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Performance Of UASB Reactor At Different Flow Rate Treating Sewage Wastewater

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Abstract: Two identical Upflow Anaerobic Sludge Blanket (UASB) reactors named (R1 and R2) were used to treat the sewage from the effluent of the reactors at different flow rates (Q) and organic loading rate (OLR). The sewage wastewater was characterized for various parameters as per standard method of analysis and treatment results were analyzed in terms of Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Dissolved Solids (TDS) and Volatile Suspended Solids (VSS) of effluent at different flow rates. The experiments were performed to study the effect of flow rate on biomass washout and COD removal efficiency of the UASB reactors. The best efficiency of COD removal is achieved at 2 ml/min of 74.2% and 73.4 % of reactors R1 and R2, respectively. The TSS removal is best accomplished at 2ml/min which is 85.7% and 86%, and TDS diminutions upto 80.3% and 84.5% at 2 ml/min of reactors R1 and R2 respectively. The VSS removal efficiency varies from 82.8% and 84% were noticed at flow rate 2 ml/min of reactors R1 and R2 respectively. So it was concluded that the UASB reactors were operated best at 2 ml/min.
Keywords: Sewage; UASB reactor; COD; VSS; TSS.

1. Introduction

In a developing country like India, sewage waste has become a major source of pollution and major health concern causing water pollution[1]. In many countries, UASB has been applied for the treatment of high strength wastewater, but in India, it has been employed for the treatment of domestic wastewater[2]. An UASB reactor requires a long time for start-up, e.g. from 2 – 3 weeks in good conditions ($t > 20^oC$) and sometimes the start-up can take up to 3 – 4 months. In start-up process, hydraulic loading must be 50% of the design hydraulic loading. The start-up of the UASB reactor can be considered to be complete once a satisfactory performance of the system has been reached at its design load. The present study is carried out for physico-chemical analysis of the Sewage Wastewater and effect of flow rate on biomass concentration from effluent of UASB reactor.

While designing UASB following parameters such as reactor operational conditions (temperature, organic loading rate, hydraulic retention time and up-flow velocity), influent characteristics (influent concentrations, influent particle size and influent particle charge) and sludge bed characteristics (particle size distribution, extra cellular polymeric substances and charge) should be considered as they affect the efficiency of UASB reactor[3]. Formation of good granular sludge is the prominent characteristics of UASB reactor to obtain higher COD removal efficiency[4]. Bhunia and Ghangrekar, 2008[5] studied the influence of influent chemical oxygen demand

(COD), up-flow velocity of wastewater, and cationic polymer additives in inoculums, on biomass granulation and COD removal efficiency in up-Granulation was obtained after 15-35 days when between 0.5 and 2.0 m/h up-flow liquid velocity was applied, [6]with an organic loading rate (OLR) of 8 g COD.L^{-1}.d^{-1} . The high treatment performance can be attributed to the intense mixing regime obtained by high hydraulic and organic loads[7].

2. Materials and methods

Two identical UASB reactors were used to find out the granular particle size analysis in terms of TSS and VSS washout from the reactors at different flow rates (Q) and organic loading rate (OLR). The details of sampling and reactor setup are given below:

2.1 Sampling and Bacterial inoculums

The anaerobic granular sludge used in the experiment was obtained from Haryana Associate Distillery Hisar, sewage sludge from the septic tank of GJUS&T hostel and cow dung from Shri Kurushetra Gaushala Hisar, in pre-cleaned plastic container of 5 liters. The waste water sample was collected from the septic tank of boy's hostel in the university campus. Floating impurities were removed from the sample. At lab scale two UASB reactors were used to investigate the characteristics of sewage sample and each reactor working volume is 14L.

2.2 Experimental Set up

The study was conducted in identical two lab scale UASB reactor of about 15 liter volumes. The reactors consist of an Acrylic pipe in cylindrical shape with 60 cm height having 19.2cm diameter. There are one inlet, one outlet and having four sampling nose. The reactor was connected to the feed tank through a peristaltic pump (Master Flex L/S, model: 77200-50, mfg. by: Core Parmer Instrument Company), which can discharge constant flow rate. The feeding was done at the bottom of the reactor to avoid dead zone at the bottom of reactors. The homogeneity of feed was achieved by recirculation of the effluents through the peristaltic pump at room temperature 30±5.

2.3 Analysis

All the samples collected from the UASB bioreactors were analyzed for the following parameters like pH, COD, TSS, VSS, TDS and VFA were analyzed in accordance with the analytical procedures given in standard methods[8] . Temperature and pH were determined immediately after sampling to avoid any change due to the CO_2 evolution using a pH meter (pH Tutor, Mfg. by: Eutech Instruments). All chemical analysis was carried out in duplicate to ensure the validity of the results.

3. Results and discussion

This study was carried out for 252 days to check the pH, COD, TSS, TDS, VSS, VFA and particle size of washout biomass (VSS) from the UASB reactors R1 and R2 in lab-scale conditions. The detailed characteristic of sewage wastewater for study is shown in Table 1.

Table 1 Characteristics of Sewage wastewater under study

Parameters	Values
pH	6.85
COD	980 (mg/l)
Total Suspended Solids (TSS)	280 (mg/l)
Total Dissolved Solids (TDS)	2360 (mg/l)
Volatile Suspended Solids (VSS)	267 (mg/l)

3.1 Effect of Organic Loading Rate & Flow Rate

Initially, two laboratory scale UASB reactors R1 and R2 were operated under identical operating conditions at temperature 30±5°C. The experimental details for organic loading rate and flow rate are shown in Fig. 1. In the beginning flow rate and OLR were 2 ml/min and 0.05 Kg.COD/m^3/d respectively of reactor R1 and R2 and subsequently, flow rate was increased from 2 to 4, 8, 16, 32 and 64 ml/min; the OLR was applied from 0.05 to 0.12, 0.28, 0.62, 1.57 and 3.47 Kg COD/m^3/d for 42 days experiment. From the results, a significant increase in OLR was observed with increase in flow rate; it indicates that organic matter decomposition decreases with increase in flow rate 64 ml/min. It seems that there is no complete decomposition of organic matter properly at flow rate 64 ml/min. The maximum COD were removed at flow rate 2 ml/min in both the reactors R1 and R2 were 74.2% and 73.4%.

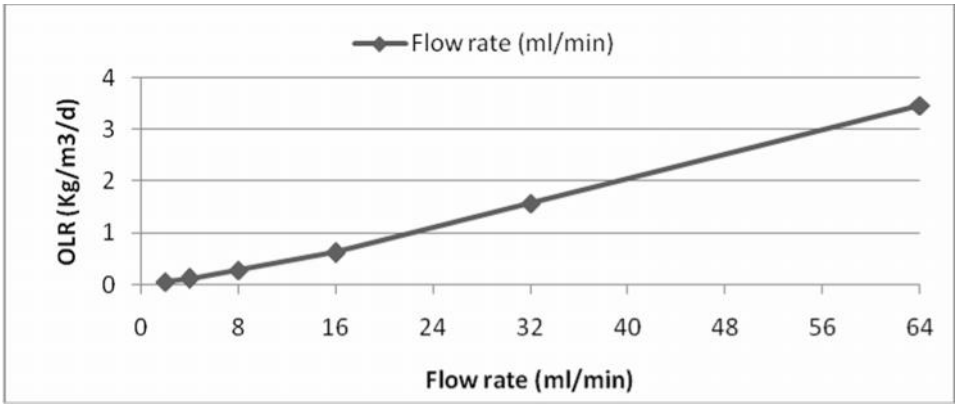


Figure 1 Flow rate (Q) and organic loading rate (OLR)

3.2 pH change in reactors R1 and R2

The pH values of the sewage wastewater are shown in Fig. 2 and 3. The pH value of the reactor R1 and R2 were in the range of 6.1-8.3 and both the reactors, pH was in optimum range which is required for anaerobic degradation of organic matter in UASB reactors (shown in Fig. 2 and 3). The initial pH of the wastewater was 8.3. The pH was decreased at the 7^{th} days and the pH in both the reactors was decreased rapidly after 7 days. At the end of 42^{nd} day, pH of reactors R1 and R2 at flow rate 64 ml/min was declined (6.1 and 6.2 respectively) more, it may be due to accumulation of VFA in the reactors at high flow rate.

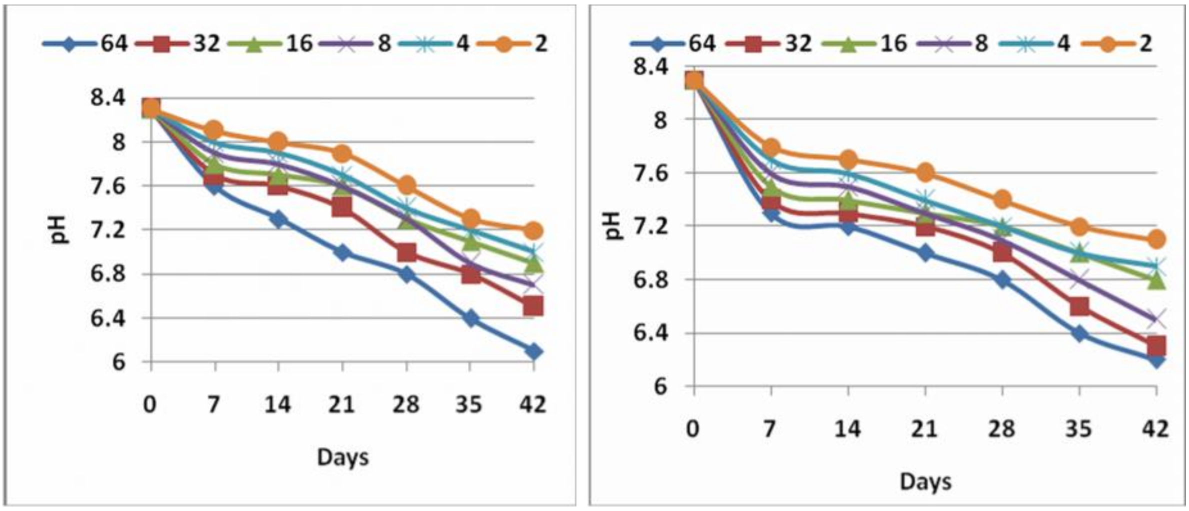
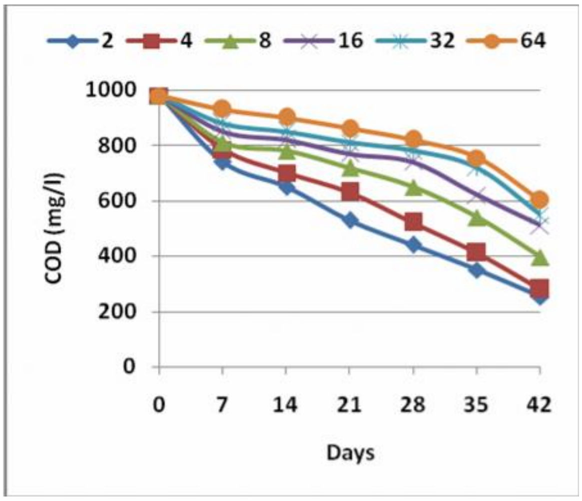


Figure 2 and 3 pH profile of reactor R1 and R2 respectively

3.3 Chemical Oxygen Demand (COD)

COD was measured on oxygen equivalent of the organic material present in wastewater. COD concentrations of the effluent from the reactor (shown in Fig. 4 and 5). Initially, the reactors were continuously feed at particular OLR (0.05 $KgCOD/m^3/d$) and flow rate (2ml/min), after 7 days the OLR and flow rate were increased. The raw sewage wastewater having COD (980 mg/l) was applied to UASB reactors, operating at temperature (30±5°C). After 42^{th} days, the COD was decreased to 252 and 260 mg/l of reactor R1 and R2 respectively at flow rate 2 ml/min. In second stage, the COD in both the reactors at flow rate (4ml/min) were increased up to 280 and 300 mg/l in reactors R1 and R2 respectively. Further, at flow rate (64 ml/min) the COD were increased up to 602 and 612 mg/l at 42^{nd} day of reactor R1 and R2 respectively (shown in figure 4.4 and 4.5). The results of the study revealed that at the low flow rate (2ml/min), the COD removal efficiency was better than the high flow rate (64ml/min) in both the reactors because, at 64 ml/min flow rate, there is a chance of wash out of organic matter along with the effluent, it may be due to low retention time at maximum flow rate. At flow rate (2ml/min), the removal percentages of COD were 74.2% and 73.4% respectively of reactors R1 and R2. The percent removal of COD at flow rate (4 ml/min) was observed 71.4% and 68.3%. The low removal COD (38.5 and 37.5%) were observed at flow rate (64 ml/min) in reactor R1 and R2 respectively.



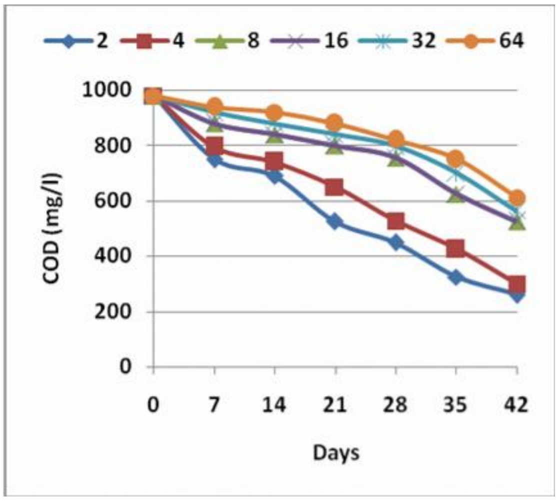
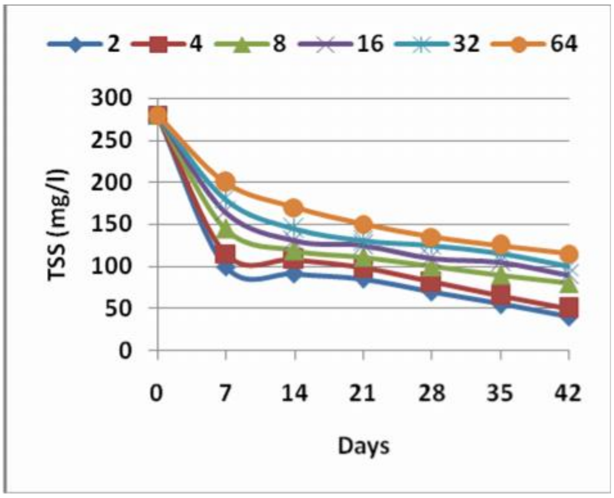


Figure 4 and 5 COD profile of reactor R1 and R2 respectively

3.4 Total Suspended Solids (TSS)

Initially, TSS of the sewage wastewater was 280 mg/l. The TSS was declined drastically in both the reactors R1 and R2 at (2 ml/min), 7th day the percent removal of TSS was observed 64.3% and 65.4%, and at 42nd day the percent removal was 85.7% and 86% in reactors R1 and R2, respectively. At flow rate 4 ml/min on 7th day, the removal rate was 58.9% and 54.3% and 82.1% and 81.4% for 42nd day observed in reactors R1 and R2 respectively. The removal percent of TSS, decreased as flow rate increased and this trend was continued for 8, 16 and 32 ml/min. At 64 ml/min the TSS removal was 28.6% and 21.4%, observed on 7th day and 58.9% and 53.6%, were observed on 42nd day in reactors R1 and R2 respectively (Shown in Fig. 6 and 7), This may be due to increased in flow rate, results in agglomeration of organic matter in effluent. It indicates that at 2 ml/min there is well stabilization of sludge granules and best treatment efficiencies were observed in reactors R1 and R2.



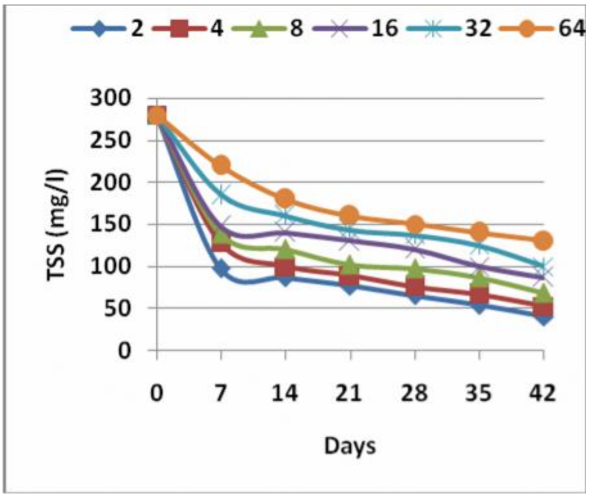
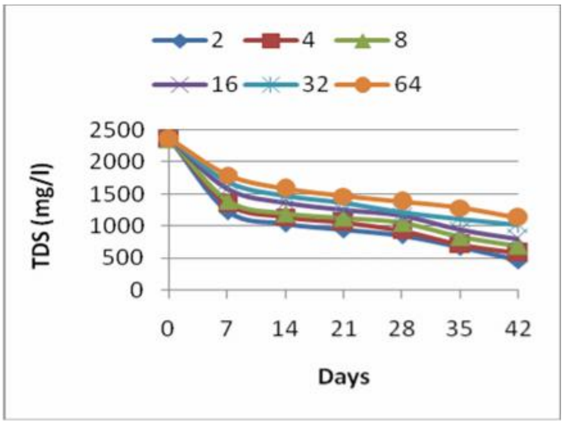


Figure 6 and 7 Variation of TSS at different flow rate of reactor R1 and R2 respectively

3.5 Total Dissolved Solids (TDS)

Initially, TDS of the sewage wastewater was 2360 mg/l. The TDS was decline in both the reactors R1 and R2 at (2 ml/min), at 7th day, the percent removal of TDS was observed 47.8% and 47.6%, and at 42nd day the percent removal was observed 80.3% and 84.5%, respectively in reactors R1 and R2 respectively. At flow rate 4 ml/min on 7th day the removal rate was 42.8% and 42.5% and 75.63% and 79.8% for the end of experimental day in reactors R1 and R2 respectively. The removal rate of TDS was decreased as flow rate increased and this trend were continued for 8, 16 and 32 ml/min. At 64 ml/min the TDS removal were 32.2% and 27.9%, observed on 7th day and 52.1% and 60.6%, were observed on 42nd day of reactors R1 and R2 respectively (Shown in Fig. 8 and 9). The decrease in TDS concentration may be due the gradual consumption of the dissolved organic matter by methanogens in the form of food[9].



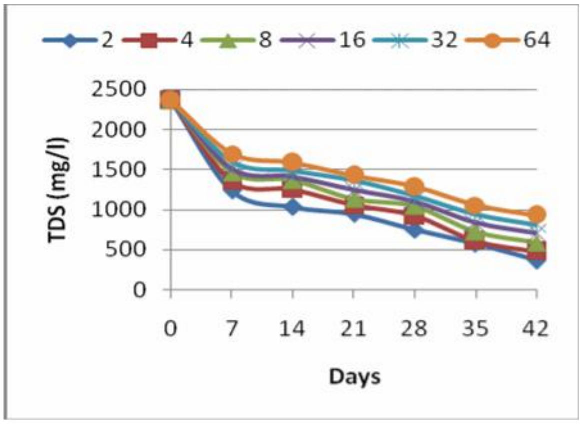
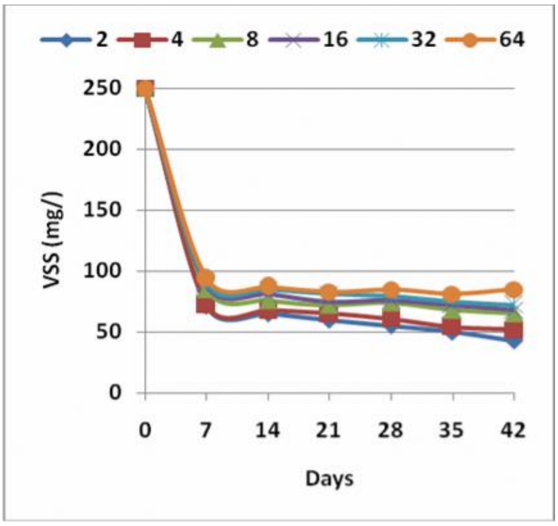


Figure 8 and 9 Variation of TDS at different flow rates of reactors R1 and R2 respectively

3.6 Volatile Suspended Solids (VSS)

The VSS represents the biomass concentration of the sewage wastewater was 250 mg/l. The total VSS was decline at flow rate 2 ml/min, on 7th day the percent removal were 71.6% and 72% and 42nd day 82.8% and 84%, observed of reactors R1 and R2 respectively. This may be due to the new environment for microbes. In second stage at 4 ml/min, removal rate were 71.2% and 70.4% on 7th day and 79.2% and 81.6% on 42nd day, were observed of reactors R1 and R2. There was a decrease trend was observed in VSS percentage removal rate at flow rate 8, 16 and 32 ml/min. At flow rate 64 ml/min, a sharp decrease in VSS was 62.4% and 64% on 7th day and 66% and 73.2% on 42nd day, were observed of reactors R1 and R2 respectively (shown in Fig. 10 and 11) It indicates as flow rate increases, it's up-flow velocity increases that is more wash out of biomass at maximum up-flow velocity which increases their VSS content in effluent.



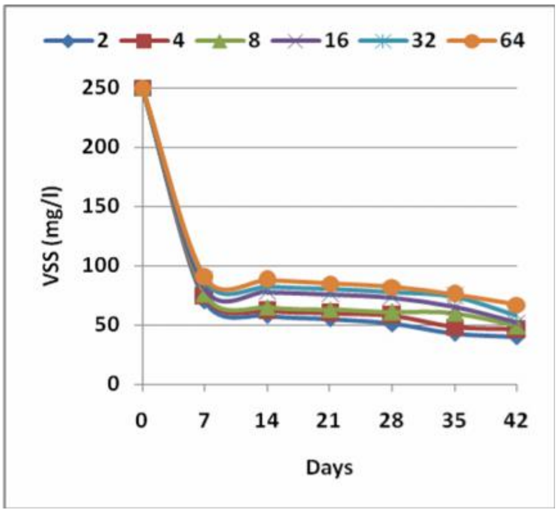


Figure 10 and 11 Concentration of VSS of reactors R1 and R2 at different flow rate respectively

Conclusions

The success of UASB reactors is related to their capacity for biomass accumulation by settling without any disturbance. The analysis of particle size distribution is of vital importance for monitoring of UASB reactors. In this study, a simple technique for determination of particle size distribution is presented. No equipments are needed. The following conclusions are given below:

1. There is no much change in the pH of the rectors.
2. The best efficiency of COD removal is achieved at 2 ml/min of 74.2% and 73.4 % of reactors R1 and R2, respectively.
3. The TSS removal is best accomplished at 2ml/min which is 85.7% and 86%, and TDS diminuition upto 80.3% and 84.5% at 2 ml/min of reactors R1 and R2 respectively.
4. The VSS removal efficiency varies from 82.8% and 84% were noticed at flow rate 2 ml/min of reactors R1 and R2 respectively.
5. There should be more washout of biomass when we increase the flow rate from 8 to 64 ml/min.

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