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START-UP REGIME OF TWO-PHASE UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR

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ABSTRACT

In the present study, an attempt has been made to start-up a bench scale two phase upflow anaerobic sludge blanket (UASB) reactor with sago wastewater as feed. The reactor was started with sago wastewater as feed with initial COD of 2200 mg/L. Entire process was carried out for 57 days with hydraulic retention time (HRT) of 24 h. Maximum COD removal at the start-up period in the reactor was 91.0 %. Volatile fatty acid (VFA) was under stable level for efficient operation of the reactors. The pH of feed was maintained in range of 6.2-6.8 for efficient survival of microorganisms. At maximum COD reduction the biogas production was high as 72 L/d.

INTRODUCTION

Rapid urbanisation and industrialization pose severe problems in collection, treatment and disposal of effluents in developing countries. Decreasing capacity of water bodies need for water conservation and growing public awareness of clean environment bring to fore the need for an appropriate cost effective and resource recovery based wastewater treatment system. With many options the anaerobic treatment process stands ahead because of minimum sludge formation and production of energy in the form of methane. Research on anaerobic digestion is going on for past several decades and the duration of digestion process has come down drastically with high rate anaerobic process. The size of these digesters is small and the loading rate has become high, because of the retention of active granules. Buzzini *et al*. 2006 has revealed that granular biomass with excellent settling properties can be cultivated from these reactors.

Among the high rate anaerobic process, the UASB process stands ahead for it wide ranging application for all types of wastes. The only draw back of process is the slow start-up in the absence of granular seed sludge. The start-up of UASB is the time required by the reactor to achieve equilibrium. Granulation and start-up are the important features in the operation of a UASBR. Soto *et al*. 1997 reported the influence of temperature on granulation during the start-up of the reactor. The delay in the start-up could be due to incorrect mixing within the reactor, the lack of formidable atmosphere for biomass survival. Schmdit

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et al. (1996) found that a granular sludge will gradually develop on heavier primary nuclei as result of attachment, entrapment of newly generated bacterial matter, in the later phase secondary growth nuclei will be formed by distributions of attached bacterial film or break up of larger bacterial aggregates. Lettinga *et al*. 1985 found that during initial stages of start up the heavier sludge granules formed due to bacteria should be made retained, whereas the dead cells , which are lighter are allowed to be washed out and these washed out sludge should not be returned back to avoid the depression of the retained sludge (Kennedy *et al*. 1982). Zeeude *et al*. (1984) observed that during the start-up of high strength wastewater, mechanical mixing has adverse effects. Due to fragile character of anaerobic sludge flocs as compared to denitrifying sludge a more intensive mechanical agitation becomes detrimental for sludge retention in the reactor. Thus discussed by Lettinga *et al*. (1985) a mild and homogenous mechanical mixing with 10-30rpm for a minute for every 10 minute suite the formation of granular sludge and this is been achieved by the gas bubbles produced during the start-up of the reactor. This study examines the feasibility of accelerated start-up in a bench scale hybrid Upflow anaerobic sludge blanket reactor. Shortening the start-up time bears practical significance as it can raise attractiveness of HUASB reactor application by saving time and money.

MATERIALS AND METHODS

Biomass

The methanogenic granular sludge with unknown microorganisms used in this study was procured from the anaerobic digester treating tapioca starch effluent of M/s Srimannarayana sago factory, Rasipuram, Tamilnadu, India. Before loading the reactor the granular sludge was clearly washed, filtered through fine mesh to avoid all the inorganic mineral contents. The volatile suspended solids content of the sludge was then estimated as 45000mg/L (APHA 2005).

The synthetic starch wastewater was prepared by dissolving tapioca starch powder procured from a starch and sago manufacturing unit. One gram of starch powder was dissolved in 1 L of water to give a COD concentration of about 2200 mg/L. The dissolved starch powder was pre-acidified before being fed into the reactors to avoid the settling of starch particles at the bottom of the influent container. Ammonium chloride and potassium dihydrogen orthophosphate were added along with magnesium chloride, calcium chloride and ferric chloride to adjust the C:N:P ratio to 100:5:1. This is a proprietary nutrient mixture available for biological treatment systems (McDougall 1994).

Experimental setup

A bench-scale two-phase up-flow anaerobic sludge blanket reactor system was used in this study (Figure 1). It consists of 4 L acidogenic and 15 L methanogenic up-flow reactors. The reactors were installed at different levels to maintain sufficient hydraulic flow, to achieve proper fluidisation and mixing of sludge granules inside the reactors. The Gas Liquid Solid Separator (GLSS) was installed at the top of the UASB reactor, which effectively separates the treated effluent, sludge granules and biogas. In addition to GLSS arrangement, PVC spirals (size 26 mm, surface area 500 m^2/m^3 and void ratio 87%) were also packed for a height of 20 cm (located in between the reactor height of 1.95 m level). The spiral will retain the biomass in addition will give a polishing effect to the effluent. The sludge granules trapped in the GLSS and spiral will return back to reactor as soon as the gas entrapped inside has been released. The biogas generated was measured by water displacement method. The pH of the influent was adjusted to 6.5-7.0 by the addition of sodium bicarbonate. A variable-speed peristaltic pump was used. The reactor was seeded with sludge obtained from a high-rate anaerobic digester from a starch waste treatment plant.

Analytical procedure

All analyses were carried out in accordance with Standard Methods (APHA, 2005). Gas production, COD, pH and VFA were carried out daily. Volatile Suspended Solids (VSS) was recorded weekly. COD was measured using the closed reflux method and gas production using a water displacement method.

RESULTS AND DISCUSSION

Concentration of pH

Figure 2 shows the inlet and outlet pH of the reactor during start-up. The inlet pH of the reactor was in the range of 6.2 to 6.8 which may be suitable for the growth of microorganisms. The outlet pH was consistently increasing with increase in the time of operation and found to be in the range of 7.6 to 8.1 during the start-up period of the reactor. This pH range was found to be within the optimal range (i.e.,

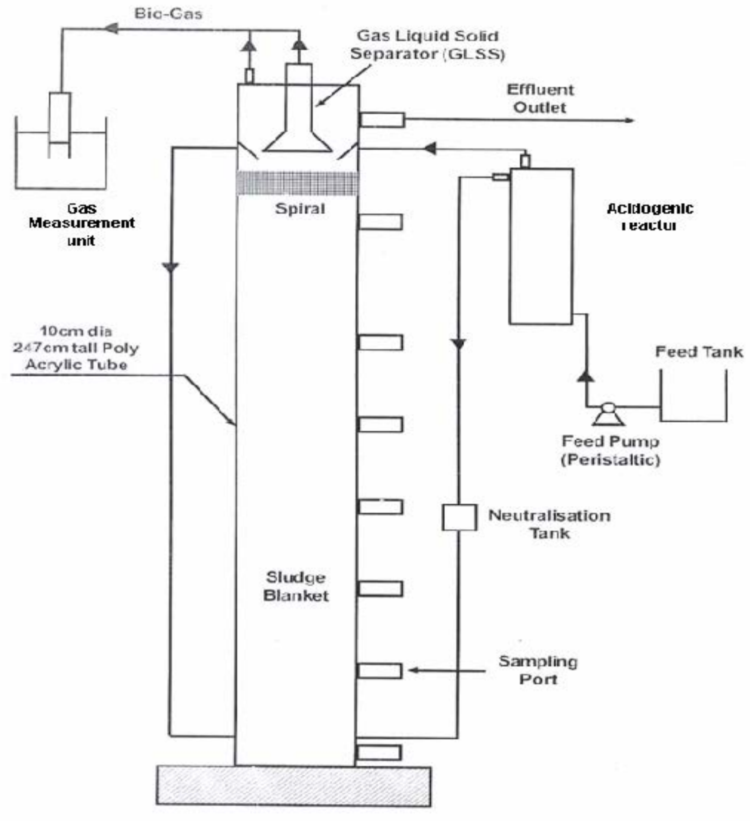

Fig. 1 Schematic representation of UASB reactor

6.6-7.6) for sustaining the acidogenic and methanogenic activity in the reactor (Bal *et al*. 2001).

The pH maintained inside the reactor may be due to the interaction of carbon dioxide- bicarbonate buffering and volatile acids-ammonia formed from the process (Bisselli *et al*. 1975). The above pH range is also indicative of a healthy environment in the reactor.

Removal of COD

The COD concentration of the feed (influent) and the effluent of the reactor vary from 2120-2280 mg/L and 200-2184 mg /L respectively. Figure 3 shows the COD removal efficiency during the start-up of the reactor. From the Figure 3 it is obvious that the reactor has steady start up from the day one onwards and gradually increased upto 53rd day and attained steady state from 54th day. Maximum COD removal during the start up period of the reactor was 91%.

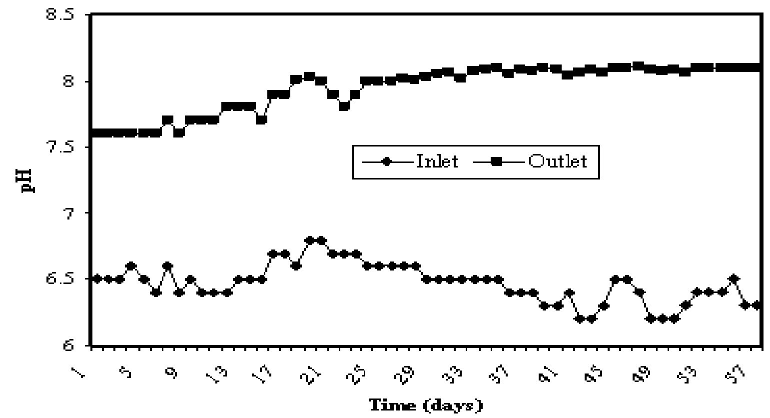

Fig. 2 Concentration of pH during start-up

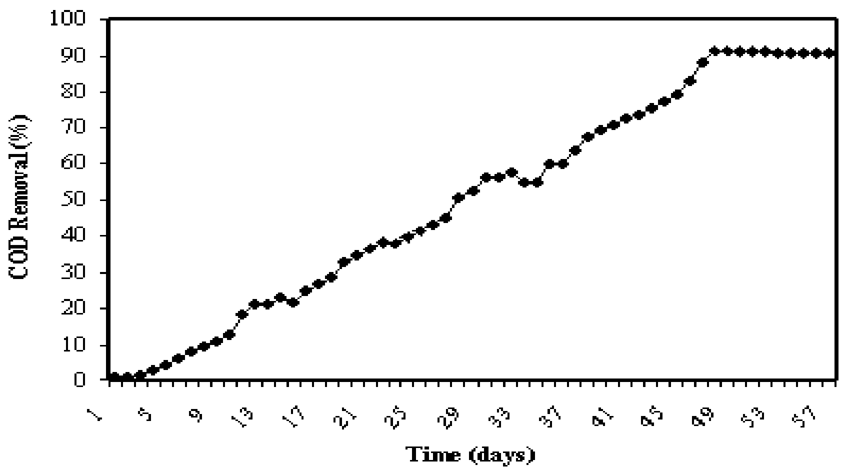

Fig. 3 Removal of COD during start-up

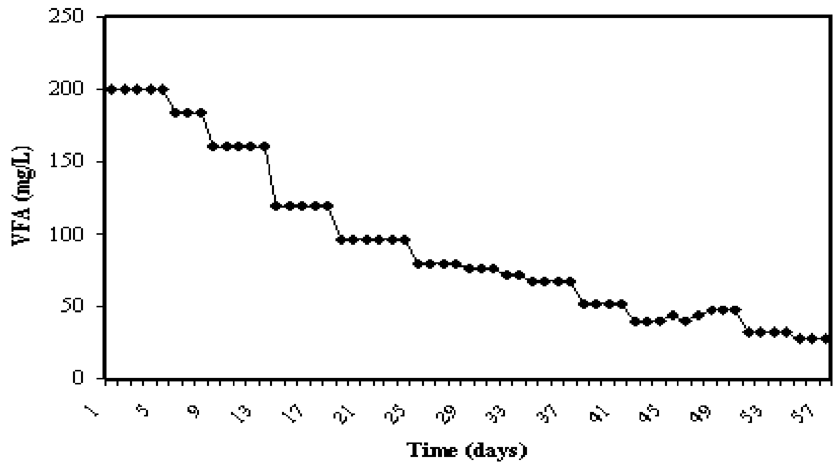

Fig. 4 Concentration of VFA during start-up

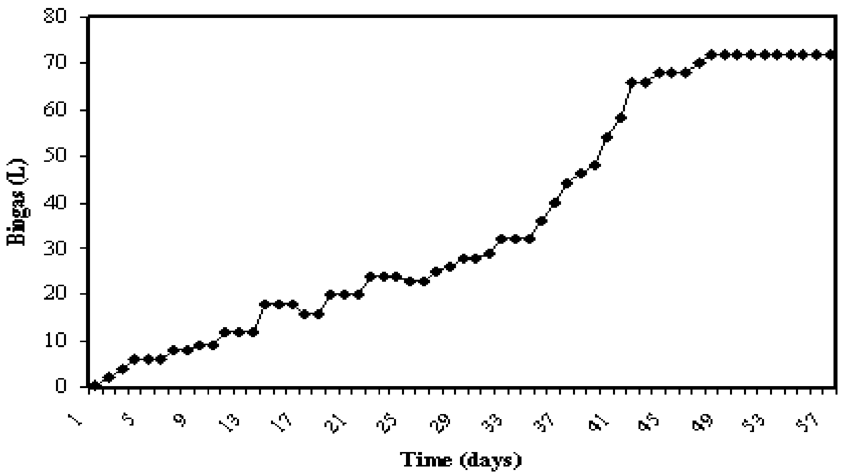

Fig. 5 Biogas production during start-up

Show *et al.* (2004) had reported 80% COD removal for stressed loading during the start up period of a UASB reactor. Ahn *et al.* 2003 revealed 80% COD removal within 30 days start-up of UASB reactor.

Volatile fatty acid

Anaerobic reactor instability is generally manifested by marked and rapid increase in volatile fatty acid concentration (Bal *et al.* 2001). The volatile fatty acid concentration of the UASB reactor is presented in Figure 4. From the figure it is evident that the volatile fatty acid concentration was 200mg/L at the beginning of the start up and reduced slowly to 28mg/L when the reactor attained the equilibrium condition. Volatile fatty acid less than 250mg/L would be the stable condition to operate UASB reactor (Rajeshwari *et al.* 2000).

Biogas

The biogas production during the start-up period of bench scale UASB reactor was shown in Figure 5. The biogas production for first 23 days was very less and after that the biogas production was high which indicate the stability of the methanogenic reactor. For the first 20 days the biogas production was upto 26 l/d and from 24th day to 57th day the biogas production reaches 72 L/d. It can be seen that the biogas yield increases with increase in COD removal (%) for methanogenic reactor and the maximum biogas yield obtained was 0.39 m^3/kg COD removal at steady state condition. Senthilkumar *et al.* (2009) had reported the biogas production during start-up period was about 27 L/d using a bench scale reactor of 15 L total volume. Govindaradjane *et al.* (2010) reported that the biogas yield of 0.30 to 0.31 m^3/kg COD in a UASB and HUASB reactor.

CONCLUSIONS

In order to achieve a successful start-up, it is recommended that the reactor be started up at a lower loading rate and the COD removal efficiency must be monitored carefully. With sufficient control of the operating parameters, the first start-up of the season takes approximately 45 days and, should the plant be shutdown during the season, it can be started up within a day. Once the plant has been successfully started up, fluctuations in the volumetric loading rate do not significantly affect the performance of the reactor. The results obtained in this study point out the feasibility of UASB system for the treatment of high strength soluble wastewater with COD values higher than 3000 mg/L. The maximum COD removal achieved during start-up period in the reactor was 91%. The pH, VFA and alkalinity of the reactor were under stable conditions throughout the period of start-up. The biogas yield was found to be 72 L/d. More research can be done in this field for treating high strength industrial wastewater like pharmaceutical, dairy, sago wastewater using UASB reactors.

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