International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol.2, Issue.3, May-June 2012 pp-602-606 ISSN: 2249-6645

Treatability Studies on Hybrid Up-Flow Anaerobic Sludge Blanket Reactor for Pulp and Paper Mill Wastewater

T. Subramani[1] S. Krishnan[2] P. K. Kumaresan[3] P. Selvam[4]

[1]Professor & Dean, Department of Civil Engineering, VMKV Engg College, Vinayaka Missions University, Salem, India,
[2]Associate Professor & Head, Dept. of Mechanical Engg., Mahendra College of Engineering, Salem
[3]Professor & Dean, Examination, VMKV Engg. College, Vinayaka Missions University, Salem
[4]Professor & Dean, Department of Computer Science & Engineering, VMKV Engg College, Salem

ABSTRACT: In India, Pulp & paper industries have been large uses of portable water and consequently large generator of waste water. Anaerobic treatment of paper processing waste water has a distinct advantage of recovery of inherent energy in the form of methane gas with much less sludge production. A hybrid reactor that capitalizes on the positive features of anaerobic filter(AF) and up-flow anaerobic sludge blanket (UASB). The main objective of this thesis is to find out the start up of the hybrid up-flow anaerobic sludge blanket (HUASB) reactor for treatment of pulp & paper mill waste water. The study was conducted using Lab-scale HUASB reactor of volume 4.3Lit at ambient temperature with packing materials in the top one third of the reactor. The reactor was made of PVC material with internal diameter of 9.5cm and height of 61cm. The reactor was initially filled with 2Lit of cow dung. Remaining volume is filled with seed sludge and paper mill waste water at the ratio of 1:2, with a low organic loading rate (OLR) of 1 kg COD/m3.d and 24 hours hydraulic retention time (HRT).The initial characteristics of the paper mill waste water were studied. Reactor was designed and fabricated. Start-up was done and waiting for the steady state condition to be reached. Further study on different loading by reducing HRT will be done after obtaining the steady state.

KEYWORDS: Treatability, Pulp, Paper Mill, Wastewater

1. INTRODUCTION - GENERAL

In the rush towards industrialization, it became expedient for people to produce more products and to use more. This had resulted in large scale generation of wastes, a significant portion of which is considered to be hazardous. The wastes are disposed to the environment which poses problems to environment and also to human beings. The biological waste water treatment offers one of the major steps in eliminating biodegradable organic matter present is many industry effluent. Aerobic and anaerobic treatment systems are the major alternatives in biological treatment methods.

2. Background Of Anaerobic Treatment System

In the past, aerobic treatment system was favored as it was considered to be reliable, stable and efficient. However, aerobic treatment systems require large amounts of power for aeration and mixing, whereas power requirement for anaerobic process is relatively low.

When compared to aerobic, anaerobic system has more potential for energy production in the form of methane gas. The energy required for the stabilization of 1kg COD/d is 20-30W for aerobic systems. It is known that in aerobic metabolism approximately one third of metabolized COD mass is oxidized and two third of the metabolized mass in anabolised. In contrast, a very large fraction of digested organic material (about 97%) is transformed into methane in the anaerobic digestion. Only about 3% of metabolized mass in anabolished resulting in very less production of sludge(Table.1-Van Haandel and Liettinga, 1994). Inspite of these advantages; their utilization was limited to stabilization of the sludge and solid wastes.

Table. 1 Comparison of aerobic and anaerobic treatment systems (adopted from van haandel and liettinga, 1994)

SL. NO	Parameter	Aerobic system	Anaerobic system
1.	Energy required (W/kg COD.d)	20-30	35*
2.	Sludge production (kg VSS /kg COD)	0.2-0.3	0.05-0.15
3.	Nature of excess sludge	unstable	stable

*Anaerobic systems have potential for energy production.

The steep increase in energy prices in the 1970s reduced the attractiveness of aerobic treatment systems and intensified once again the research efforts towards the developments of systems with lower energy consumption such as modified aerobic digestion rather than aerobic metabolism the removal of organic matter from waste water.

With the development of high rate anaerobic reactors, the anaerobic waste water treatment is becoming an accepted technology for a variety of industrial waste water. High rate anaerobic digestion in recent years has been developed with a sound scientific and engineering foundation and is regarded as a mature technology (Iza et al., 1991). Thus high rate anaerobic treatment has emerged as a viable alternative for the treatment of many industrial and municipal waste water.

During the last few years, there are number of high rate anaerobic systems such as anaerobic filter (AF), up-flow anaerobic sludge blanket (USAB) reactors and expanded /fludized bed reactors have been developed in the last few years. All these systems are based on some kind of sludge immobilization principle in order to retain as much viable sludge as possible. One of the common threads that link these various processes is their ability to effectively separate SRT and HRT. This permits the design to be based upon the degradation capacity of anaerobes and not upon the growth rate which results is the reduction of treatment times from days to hours. Among the various high rate anaerobic reactor design, UASB (Lettinga et al., 1980; Fang et al., 1990) and AF (Suidan et al., 1983; Young and Young, 1991) have been successfully commercialized and hundreds of full scale systems have been installed worldwide.

3. HYBRID UPFLOW ANAEROBIC SLUDGE BLANKET (UASB) REACTOR

The HUASB reactor is a combination of a UASB unit at the lower part and an anaerobic fixed film unit at the upper (Lee Jr et al., 1989). This reactor enjoys the advantages of both UASB (which ensures good contact between biomass and substrate) and anaerobic filter (AFs can retain more biomass within the reactor) (Abid alikhan et al., 2003). This kind of reactor is called by various names viz., Sludge Bed Filter (SBF), Up-flow Bed Filter (UBF), Hybrid Up-flow Anaerobic Sludge Blanket (HUASB) reactor or simply "hybrid" reactor.

The standard HUASB reactor has a filter packing located in the upper third of the reactor without Gas Liquid Solid (GLS) separation device.

This kind of a design has the following advantages apart from main benefits of high rate anaerobic reactors:

i). Biomass is free to accumulate in the unpacked zone.
ii). For the absence of media, the concentration and level of sludge blanket is easily monitored.
iii).The packed zone at the top acts as a GLS separator that assists in the retention of the non-attached sludge bed.
iv).The packing provides a polishing zone of attached biomass that improves process stability under transient operating conditions.
v). The reduced cost of the packing media.
vi).It is a feasible alternative design also in respect of UASB reactors in many cases when the granular biomass is difficult to cultivate or to maintain and thus UASB doesn't offer warranty of stable operation.

4. OBJECTIVES OF THE PRESENT STUDY

The objectives of the present study are

- ❖ To review the existing literature pertaining to anaerobic digestion process and management of paper mill waste water.
- ❖ To study the physico – chemical characterization of paper – pulp industry waste water.
- ❖ To study the start-up time and optimum Hydraulic Retention Time for HUASB reactor under normal loading condition with same feed of Paper mill waste water.
- ❖ To study the performance of the reactor for optimum Biogas production efficiency by varying the micro organism in the HUASB reactor.

5. MATERIALS COMPOSITION OF WASTE

The effluent which is the bagasse wash water was collected from the primary clarifier in pulp and paper industry. The collected sample was kept in plastic cans in a freezer at room temperature and was studied for its characteristics.

5.1 SEEDING SLUDGE

The seed sludge was also collected from the pulp and paper industry. This was used as the inoculum because the sludge had sufficient number of acetogenic and methanogenic bacteria.

6. METHODS

The study conducted was divided into 3 aspects, they are

i. Reactor set-up.
ii. Process start-up.
iii. Operation and Monitoring.

7. REACTOR SET-UP

The laboratory scale Hybrid UASB reactor (Figure.1) was fabricated using transparent flexi glass material with an internal diameter 9.5cm and overall height of 61cm. Total volume of the reactor was 4.32Lit and it working volume was 2.3lit (Table.2) A gas head space of 1Lit was provided at the top of the reactor and sampling port were located at equal intervals.

The top third of the reactor was filled with pleated PVC rings. These parking media were floating against fixed screen. The waste water entered under sludge bed through a feed distribution pipe. The effluent pipeline was connected to a water seal to prevent escape of the gas through effluent. The gas will be measured by water displacement method. Peristaltic pump was used for feeding the reactors. The reactor was supported by a frame structure made up of metal.

The following components of the HUASB reactor are,

i. Inlet and outlet distribution system
ii. Sampling ports
iii. Packing media
iv. Gas collection set up

Table 2 Construction Details of Huasb Reactor

Sl. NO.	Particulars	Specification
1.	Reactor type	Circular P.V.C. pipe
2.	Diameter	9.5cm

3.	Total height	61cm
4.	Working volume	2.3Lit
5.	Total Volume	4.32Lit
6.	Packing media depth	15cm
7.	Nos. of sampling port	5
8.	Port interval	11cm

7.1 INLET AND OUTLET DISTRIBUTION SYSTEMS

At the bottom, the feed inlet pipe of 8mm diameter was provided which is connected to peristaltic pump, through ¼ inch check valve and silicon tubing arrangement, for pumping the feed. This 8mm diameter was enough to avoid clocking in the inlet pipe due to bio mass in the feed. The end of inlet pipe was kept open and bent towards bottom. A clearance of 5cm was provided between the feed distribution pipe and the reactor bottom. Because of this arrangement the feed splashed against the bottom and uniformly distributed while moving up. Just over the packing media a collection tube ¼ inch check valve was connected to collect the processed influent and is connected to outlet.

7.2 SAMPLING PORTS

In order to determine the sludge concentration profile over the reactor height the reactor was fixed with sampling ports made up of brass pipe ¼ inch check valve is connected below the packing.

7.2 PACKING MEDIA

Two fixed screens at a gap of 15cm and a distance of 15cm from the top of the reactor were fixed. The gap between these screens was filled with packing media such as PVC rings ID 1.1cm and OD 1.4cm in 175Nos. This was provided for better solid capture in the system and to prevent the loss of large amount of the UASB reactor solids due to process upsets or changes in the UASB sludge blanket characteristics and density.

7.4 GAS COLLECTION SET-UP

Gas is collected through the gas vent opening provided at top of the reactor. Amount of gas displaced is collected in the mad rid bottle. This collected gas will cause rise in water level in the water displacement jar.

7.5 DESIGN OF THE UASB REACTOR

7.5.1 Volume of the Reactor $V = \Pi r^2 h$

Internal Diameter of the Reactor = 9.5 cm

Volume of the reactor = $(\Pi/4) \times (0.095)^2 \times 0.61$

$= 4.32\text{x}10^3\ m^3$

7.5.2. Flow rate $Q = \text{Volume} / \text{Time}$

{If the COD concentration is 750-3000 mg / lit , the Hydraulic Retention Time (HRT) is 6 – 24 Hours}

Assuming the HRT is 24 Hours (or) 1 Day

$Q = (4.32 / 1)$

$= 0.18$ Lit / Hr.

(or)

$Q = 4.32$ L /.day

7.5.3. Volumetric Hydraulic Loading

(VHL) = Q/V

VHL = 0.18 / 4.32

= 0.042 / Hr.

(or)

VHL = 4.32 L / L.day

7.5.4 Organic Loading Rate

(OLR) = $Q \times S_0 / V$

$= 4.32 \times 2.8 / 4.32$

= 2.8 gm of COD / Lit .Day

7.5. 5. Up-Flow Velocity

(v) = Q /A (or) $Q \times H / V$

$= 2.8 \times 0.61 / 0.00432$

= 0.025m /Day.

V = $2.8 \text{ X } 10^{-7}$ m / sec.

8 START-UP OF THE REACTOR

The reactor was inoculated with digested sludge obtained from primary clarifier. Initially the reactor was inoculated with 35% of cow dung remaining volume is filled with seed sludge.

9 OPERATION AND MONITORING

The operation and monitoring was done in order to find out the feasibility of the hybrid up-flow anaerobic sludge blanket (HUASB) reactor. In the operation phase the reactor was operated in continuous mode for different flow rate for the 4.32L /day (or) $5\text{x}10^2\ m^3$/ sec

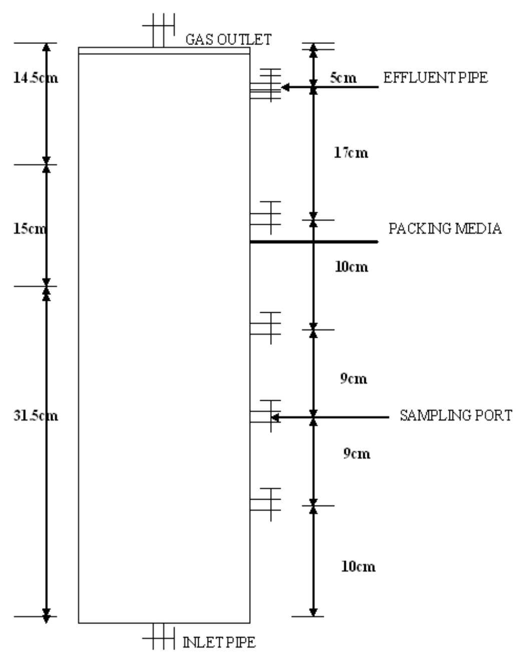

Figure 1 Hybrid Up-Flow Anaerobic Sludge Blanket Reactor

The pH of the reactor is always maintained neutral by adding necessary amount of base (or) acid solution. The outlet pH was found to be in range of 7.5 to 7.6.

10 RESULT

The waste water was collected from the pulp and paper industry. The waste water was analyzed for their characteristics.

10.1 CHARACTERISTICS OF PAPER MILL WASTEWATER

The paper mill waste water sample was carried out to determine general characteristics. The results obtained are shown in Table 3.All the values are in mg/lit except pH.

10.2 SEED SLUDGE CHARACTERISTICS

The seed sludge was obtained from secondary clarifier unit from the pulp and paper industry. The seed sludge sample was carried out to determine the following parameters are shown in Table .4

Table. 3 Characteristics of Wastewater

Sl.no.	Parameter	Concentration (mg/l)
1.	pH	5.0
2.	Total solids	4350
3.	Total dissolved solids	3260
4.	Total suspended solids	1020
5.	Total fixed solids	3530
6.	Volatile solids	1030
7.	Alkalinity	650
8.	Chlorides	895
9.	COD	2875
10.	BOD	675
11.	Electrical Conductivity (ms/cm)	2.20
12.	Heavy metals	
	chromium	0.069
	Ni, Cd, Pb	Non-detectable

1. DISCUSSION - START-UP OF THE REACTOR

The reactor was initially filled with cow dung at 35% of working volume. The remaining volume was filled with seed sludge.

Start-up of the reactor is in initial phase, since it is an anaerobic reaction which takes long time for reacting the steady state condition and gas production.

2. OPERATION AND MONITORING

The operation and monitoring was done in order find out the following parameter such as pH, TDS, VSS, Alkalinity, COD and BOD of the treated effluent.In the phase 1 start-up was done. Only flow rate is regulated and waiting for the steady state condition to be achieved.

Table 4 Characteristics of Seed sludge

Sl.no.	Parameter	Concentration (mg/l)
1.	pH	8.0
2.	Total solids	5960
3.	Electrical Conductivity	3.33
4.	Total fixed solids	4860
5.	Volatile solids	1100
6.	Alkalinity	975
7.	Chlorides	457
8.	COD	2550
9.	BOD	473
	Heavy metals Cr, Ni, Cd, Pb	Non- detectable

All the values are in mg/lit except pH.

REFERENCES

[1]. Lettinga, G., A.F.M. Van Velsen, S.W. Homb, and A.Klapwisk, 1980, "Use of Upflow Sludge Blanket Reactor Concept for Biological Waste water Treatment", Biotechnology and Bioengineering, No. 22, pg. 699-734.
[2]. Coates, J and Colleran, E., (1990)., "Operational performance of Hybrid Upflow Anaerobic Reactor treating a synthetic feed." 10, 162-171.
[3]. Yogita Chuphal, Shachi Shah and Indu Shekhar takur (2007), "Optimization of Upflow Anaerobic Sludge Blanket Reactor for treatment of Pulp and Paper mill effluent," 26(1): 49-53.

[4]. Metcalf and Eddy (2003) " waste water Engineering treatment and Reuse". Tata McGraw - Hill Edition.

[5]. Arun Kansal, K V Rajeshwari, Malini Balakrishnan, Kusum Lata, V V N Kishore, (1998) "Anaerobic Digestion technologies for energy recovery from industrial wastewater- a study in Indian context". TERI information Monitor on Environmental Science3(2): 67-75

[6]. Trlche, A. and Vieira, S M.M., (1991)., "Discussion reports on reactor design of anaerobic filters and sludge bed reactors." Wat Sci Technol., 24, 193-206.

[7]. Chawla, O.P., "Advances in Biogas technology", Indian Council of Agricultural Research, New Delhi, 1989, page-144.

[8]. Raghu Rama Sharma, S. and Bandyopandhy Y.M. (1991) "Treatment of pulp and paper mill effluent by upflow anaerobic filter". Indian J. Environ. Hlth. Vol. 33, No.4, pg. 456-463.

[9]. Hall ER, Cornacchio L-A - "Anaerobic Treatability of Canadian pulp and paper mill waste water". Pulp pap can 1988; 89(6): 100-4.

[10]. Campos, C.M.M. and Anderson, S.A.- "Effect of liquid upflow velocity and substrate concentration on the start-up of UASB reactor" . Water Science and technology (1992), vol-25(7), pg-41-50.

[11]. Muna Ali, T.R. Sreekrishnan – "Anaerobic Treatment of agricultural residue based pulp and paper mill effluents for AOX and COD reduction "– Department of Biochemical Engineering and Biotechnology, IIT, Delhi. (2000) Vol:36, pg no:25-29.

[12]. K. Kavitha and A.G. Murugesan – "Efficiency of Upflow Anaerobic Granulated sludge blanket reactor in treating fish processing effluent " - Manonmaniam Sundaranar University, Sri Paramakalyani Centre for Environmental Sciences, Alwarkurichi, Tamilnadu, Journal of Industrial Pollution Control 23(1) (2007), pg 77-92.

[13]. Lettinga, G. and Hulshoff Pol, L.W. 1986. "Advanced reactor design, operation and economy. Wat.Sci. Technology. 18(12): 99-108.

[14]. Kavitha, K. and A.G. Murugesan, 2004. "Performance evaluation of paper mill effluent in a granular bed UASBR". Jr. of Indian. Environ & Ecoplanning. 8(3) :551-556.

[15]. Chaudhry, S., Manthan.M., Saroo N., Rohella R.S., - "Anaerobic Treatment of Pulp and Paper mill effluent "– a case study Indian journal of Environmental health (1999) 41(1): 74-5.

[16]. M.M. Ghangrekar, U.J. Kahalekar, S.V.Takalkar - "Design of Upflow Anaerobic Sludge Blanket Reactor for treatment of organic waste waters"- (2003) Indian journal of environmental health Vol-45, No:2, Pg no:121-132.

[17]. J.R. Banu, S. Kalliappan; I.T.Yeom – "Treatment of domestic wastewater using upflow anaerobic sludge blanket reactor "- centre for environmental studies(CES) Anna university, Chennai. (2007), Institute of journal Environmental Science & Technology, 4(3): 363-370.

[18]. K.R. Chakravarthi, M.Singanan and K.Somasekhara Rao – "A correlation study on physicao-chemical characteristics of paper mill effluent," Nuzvid. (1995), Indian journal of Environmental protection vol: 16 (1), pg: 46-49.

[19]. R.F. Hickey, W.M. Wu, M.C. Veiga and R. Jones - "Start-up, operation, Monitoring and control of high rate anaerobic treatment systems" – Michigan Biotechnology Institute, Lansing, USA, & Environment Canada, Waste water technology center, Canada.—Wat. Sci. Technology, Vol. 24, No. 08, pg. 207-255, (1991).

[20]. Dr. K.S. Jayantha, " Biogas production from high strength waste using upflow anaerobic sludge blanket (UASB) reactor "– A laboratory scale study.

[21]. Fang, H.H.P. and Chui, H.K. 1995. "Performance and sludge characteristics of UASB process treating propionate –rich waste water" – wat. Res. 29 (3) : 895-898.

[22]. Rajamani, S. Suthanthra Rajan, R., Ravindranath, E., Muldeues, A., Vangeoneslijn, J.W. and Damgerwef, J.S. 1995—"Treatment of tannery waste water using upflow anaerobic sludge blanket (UASB) reactor, 30th leather research industry Get. Together Report, 57-60."

[23]. Ozturk, L, V. Eroglue, G. Ubay and I. Permir, 1993, "Hybrid upflow Anerobic Sludge Blanket Reactor (HUASBR) – Treatment of Dairy Effluents " , water science and Technology, No. 23, pg.77-85.

[24]. Guiot, S.R. and L. Van den Berg, 1984, "Performance of an Upflow Anerobic Reactor Combining a Sludge Blanket and a Filter Treating Sugar Waste", Biotechnology and Bioengineering, No-27, pg: 800-806.

[25]. Borja, R., C.J. Banks and Z. Wang, 1995, "Performance of Hybrid anaerobic reactor, combining a sludge blanket and a filter, treating slaughter house waste water", Applied micro biology and biotechnology, No.43, pg.351-357.