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Anaerobic Treatment of Pulp and Paper Mill Wastewater Using Hybrid Upflow Anaerobic Sludge Blanket Reactor (HUASBR)

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Abstract: The Pulp and Paper industry is one of India's oldest and core Industrial sector which produces large amount of pollutant loads, discharged into environment. These effluents cause considerable environmental impact since it contains biodegradable organic material and compounds toxic to living organisms. It will become a threat to living organisms if the effluent is not treated before discharge. The present study is about the treatment of Pulp and Paper mill wastewater using Hybrid Up flow Anaerobic Sludge Blanket (HUASB) Reactor. The main objective of this study is to assess the stability of Hybrid Up flow Anaerobic Sludge Blanket (HUASB) Reactor for various parameters like pH, Total suspended solids and COD removal. Here, a specific packing media of Polypropylene polyhedral spherical balls were used in the reactor. The typical physiochemical and biological characteristics of hardwood/Bagasse wastewater were studied. The characteristics of seed sludge were also analysed. The maximum effluent COD removal efficiency of 87% achieved when the reactor was operated at an OLR of 0.71KgCOD/m^3d. Finally, the biofilm growth on Polypropylene polyhedral spherical balls was also measured.

Keywords: Chemical oxygen demand; Hybrid Up flow Anaerobic Sludge Blanket Reactor;Organic loading rate; Pulp and Paper mill Wastewater.

I. INTRODUCTION

The paper industry is one of the largest industries in India, consuming large amount of water, [10]. Indian paper mills take a wide variety of cellulosic and non-cellulosic raw materials. The pulp and paper mill in India utilizes different cellulosic materials about 43% wood forest based, 28% agro based and 29% waste paper based on the total installed capacity [1]. These effluents are strongly coloured owing to the presence of lignin, resin, tannin and chlorophenolic compounds that are resistant to biodegradation. However, very few information are available on the applicability of treating real pulp and paper mill waste water by anaerobic digestion (especially model/pilot/full-scale HUASBR). Anaerobic digestion is used in treatment of wastewater obtained from olive mill [7], dairy [8], slaughter house [6] and dye bath effluents [3]. But in case of Pulp and paper mill waste water, it is not used as widely as the activated sludge process [9]. Hence, pulp and paper mill waste water needs detailed study. The Up flow anaerobic sludge blanket (UASB) reactor introduced by [4] has become a popular high-rate anaerobic treatment system throughout the world [5]. In the journal article [11], the Hybrid up flow anaerobic sludge blanket (HUASB) reactor is a new concept which is the hybridized version of an UASB reactor with a random packing media at the top of the reactor. In which upper portion of 50-70% is filled with either floating (or) stationary materials to retain some of the escaping biomass. This HUASB reactor combines the merits of UASB (Suspended growth system) and fixed film reactors (Attached growth system). This type of reactor is of particular value in a situation when the rate of sludge granulation is slow and there is a need to accelerate the reactor start-up [2]. In recent years, HUASB reactor has proved to be a more versatile anaerobic treatment in treatment of industrial wastewater. Therefore an attempt was made to measure the treatability performance of HUASB reactor using pulp and paper mill wastewater.

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II. LITERATURE REVIEW

As per [8] a high water usage between 20,000 and 60,000 gallons per ton of the product and results in about the same large amount of wastewater generation. According to [7], the load of chlorinated phenols and acids in the wastewaters of hardwood Kraft mill was three to eight times lower than it was in softwood Kraft mill. The effluents from the industry cause slime growth, thermal impacts, scum formation, colour problems, and deterioration of aesthetic beauty of the environment [9]. [10] reported about the health impacts like diarrhea, vomiting, headache, nausea, and eye irritation on children and workers due to the pulp and paper mill wastewater discharged to the environment. The effluents from the industry cause slime growth, thermal impacts, scum formation, colour problems, and deterioration of aesthetic beauty of the environment [9].

III. METHODOLOGY

A. *Reactor Design*

A laboratory-scale HUASB reactor made of all-glass cylindrical columns with an overall capacity of 7.85 litres (inside diameter 10 cm and overall height 90 cm) and effective volume of 6.51 litres was fabricated for this study. (Fig. 1) shows 2-D representation of the reactor designed for conducting the study. The reactor consists of 50 cm depth liquid portion at the bottom, 25 cm packing depth provided above the liquid zone, and top 10 cm for gas collection. Hoods are provided at top and bottom of the reactor for gas venting and probable sludge accumulation, respectively; along with three different sampling ports at appropriate locations. Good quality PVC tubing was provided for the influent flow and gas collection. (Table 1) shows the design features and dimensions of the HUASB reactor used in the study. (Fig. 2) shows the polypropylene polyhedral spherical balls (heat and corrosion resistant) were used to pack the reactor. The typical specifications and characteristics of these packed media are shown in (Table 2).

TABLE 1
Design features of Model HUASB reactor

Sl. No.	Feature	Specification
1	Reactor type	All-glass and cylindrical
2	Internal diameter	100 mm
3	Overall height	1050 mm
4	Overall capacity	7.85 L (7850 mm^3)
5	Working volume (including packing depth)	6.5 L (6500 mm^3)
6	Maximum packing media depth	250 mm
7	Number of sample ports	3

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TABLE 2
Specifications of Polypropylene Polyhedral Spherical Balls

Sl. No.	Specification	Value
1	Colour	White
2	Diameter	30 mm
3	Height	30 mm
4	Weight	8.86 g/piece
5	Specific gravity	0.92
6	Total specific surface area	356 m^2/m^3

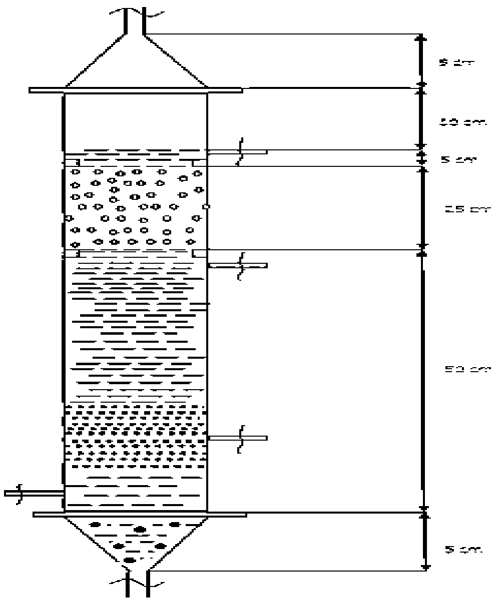

Fig. 1 Laboratory scale HUASBP reactor

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Fig. 2 Photograph of the polypropylene polyhedral spherical balls (Packing media)

B. *Seed sludge and Start-up of HUASBP reactor*

The reactor performance was undertaken at a very low influent flow-rate, such as 0.3, 0.4, 0.5, 0.7, and 0.9 ml/min, so as to arrive at the respective HRTs of 16.2, 12.15, 9.72, 6.94, and 5.4 d, based on the effluent COD value of 11,312 mg/l and on overall reactor volume of 7L. However, the OLR was varied between 0.71 kgCOD/m^3/d for 16.2 d HRT and 0.23 kgCOD/m^3/d for 5.4 d HRT. At each HRT the reactor was run until steady-state condition is attained with respect to COD removals. Further, at end of each day, about 100 ml of sample volumes were collected from the different ports, and analysed for COD, TSS, and pH. However, the influent COD was also analysed on daily basis.

C. *Assessment of Pollution Potential of Bagasse/Hardwood Plant*

The physicochemical characteristics of the raw wastewater originating from the hardwood/bagasse unit are shown in (Table 3). A typical COD/BOD ratio of 2.2 was noticed for the wastewater, on the basis of respective total values. Although the COD/BOD ratios vary between 3.5 and 8, for various Indian-based pulp and paper mill industries, the typical COD/BOD ratio for a particular wastewater originating from each unit may be less than the reported values. Hence, the COD/BOD ratio of 2.2 for this wastewater signifies the suitability of biological treatment. Further, since the average COD value, during the sampling period was about 11,312 mg/l, anaerobic treatment was adopted.

TABLE 3
Characteristics of Inoculums

Si. No.	Parameters	Value
1	Colour	Green
2	Odour	Odourless
3	Total solids	43.440 mg/L
4	Total Dissolved solids	2.580 mg/L

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5	Total volatile solids	36.160 mg/L
6	Total dissolved volatile solids	2.440 mg/L
7	Total fixed solids	7.280 mg/L
8	Total dissolved fixed solids	0.140 mg/L
9	Total suspended solids	40.860 mg/L
10	Settleable solids	Nil
11	pH	6.89
12	Acidity	60 mg/L as $CaCo_3$
13	Alkalinity	4480 mg/L as $CaCo_3$
14	Volatile Fatty acids	14,057 mg/L as $CaCo_3$
15	Total COD	10,944 mg/L as $CaCo_3$
16	Dissolved COD	2128 mg/L
17	Total BOD_5 @ 20^oC	5646 mg/L
18	Dissolved BOD	1520 mg/L
19	COD/BOD ratio	1.93 (Total)
20	COD/BOD ratio	1.4 (dissolved)

IV. RESULT

A. *Performance of reactor after start-up*

It is appeared that the variations in pH at all the ports were almost gradual and the respective pH values ranges between 4.51 and 5.74; 4.6 and 5.79; and 4.91 and 6.32, at ports 1, 2, and 3. (Fig. 3) shows the variations of pH in HUASB reactor, at different ports throughout the study. It is evident that the respective maximum deviations of pH values measured at ports 1 and 3 were 2.02, 0.81, 0.35, 0.66, and 0.8 for the phases 1 to 5. (Fig. 4) show the performances of the HUASB reactor, based on COD removals (combined and separate variations), for all HRTs. From (Fig. 4) it is seen that the removal of COD was drastic (about 87%) during Phase 1of operation having the HRT and OLR of 16.2 d and 0.71 COD/m^3d. In Phase 1 operation, the COD removals were slightly higher at ports 2 and 3 when compared to that at port 1; and, the variations of COD removals at ports 1 and 3 varied between 5 to 15%. Based on these variations in

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COD removals and considering the dense cluster data of Phase 1(in between 1st and 28th d), a fair linear variation between the two parameters can be expected to obtain the average rate of COD removal; and this was around 2.85% removal of COD per d of operating time of the reactor. In the last phase of the reactor operation, overall maximum removal of COD was around 97% could be seen. (Fig. 5) shows respective combined variations in TSS, at all the ports. As expected and unlike the pH variations and COD removals at various ports, the trends in the concentrations of TSS decreases from port 1 to port 3, under all HRTs . For phase 1 of reactor operation, the TSS removals were drastic between 5,132 and 2,660 mg/l. It can be observed that the respective maximum deviations of TSS measured at ports 1 and 3, are 2520, 504, 124, 588, and 32 mg/l for the phases 1-5.

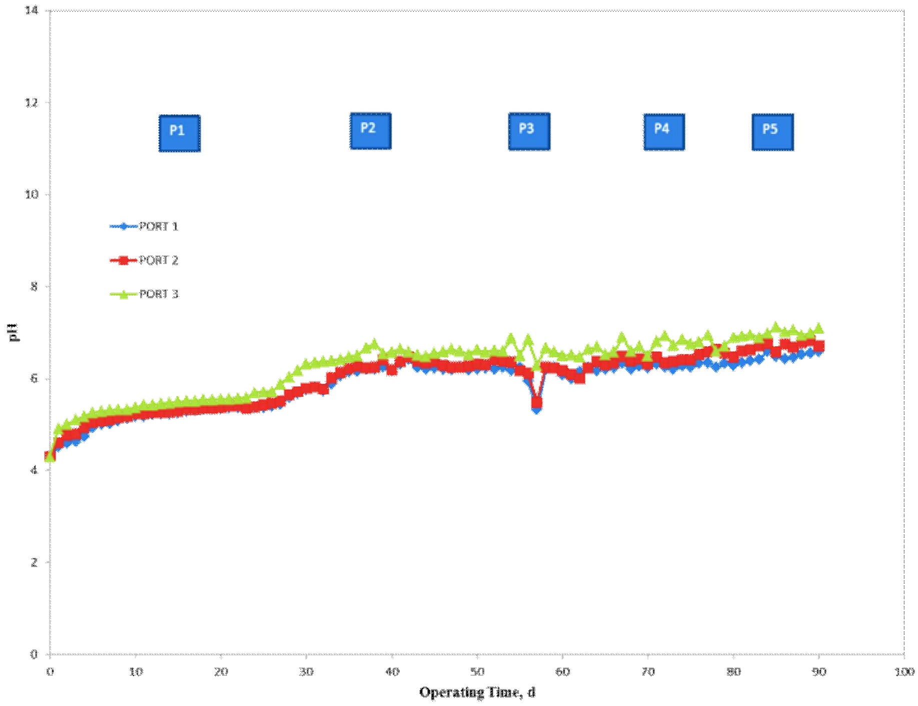

Fig. 3 Performance curves of HUASBP reactor for variations in pH

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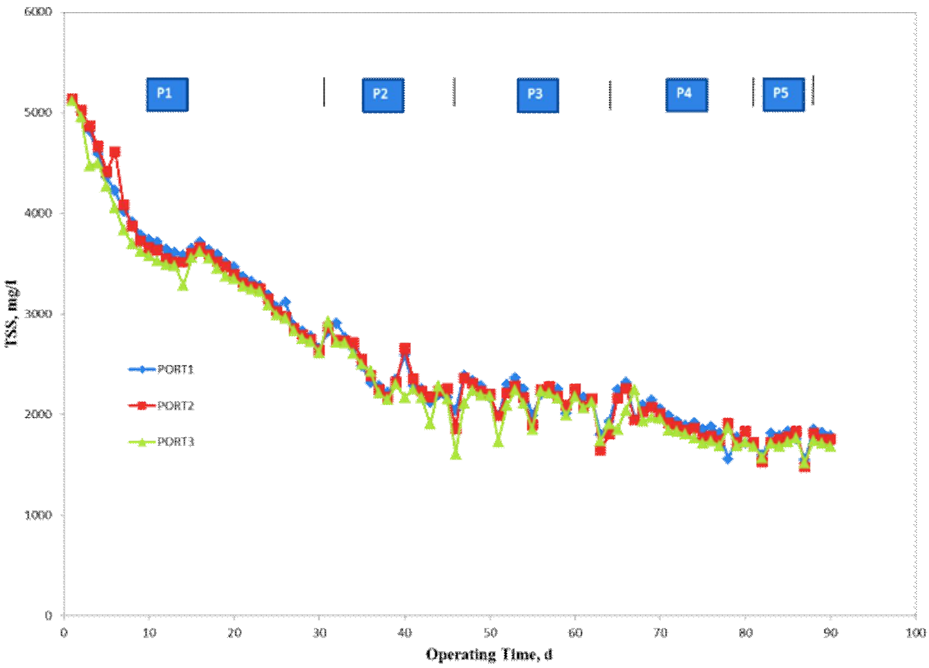

Fig. 4 Performance curves of HUASBP reactor for variations in COD removals

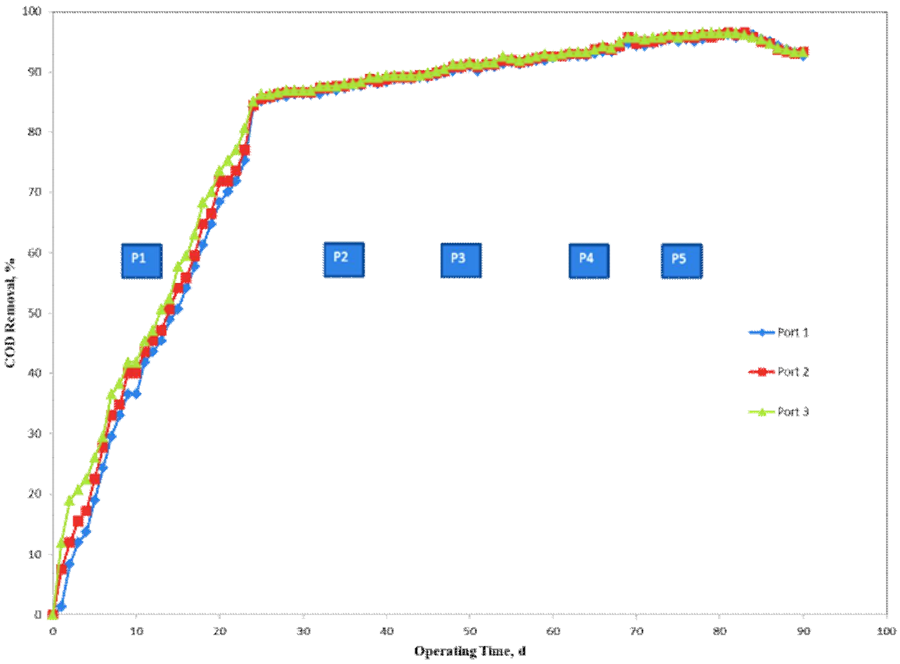

Fig. 5 Performance curves of HUASBP reactor for variations in TSS

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B. *Biomass Accumulation within the Reactor*

At the end of phase 5 of operation of HUASB reactor, an attempt was made to assess the biomass (both volatile and non-volatile matter) accumulated within the reactor. From the investigation, the total sludge (including sludge blanket) accumulated at the bottom was about 700 ml/l and the approximate sludge blanket thickness was about 5 cm. Moreover, the biomass accumulation on the polypropylene polyhedral spherical balls (about 32 numbers) was also quantified. From this, about 1 to 3 mm thick biofilm accumulation was observed on each ball of the packing material. Also, about 2.5 g of dry biomass was noticed on each piece of packing material.

V. CONCLUSION

The HUASB reactor and polypropylene polyhedral spherical balls are suitable in treating pulp and paper mill effluent. At higher HRTs, maximum COD removal will be obtained. A fair correlation is expected between COD removals and variations in pH within the reactor. Slightly or insignificant variations in the performance parameters can be expected at different significant levels in the reactor. The sludge blanket thickness is significant (about 5 cm) without hindering the process operation. The biomass attachment and accumulation is predominant over the surface of the polypropylene polyhedral spherical balls.

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