Authority of Organic Loading Rate and Hydraulic Retention Time on the Efficiency of a HUASB Bioreactor Treating Vegetable plus Fruit Waste

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Abstract - The efficacy of the Hybrid Up flow Anaerobic Sludge Blanket reactor in treating fruit waste has been discussed in this study. HUASB reactor is a combination of a UASB unit at the lower part and an anaerobic fixed film at the upper end. The reactor with a total volume of 10 L and plastic cut rings as packing media was operated at varying Hydraulic Retention Time (HRT) for a period of 110 days. The seeding of the reactor was done with effective micro-organisms. The loading rates on the reactor were increased in steps for three different Hydraulic Retention Time to assess the maximum loading capacity of the reactor and to study the performance of the reactor at different loading rates and HRT. For increase in loading rates each and every time for various HRT, very short duration of 3 to 5 days, was required for achieving the steady state at elevated loading up to about 33.72 kg COD/m^3.d. The time required to achieve steady state due to increase in loading by increasing COD concentration was lesser than a week under all loading rates. The COD concentrations mainly used for these laboratory experiments were between 1050 mg/l and 8430 mg/l and performance of the reactor up to 92 % of COD removal efficiency was evaluated. The sludge age required to get good COD reduction (around 92%) was observed to be more than 30days i.e. Startup period-exactly 30 days. After 30 days of startup, the reactor produced appreciable decrease in COD of wastewater and removed solids efficiently. Maximum COD removal efficiency of 92.97 % was achieved for HRT 6 hrs. The ideal OLR for the reactor in producing biogas was 24.20 kg COD/m^3.d and for COD removal efficiency it was 20.84 kg COD/m^3.d. Biogas production of 720 ml/d was observed at the time of operational period. Henceforth, HUASB reactor with effective microorganisms as the seed was observed to perform well in treating fruit waste and helped in quick startup time for the reactor. The findings of the study open up newer possibilities of design low cost and compact onsite treatment systems with very short retention periods. HUASB reactor appears to be a promising alternative for the treatment of fruit waste in developing countries like India. Further reported studies on starch-based waste stream (like cassava, tapioca) using HUASB reactor are rather rare [Govindaradjane, 2006].

Keywords : Hybrid Up flow Anaerobic Sludge Blanket, HRT, Micro-organisms, COD and Organic Loading Rate.

I. INTRODUCTION

The previous two decades had shown much progress and great achievements within alternative energy and environment protection. Wind mills, solar collectors, solar cells, biogas - there were great expectations to these areas. Experiences were being gathered. Biogas, in that respect, was lagging behind. The number of biogas plants could by no means stand up to the number of windmills and solar collectors created. But nothing ventured, nothing gained. 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. Aerobic and anaerobic treatment systems are the major alternatives in biological treatment methods.

II. MATERIAL AND METHODS

HYBRID UPFLOW ANAEROBIC SLUDGE BLANKET (HUASB) REACTOR:

Up flow Anaerobic Sludge Blanket (UASB) reactor is one such anaerobic system that treats effluents having high organic content. Hybrid UASB (HUASB) is an improvisation over the conventional UASB that can be used for a wide variety of effluents. 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.

III. TREATMENT PHASE

In the operation phase the reactor was operated in continuous mode. Operation of the HUASB reactor was divided into three periods. During phase1, the reactor was fed with various organic loading rates for hydraulic retention time of 24h. During phase 2 hydraulic retention time of 16h was maintained and 6h of hydraulic retention time was maintained during phase 3 for various organic loading rates. The change in organic loading rate and hydraulic retention time was done each and every time when the steady state occurs at each time.

PHASE 1

Phase1 operation started on 21st September 2016 and ended on 27th December 2016. Initially the reactor was fed with organic loading rate of 1.05 kg COD/m^3.d and increased up to 8.43 kg COD/m^3.d for hydraulic retention time of 24h. Flow rate maintained in the reactor and inlet COD fed to the reactor is given in table 7.

S.No	Flow Rate (L/d)	Inlet COD (mg/L)	OLR (kg COD/m^3.d)
1.	10	1050	1.05
2.	10	2160	2.61
3.	10	3005	3.00
4.	10	4360	4.36
5.	10	5210	5.21
6.	10	6050	6.05
7.	10	7200	7.20
8.	10	8430	8.43

Table.1. Operational Conditions Maintained in the HUASB Reactor during Phase 1 of the Treatment Phase for HRT 24 H

PHASE 2

Phase 1 of the reactor attains the steady state condition on 27th December 2016. Phase 2 commenced on 27th December onwards with an organic loading rate of 1.50 kg COD/m^3.d for hydraulic retention time of 16h. The reactor attains the steady state on Feb 6 for 16h HRT.

The reactor was fed with eight different organic loading rates and the change in organic loading rate occurs when the reactor attains the steady state condition. Table 8 shows the inlet COD fed to the reactor and the loading rates of the reactor.

S. No	Flow Rate (L/d)	Inlet COD (mg/L)	OLR (kg COD/m^3.d)
1.	15.15	1050	1.50
2.	15.15	2160	3.27
3.	15.15	3005	4.5
4.	15.15	4360	6.60
5.	15.15	5210	7.89

6.	15.15	6050	9.16
7.	15.15	7200	10.90
8.	15.15	8430	12.77

Table.2. Operational Conditions Maintained in the HUASB Reactor during Phase 2 of the Treatment Phase for HRT 16 hours

PHASE 3

The reactor was operated for 110 days and attains steady state at this day. Phase 3 started on 6th Feb 2017 and the steady state was observed on the 30th day. The reactor was fed with various organic loading rates for hydraulic retention time of 6h.4.2 kg COD/m^3.d of OLR was initially given to the reactor. Operational conditions maintained in the HUASB reactor during this period are given in table 9.

S. No	Flow Rate (L/d)	Inlet COD (mg/L)	OLR (kg COD/m^3.d)
1.	40	1050	4.2
2.	40	2160	8.64
3.	40	3005	12.02
4.	40	4360	17.44
5.	40	5210	20.84
6.	40	6050	24.2
7.	40	7200	28.8
8.	40	8430	33.72

Table.3. Operational Conditions maintained in the HUASB reactor during Phase 3 of the Treatment Phase for HRT 6 h

IV. RESULTS AND DISCUSSION

The treatability studies of the fruit waste was conducted by HUASB reactor by providing various organic loading rates of

i) 1.05, 2.16, 3.00, 4.36, 5.21, 6.05, 7.20, 8.43

ii) 1.50,3.27,4.5,6.60,7.89,9.16,10.90,12.77

iii) 4.2,8.64,12.02,17.44,20.84,24.2,28.8,33.72

in terms of COD with varying Hydraulic Retention Time of 24hrs, 16hrs, 6hrs.

pH

The pH is a very important variable in the HUASB process. When the pH in the reactor is too low (<6.0), the consumption of fatty acids gets strongly inhibited. If the pH is too high (>8.0), the bacteria are limited in their growth by the low concentrations of unionized fatty acids. The pH determines the growth of both methano-gens and acido-gens. So, the pH of the effluent in the inlet and outlet during the granulation and after granulation was maintained between 6.3 and 7.9. On the 5th day the inlet and outlet pH were 6.11 and 6.30, while it was 6.81 and 7.11; 7.12 and 7.30; 7.54 and 7.8 on the 30th, 60th and 110th day. Moreover, the pH was maintained from 7.1 to 7.8 which favored the growth of long filamentous bacteria and increased the reactor efficiency by forming granular biomass. Sodium bicarbonate was added to maintain digester pH for the proper regulation of the reactor. Maximum pH was deserved (7.8) on the 110th day. The increase in pH of the outlet was due to conversion of stronger acids, i.e., volatile fatty acids to a weaker carbonic acid. The analysis of the effluent coming out of the HUASB reactor showed the ph was within the safe limits in this experiment. Failure of the digester due to VFA accumulation can be controlled by maintaining the pH. Table 10 shows pH of the fruit waste during the granulation period of the reactor. Effluent pH of the HUASB reactor at various organic loading rates for different HRTs is shown in table 1, 2, 3.

OUTLET	DAY	INLET
6.30	5	6.11
7.22	10	7.16
7.30	15	7.05
7.42	20	7.13
7.46	25	7.24

7.11	30	6.81
7.29	35	7.03
7.25	40	7.18
7.23	45	7.17
7.51	50	7.09
7.54	55	7.14
7.54	60	7.30
7.35	65	7.18
7.19	70	7.15
7.47	75	7.12
7.55	80	7.14
7.32	85	7.19
7.40	90	7.16
7.90	95	7.76
7.66	100	7.14
7.30	105	7.10
7.45	110	7.60

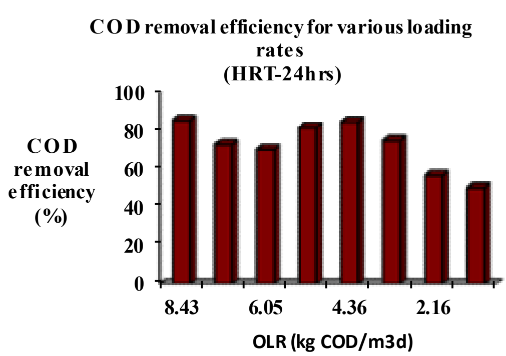
Table.4. P^H of the Fruit Waste during the Granulation Period of the HUASB Reactor

COD REMOVAL EFFICIENCY

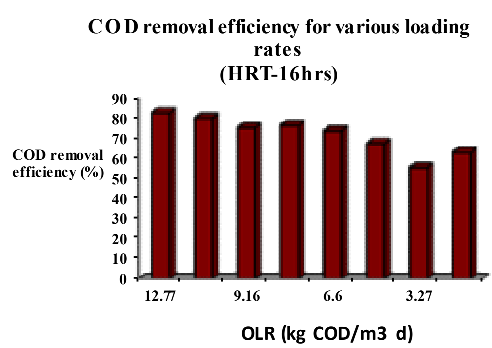
The COD removal efficiency depends mainly on Organic Loading Rate and Hydraulic Retention Time. During the startup period the reactor was fed with a very low inlet COD of 150 mg/L and poor removal efficiency (30%) was observed. This may be mainly due to the slow microbial growth in the reactor. Under low loading rates the COD removal efficiency was not up to the expected level mainly because of the insufficient mixing provided by the biogas generated. The COD removal efficiency of 60 % was reached on the 25th day. The removal efficiency increased in a wise manner throughout the treatment period due to the action of the effective microorganisms along with the anaerobic microbes' rate. This initial period was mentioned as "stabilization period" or "acclimatization period". This period is considered as more essential for the better development of compact biogranules.

The formation of concentrated biomass after the start-up period can withstand high organic loading. So, after the startup process the reactor was fed with various organic loading rates for varying HRT. The COD removal efficiency for varying organic loading rate and hydraulic retention time is given below:

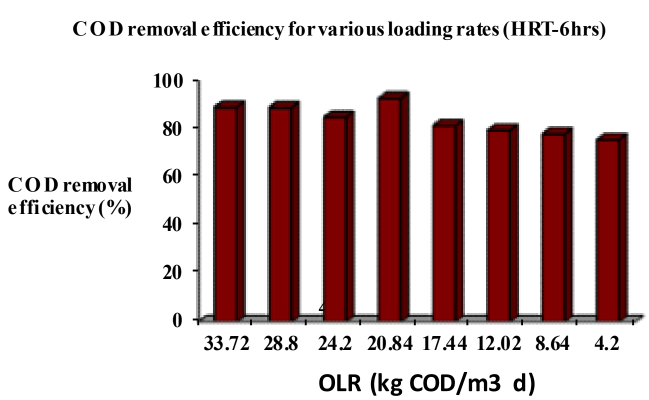
FLOWCHART .1



FLOWCHART .2

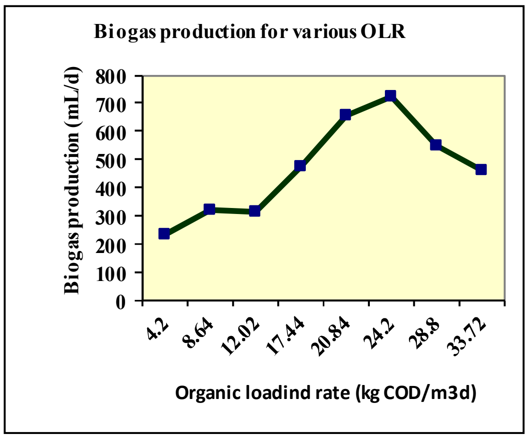


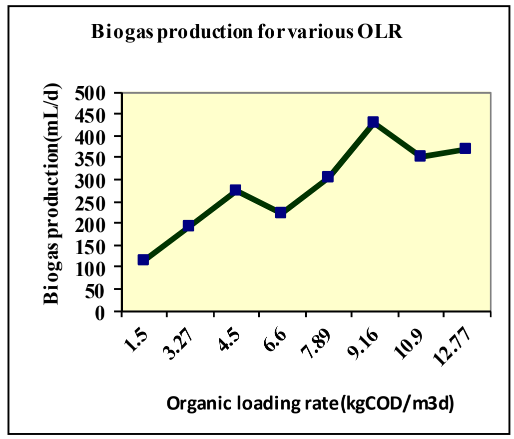
FLOWCHART .3

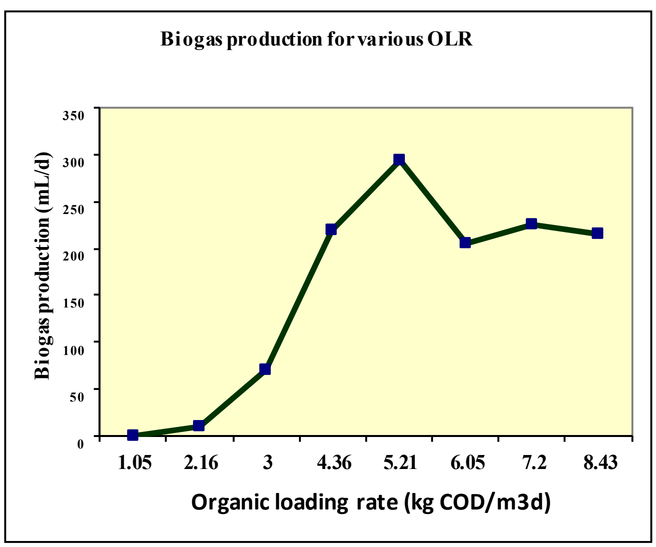


BIOGAS PRODUCTION

After the 30 days of the startup period, the biogas was produced by the granules and it was recorded every time when the organic loading rate gets changed. The biogas production rate was observed as significant in various COD loading rates during this study. The biogas generation was generally increased with an increase in organic loading rate. This was because of the maximum substrate utilization by the organisms in the reactor. The sharp reduction in biogas production at organic loading rate of 33.72 kg COD/m^3.d was mainly because of the Sulphate reduction and in addition to that some quantity of gas escaped along with the effluent. The gas production rate reached steady state at a hydraulic retention time of 6h after the 110th day the quality of gas recovered was considerable and it may be utilized as valuable fuel. Maximum gas production of 720 ml/d was achieved at a hydraulic retention time of 6 h for organic loading rate of 24.2 kg COD/m^3.d. Table 17, 18, 19 represents the biogas production for varying OLR and HRT. Graphical representation of biogas productions is shown in graph1, 2, and 3.







V. CONCLUSION

The results obtained from the present laboratory investigation reveals that the application of Hybrid Up flow Anaerobic Sludge Blanket Reactor for the treatment of fruit waste had proved to be a cost effective method. From the performance evaluation of HUASB reactor the following conclusions were drawn:

- A start up period of 30 days was required to acclimatize the anaerobic bacteria with 1050 mg/l of inlet COD at HRT of 24 hours.
- Once the HUASB reactor is properly started with good quality of sludge granules, the reactor can effectively handle organic loading rate up to 33.72 kg COD/ m^3.d.
- For increase in loading due to change in influent COD, shorter time is required to achieve steady state at the new loading.
- COD removal efficiency and the rate of removal of Total Solids increased with an increase in Organic Loading Rate.
- Maximum COD removal efficiency of 92.97 % was achieved at an Organic Loading Rate of 20.84 kg COD/m^3.d for HRT 6 hours.
- Biogas production of 720 ml/d was observed at an OLR of 24.2 kg COD/m^3.d for HRT 6 hours.

Thus the present study infers that the packing media (plastic rings) present in the HUASB reactor was able to retain high biomass concentration without any serious sludge wash out even at higher organic loading rates. HUASB reactor was successfully used to study the biodegradation of fruit waste up to ratio (1050:8430 mg/L) and the results shows that it is important to consider the fruit waste to avoid toxic effects. Moreover, Gas-Liquid-Solid separator device need not be specially designed for HUASB reactor because the packing media itself acts as a GLS separator in HUASB hence proving the reactor to be an economically feasible one (an extremely simple and inexpensive design). Short duration of 30 days was only required for the startup period because of the use of Effective microorganisms as a seed. From the foregoing, it is evident that the HUASB system can be effectively used for treatment of fruit waste in developing countries like India, since the system can be designed with relatively short HRT. Further, the biogas generated during the process adds attraction as it can be used as a fuel.

VI. SCOPE OF THE FUTURE STUDY

- The study can be performed by choosing varying parameters like BOD, chlorides, nitrogen.
- Study on the morphology and the characteristics of the sludge blanket and a microbial population can be done using Scanning Electron Microscope (SEM).
- Hydrogen as a quick indicator of organic shock loading in HUASB reactor can be investigated.
- Two stage anaerobic treatment of vegetable waste using Hybrid Up flow Anaerobic Sludge Blanket reactor can be studied.

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