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Biological Remediation of Parboiled Rice Mill Wastewater Using UASB

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Abstract

Rice is one of the popular foods in India. Rice is produced by milling paddy in rice mills. The paddy is partially boiled to reduce the fats and to make it delicious. Water is used for partial boiling of paddy that generates wastewater. The wastewater is acidic, high BOD and COD contents and COD/BOD ratio ranges as 1.68 to 1.76. Thus anaerobic treatment shall be used to treat this wastewater. The UASB pilot plant is installed at rice mill and the treatment is monitored for 21 days. The COD removal is achieved up to 70.37% and the gas production is in the range of 0.47 to 0.64 cu m/kg of COD removal. UASB system is found great potential to remove the pollutants. The plant require small land, easy to construct, less capital and maintenance cost and high rate of anaerobic treatment. Effluent is odourless and contents less organic matters hence can be used for irrigation purpose after aerobic treatment. Therefore, this process shall be effectively used to treat the parboiled rice mill wastewater.

Keywords: Parboiled rice mill, wastewater, anaerobic treatment, pilot plant, biogas

Introduction

Rice with cover is called as paddy. Paddy is a major crop grown all over the world. Rice contents fats, carbohydrates, starch, vitamin B & C. Rice is one of the complete foods in our diet. It is now grown in India, China, Japan, Indonesia, Pakistan, Thailand, Sri Lanka, Korea, Italy, Spain, Egypt and many other countries of the world. In India rice is the most extensively grown crop occupying every year an area of about 64 Million Acres and confined mainly Maharashtra, Bihar, UP, MP, Assam, AP, Tamilnadu, West Bengal, and Orissa. The yield of rice per acre in India is 425 kg [1, 2, 5].

In ancient days people were using paddy just by removing its cover in the field itself, with the increase in demand vice versa in population, it was not possible to process the rice on large scale. To overcome this the techniques were developed to produce rice by milling paddy and this was the origin of rice mills. The people have developed their own techniques to reduce fats and prepare a delicious food using boiled rice, but it is actually partially boiled rice. So to prepare this parboiled rice industrialists come forward to manufacture parboiled rice on large scale. Parboiled rice is mainly consumed in AP, MP, Kerla, Tamilnadu, Karnataka, Orissa, and Bangladesh [2, 3, 4, 5].

Parboiled rice mill constitutes an important industry amongst the various food processing industries like Diary, Fruit, Sugar, Fish, Poultry, Vegetables, Potato etc. The parboiled industries are mainly located in MP, AP, UP, Orissa and Maharashtra mainly in GONDIA [5].

The wastewater from parboiled rice mill contains high load of organic matters and produces intense disagreeable odour. When the wastewater discharges into the stream/river, it depletes the dissolved oxygen of river/stream water. This is harmful to aquatic life. The wastewater is putrescible because of organic matter, which creates odour and unwanted insects. Pounding of wastewater in surrounding areas may leads to disease like malaria etc. Therefore it is very essential to treat wastewater before disposal. Presently the wastewater from the mill is being disposed to nearby nallah or on the land. This forms pond on the roadside and creates nuisance for the pedestrians, traffic, underground water pollution, mosquito-breeding and affecting the aesthetic of the area [1, 2, 3, 4, 5].

Literature Review

Characteristics of food processing waste are depends upon the raw material, process and product made. Some researchers has carried out the characterization of food processing industry waste and suggests suitable treatment [6, 7, 8]. Bonkoski and Gillespie have studied feasibility of anaerobic/aerobic treatment system for wastewater from the wheat starch processing plant operated by industrial Grain Products Ltd. at Thunder Bay, Ontario [9].

Ganorkar intensively studied the characteristics of parboiled rice mill wastewater by operating full scale plant and find out the characteristics with anaerobic treatment followed by aerobic treatment [2].

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Various authors have suggested the methods of treatment for different food processing wastes. The methods of treatment can be broadly classified as

a) Prevention of waste and waste strength reduction,
b) Reuse of wastewater or by product recovery,
c) Conventional methods of treatment-Physiochemical method, Biological methods, Land application methods and
d) Specific approach [10, 11].

Biological treatment of waste can be carried by aerobically or anaerobically, for best suitable and economical approach anaerobic treatment followed by aerobic treatment is preferred. The food processing waste is easily biodegradable and having high load of organic matter, it is therefore two stage treatment is essential to bring the composition of waste in prescribed limit [12, 13, 14, 15].

As reported paper of Borup and Fenhance, anaerobic treatment of wastewater from a lemon peel washing plant using a full scale up flow anaerobic sludge blanket reactor configuration to attain a COD removal of 81% is possible. Case history of the thermophilic anaerobic chemostat process used to treat wheat starch wastewater and attain over 80% BOD reduction [10].

Bonkoski et.al have studied the ANAMET process for treatment of a wheat starch plant effluent at full-scale level. It consists of an anaerobic contact reactor followed by an aerobic sludge plant. The COD removal reported as 90% and BOD removal as 96% [9].

Pette *et al*. Have studied on the feasibility of full-scale anaerobic treatment of Beet Sugar wastewater. An UASB reactor was installed and this was a very suitable treatment process found for soluble industrial waste. Very short hydraulic retention time (3-8 Hrs) could be applied with medium concentrated wastewater (1-3 kg/m3 of soluble COD). With more concentrated wastewater 10-50 kg/m3, longer HRT (apprx. 1 day) have to be applied. In both cases however a reduction of 80% to 98% of a soluble COD load of approximately 15 kg COD/m3/d could be obtained. The production of biogas is depends on the wastewater composition and amounts to 0.35 to0.56 m3/kg COD removed [16].

Hajipakkos have studied the suitability of anaerobic digestion for the treatment of a coffee waste demonstrated in a full scale UASB plant. The treatment plant comprised of primary settlement tank, pre-acidification tank, a UASB reactor and submerged aerated filter. The first three units were installed so as to obtained consent conditions in terms of COD, BOD and S. S. The UASB reactor was monitored for four months with average volumetric loading rate of 5.24 kg CODm^3/d at an influent COD load of 4610 kg/d and 54.6% of COD removal and 74.6% of BOD removal was observed [17].

Methodology

Materials

The Prem Rice Mill, M.I.D.C. Gondia was selected for the wastewater analysis. Wastewater was collected from two sampling points of the rice mill. The analysis of wastewater was done in Environmental Engg. laboratory of M.I.E.T. Gondia as per the standard methods of analysis.

Mechanical Process of Manufacturing of Parboiled Rice: First the paddy was screened in order to remove the impurities like stones, cow dung, sticks, soil lumps etc. the screened paddy is allowed to fill in the cylindrical steel container up to the mark with the help of conveyer belt. Then the water is poured in cylindrical tank up to a level 15 cm above the paddy mark. Steam is allowed to pass inside the cylinder. The recycling of the hot water is carried out so as to maintain the specific temperature 70 to 100ºC for a period of 4 to 6 hours as per the season. To maintain this temperature stem is supplied as per requirement. After allowing the paddy in contact with hot water for this period. Water is drained off and paddy is ready for drying. After drying the paddy milling is taken up to remove the cover.

Water Requirement: The processing capacity of rice mill varies from 50 tones to 150 tones per day. It is observed that volume of water required is 1.0 to 1.50 liters per kg of paddy processed.

Sources and Quantity of Waste Water: The source of wastewater is only discharged from parboiling unit. The Volume of wastewater generated is 0.40 to 0.52 liters per kg of paddy processed. The wastewater discharged daily is about 30 cum.

UASB Reactor Pilot Plant: For the construction of UASB reactor pilot plant, a 150mm dia. PVC pipe 2.0 m. high was erected on the M.S. angle framework. Two PVC tubes were kept over the framework to feed the wastewater in the reactor. The inlet pipe 12mm dia was used to enter the influent in to the reactor from bottom. A PVC funnel 130mm diameter is kept inverted on the top of the reactor. Four numbers of sampling points were kept at the heights of 0.40m, 0.8m, 1.50m, and 2.0m. to collect the samples for analysis. The gas collection system was developed to collect the gas by connecting the gas outlet with small glass bottle of three lit. capacity. The outlet was provided at top of the tractor i.e. at 2.0 m. from the bottom of the reactor.

Hydraulic Testing of Pilot Plant: Hydraulic testing of the plant was carried out after the complete construction and erection of the pilot plant by discharging the influent from the top tubs [18, 19, 20, 21, 22]. Following problems were come across during testing and rectified as discussed below.

Flow Rate Adjustment: For 24 hours the total flow of wastewater is 0.1 Cum./day. Then the flow rate becomes 0.0042 Cum/h. For the required flow rate the PVC tub was installed over the top of the reactor of the capacity of 0.05 Cum. A tap was fixed and the wastewater was allowed to fall in the small pipe. The flow rate was adjusted by adjusting the tap and the required flow rate is maintained. The details are shown in Fig.1.

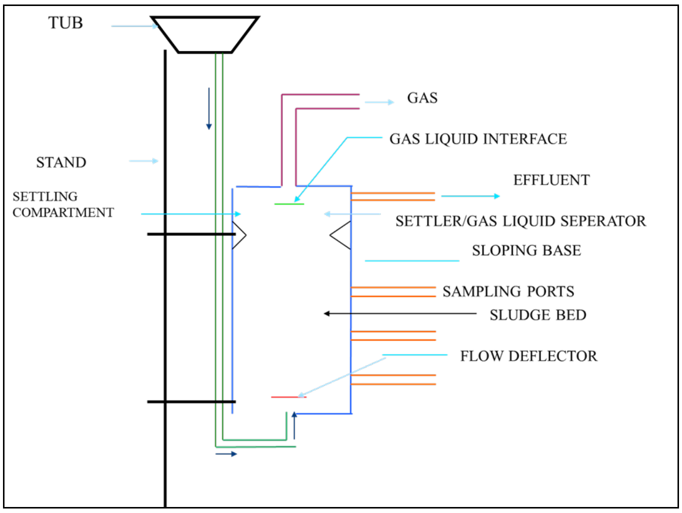

Fig 1: UASB Reactor

Leakages: Small leakages were observed from bottom cap and sampling points of the reactor while testing. This problem was overcome by using araldite and PVC liquid sealant.

Air Locks: While testing the wastewater not flowing freely through the reactor. To overcome this problem the air is removed from sampling points by opening the clips.

Dust Problem: The dust was flowing in the rice mill campus which creates nuisance in the area. Due to dust the characteristics parameters may be affected. This problem was removed by covering the tub and funnel with cotton cloth.

Nutrients and Chemical Requirements: After the extensive characterization of the wastewater of parboiled rice mill, it was noticed that the wastewater was acidic and nutrients deficient. Therefore the nutrients should be added in the wastewater as per the required doses.

The Requirement of Nitrogen and Phosphorus in the Proportion of BOD: N : P as 100 : 2.5 : 0.5 should be supplied to the waste water to meet the nutrient deficiency. The doses of glucose and urea were supplied as; 100 gram glucose contains 100mg phosphorus and one gram urea contains 0.46 gm nitrogen. The doses of GLUCOSE and UREA are found out to be 100gm/Cum and 130 gm/Cum of wastewater respectively.

Lime requirement: Due to variation of pH in every batch it was very difficult to calculate the exact dose of lime. But for neutralization the range of lime dose required was 0.25 to 0.75 kg/Cum. of wastewater.

Working of UASB Reactor: There were eight conical cylinders in rice mill. The wastewater from the conical cylinder was discharged in two shifts, one at 5.00 AM and another at 5.00 PM daily. This process varies from season to season. During peak period the maximum discharge of wastewater was 30 Cum/day. The wastewater was collected in a drum. The tub was filled with wastewater and nutrients, glucose and urea were added in required quantity in the wastewater and the pH was checked. The tap was opened as per required flow and the wastewater was allowed to enter into the small vertical pipe. Through this vertical pipe the wastewater flows upward in the reactor. The treated wastewater was collected by the collection system at top and discharged into the stabilization tank. The effluent was detained for the period of 10 days. The effluent from the stabilization tank, then discharged into the nearby nallah or may be used for irrigation purpose. Gas collection device was installed at the top of the reactor and the record is maintained [18, 19, 20, 21, 22].

Early Start-up of UASB Reactor: For early startup of the reactor the sludge from gobar gas plant transported from Gondia was filled in the reactor up to full depth. For three days the reactor was operated with the same sludge of gobar gas plant at the flow rate of 100 Lit/day. Then the reactor is operated by using 25% wastewater of rice mill and 75% gobar gas sludge for next three days. For the next phase of three days the 50% of each i,e. wastewater and gobar gas sludge are used to operate the reactor. The dosing of wastewater is increased as 75% and reactor is operated for next six days. Then 100% wastewater from mill was used in reactor adopting flow rate 0.1 Cum/day [18, 19, 20, 21, 22, 23].

Gas Collection: For the gas collection from the reactor an arrangement is made by using five liters capacity glass bottle. The assembly was installed near the pilot plant. (Refer Fig. 2)

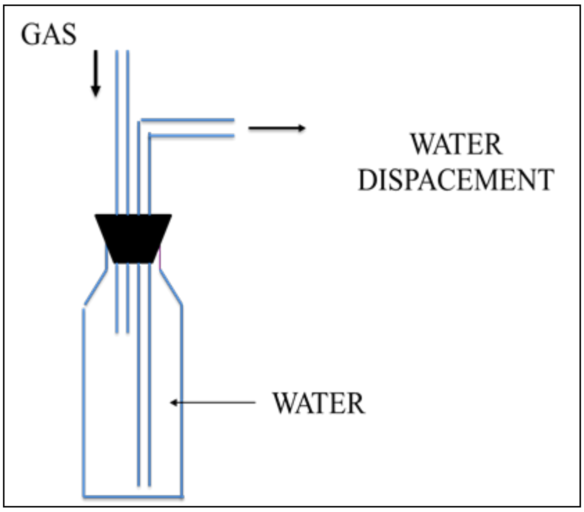

Fig 2: Gas Collection Assembly

Results and Discussion

Quantity of Wastewater: The quantity of wastewater generated per day from a parboiled rice mill at Prem Rice Mill Gondia was 30 Cu.m. per day. Four numbers of cylinders were used, each cylinder has capacity of 50 to 55 bags and each bag contains 70 to 80 Kg of paddy. The plant was operated in two shifts.

Quality of Wastewater: The characterization [24] of wastewater from Prem Rice Mill, Gondia are shown in Table 1. pH variation and TS variation during the anaerobic process has been depicted in Fig. 3 and Fig. 6.

Table 1: Characterization of wastewater

Sr. No.	Parameters	Range	Average
1	Colour	Brown to yellowish	Brown
2	Odour	Foul	Fowl
3	pH	4.2 to 6.5	5.29
4	Temperature (oC)	46 to 60	59.4
5	Alkalinity (mg/L)	320 to 720	469
6	Total solids (mg/L)	3540 to 10500	6454
7	Total v. Solids (mg/L)	2540 to 7960	4813
8	BOD (mg/L)	1900 to 4550	3105
9	COD (mg/L)	3200 to 7680	5376
10	COD/BOD RATIO	1.68 to 1.76	1.74

It is observed from the Table 2 that during initial period COD removal fluctuations are due to instability of the reactor. About 70.37% COD removal was observed in UASB at organic loading rate of 6.11 kg COD/m3/day with hydraulic detention time of about 17 hours (Refer Fig. 4 and Fig. 5). COD reduction was also found due to addition of lime to maintain the pH. The optimal efficiency was observed for the UASB reactor for HRT about 17 hours.

Table 2: COD removal through UASB reactor

Date	Flow M^3/d	HRT Hrs.	OLR KgCOD/m3.d	COD (mg/L)			% COD Reduct.
				Raw	Influ.	Efflu.	
Day 1	0.01	84.82	1.086	4800	3840	1920	30.12
Day 2	0.01	84.82	1.45	5600	5120	2880	43.75
Day 3	0.01	84.82	1.40	5400	4960	2560	48.38
Day 4	0.02	42.41	2.26	4325	4000	2240	44.00
Day 5	0.02	42.41	2.35	4480	4160	2500	39.9
Day 6	0.025	33.92	4.07	5920	5760	3680	36.11
Day 7	0.025	33.92	2.49	4000	3520	1760	50.00
Day 8	0.025	33.92	2.72	3840	3840	1600	58.33
Day 9	0.015	56.55	1.81	4280	4280	2350	45.09
Day 10	0.03	28.27	1.76	4480	4160	2720	34.64
Day 11	0.03	28.27	4.61	5760	5440	2560	52.94
Day 12	0.03	28.27	4.48	5760	5280	2080	61.29
Day 13	0.04	21.2	5.25	5120	4960	1920	65.52
Day 14	0.04	21.2	6.10	4800	4640	1620	66.67
Day 15	0.05	16.96	5.65	4160	4000	1280	68.00
Day 16	0.05	16.96	6.62	5760	4608	1440	68.75
Day 17	0.05	16.96	6.11	5440	4320	1280	70.37
Day 18	0.05	16.96	5.88	5184	4160	1440	69.23
Day 19	0.05	16.96	5.65	5120	4000	1200	70.00
Day 20	0.05	16.96	5.97	5184	4220	1310	69.00
Day 21	0.05	16.96	5.98	5280	4230	1280	69.73

An attempt was made to assess the performance of the reactor by observing the gas production [21, 22, 23]. The amount of gas production is directly proportional to the COD removal. The gas production varies in the range of 0.47 to 0.64 m3/kg of COD removal which is quite higher than the range reported in literature i,e 0.45 to 0.50 m3/kg of COD removal. The gas was burning with blue colour. The gas collection data is shown in Table 3 and Fig. 7.

Table 3: Gas production

Date	Discharge	Infl. COD	Efflu. COD	COD Reduct.	COD Reduct.	Gas Prodn.	Gas Prodn.
	m^3/d	mg/L	mg/L	mg/L	kg/d	m^3/d	m^3/kg
Day 16	0.05	4608	1440	3168	0.158	0.079	0.52
Day 17	0.05	4320	1280	3040	0.152	0.072	0.47
Day 18	0.05	4160	1440	2720	0.136	0.086	0.64
Day 19	0.05	4000	1200	2800	0.140	0.072	0.51
Day 20	0.05	4220	1310	2910	0.145	0.0756	0.52
Day 21	0.05	4230	1280	2950	0.147	0.0768	0.55

An attempt was also made for the treatment of wastewater by using coagulants like alum, lime and ferrous sulphate. The COD removal was found up to 28% and Total solids removal up to 20% with alum.

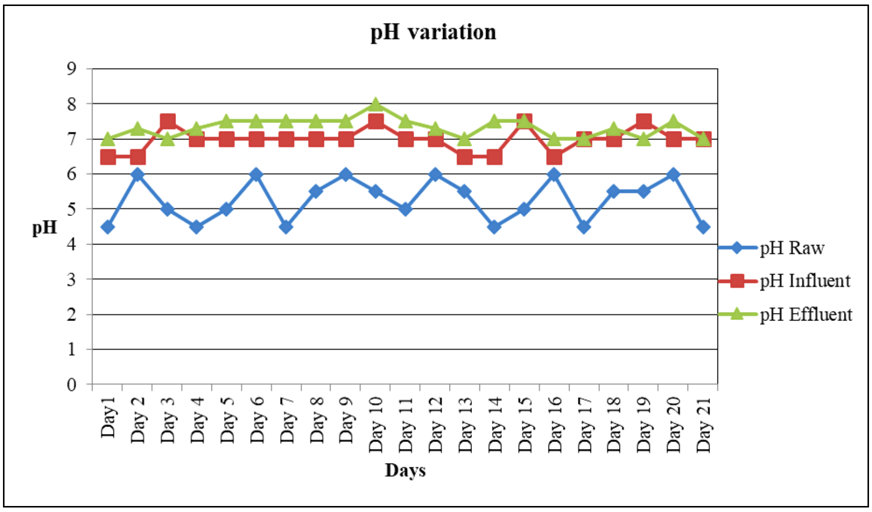

Fig 3: pH Variation

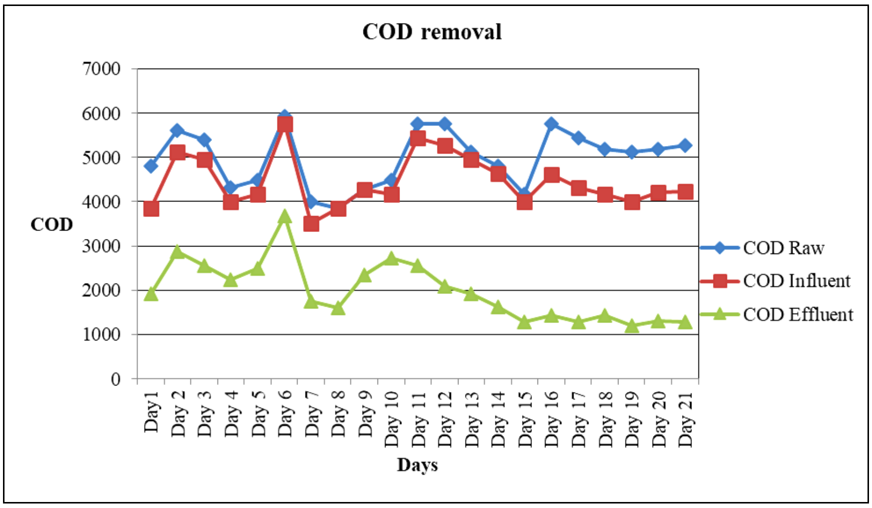

Fig 4: COD Variation

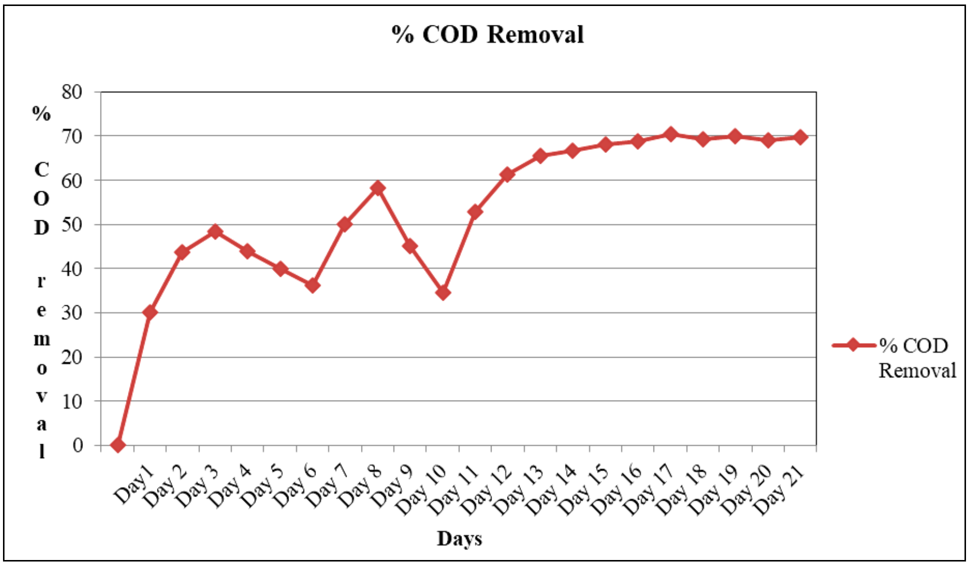

Fig 5: COD Removal

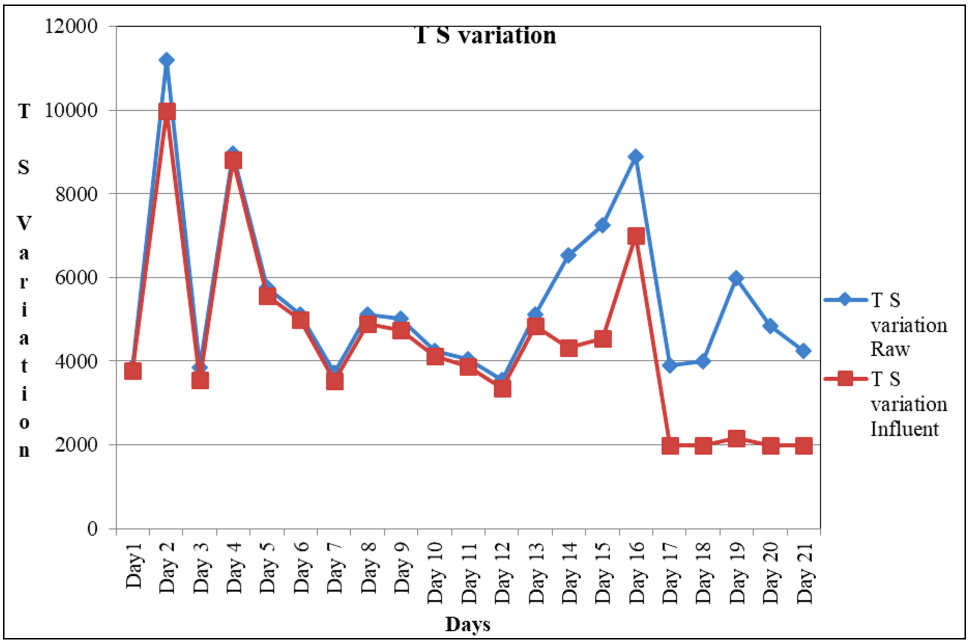

Fig 6: TS Variation

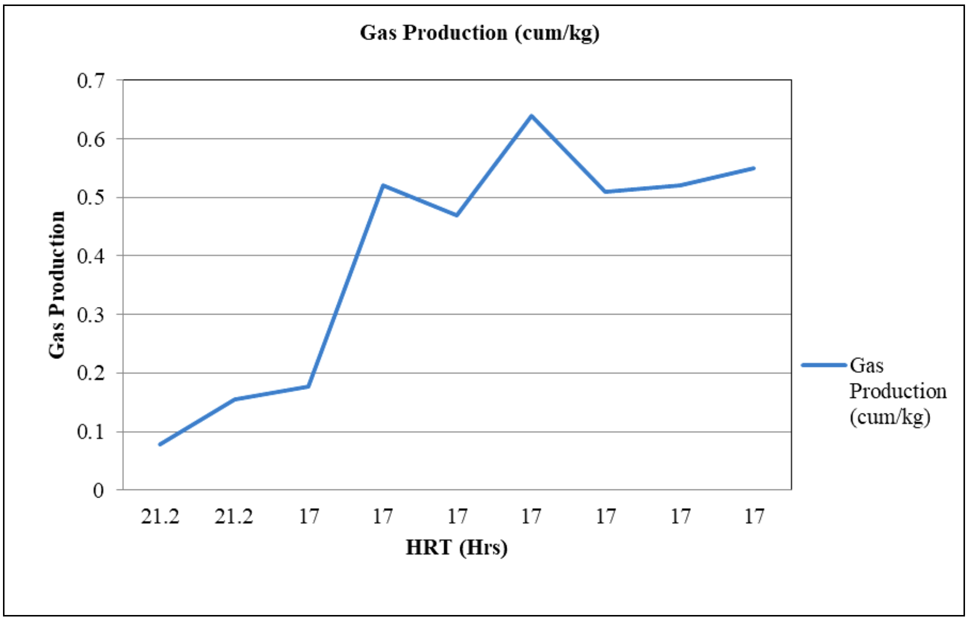

Fig 7: HRT vs Gas Production

Conclusion

By extensive study of parboiled rice mill wastewater treatment using UASB following conclusion are drawn:

The wastewater is acidic hence it is suggested to add lime to neutralize it. The nutrient content in the wastewater being very less hence nutrients should be added in the wastewater for biological treatment method. The COD/BOD ratio ranges from 1.68 to 1.76, which indicates that the wastewater is easily biodegradable and biological treatment method is the most suitable approach for the treatment of wastewater.

The COD removal up to 70.37% is achieved in the treatment period. More COD removal can be achieved by adding alum and aeration process such as stabilization tank to meet the standards to discharge on land. The gas production is in the range of 0.47 to 0.64 m^3/kg of COD removal, which is very influencing. The biogas from the system may be used to meet the energy requirement of the industry during load shading as well as for domestic purpose. With the time the pH is lowered hence the wastewater should be removed as early as possible from the parboiling unit.

As in Gondia 70 parboiled rice mills are running, the large scale UASB plant can be constructed in co-ordination among all the owners. The gas generated may be used as an energy or as a fuel for vehicles. UASB system as great potential to remove the pollutant in parboiled rice mill wastewater.

Small land is required, easy to construct, low capital and maintenance cost, less skilled supervision and high rate anaerobic treatment UASB process. Effluent is odourless and contents less organic matters hence can be used for irrigation purpose.

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