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Treatment Of Sugar Industry Wastewater By Upflow Anaerobic Sludge Blanket Reactor

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Abstract: Rapid urbanization and industrialization in the developing countries like India are facing severe problems in collection, treatment and disposal of effluents. Unmanaged organic waste fractions from industries, municipalitiesand agricultural sector decompose in the environment resulting in large scale contaminationof land, water and air. This is leading to serious public health problems and environmental degradation.Unfortunately, due to the lack of knowledge, financial support and sometimes unwillingness to spend on treatment of wastewater, most of sugar industries in developing countries discharge their wastewater withoutadequate treatment. This not only creates problem but also wastes the water resource.

For treating the biodegradable impurities, the natural choice is biological treatment,which could either be aerobic or anaerobic. But anaerobic digestion is an attractive waste treatment practice in which both pollution control and energy recovery can be achieved. Many industrial wastes are ideal candidates for anaerobic digestion[3,4,11,14]. In the recent years energy considerations and environmental concerns have increased the popularity of anaerobic process.

Sugar industry wastewater was treated in a UASB reactor seeded with non-granular mixed septic tank sludge. The study was carried out at ambient (26-39^{o}C) conditions, in a laboratory scale reactor of effective volume of 8.4 ltrs. The reactor was operated in two phases. In the I phase, OLR was gradually increased from 1g COD/l.d to 6 g COD/l.d and HRT was reduced from 48 to 12 hrs respectively. The granule formation was observed on the 42nd day. When HRT was reduced to 12 hrs, the granules disintegrated. In the II phase (from 61st day) restabilisation process was restarted with an increased HRT of 24 hrs and decreased OLR of 2g COD/l.d. Further a gradual increase of OLR to 4.67 g COD/l.d and reduction in HRT to18 hrs was done. Granules were once again seen within a very short period of 14 days. The COD removal efficiency obtained ranged from 80 to 96 %. The COD removal rate linearly increased with increase in OLR.The ratio of VFA to alkalinity was varied between 0.14 to 0.3 during the treatment. Maximum volumetric biogas production was 13.72 L/ d. at OLR of 6 g COD/L. d. Themethane content in the biogas was found to be 71% at steady state conditions. A successful start-up with non-granular mixed septic tank sludge was achieved within 100 days of operation.
Keywords: UASB reactor, sugar industry wastewater, non-granularsludge, ambienttemperature, OLR,HRT.

Introduction

India is the second largest country manufacturing sugar from cane in the world. There are 488 in operation sugar mills in the country with a production of 145.39 lakh tonnes of sugar [(12)]. Sugar industry plays an important role in India's economy. It is the largest processing industry next to textiles. Located in rural areas, sugar mills have an intrinsic symbiotic relationship with the rural masses and serve as a nerve center for rural development.

It is one of the major commercial crops grown here in Karnataka and is one of the major sources of revenue for majority of the farmers. The production of sugar involves enormous amounts of water and energy. The main energy source is the combustion, usually bagasse and other low quality fossil fuels with high sulphur content are used. In sugar production, the water used for processes such as cane washing, clarification of juice, cleaning of evaporators, heaters and purging boilers, cooling systems and sanitary services are discarded.

Sugar cane industry generates 0.2-1.8 m^3/tonne waste water with COD 1800 to 3200 mg/L, BOD 720 – 1500 mg/L [(11)]. Sugar wastewaters if disposed off into the water bodies untreated, can contaminate surface and subsurface waters. The BOD/COD causes rapid depletion of oxygen content of the waters, creates foul smell, renders the stream unfit for propagating aquatic life, drinking and for other purposes .

Rapid industrialization has tremendously increased the volume of wastewater to be disposed off, while the capacity of receiving water to accept the increasing inorganic and organic loads remains the same. This has resulted in a rapid deterioration of quality of surface water and at the same time stimulated concerned government agencies to introduce and enforce more stringent legislation. Forced by the legislation, industries are looking for the low cost solutions for the required reduction of pollution load.

At present conventional methods are being used to treat the wastewater of sugarcane industry which require more space and power and there is no considerable recovery of energy. Identification of technologies for the gainful utilization of sugar wastewater will convert this waste into a valuable byproduct. This will improve the profitability and health of the sugar industry and also ensure quick disposal of potential pollutants. According to analysts selling price of the sugar falling below the cost of its production for most of the industries during the recent years, hence most of the industries have now diversified into byproduct utilization for their financial betterment[15]. At this stage investment in costly conventional treatment methods are not feasible.

The effluent from a sugarcane factory has a very low buffering capacity and the alkali requirement is high leading to high operational cost. Anaerobic treatment is the answer for it. India, being a tropical country and this high temperature favor the growth of methanogens leading to mesophilic digestion. A technology is acceptable to an industry if it requires less capital, less land area and is more reliable when compared to the other well established options. Befitting this requirement, anaerobic digestion system translates into the process, being able to run at high organic and hydraulic loading rates with minimum operational and maintenance requirements. To choose the most appropriate reactor type for a particular application, the amount of active biomass retained by a reactor per unit volume, contact opportunity between the retained biomass and the incoming wastewater and diffusion of substrate within the biomass are necessary[4,11]. In all these considerations, UASB reactor stands out distinctively as the best choice.

In the present study Up flow Anaerobic Sludge Blanket (UASB) reactor is used in treating sugar waste water with varying HRT and varying feed concentrations at ambient conditions.

Materials And Methods[6]

A laboratory scale UASB reactor using 5mm thick acrylic pipe, with an effective volume of 8.4 L, 100 mm external diameter and overall height of 1360 mm was fabricated. The reactor was provided with an inlet at the bottom and an outlet at the top as the gas outlet and another at a distance of 40 mm from the top of the reactor as the outlet for the treated wastewater or effluent, at the same level a gas liquid solid (GLS) separator was provided[(2)]. Baffle arrangement was also made to guide the gas bubbles into the separator to capture the evolved gas and to allow the settling of suspended solids. 5 sampling ports were provided at a distance of 220 mm c/c all along the reactor. Bottom sampling port was at a distance of 215 mm from the base. The effluent tube was provided with the water seal to avoid the escape of gas through the effluent.Brass checkvalve of ¼ inch size was fixed at the bottom of the reactor to facilitate the sludge withdrawal. To maintain the desired up flow velocity of the feed, Miclins peristaltic pump of model PP20 was used. The gas outlet was connected to a wet gas flow meter through rubber tubing. The lid of the bioreactor and other fittings were sealed to maintain strict anaerobic conditions inside the reactor. The reactor was supported by mild steel framed structure and the whole apparatus was covered with cardboard and plastic sheets so as to avoid the effect of sunlight and formation of fungus.The photograph and schematic representation of the experiment setup is shown below in figure-1.

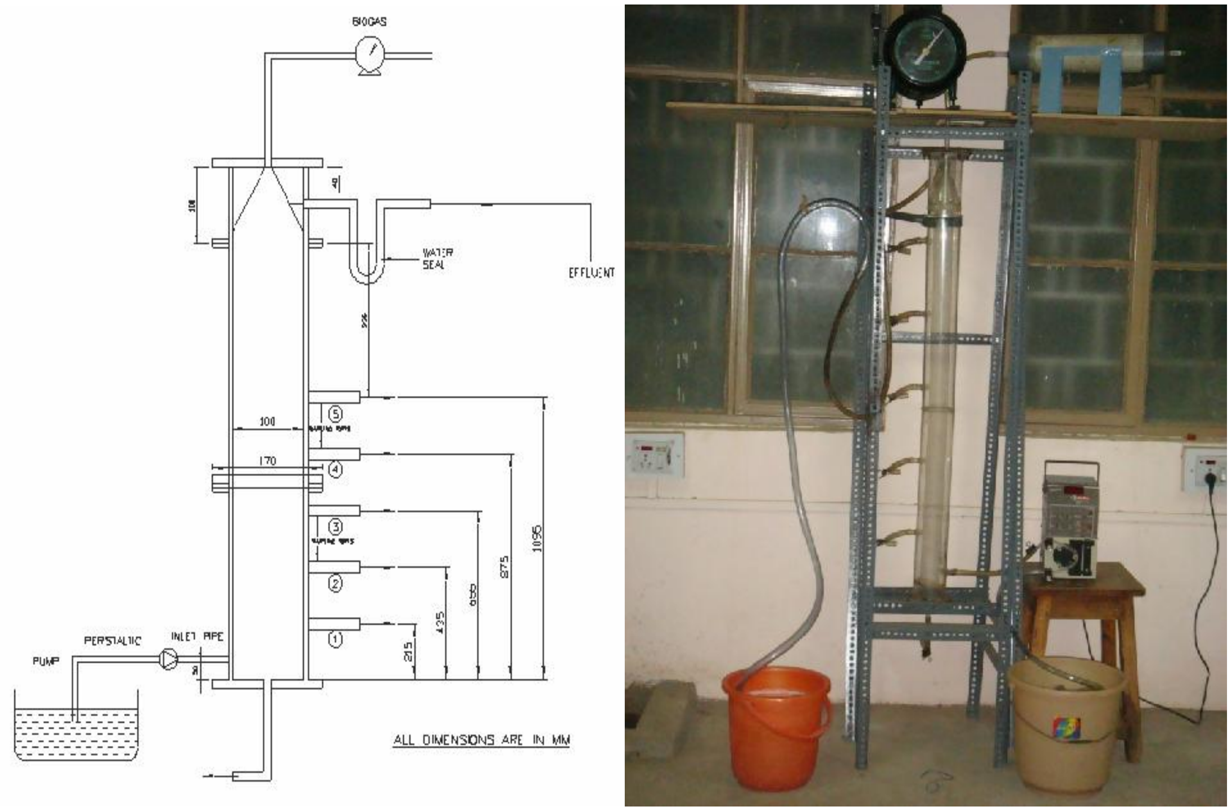

Figure-1: Experimental Setup

A non- granular mixed septic tank sludge[8] whose efficiency was checked with the help of a batch reactor was used. The sludge was sieved to separate the coarser impurities and debris and was used as inoculums for the reactor.

Synthetic sugar wastewater was used as the substrate. The composition of the substrate is given as below in Table-1.

Table-1:Composition of the substrate used in the study[5]

Component	Concentration (g/L) for COD = 2000 mg/L
Sucrose	2
$(NH_4)_2 SO_4$	0.1
K_2HPO_4	0.052
KH_2PO_4	0.04
$(NH_4)HCO_3$	0.4
$NaHCO_3$	3.2
$KHCO_3$	3.2
Yeast extract	0.02

The various chemicals used in the UASB reactor operation and analyses of parameters were bifurcated as micro and macro nutrients. The solutions of macro and micro nutrients added to the reactor [10] are given below in Table-2.

Table-2: Composition of macro and micro nutrients[10]

Reagents	Concentration (gL^{-1})	
1.Macronutrients		
NH_4Cl	10.0	Solution I
K_2HPO_4	2.0	
2.Micronutrients		
H_3BO_3	0.05	Solution II
$FeCl_2.\ 2H_2O$	2.00	
$ZnCl_2$	0.05	
$MnSO_4$	0.5	
$CuCl_2.\ 2H_2O$	0.03	
$(NH_4)_6\ Mo_7\ O_{24}.\ 4H_2O$	0.05	
$AlCl_3.\ 6H_2O$	0.05	
$CoCl_2.\ 6H_2O$	2.00	
$MnCl_2$	0.25	
$MgCl_2$	1.00	
EDTA	0.05	
$NiCl_2.\ 6H_2O$	0.25	
HCl	1.00	

The samples were collected from the feed tank and from the outlet provided in the reactor and were analysed immediately after collection. The flow rate, pH of the influent and effluent;and quantity of the biogas generated were recorded daily. The parameters such as influentand effluent COD, VFA, and alkalinity and methane content of the biogas were measured twice a week. The COD concentrations in thefeed were determined every time the substrate was changed. Total solids (volatile and suspended) and BOD weremeasured at steadystateconditions. The performance parameters such as pH, VFA, solids,
alkalinity, COD & BOD were analysed as per the Standard methods (APHA/AWWA/WEF, 1992) and NEERI Manual (1998)[1,13].

Operations Carried Out During The Study

The synthetic waste water was prepared with an initial COD of 2000 mg/L. An HRT of 48 hrs was selected. This low HRT was selected in order to allow the sludge to acclimatize itself to the environment. COD removal efficiency was tested on the fifth day (from the day of reactor start) COD removal efficiency of 68.4 % was observed. On 9th day the reactor produced biogas of 0.96 L/day. Since then a gradual increment in the biogas is observed. The reactor was operated in two phases, in the first phase an initial loading with feed COD concentration of 2000 mg/L and HRT of 48 hrs(OLR of 1g.COD/L.d) was considered. The feed concentration and the HRT were gradually varied alternately upto a feed concentration of 3000 mg/L and an HRT of 12 hrs (OLR of 6g.COD/L.d), based upon the attainment of steady state condition. In the second phase a reduced feed concentration of 2000 mg/L and an increased HRT of 24hrs (OLR of 2.5 g.COD/L.d) were considered as the initial loading. Further similar to the first phase the feed concentration and HRT were gradually varied alternately upto a feed concentration of 3500 mg/L and an HRT of 18 hrs(OLR of 4.67g.COD/L.d). The first phase was of 60 days and the second phase was of 40 days. The state of loadings in the reactor can be depicted as below in Figure-2.

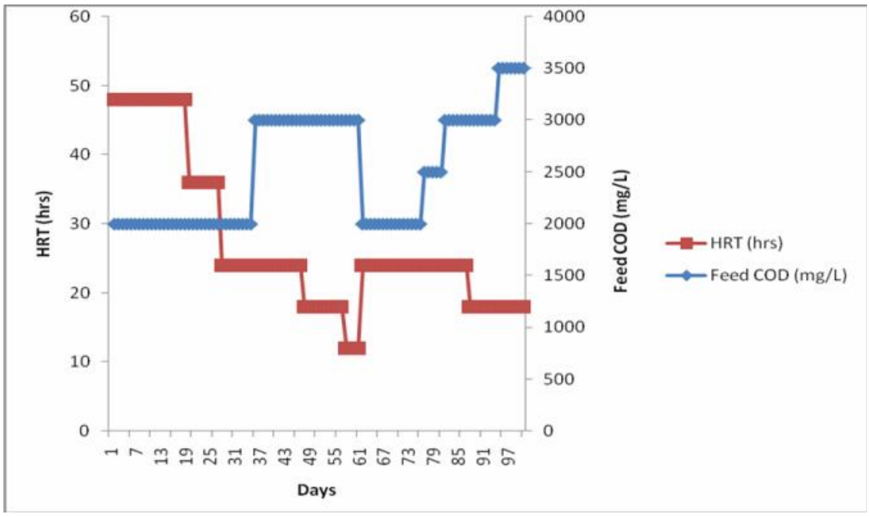

Figure-2: Stepwise increase in feed concentration and reduction of HRT

Results And Discussions

Granule Formation

The entire study can be bifurcated into 2 phases, Phase I (Day 1 to 60) and Phase II (Day 61 to 100). In I phase, organic loading rate varied from 1 to 6 g COD /L.d. On the 42nd day of the experiment granules of the size of 2 to3mm were seen extensively and few 5mm granules were also observed. On 59th day the granules formed disintegrated to less than 2mm. At the time ofdisintegration of the granules the reactor was being operated with OLR of 6 g COD/L.d. In order to stabilize the granule formation process, the experiment was continued in II phase with reduced feed concentration and HRT. The organic loading rate (OLR) varied from 2 to 4.67 gm COD / L.d. On 74th day again granules of size 2 to 3mm were seen. On 80th day the granules of size 2mm had increased and few more 3mm were observed. These were stable. On 100th day (last day), after attainment of steady state condition, the experiment was concluded OLR of 4.67 gm COD / L.d.

The granules obtained in both the phases are shown in Figure-3.

Figure-3: Closer View of the granules seen in II phase.

VFA and Alkalinity

VFA and alkalinity together are the good indicators for evaluating the process stability of the anaerobic reactor since total alkalinity reflect both levels of VFA and bicarbonate, and under unstable conditions increased VFA reduce bicarbonate resulting in constant total alkalinity [9]. As reported by Zhao and Viraraghavan (2004) [7],[8] if the ratio of VFA to alkalinity exceeds 0.8, the inhibition of methanogens occurs and process failure is apparent, increase above 0.3 to 0.4 indicate system instability and a proper ratio is between 0.1 to 0.2.The variations of VFA andalkalinity during the study period are shown in Figure 4.The ratio of VFA to alkalinity was varied between 0.14 to 0.3 during the treatment.

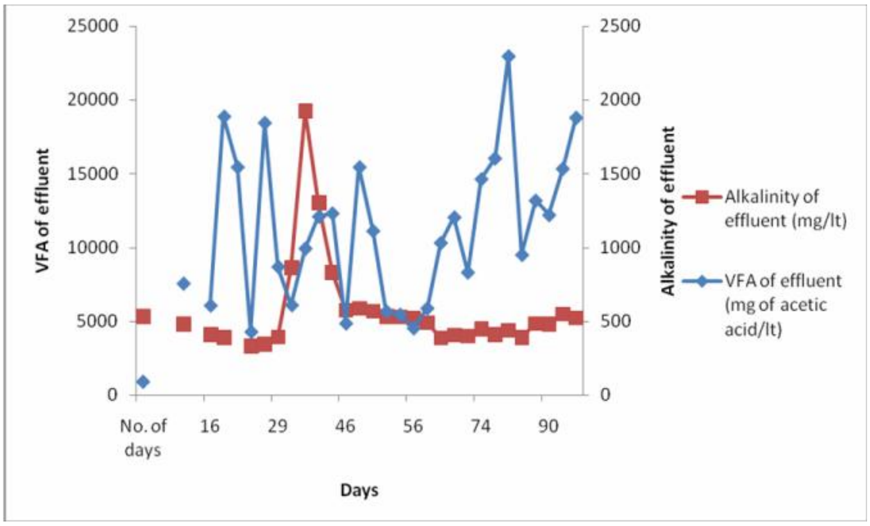

Figure-4: Variation of alkalinity and VFA in effluent samples.

Reactor performance

In the initial stage there was an average 95% removal efficiency. Further as the OLR was gradually increased, with the formation of granules the removal efficiency was observed between 93 % and 90%. But at 6 g COD/L.d, when the granules disintegrated removal efficiency reduced to 81 %.The second phase was again initiated with an OLR of 2 g COD/l.d. At this stage the removal efficiency observed was 93% and a very fast granule formation with sizes 2 to 3 mm was noted. Further OLR was increased from 4 to 4.67 g COD/l.d, the observed removal efficiency was 96% in both stages. Hence we can state in the initial condition the removal efficiency went The variation of COD removal efficiency with OLR during the experiment is shown in Figure-5.

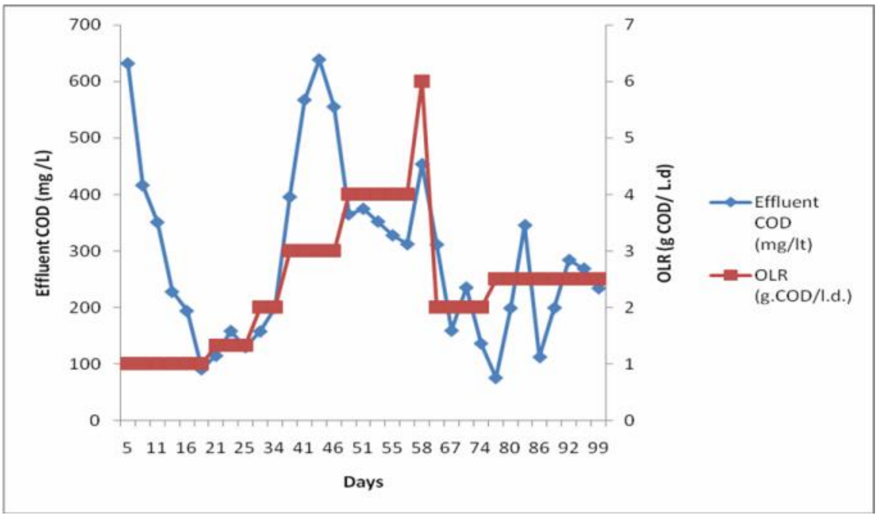

Figure-5: Variation of COD removal efficiency with OLR during the experiment

Biogas production

In the initial phase the biogas production was very low. As the time progressed granulation of biomass was seen and simultaneously there was increase in biogas production. After granule formation it reached a peak of 13.72 L/day. In the second phase the emission of total biogas increased to a peak of 4.46 L/day before granule formation and when the granules were observed it reached a peak of 15.51 L/day with 71 % methane at steady state condition. The temperature also favoured the production of biogas, a temperature range of 28-29^{o} C was the most favouring range. The variations are shown in Figure-6.1 & 6.2.

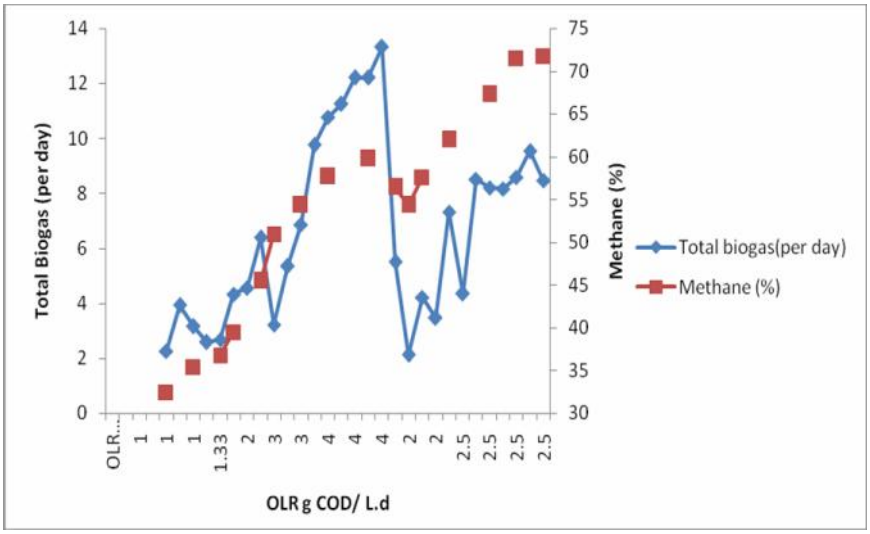

Figure-6.1: Variation of Total biogas with OLR

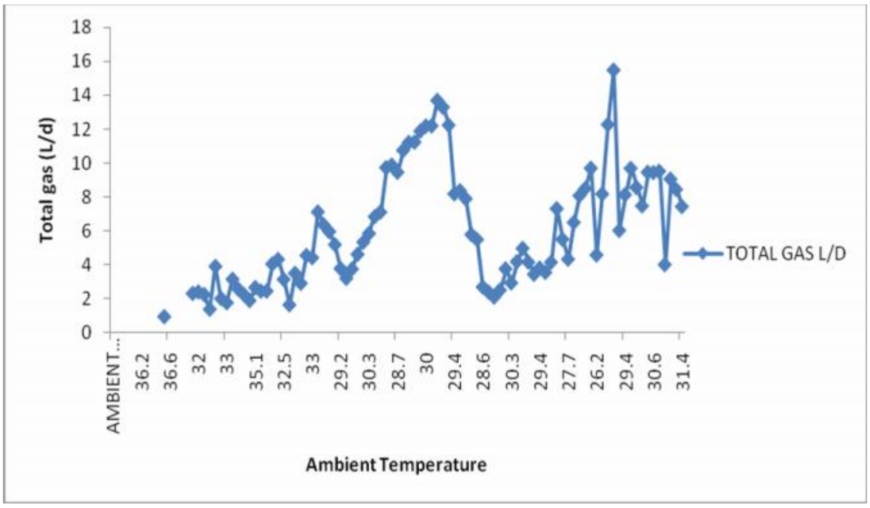

Figure-6.2: Variation of Total biogas with ambient temperature

Conclusion

Startup of an UASB can be achieved in a shorter period of 42 days with active non granular mixed septic tank sludge as a seed and suitable nutrient addition.UASB is feasible to treat sugar industry waste water efficientlywith a COD removal efficiency of 96%. Granule formation increased the biogas production and at an OLR of 4 g COD /L day, 15 L/d biogas was generated with 71 % methane content. A temperature range of 28-29^{o}C favored maximum gas production.

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