89.0 % at the organic loading of 0.8 kg COD/m^3/d while at the highest loading of 3.2 kg COD/m^3/d the reductions were 80.2 % (Table 4) which were much above than what has been encountered with Fugino spiral media. In case of Biopac media, the final effluent was very clear with no turbidity and no odor. All other parameters were well within the limits and much better than Fugino spiral media.

Gas production varied between 0.222–0.292 m^3 gas/kg COD added for the loading varying between 0.8 kg COD/m^3/d to 3.2 kg COD/m^3/d (Table 4) in case of Biopac media while in Fugino spiral media the gas production was comparatively on the lower side and it varied between 0.208 – 0.280 m^3 gas/kg COD added (Table 3). It can be seen that among the two media studied, Biopac media seems to be better than the Fugino spiral media but in reality even Fugino spiral media is good as the packing material in the fixed film fixed bed reactor.

Table 4: Physico-chemical Characteristics of Treated Parboiled Rice Manufacturing Wastewater at 1 Day HRT (Biopac Media)

Sr. No.	Parameters	Organic Loading Rate (kg COD/m^3/d)			
		0.8	**1.6**	**2.4**	**3.2**
1.	pH	7.30	7.25	7.18	7.10
2.	Alkalinity as $CaCO_3$	242	281	320	356
3.	Turbidity (NTU)	4.1	4.7	5.3	5.9
4.	Suspended Solids	5.2	7.7	13.1	16.3
5.	Chemical Oxygen Demand (COD)	88	222	428	634
6.	% COD reduction	89.0	86.1	82.2	80.2
7.	Biochemical Oxygen Demand (BOD)	36	104	218	338
8.	% BOD reduction	92.7	89.2	85.2	83.0
9.	Sulphate as SO_4^{--}	25	29	33	39
10.	Total Phosphate as PO_4^{---}	23	26	30	34
11	Sodium as Na	13	15	18	22
12.	Potassium as K	0.92	2.0	2.12	2.26
13.	Total Ammonical Nitrogen as NH_3-N	131	142	154	163
14.	Total Kjeldhal Nitrogen as N	40	44	52	60
15.	Volatile acids as CH_3COOH	55	78	82	86
16.	ml of gas/day	700	1248	1714	2131
17.	m^3 gas/kg COD added	0.292	0.260	0.238	0.222
18.	**Heavy Metals**				
	Zinc (Zn)	0.079	0.088	1.002	1.019
	Lead (Pb)	BDL	BDL	BDL	BDL
	Cadmium (Cd)	BDL	BDL	BDL	BDL
	Nickel (Ni)	BDL	BDL	BDL	BDL
	Cobalt (Co)	BDL	BDL	BDL	BDL
	Manganese (Mn)	0.090	0.106	0.120	0.131
	Iron (Fe)	1.649	1.667	1.695	1.719
	Chromium (Cr)	BDL	BDL	BDL	BDL
	Copper (Cu)	0.101	0.122	0.134	0.141

*All values are expressed in mg/l except pH, turbidity, percentage reduction, ml of gas/day, and m^3 gas/kg COD added

**All the readings are an average of six sets

***BDL = Below Detectable Level

Fig.3. Experimental setup

CONCLUSION

Anaerobic fixed film fixed bed bioreactor has enormous potential for stabilization of Parboiled rice manufacturing wastewater. The reactor system packed with Biopac media showed the BOD and COD reduction in the range of 83.0-92.7% and 80.2- 89.0% respectively whereas the reactor packed with Fugino spiral media showed the BOD and COD reduction in the range of 79.4-90.6% and 76.7-86.1% respectively. Hence, from the comparative results it can be concluded that for the treatment of parboiled rice manufacturing wastewater Biopac media is more efficient than Fugino spiral media. In reality, both the media matrix are suitable for anaerobic fixed film fixed bed bioreactor.

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