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START UP OF UASB REACTOR WITH CONCENTRATED ABATTOIR STABILIZATION POND SLUDGE

Doris O. Tenorio and Goen E. Ho
Environmental Science, Murdoch University
Murdoch, Western Australia 6150

SUMMARY

The suitability of concentrated abattoir stabilization pond sludge for the start-up of UASB reactors was studied in a continuous laboratory set-up. A mixture of volatile fatty acids (acetic, butyric and propionic) was used as substrate to establish the optimum parameters for the start-up.

The concentrated sludge had the capacity to handle a high loading condition (15 kg COD/m³ of reactor-day) within 5 weeks of operation. The range of % COD reduction was 78%-94%. Different sludge concentrations gave similar VFA and COD reductions. This can be attributed to the severe washout of the sludge at the initial phase of operation and the eventual retention of similar sludge concentrations of approximately 20 kg VSS/m³ of reactor.

INTRODUCTION

The upflow anaerobic sludge blanket (UASB) reactor is a significant development in wastewater treatment technology, and has been extensively applied at full scale (Lettinga *et al.*, 1987). It allows retention of a high concentration of microorganisms in the reactor and hence reducing residence time of wastewater in the reactor and still achieves a high removal rate of COD. For efficient performance of this system it is necessary to form and maintain a highly settleable or granular type of sludge in the reactor, to capture biodegradable organic matter in the wastewater and eventually convert it to methane.

Reactor start-up is a critical step in UASB operation, since it can take the order of months to build the required bacterial biomass in the reactor. It is desirable to use a sludge with a high methanogenic activity and good settleability, which should preferably come from another anaerobic digester treating the same wastewater. This type of sludge will not only shorten the period of start-up but will also ensure the success of operation. Since this type of sludge is not presently widely available, it is important to find alternative sludge sources which have sufficient methanogenic activity and are relatively abundant.

Abattoir stabilization ponds are a potential source of sludge for the start-up of UASB reactors, for two main reasons. The first is the general anaerobic nature of the first few ponds and the presence of a balanced mixture of organic compounds which stimulate the growth of many different types of anaerobic bacteria.

This study was conducted to determine the suitability of concentrated abattoir stabilization pond sludge for the start-up of UASB reactors. The rationale behind the study was that concentrated sludge should contain more of the right types of bacteria suitable for start-up and hence reduce start-up time. The main objective was to determine the effect of initial sludge concentration on the rate of volatile fatty acids (VFA) degradation, chemical oxygen demand (COD) reduction and biogas production during start-up.

MATERIALS AND METHODS

Sludge collection and preparation:
Sludge samples were collected from an abattoir stabilization pond in Harvey, Westem Australia. Sludge was centrifuged at 8000G for 15 minutes to concentrate the suspended solids.

<u>Experimental set-up:</u>

Three identical laboratory reactors were designed and fabricated based on UASB reactors described in the literature (Souza, 1986 and Lettinga *et al.*,l987). The reactor height was 411 mm with an internal diameter of 82 mm and a working volume of 1.92 L. A water jacket sorrounded each reactor in order to maintain a constant operating temperature of 37°C.

A schematic diagram of the experimental set-up is shown in Figure 1. The gas was collected from the top of the reactor and measured by water displacement using an inverted graduated cylinder. A water seal was placed in between the gas storage cylinder and the reactor to maintain a slight positive gas pressure in the reactor.

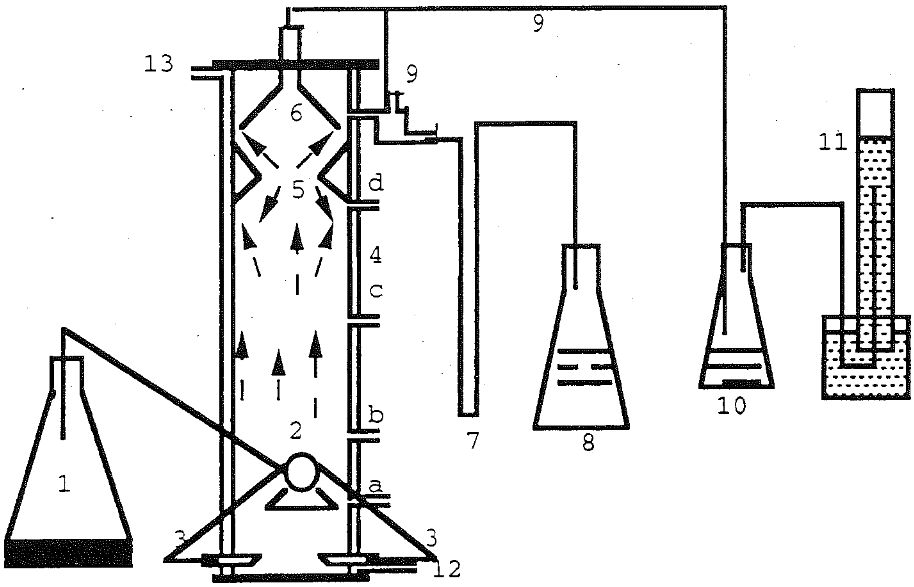

Figure 1. A schematic diagram of the experimental set-up.

1. Feed container; 2. Peristaltic pump; 3. Feed inlet; 4. Sampling points (a to d); 5. Gas solid separator; 6. Gas collector; 7. U-tube for effluent outlet; 8. Effluent container; 9. Gas outlet; 10. Water seal; 11. Gas storage; 12. Heating water inlet; 13. Heating water outlet

<u>Synthetic substrate:</u>

A mixture of VFA (acetic, butyric and propionic) was used as substrate in order to establish the optimum start-up parameters. A stock solution of VFA and basal nutrients was prepared with a modified composition based on Wiegant and Lettinga (1985). The preparation of trace metal solution (TMS) was from Kosaric *et al.* (1985) and Wiegant and Lettinga (1985). In order to make a synthetic substrate with a COD value of approximately 2500 mg/L (VFA 600mg/L) the following amounts of stock solutions were mixed: 7.5 mL VFA, 10 mL basal nutrient, 1 mL trace metal solution (TMS) and 0.1 g yeast, diluted with distilled water to make 1 L of solution. The amounts of the stock solutions were increased to achieve the desired COD values. The solution was adjusted to pH 7 with 10N NaOH.Reactor operation:

Three reactors (reactor 1 (R_l), reactor 2 (R_2) and reactor 3 (R_3)) were operated in parallel with three starting sludge concentrations of 20, 30, and 40 g VSS/L-reactor respectively. Each was operated in 3 stages (I-III) for 15 days each stage over a period of 45 days, with a constant hydraulic residence time (HRT) of 12 hrs.

Initially the reactors were purged with N2 gas, filled with sludge and incubated overnight at 37°C.

Synthetic substrate was pumped in at the desired flow rate. Initial influent COD was 2500 mg/L and increased stepwise to 5000 mg/L and finally to 7500mg/L.

At the end of each phase, samples of sludge (20 ml) from sampling points along the height of the reactor were taken. The samples were then combined to obtain the mean total solids (as VSS) in the reactor.

Analysis:

Suspended solids(SS) and volatile suspended solids (VSS) of the sludge were measured following Standard Methods (APHA, 1985). The appearance of the biomass formed at the end of reactor operation was viewed under a scanning electron microscope (SEM) Philips 501B.

Daily analysis was conducted for biogas production, methane (CH4) concentration, effluent pH, VFA, COD and solids washout as VSS. COD influent was measured as required. Both VFA and methane (CH4) concentrations were determined by gas chromatography (GC) using a Varian Model 3700 equipped with a flame ionization detector. The GC column was packed with Porapak QS (80-100 mesh) and the column temperature was 100°C for methane and 190°C for VFA. Samples for COD analysis were digested by closed reflux and measured using the procedure described in Standard Methods (APHA, 1985).

Daily methane production was computed from biogas production and CH4 concentration based on the equation below.

VCH_4 (ml) = (Vb*Tc)*%CH_4

Where: VcH_4 = volume of CH_4 produced

Vb = volume of biogas measured

Tc = Temperature correction

%CH_4 = methane concentration (modified from Viega *etal.*, l990)

The volume of biogas was corrected to standard temperature (O°C).

RESULTS AND DISCUSSION:

The VSS content of the concentrated sludge was 82 g/L (37% of solids content).

The loading conditions imposed (as g COD/L reactor-day) and the specific loading rates (g COD/g VSS) are shown in Table 1. The specific loading rates for R_1 were higher than R_2 and R_3 in all phases of operation. In phase II and phase III specific loading rates for R_2 and R_3 were similar.

Table 1.
The organic loading condition and specific loading rates during the period of operation.

Phase	g COD/L reactor-day	g COD/g VSS-day	
	R_1	R_2	R_3
I 5.1±0.3	0.27	0.18	0.12
II 10.6±0.3	0.78	0.54	0.56
III 15.4±0.3	0.87	0.63	0.64

Solids Washout:

Table 2 shows the solids washout, sludge concentration in the reactor and sludge yield (measured as VSS) during the period of operation. It should be noted that VSS in the reactor was determined by sampling from four ports, and interpolation was used to obtain the total VSS in the reactor. This may explain the negative yield figures in Table 2. A high washout occurred in phase I, especially in R_3, which reached approximately 44% of initial VSS followed by R_2 (31%) and R_1 (29%). In phase II, R_2 washout was higher than R_1 and R_3 due to the higher concentration of sludge in R_2 (Table 2). Washout in phase m was similar for all reactors.

Table 2.

Comparison of VSS concentration in the reactor and sludge yield.

Phase	(a)Initial VSS (g)	(b)Total VSS washout (g)	(c)Measured VSS at the end of phase (g)	(*d)Yield VSS in the reactor (g)
REACTOR 1				
I	40.0	11.5	27.4	- 1.1
II	27.4	6.3	34.4	+13.3
III	34.4	7.6	38.4	+ 11.6
REACTOR 2				
I	60.0	18.5	39.7	- 1.8
II	39.7	11.7	47.1	+19.1
III	47.1	7.4	37.7	-2.1
REACTOR 3				
I	80.0	34.8	37.1	- 8.2
II	37.1	7.3 4	5.4	+15.6
III	45.4	7.3 4	1.2	+3.1

*d = c- (a-b)

The occurrence of high solids washout in the initial stage of operation is common and is observed in the studies of start-up with digested sewage sludge (Hulshoff Pol *et al.*, 1983; Mahoney *et al.*, 1987). A major reason is gas production which expands the sludge bed. A high washout in R_3 is attributed to the sludge holding capacity of the reactor, the sludge bed expanded to the gas solids separator, resulting in sludge carry over.

The constant HRT might contribute to solids washout in R_2 and R_3. The combination of low flowrate and high sludge concentration might not promote selection of settleable sludge. Despite the loading condition being increased, the increase in gas production did not appear to be sufficient to mix the sludge.

<u>Appearance and characterization of sludge:</u>

The sludge analyzed at the end of operation showed that the sludge formed into small flocs of solids less than 3 mm. The sludge solids were easily dispersed when pressure was applied. SEM micrograph in Figure 2 shows that sludge from all reactors contains sarcina-type micoorganisms.

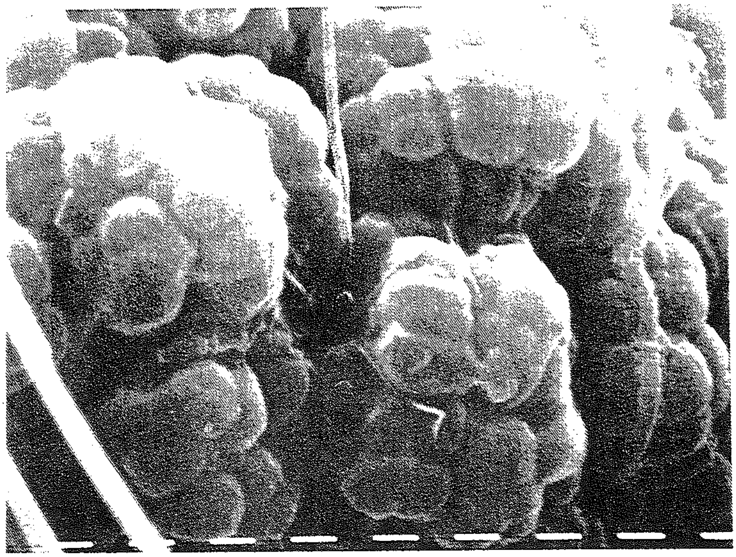

Figure 2. SEM micrograph of sludge samples at the end of operation (bar = 1 µm; magnification 5000x)

COD reduction and VFA degradation:

The reduction of influent COD was a good indicator of reactor performance. Figure 3 shows the relationship of COD input and consumption against time. A high % COD reduction was observed in all reactors. In phase I % COD reduction of R_1 (84%) was lower than R_2 and R_3 (approximately 92%). Increased loading conditions for phase II saw a decrease of COD reduction in all reactors, (R_1 79%, R_2 83% and R_3 90%), followed by a further COD reduction in phase III (R_1 87%, R_2 85% and R_3 90%).

These results show that a high COD reduction was obtained with a higher COD/VSS ratio. The results also indicate that following a step increase in COD loading, COD reduction dropped until there was a further build up of sludge (as VSS) in the reactor.

Degradation of VFA was rapid with butyric acid disappearing at a fast rate followed by propionic and acetic acid. The slow degradation of acetic acid was caused by its production from the former two acids.

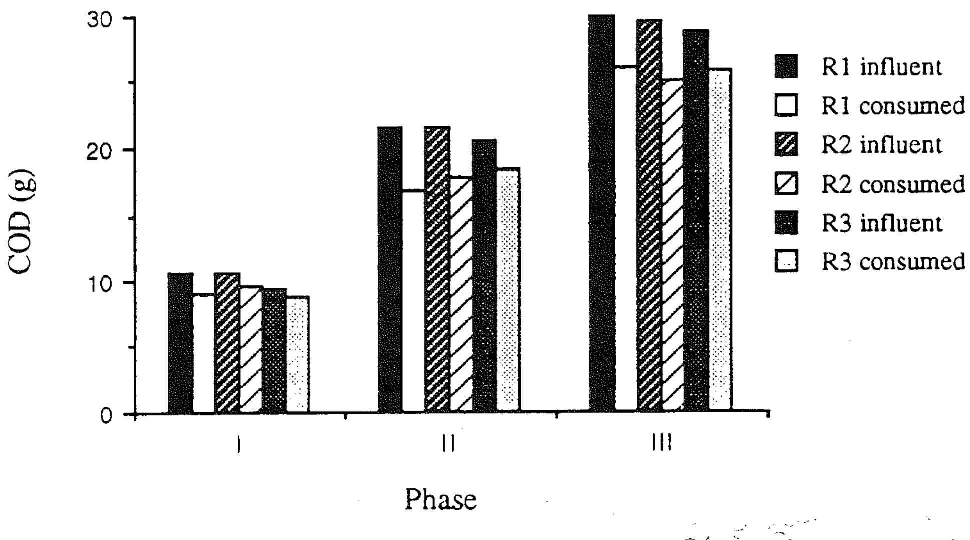

Figure 3. Comparison of average COD input and consumption during the phases of operation.

Effluent pH:

The effluent from the reactor had a pH range of 7.67 to 8.06 during operation. pH increased slightly from phase I to phase m. The pH increase from the influent to the effluent stage is due to the degradation of organic acids.

Biogas production:

Figure 4 shows biogas production in each operational phase. A high methane concentration occurred in phase I, (80% for R_1, 84% for R_2 and R_3). A decrease in CH4 concentration was observed in R_2 and R_3 in phase II (to approximately 80%) and III (78%), whereas an increase in CH_4 concentration was observed in R_1 (76% in phase II and 80% in phase III). The high CH_4 concentration was due to the high pH of the mixed liquor in the reactor absorbing CO_2 from the biogas.

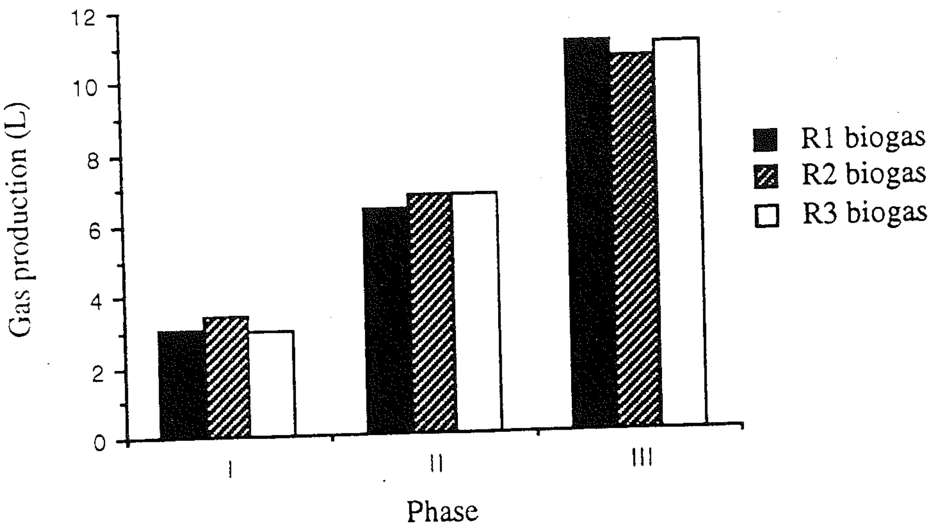

Figure 4. Average biogas production during the phases of operation.

In phase I R_2 had a higher CH_4 production in relation to COD consumption (0.30 LCH_4/gCOD), followed by R_3 (0.28 LCH_4/gCOD) and R_1 (0.27 LCH_4/gCOD). In phase II there was no change in the coefficient. Then in phase III there was an increase, R_1 had the highest value (of 0.34 LCH_4/gCOD) followed by R_2 and R_3 (0.32 LCH_4/gCOD).

CONCLUSIONS:

Concentrated abattoir stabilization pond sludge was suitable for the start-up of UASB reactor

All reactors showed a high COD reduction and methane production using VFA substrate and could handle a loading condition of 15 g COD/L reactor-day within 5 weeks. Initial concentration of concentrated sludge did not appear to affect start-up for the range studied. The limiting factor for the use of concentrated sludge was the initial washout of VSS from the reactor. The sludge formed is in the form of flocs.

Further investigation is needed in order to establish other factors affecting start-up, i.e. reduced HRT and the use of complex substrate and control of initial washout of solids.

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