Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

Nature Environment and Pollution Technology An International Quarterly Scientific Journal	Vol. 9	No. 1	pp. 29-34	2010

Original Research Paper

Start-up Performance of Hybrid Up-flow Anaerobic Sludge Blanket Reactor Treating Pulp and Paper Mill Effluent

R. Praba Rajathi, K. Ashok Kumar and T. Meenambal
Department of Civil Engineering, Govt. College of Technology, Coimbatore-641 013, T.N., India

Nat. Env. Poll. Tech.
ISSN: 0972-6268
www.neptjournal.com

Hybrid UASB reactor
Hydraulic retentiion time
Organic loading rate
Pulp & paper mill effluent
Start-up performance

ABSTRACT

A study was performed on hybrid up-flow anaerobic sludge blanket reactor to identify the start-up time and optimum HRT required for treatment of pulp and paper mill wastewater. Initially, the reactor was loaded at an OLR of 0.117 kg COD/m^3.hr and HRT of 24h. Loading rates were increased by reducing HRT 24, 20, 16, 14, 12, 10, 8, 6h, which corresponds to the OLR of 0.117, 0.141, 0.175, 0.201, 0.233, 0.294, 0.348, 0.458 kg COD/m^3.h. An optimum HRT of 8 h, HUASB reactor shows COD and TSS removal efficiency of 80% and 85% respectively. When HRT was reduced beyond 8h, lower COD removal efficiency of 71% and TSS removal efficiency of 70% were observed. Finally, the reactor took 120 days for complete start-up. The granule formation was observed inside the reactor by drawing the sample along the port, which shows sizes of 1-2 mm.

INTRODUCTION

The pulp and paper industry is a major industrial sector utilizing huge amounts of lignocellulosic materials and water during the manufacturing process, and releases large amount of wastewater (Fukuzumi 1980). The pulp and paper wastes characteristically contain high COD which may be harmful if disposed off without treatment into the environment. The conventional treatment options are known to have low treatment efficiency owing to high concentrations of solids present in the wastewater. Literature references indicate that most of the negative aspects of high rate anaerobic digestion can be overcome by restricting the supporting material to the top 25 to 30% of the reactor volume (Guiot & Van den Berg 1984, 1985). This would further help realize the advantages of both fixed film and up-flow anaerobic sludge blanket treatment. This kind of reactor is often called hybrid up-flow anaerobic sludge blanket reactor (HUASB) and considered more stable for the treatment of a series of soluble or partially soluble wastewaters (Tilche & Vieira 1991). Over the years, HUASBs have been used to treat variety of industrial effluents (Coates & Colleran 1990, Shivayogimath & Ramanujam 1999). Up-flow anaerobic sludge blanket reactor represents an attractive method for wastewater treatment at the pulp and paper mill facilities since it contains high COD and total suspended solids.

The UASB reactor is the most widely and successfully used high rate anaerobic technology for treating several types of wastewaters. The success of the UASB reactor can be attributed to its capability to retain a high concentration of sludge and efficient solids, liquid and water separation.

Start-up is often considered to be the most unstable and difficult phase in anaerobic digestion. In high rate anaerobic reactors, finding optimum hydraulic retention time (HRT) is highly significant in order to avoid biomass washout. Surface roughness of media is considered as one of the important parameters in start-up of reactor since attachment of microorganisms on the smooth surface media is very difficult at early stages. Keeping these points in view, present study aims at evaluating the start-up time and optimum HRT required for the treatment of pulp and paper mill wastewater using hybrid up-flow anaerobic sludge blanket reactor.

MATERIALS AND METHODS

The schematic of HUASB reactor is illustrated in Fig. 1. Bench scale HUASB reactor was fabricated using transparent plexi glass material with an internal diameter of 9.5cm and overall height of 61cm. Total volume of the reactor was 4.32 L and its working volume was 2.3 L. A gas headspace of 1 L was provided at the top of the reactor and sampling ports were located at equal intervals. The top third of the reactor was filled with pleated PVC rings. These packing media were floating against fixed screen. The effluent pipeline in turn was connected to a water seal to prevent the escape of gas. A peristaltic pump was used for feeding wastewater into a reactor. The gas was measured by water displacement method. The reactor was supported by a frame structure made-up of metal. Details of HUASB reactor are given in Table 1.

Table 1: Details of hybrid UASB reactor.

Sl. No.	Particulars	Specification
1.	Reactor type	Circular cross section
2.	Diameter	9.5cm
3.	Total height	61cm
4.	Working volume	2.3 L
5.	Total volume	4.32 L
6.	Packing media depth	15 cm
7.	No. of sampling ports	5
8.	Port interval	11cm

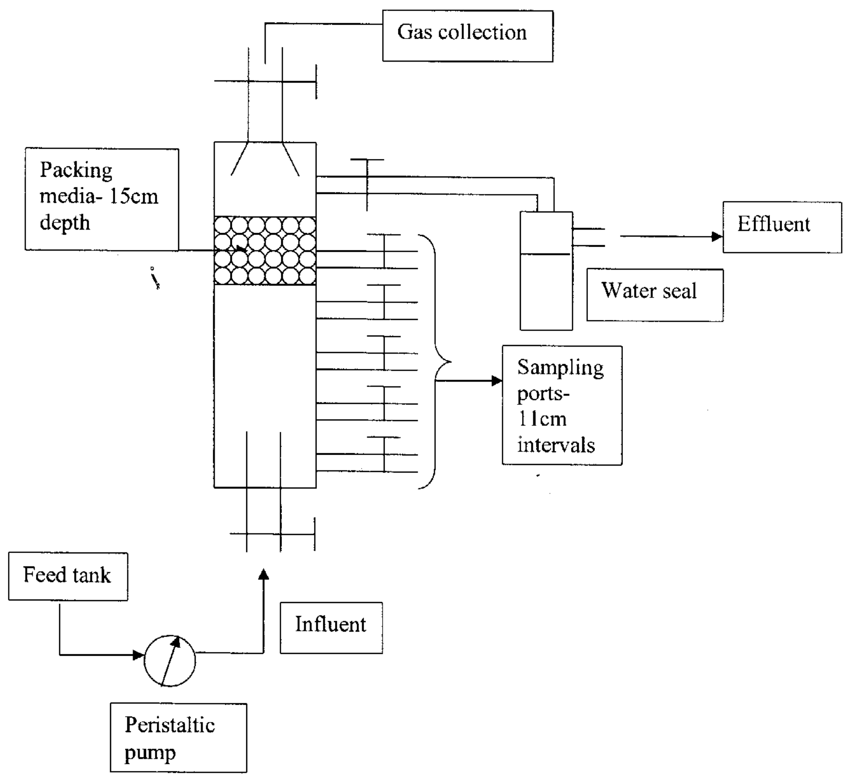

Fig. 1: Set-up of hybrid up-flow anaerobic sludge blanket reactor.

Paper mill wastewater generated from a pulp and paper mill, located in Karur district, Tamilnadu was used as a substrate. The wastewater used as feed was kept in plastic cans at 4°C. The reactor was seeded anaerobically with a non-granular sludge obtained from wastewater treatment plant of the paper mill. The influent and effluent flow rates, pH and biogas production were monitored daily. Total COD, TSS, TS and alkalinity in influent and effluent and biogas composition were measured at regular intervals. pH, COD, TS, TSS and alkalinity were analysed by standard methods (APHA 1998). The biogas composition was measured by water-displacement method.

Characteristics of pulp and paper mill wastewater: Characteristics of wastewater are summarized in Table 2. Feed total COD was maintained at approximately 2820 mg/L throughout the start-up period by dilution with tap water.

Granulation of HUASB reactor: Good performance of HUASB reactor depends mainly upon the formation of a bed of well settling and highly active granular sludge, with a low sludge value index and a high methanogenic activity (Gatze Lettinga et al. 1980). The sludge obtained from the paper mill treatment plant was used for the granulation process. To induce granulation process, 1 L of cow dung was added before the start-up of the reactor. The favourable environmental conditions were provided for the growth of anaerobic bacteria. Shock loading was avoided to prevent the loss of microbial biomass (Shivayogimath 2003). During the granulation process, the suitable operational conditions were strictly followed (Table 3).

RESULTS AND DISCUSSION

The reactor was seeded with 1 L of cow dung and 1 L of seed sludge obtained from the wastewater treatment plant of paper mill wastewater and fed with wastewater at an OLR of 0.117kg COD/m^3.hr. Fig. 2 presents variations in pH during the start-up process. The pH of the effluent from the reactor was in the range of 7.0-8.0. It is known that pH less than 6.8 and greater than 8.3 would cause souring of the reactor during anaerobic digestion (Stronach et al. 1986, Wheatly 1991). Consistent pH level of 7.0-8.0 was maintained in the effluent indicating healthy environment. The alkalinity was increased when loading rate was increased.

Effect of HRT on COD and TSS removal efficiency: The reactor was started with an OLR of 0.117 kg COD/m^3.hr and maintained in batch mode for 10 days until the production of gas and another 5 days it was continued in the same loading in continuous mode to enhance the growth of microbes in the media. Subsequently, the OLR was increased stepwise to 0.141, 0.175, 0.201, 0.233, 0.274, 0.348 kg COD/m^3. hr by reducing the HRT to 24, 20, 16, 14, 12, 10, 8 hrs respectively.

The COD and total suspended solids removal efficiency of 80% and 85% were achieved at an OLR of 0.348 kg COD/m^3.hr. Reduction in HRT less than 12 hrs showed increased trend in COD removal efficiency. But, there is a decrease in removal efficiency at the HRT of less than 8hrs. Reduction in HRT (less

Table 2: Characteristics of pulp and paper mill effluent (All values are in mg/L except pH).

Parameter	Values
pH	5.0
Total solids	4350
Total dissolved solids	3260
Total suspended solids	1020
Total fixed solids	3530
Volatile solids	1030
Alkalinity	650
Chlorides	895
COD	2875
BOD	675

Table 3: Operational conditions for granulation process.

Sl.No.	Parameter	Amount
1.	pH	6.5-8.0
2.	TSS	750-1010
3.	COD	1750-2280
4.	Alkalinity	550-600

*All values are in mg/L except pH.

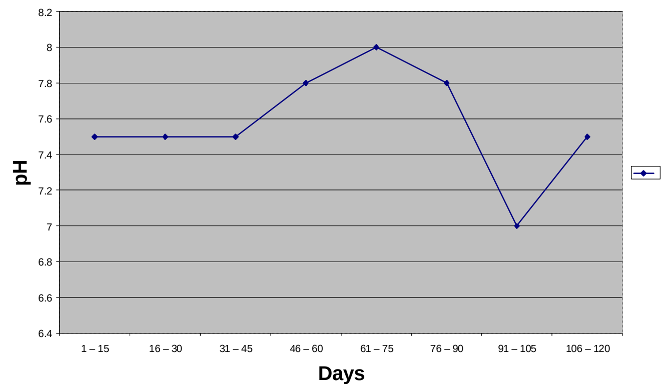

Fig. 2: Effluent pH variation during start-up process.

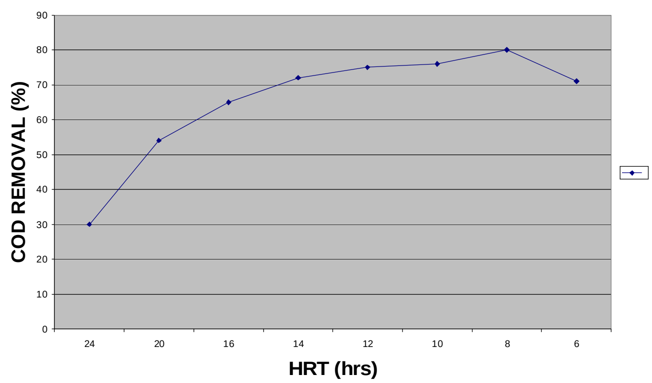

Fig.. 3: Effect of HRT in COD removal efficiency.

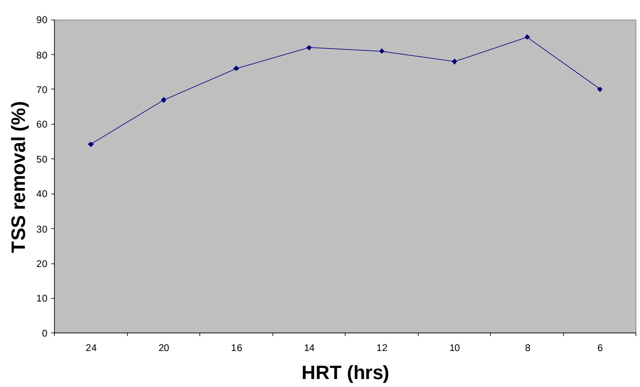

Fig. 4: The effect of HRT in TSS removal efficiency.

Table 4: Operational parameters and treatment efficiencies of HUASB reactor during start-up.

Time (Days)	HRT (hrs)	Influent COD(mg/L)	OLR (kg.COD/m^3.h)	COD removal efficiency(%)	Biogas production(L/d)	TSS removal efficiency(%)	Effluent pH
1-15	24	2820	0.117	30	0.3	54.2	7.5
16-30	20	2820	0.141	54	0.8	67	7.5
31-45	16	2800	0.175	65	1.1	76	7.5
46-60	14	2810	0.201	72	1.5	82	7.8
61-75	12	2795	0.233	78	1.8	81	8.0
76-90	10	2940	0.294	76	2.4	78	7.8
91-105	8	2780	0.348	81	2.0	85	7.0
106-120	6	2750	0.458	71	2.1	70	7.5

than 8hrs) showed decrease in COD removal and sludge washout, which may be due to the short contact time between biomass and substrate. Hence, the optimum HRT was found to be 8hr for HUASB reactor. Finally, the reactor took 120 days for complete start-up. The start-up summary is shown in Table 4.

During the start-up period of 1-75 days, the reactor showed the total suspended solids removal efficiency of 30-78% of an OLR of 0.233 kg COD/m^3.hr. Reduction in HRT from 8hrs to 6hrs showed decrease of TSS removal efficiency from 85 to 70% in HUASB reactor. It is evident from the Fig. 3 that at a HRT of 8h, the COD removal efficiency was increased to 81%. The effect of HRT in TSS removal efficiency is shown in Fig. 4.

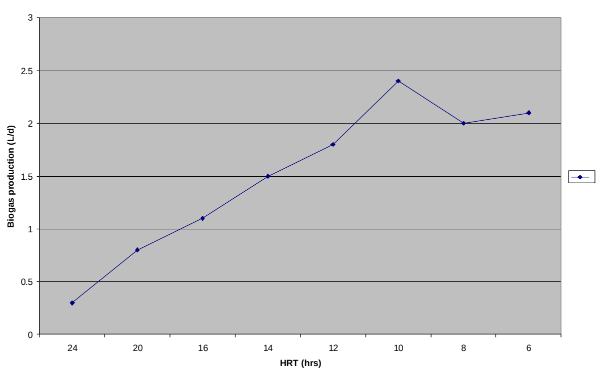

Fig. 5: Biogas production in various HRT.

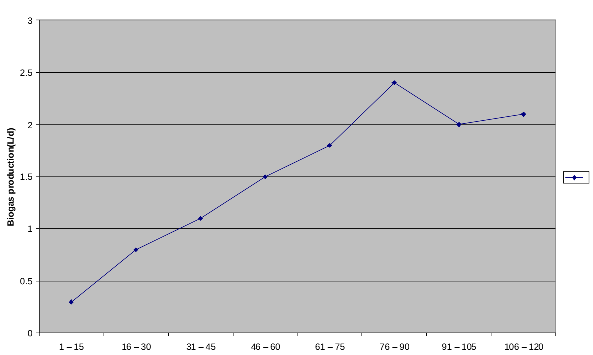

Fig. 6: Biogas production during start-up process.

Biogas production: The maximum gas collection of 2.4L/d was observed at an OLR of 0.274 kg COD/m^3.hr. Though the low gas collection was observed in reactor, the removal efficiency observed was quite good. This indicates that the lower methanization capacity was prevailing inside the reactor. However, the COD removal efficiencies were comparatively as good as 30-81%. The biogas production with various HRT is shown in Fig. 5, and the biogas production in the whole start-up process days in Fig. 6.

Formation of granules: The granulation process was started with the flow rate of 0.18 L/h using the peristaltic pump. The granule formation was observed inside the reactor by drawing the sample along the port, which shows sizes of 1-2 mm. This has proven that the possibility of granules may be occurred in attached growth in between the interstices of the packing media. At the bottom of the reactor three types of zones were formed according to the size of the particles. They are flocculent zone, settler zone and granular zone. The sludge in the bottom zone was observed to be granular in shape and had well and undigested sludge but of smaller size and smelled like well digested material. The top zone had sludge of dispersed and flocculent nature and smelled like well digested material. The sludge had a pH of 6.5-7.4 and registered an increasing trend from bottom to the top. Similar trend was noticed in alkalinity too. This was due to the production of CO_2 during the process in which the wastewater developed contact with biomass (Pathe et al. 1990). The low activity of the biomass was observed at the bottom while the middle and upper part had higher activity (Collivignarelli et al. 1990).

CONCLUSION

The reduction in COD and TSS removal efficiency at higher HRT may be attributed to higher up-flow velocity of the wastewater and the consequent reduction in contact time between organics in the wastewater and microbes. Results obtained in the present study demonstrate that the HUASB reactor achieved the COD removal efficiency of 80% at an OLR of 0.348 kg COD/m^3.hr at HRT of 8 hr and reduction in HRT less than 8 hr showed marked decreased in removal efficiency. The HUASB reactor achieved the TSS removal efficiency of 85% at an OLR of 0.348 kg COD/m^3.hr at HRT of 8 hrs. HUASB reactor took 120 days for complete start-up.

REFERENCES

APHA, 1998. Standard Methods for Examination of Water and Wastewater. 20th edition, American Public Health Association, Washington DC.

Coates, J. and Colleran, E. 1990. Effect of initial agitation on the start-up and operational performance of anaerobic hybrid reactors treating a synthetic feed. Process Biochem., 10: 162-171.

Collivignarelli, C., Urbini, G., Farneti, A., Basseti, A., and Barbaresi, V. 1990. Anaerobic treatment of municipal wastewater with full scale up-flow anaerobic sludge blanket and attached biofilm reactors. Wat. Sci. Tech., 22(1): 475-482.

Fukuzumi, T. 1980. Microbial decolourization and defoaming of pulping waste liquors. In: Lignin Biodegradation: Microbiology, Chemistry and Potential Applications. Kirt T.K, Chang, H.M. & Higuchi, T. (eds.). CRC Press, Boca, Raton, FI, USA, 161.

Gatze Lettinga, Van Velsen, A.F.M., Hobma, S.W., De Zeeuw, W. and Klapwijk, A. 1980. Use of Up-flow sludge blanket reactor concept for biological wastewater treatment especially for anaerobic treatment. Biotechnology and Bioengineering, 22: 699-734.

Guiot, S.R. and Van den Berg, L. 1984. Dynamic performance of an anaerobic reactor combining an up-flow sludge blanket and a filter for the treatment of sugar waste. Proceedings of the 39th Annual Purdue Industrial Waste Conference, Lafayette, 705-717.

Guiot, S.R. and Van den Berg, L. 1985. Performance of an up-flow anaerobic reactor combining a sludge blanket and a filter treating sugar waste. Biotechnology and Bioengineering, 27: 800-806.

Pathe, P., Nandy, T. and Kaul, S.N. 1990. Up-flow anaerobic sludge blanket reactor for wastewater treatment - An introduction. Indian J. Environmental Protection, 10(7): 493-501.

Shivayogimath, C.B. and Ramanujan, T.K. 1999. Treatment of distillery spent wash by hybrid UASB reactor. Bioprocess Engineering, 21: 255-259.

Shivayogimath, C.B. 2003. Organic shock loading studies of hybrid UASB reactors treating distillery spent wash. J. of Industrial Pollution Control, 19(1): 82-83.

Stronach, S.M., Rudd, T. and Lester, J.N. 1986. Anaerobic digestion process in the industrial wastewater treatment. Springer-Verlag, Berlin, Germany.

Tilche, 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.

Wheatly, A. 1991. Anaerobic Digestion: A Waste Treatment Technology. Elsevier Science Publishers Ltd.