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Original Research Paper

Influence of Effective Microorganisms (EM) During Startup of Anaerobic Treatment of Pulp and Paper Mill Wastewater in HUASB Reactor

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ABSTRACT

Anaerobic treatment of bagasse wash water from paper and pulp mill was studied using a lab scale HUASB reactor of 7.88 L effective volume with three phase system. The initial characteristics of bagasse wash water were: pH 5.2-6.5, TCOD 2000-6000 mg/L, BOD 900-2500 mg/L, TS 4000-4500 mg/L, VSS 1000-1500 mg/L. The reactor was loaded with pulp and paper mill wastewater, seed sludge and activated Effective Microorganisms (EM) operated on continuous mode for a period of 130 days with an HRT varying from 24 to 8 hrs and start up with successful granulation has been achieved. An optimum TCOD removal was attained at the OLR of 7.8 kg COD/m^3/day with TCOD removal of 81% with a gas production of 2.66 L/L per day and 70% of methane gas content with a production rate of 0.29 m^3/kg COD removal were observed. The introduction of effective microorganisms has aided the start up period in an efficient way for better acclimatization inside the reactor that facilitate the biomethanation. The SEM analysis also shows stabilized *Methanothrix* and other microorganisms present in the reactor at the end of the start up.

INTRODUCTION

The rise in literacy, education and income and overall economic growth has necessitated for more production of paper and thereby the pulp and paper industrial process generate large quantity of wastewater (Jaakko Poyry Management Consulting 2002). At present there are about 700 pulp and paper mills in India in which agro residue and recycled fibers including bagasse are used for the manufacture of paper. Each tonne of manufactured paper requires about 100-250 m^3 of water (Singh 2004) with a corresponding wastewater generation of 75-225 m^3 (Ansari 2004). The Ministry of Environment and Forest (MoEF), Govt. of India has categorised this industry as a Red Category among 17 high polluting industries. Hence, it is mandatory to take appropriate measures to discharge the effluent into the receiving bodies complying the discharge standards by the Central Pollution Control Board.

The hybrid upflow anaerobic sludge blanket (HUASB) reactor is a high rate anaerobic system which yields high efficiency of organic loading rate with low HRT and lesser operating cost, especially in tropical countries like India where environmental conditions are highly favourable (Chernicharo 1977). The HUASB reactor is a combination of up-flow anaerobic sludge blanket reactor and anaerobic filter. The lower part of the HUASB reactor consists of UASB portion where flocculent and granular sludge is developed. The upper part of the reactor serves as a fixed film reactor. The HUASB reactor has been successfully tested for the various industrial wastewaters generating in swine, soft drink, slaughter house, pulp & paper, coffee processing, palm oil and pharmaceutical wastewater (Pokhrel & Viraraghavan 2004).

Some of the important environmental factors affecting anaerobic digestion are temperature, pH, nutrients and absence of excessive concentrations of toxic compounds in the influent. Nutrients (macronutrients, nitrogen, phosphorus, micronutrients) are required for the proper anaerobic digestion. Lettinga (1996) has studied the limitation of surface speed to avoid washout of sludge, that is also another factor which is in the range of 0.5-0.7m/h is ideal for this reactor.

Effective Microorganisms (EM) is a group of organisms that have a reviving action on humans, animals, and the natural environment and have also been described as a multiculture of coexisting anaerobic and aerobic beneficial microorganisms (Higa 1995, EM Trading 2000). The basis for using these EM species of microorganisms is that they contain various organic acids due to the presence of lactic acid bacteria, which secrete organic acids, enzymes, antioxidants and metallic chelates. One of the major benefits of the use of EM is the reduction in sludge volume. Theoretically, the beneficial organisms present in EM should decompose the organic matter by converting it to carbon dioxide (CO_2), methane (CH_4) or use it for growth and reproduction.

Activated effective microorganisms (AEM): EM is available in dormant state and require activation before application. Activation involves the addition of 7 L of chlorine free water and 1.5 kg of brown sugar to 3L of dormant EM one week prior to application. These ingredients were mixed to-

Table 1: Characteristics of EM.

S.No.	Microorganisms	Concentration in %
1	*Bacillus* species	25
2	*Pseudomonas striata*	25
3	*Pseudomonas fluorescence*	25
4	*Trichoderma vilide*	25
5	Fermented broth	99
6	Preservatives	1

gether in a 20 L container and stored at a minimal temperature. The pH of the EM should be about 4.5 (Newton 2002 pers. comm.). The characteristics of EM were analysed, and the result are given in Table 1.

MATERIALS AND METHODS

Experimental setup: The schematic diagram of the laboratory scale HUASB reactor is shown in Fig. 1. The total volume of the reactor is 9.88 L and the effective volume is 7.88 L, with a square sectional size of 0.15m × 0.15m × 0.43m height. The lower part will act as UASB in which suspended growth and granulation will take place. The total height is divided into three parts in which the middle portion is filled with PVC media for attached growth which acts as fixed film type. In the upper portion, gas will be collected over the tube fitted at the top of reactor through water displacement method and the effluent will be discharged at the 6th sampling port. The wastewater comprising substrates and balanced nutrients were fed in the reactor using a peristaltic pump. The initial characteristics of wastewater collected from the bagasse wash are presented in Table 2.

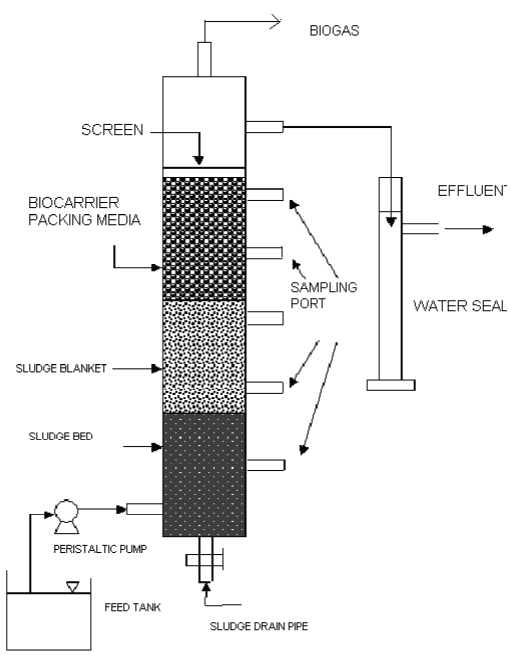

Fig. 1: The schematic diagram of HUASB reactor.

Table 2: Initial characteristics of pulp and paper mill wastewater.

S.No.	Parameters	Concentration
1.	pH	5.2- 6.5
2.	Total solids (mg/L)	4000 - 4500
3.	Total suspended solids (mg/L)	1000 - 1200
4.	Volatile solids (mg/L)	1000 - 1500
5.	Alkalinity (mg/L)	400 - 800
6.	Acidity (mg/L)	1000 - 1200
7.	Chlorides (mg/L)	700 - 900
8.	COD (mg/L)	2000 - 6000
9.	BOD (mg/L)	900 - 2500
10.	Electrical Conductivity (mS/cm)	2.20 - 2.22
11.	Nickel, Lead, Cadmium	Not detectable

Table 3: Characteristics of seed sludge.

S.No.	Parameters	Concentration
1.	Total solids (mg/L)	25000
2.	Suspended solids (mg/L)	17600
3.	Volatile suspended solids (mg/L)	10560
4.	Ratio of VSS/SS	0.60
5.	Specific methanogenic activity (SMA) kg COD/kg VSS.d	0.085

Start-up of reactor: The reactor was initially filled with 2 litres of cow dung and 2 litres of seed sludge obtained from a biogas plant, 25 mL of AEM and the remaining with pulp and paper mill wastewater gradually. Acclimatization of anaerobic bacteria was accomplished with the seed sludge whose VSS is about 10560 mg/L (Table 3) and the initial feeding rate was 7.8 L/day which corresponds to 24 hours HRT on a continuous mode. The reactor was started with an initial COD of 750 mg/L with an organic loading rate of 0.75 kg COD/m^3/d. OLR was increased in steps by decreasing HRT and varying flow rates over a period of 75 days with addition of 25 mL on each feed.

The acclimatization was accompanied by biogas production and COD removal and pH reduction. A steady state and uniform TCOD removal has attained at 75th day with an OLR of 2.50 kg COD/m^3/d and influent TCOD of 2500 mg/L. The loading and biogas production of the reactor during the start-up are presented in Fig. 7. In order to optimize HRT, various HRTs were adopted from 24 hrs to 8 hrs up to a period of 130 days. The biogas production increased and reached a maximum of 0.60 L/L of reactor volume/day at an OLR of 3.60 kg COD/m^3/d with 83% COD removal at a HRT of 12 hours. The methane gas content of 72% with a rate of methane of 0.28 m^3/kg COD removal was observed.

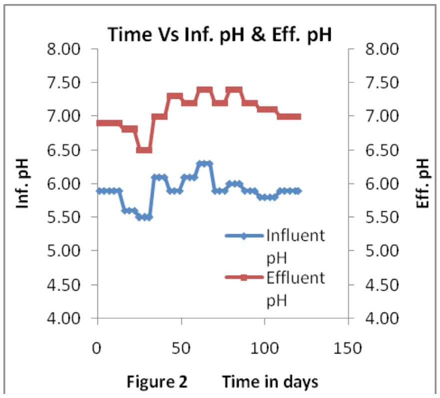

Fig. 2: Time vs. influent and effluent pH.

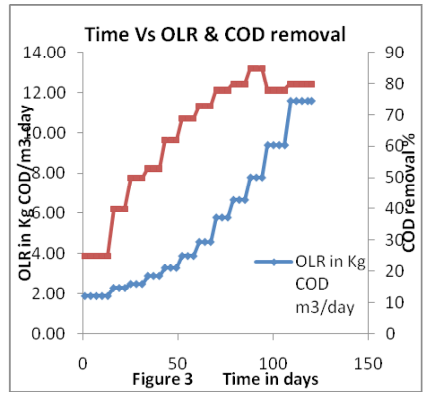

Fig. 3: Time vs. OLR and COD removal.

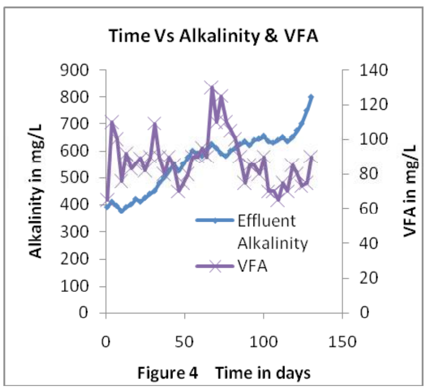

Fig. 4: Time vs. alkalinity and VFA.

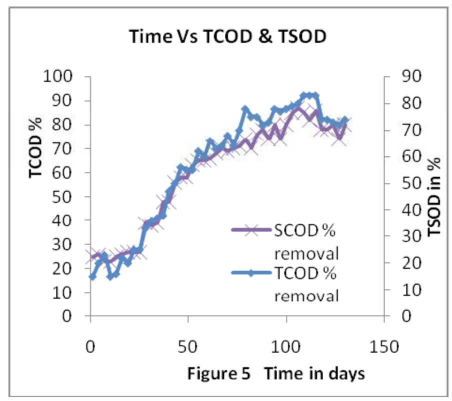

Fig. 5: Time vs. TCOD and TSOD.

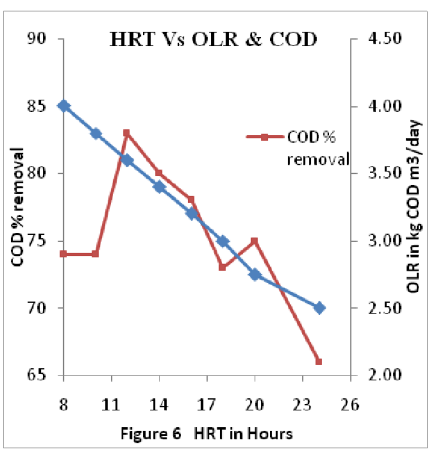

Fig. 6: HRT vs. OLR and COD.

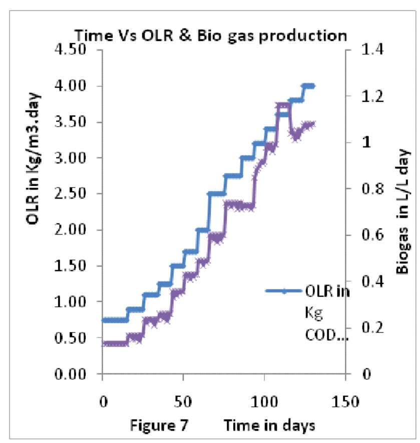

Fig. 7: Time vs. OLR and biogas production.

Fig. 2 represents the pH reduction for influent and effluent. Fig. 3 shows the relationship of time vs. OLR and TCOD removal. Fig. 4 shows the variation of alkalinity and VFA and Fig. 5 represents the reduction of TCOD and TSOD. Fig. 6 shows the relationship on HRT vs. OLR and COD, and Fig. 7 represents the OLR and biogas production.

RESULTS AND DISCUSSION

The pH of the effluent was in the range of 6.9-7.4 as also reported by Jantha & Ramanujam (1996). The optimal pH could be explained by the neutralization of hydrogen anions released from the volatile fatty acids together with the

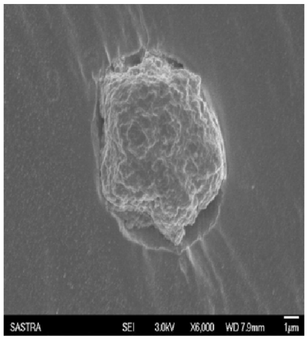

Fig. 8a: Cocci shape (*Methanosarcina*) bacteria.

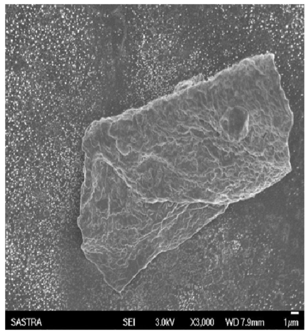

Fig. 8b: Rod shaped (*Methanothrix*) bacteria.

carbonates dissociated from the carbonic acid with the bicarbonate alkalinity inside the reactor as explained by Razo-Flores et al. (1997) and Beydilli et al. (1998). The overall duration for the start-up of 130 days, in this study was comparable to 117 days and the COD removal as reported (59% at an OLR of 6.58 kg during meat production wastewater treatment) by the studies of Ruiz et al. (1997). The TCOD removal efficiency of 83% during start-up showed that optimum and improved contact was observed during the HRT period of 12 hrs as reported by Raja Kumar et al. (2008), in treatment of poultry slaughter house. The ratio of VFA/Alkalinity showed the variation of 0.12 to 0.16 up to an OLR of 4 kg COD/m^3/d indicating healthy anaerobic environment and satisfactory methanogenic activity and no instability occurring inside the reactor as reported by Fongastitkul et al. (1994). The methane content in the biogas varied from 15% to 75% over the start-up. The optimum TCOD removal of 83% at HRT of 12 hours shows that biogas rate was influenced significantly by HRT and TCOD removal as reported by Silva et al. (1999).

The SEM analysis showed the formation of good granulation after the start-up period of 75 days as to the studies of Yue-Gen Yan & Joo-Hwa Tay (1997) who reported 98 days granulation period. The various structures of microbes photographs are presented in Fig. 8a, b.

CONCLUSION

The start-up performance of HUASB reactor proved to be successful for the treatment of wastewater containing pulp and paper mill and domestic wastewaters when operated with an OLR 3.6 kg COD/m^3/day with 12 hrs HRT. The VFA and alkalinity ratio of 0.13 shows stability condition for the biomethanisation inside the reactor. The average COD removal efficiency of 85% was achieved for the HRT of 12 hours with a gas production of 0.66 L/L and a methane gas content of 72% and rate of production of 0.28 m3/kg COD removal. Further the efficiency of the reactor was considerably increased by the introduction of AEM which was evidence by SEM analysis and shorter start-up period.

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