Chapter 16
Acclimation and Treatability Studies on Slaugter House Wastewater by Hybrid UASB Reactor

R. Loganath and Debabrata Mazumder

Abstract The slaughterhouse wastewater (SWW) is highly influenced by carbonaceous and nitrogenous organic matter aside from significant quantity of dissolved inorganics. There are different streams of SWW, composite of which is exceptionally perfect for secondary biological treatment. The amount of biodegradable organic substances present in the slaughterhouse stream recommends that the anaerobic treatment process could be actualized as the best decision. In this study, the biological treatment of SWW was observed using the Hybrid Upflow Anaerobic Sludge Blanket Reactor (HUASBR) at a laboratory scale setup under continuous mode operation. In this study the reactor was subjected to various Chemical Oxygen Demand (COD) loading rates in the range of (2.95–37.98) Kg COD/m^3/d under the Hydraulic Retention Times (HRT) between 24 and 6 h. The outcome of the HUASB Reactor shows that maximum COD removal efficiency of 94% can be achieved at the OLR of 18.29 kg COD/m^3/d under 10 h HRT.

16.1 Introduction

In most populated countries like India there are various kinds of industries to fulfil their everyday purposes and therefore the industrial development is also increasing every ever. As a cost of non-renewable fuels most of the large-scale commercialised industries are moving towards the anaerobic digestion as an alternative of the industrial wastewater treatment as well as for generating good renewable sources from the organic matter present in the wastewater (Eder et al. 2018; Pedroza et al. 2017; Schroyen et al. 2017; Tsapekos et al. 2017; Yasar et al. 2017). The high pollutant concentrations in the wastewater is a threat to the environmental impacts on the water bodies and it's difficult to treat in the municipal sewers. Stringent discharge standard and public awareness regarding environmental impacts on water bodies, now-a-days compel industries to treat their effluent onsite for reuse or treatment

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before its discharge to the sewers (Loganath and Mazumder 2020a, b; Loganath and Mazumder 2018a, b, c; Pradhan et al. 2017; Schaider et al. 2017; Waclawek et al. 2017). Out of available technologies of wastewater treatment, anaerobic digestion is observed to be viable for reducing the high organic loading on the receiving water bodies and sewers (Un et al. 2009; Loganath and Mazumder 2020a, b; Rajeshwari et al. 2000; Ravinadranath et al. 2010; van Lier et al. 2008; Zhang et al. 2014).

The economic impact of anaerobic wastewater processing results from the production of biogas, which contains about 50–75% methane. Capture of this gas would provide an additional source of energy in the day-to-day life, where the gap between supply and demand is wide (Antwi et al. 2017; Bazrafshan et al. 2012; Bustillo-Lecompte and Mehevar 2017; Flugaur 2003, Loganath and Mazumder 2018b, c, a). The usage of methane in vehicles and public transport systems could be encouraged due to the economy of lubricating oils, longer engine life, considerable reduction in emission of pollutants. Production and application of renewable energy, reduction of wastes, and utilization of by-products as fertilizers from anaerobic digestion has increased the attractive application of anaerobic digestion (Pedroza et al. 2017; Loganath and Mazumder 2018a, b, c; Lenz et al. 2009; El-Mashad and Zhang 2010; Verstraete 1983).

The two important concerns for SWW treatment are removal of organic matter and suspended solids. Application of high-rate anaerobic digestion like Upflow Anaerobic Sludge Blanket (UASB) has become popular for treatment of SWW over last few decades (US-EPA 2002, 2004; Johns 1995). Further modification of UASB in form of hybrid UASB is also under operation worldwide for high strength wastewater.

In last 20 years, significant research investigation has been made on HUASB reactor dealing with diverse kinds of domestic and Industrial wastewater towards removal of BOD/COD and nutrients. Since later 1990s HUASB reactor has been extensively used for up-gradation of the existing treatment plants to improve their efficiency in terms of BOD/COD and nutrients from domestic and industrial wastewater (Torkian et al. 2003; Speece 1996; Rajakumar and Meenambal 2008). In recent times HUASB reactor has also been extensively used for treatment of variety of industrial wastewater including food processing, pulp and paper, tannery, pharmaceutical, oily and petrochemical, slaughterhouse, distillery wastewaters etc. (Rajakumar et al. 2011; Rajakumar et al. 2012; Loganath and Mazumcer 2018). Although a lot of information regarding laboratory and pilot scale HUASB reactor operation is available, there is a very few literatures on HUASB reactor treating Industrial wastewater especially SWW without any special attention to explore the effects of various operating parameters on the same. Along these lines, aim of this present study is set to evaluate the performance efficiency of the HUASB Reactor with respect to the COD removal efficiency and suspended solids from SWW.

16.2 Materials and Methods

16.2.1 Fabrication of Reactor Setup

"A lab scale Hybrid Up-flow Anaerobic Sludge Blanket (HUASB) reactor" of 13.5 L liquid volume was fabricated for performance evaluation. It was fabricated utilizing acrylic fiber tube with diameter of 15 cm, height of 60 cm and thickness of 5 mm. An outlet was given at the highest point of the bio-film media, which was associated with the effluent tank. On the highest point of the reactor a three-phase separator was provided to isolate gas and solid raised because of the upward movement of the feed. The gas outlet was associated through elastic tubing to the liquid displacement system to measure the gas generation. The measure of gas produced is equivalent to the measure of liquid displaced and consequently gas produced was estimated at certain interval of time. A bio-film media of height 15 cm made of Polypropylene reticulated rings was given. Around 50 biofilms were filled inside the reactor in staggered way to facilitate microbial development and gas–liquid-solid separation. The individual surface area of each ring was 7.1 cm^{-1} and the aggregate surface region possessed by the packing was 6700 m^2/m^3. The reactors were worked at the temperature of 37 ± 2 °C. A schematic representation of HUASB reactor is appeared in Fig. 16.1.

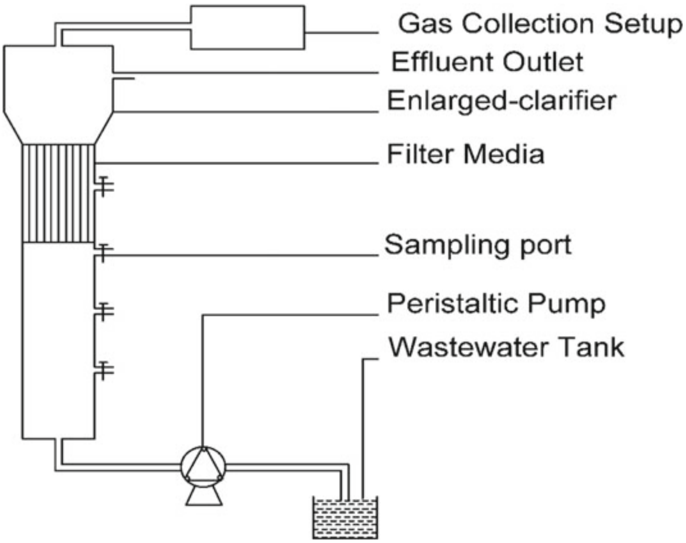

Fig. 16.1 HUASB reactor used in this study

16.2.2 Start-Up of HUASB Reactor

The HUASBR was initially filled with the anaerobic biomass from a conventional biogas plant during start-up. This AD sludge was obtained from the biogas plant located at Narandrapur, Kolkata. This plant was a traditional single stage AD plant, where generates methane from dairy animal manure slurry. AD biomass was withdrawn from the base of the sludge outlet tank. The collected sludge characteristics showed pH 6.9, Total COD 2200 mg/L & TSS 33,087 mg/L.

The reactor was fed with slowly increasing amount of SWW during acclimation phase. The SWW was collected monthly twice in the amount of 20 L/time and stored in 4 °C. Table 16.1 representing characteristics of the SWW used in this study.

The HUASB reactor was firstly fed under batch mode with a uniform retention period of 3 days over 240 days for the sake of acclimation so that it could withstand with maximum COD load of the real raw SWW. During this stage a constant temperature of (37 ± 2) °C was sustained by means of temperature controller. The first phase of HUASB reactor operation SWW was loaded with COD of 1730 mg/L and final COD concentration was increased up to 5900 mg/L with the stepwise increment.

Table 16.1 Characteristics of SWW used in this study

S. No	Measured parameters	Observed value**
1	pH	7.39
2	Alkalinity	239
3	Total COD	8426
4	Soluble COD	6294
5	Total solids	16,262
6	Total dissolved solids	8980
7	Total suspended solids	7281
8	Total fixed solids	2767
9	Total volatile solids	13,495
10	BOD	5730
11	Nitrogen	72
12	TKN	426
13	Phosphate	25
14	Conductivity	9.47
15	Salinity	2.84

Note All the values in mg/L except pH, salinity (psu), conductivity (ms/cm) and Alkalinity (mg/L as $CaCO_3$)
** Average of Six Samples

16.2.3 Analytical Procedures

All the mentioned parameters used in Table 16.1 were measured according to the Standard Methods (APHA 2005).

16.2.4 Experimental Procedure

After the batch study was over, HUASB Reactor was operated under continuous mode after the biomass was acclimated. It was run using raw SWW with variable COD concentration as well as hydraulic retention time (HRT). Thus, the organic loading rate (OLR) was increased gradually by decreasing HRT to evaluate the COD removal efficiency of the reactor. Hence, the reactor was loaded with OLR in the range of (3.13–38.11) kg COD/m^3/d on account of variation in HRT from 24 to 6 h during the continuous study.

16.3 Results and Discussion

16.3.1 Start-Up of HUASB Reactor

During start-up cum acclimation, the performance of the HUASB reactor was monitored by measuring pH, Alkalinity, initial and final COD, MLSS growth and VFA formation. Both the carbonaceous synthetic wastewater and the raw SWW were used for this purpose. During this period, a mixed solution was fed to the reactor, where the SWW was varied in the ratio of 1/20, i.e. the feed consisted of 50 ml of the SWW and 950 ml of the synthetic wastewater to make a total volume of 1000 ml. Accordingly, the amount of SWW was increased @ 50 ml in total feed volume of 1000 ml for each batch acclimation run. Under batch mode the reactor was operated over 8 months with 3 days batch retention time. The feed ratio to the reactor under batch mode operation is shown in Fig. 16.2.

The inflow SWW pH was adjusted between 6.9 and 7.2 throughout the acclimation study. Hence, the COD concentration was varied between (1730–6390) mg/L. While acclimation period after the treatment COD was observed between 950 to 720 mg/L with respect to this the COD removal efficiency was 45–88%. These observations show that the seed sludge acclimation was accomplished with the presence of raw SWW. The detailed results are shown in Fig. 16.3 and 16.4.

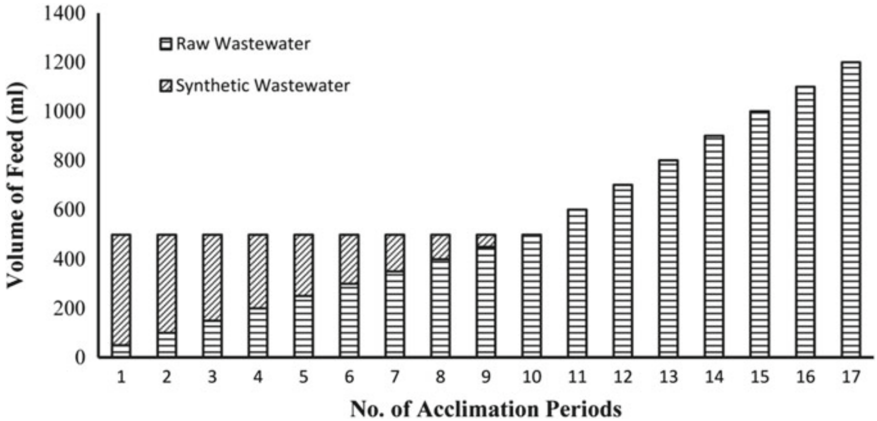

Fig. 16.2 Proposition of raw SWW and synthetic wastewater during acclimation process

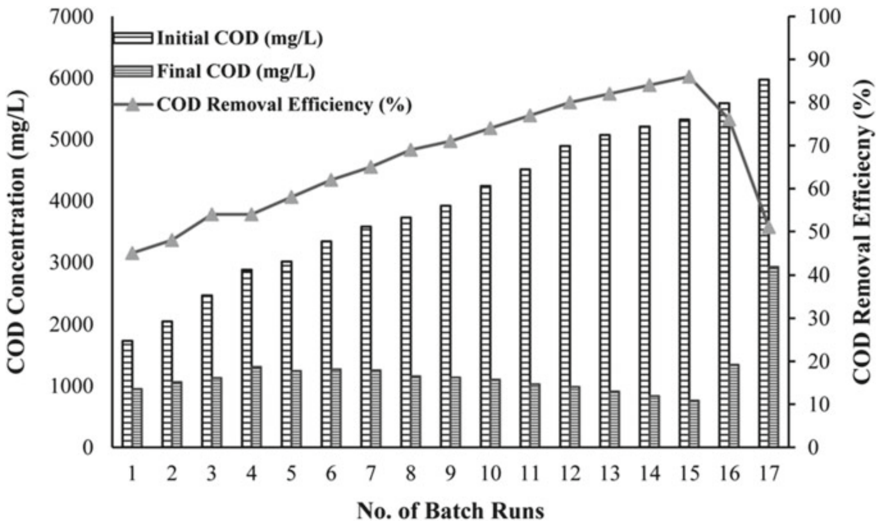

Fig. 16.3 Profile of COD removal in HUASB Reactor during acclimation

16.3.2 COD Removal Efficiency Under Continuous Mode Operation

The continuous mode of operation with the HUASB Reactor was performed with the varying OLR with respect to the HRT. The raw SWW was diluted and fed to the reactor to overcome the shock loading to the HUASB Reactor. The steady state condition of each OLR and HRT was confirmed with the three consecutive repetitive results. After every successful steady state condition, OLR was further risen with

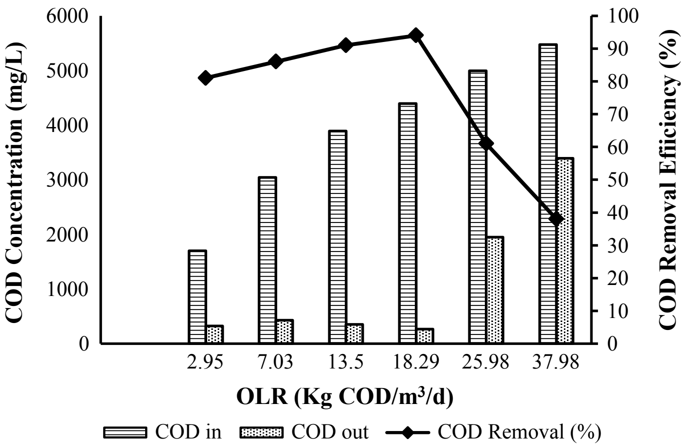

Fig. 16.4 COD removal Performance of HUASB Reactor treating Raw SWW

decreasing HRT and the reactor was monitored. In the first steady state condition OLR to the reactor was 2.95 kg COD/m^3/d with respect to the 24 h HRT. During final stage of reactor operation, the OLR to the reactor was 37.98 kg COD/m^3/d under 6 h HRT.

The maximum COD removal efficiency was observed to be about 94.8%, for the influent COD concentration of about 4390 mg/L at 10 h HRT. The optimum OLR was noted as 18.29 kg COD/m^3/d in the present HUASB Reactor under continuous mode of operation, which exhibited more than 94% COD removal efficiency. From the earlier studies, it is already proved that HUASB Reactor can handle the maximum OLR of 9.27–13.27 kg COD/m^3/d at 10 h HRT (Rajakumar et al. 2011). In this present study due to the proper acclimation of sludge with the raw SWW the maximum COD efficacy of 94% was achieved at the OLR of 18.29 kg COD/m^3/d. Therefore, compared to other studies the OLR could be increased to around 30% due to the well acclimated sludge and the addition of more surface area of attached growth media in the present treatment process.

16.4 Conclusions

The SWW contains a high amount of organic matter, representing a good source of organic carbon. HUASB reactor used in the study was satisfactorily acclimated under SWW using the anaerobic digested sludge. During acclimation phase, COD removal efficiency reached to as high as 88% even in presence of raw SWW entirely. It also performed very well towards removal of COD from SWW under continuous mode of operation. The maximum COD removal efficiency was attained up to 94%, under the influent COD concentration of about 4390 mg/L and HRT of 10 h. The optimum OLR of 18.29 kg COD/m^3/d was provided to the HUASB reactor, which showed more than 94% COD removal efficiency. Hence, the present HUASB reactor can be recommended for COD removal from high-strength wastewater generated from slaughterhouse operation.

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