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THE INFLUENCE OF VARIABLE ORGANIC LOADING ON THE START-UP OF AN ANAEROBIC FLUIDISED BED REACTOR

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SUMMARY

A stepped-loading start-up regime utilising variable organic influent concentrations in the range 1650-11600 mgCODl^{-1} was applied to an anaerobic fluidised bed bioreactor at 37°C. The reactor was sensitive to variable influent COD concentrations, but the stepped-loading aided rapid recovery from transient organic loading shocks. Variable effluent COD levels were produced but a COD removal efficiency of 76% was obtained at a final HRT of 0.5 d and an organic loading rate of 5.3 kg COD m^{-3} d^{-1}.

INTRODUCTION

Anaerobic fixed-film reactor systems such as fluidised beds are eminently suited to the treatment of high strength soluble organic wastes, at very high organic loading rates. A major impediment to the successful application of these processes, however, is the length of time necessary for start-up (Stronach et al. 1986). The current study involved starting-up an anaerobic fluidised bed under the stepped loading regime adopted by Bull et al. (1983) but with variable organic loading resulting from fluctuations in influent strength. It was intended to simulate conditions under which the rate of flow of wastewater to a treatment plant is more easily controlled by pumping than is the strength of the wastewater, which may vary temporally depending on the nature of the production processes involved.

MATERIALS AND METHODS

A 4 l laboratory scale fluidised bed reactor as described by Bull et al. (1983) was inoculated with a 30 ml seed of digested sewage sludge and maintained at 37°C. The substrate comprised a synthetic meat-based wastewater, initially amended with methanol, as detailed by Bull et al. (1983). The feed exerted a nominal COD of 2500 mgl^{-1}, but was prepared and sterilised at five times this concentration then diluted with distilled water to give final influent COD concentrations in the range 1,650 - 11,600 mgl^{-1}. The start-up operation entailed stepwise increases in hydraulic loading, as described elsewhere (Bull et al. 1983; Rudd et al. 1985), in conjunction with variable organic loading arising from the varying influent COD concentrations applied. The loading regime is shown in Table 1. Achievement of steady-state was ascertained by maintaining a constant organic loading rate from day 45 to day 50.

Influent and effluent COD, pH, total volatile acids (TVA) and suspended solids (SS) concentrations were determined daily using standard methods (Government of Great Britain 1977, 1979, 1980) and volatile (attached) solids (VS) concentrations determined at each change of hydraulic retention time (HRT) by the method of Stephenson and Lester (1986).

Table 1 The loading regime applied during the start-up of an anaerobic fluidised bed.

Day	HRT (d)	Influent flow rate (ld^{-1})	Mean Influent COD (mgl^{-1})	Organic loading rate ($kg\ COD\ m^{-3}\ d^{-1}$) mean	range
0	3.33	0.75	4361	1.36	0.91-3.63
10	1.67	1.5	4434	2.77	1.16-7.26
20	1.00	2.5	3270	3.41	2.53-4.38
25	0.63	4.0	4085	6.99	2.75-16.78
35	0.54	4.3	2845	5.34	3.12-15.54
50	0.54	4.3	2900	5.30	-

RESULTS AND DISCUSSION

Influent and effluent COD concentrations, pH values and TVA and SS concentrations for the duration of the experiment are presented in Figure 1. Increased COD loading generally resulted in a concomitant increase in effluent COD (Figure 1 (b)), with the reactor responding rapidly to transient organic shocks over the initial HRTs of 3.33 to 1.67 d. As HRT decreased below 1.67 d, however, an increase in mean percentage COD removal was exhibited (Table 2), suggesting increased tolerance of influent fluctuations as start-up progressed and the reactor microflora acclimated to the substrate. COD removal stabilised towards the end of the start-up period, when constant loading was introduced, although the removal rate was lower than that exhibited during influent variation, probably because of the short final HRT applied, and adjustment of the feed components. During the first ten days of operation, the fluidised bed was subjected to a peak influent COD concentration of 11.6 gl^{-1}. The system responded with effluent COD values of 0.75 - 1.5 gl^{-1} over the following three days. A maximum COD removal efficiency of 97% was recorded when the influent COD concentration was 3.3 gl^{-1} and the HRT was 0.63 d.

Table 2 Mean COD removal and effluent total volatile acids (TVA), suspended solids (SS) and volatile solids (VS) concentrations in an anaerobic fluidised bed during start-up.

HRT (d)	Mean COD removal (%)	Mean TVA (mgl^{-1})	Mean effluent SS (mgl^{-1})	VS (mgl^{-1})
3.33	60	159	350	1650
1.67	78	173	209	1250
1.00	82	72	98	2250
0.63	81	188	253	3450
0.54	54	313	107	4400

These results compare favourably with those of Bull *et al*. (1983) where stepped organic loading regimes without variable influent COD concentrations were applied. Comparison of influent and effluent COD concentrations (Figure 1 (b)) shows a marked attenuation of the shock-loading peaks in the latter. This may be attributed to the dilution effect of the system's recycle facility, or to the protective nature of the biofilm reducing the initial exposure of the microbial population to overload conditions and hence allowing selection of a suitable microflora; loading conditions have been implicated in the selection of different methanogenic species (Hulsoff-Pol *et al*. 1983).

Throughout start-up, the pH, TVA and SS concentrations fluctuated to a marked extent (Figure 1). TVA concentrations were lower when effluent COD values were also low, suggesting utilisation of excess acids by assimilating bacteria. Severe COD overloading of the reactor resulted in short-term fluctuations in TVA concentrations, and hence pH, with TVA levels

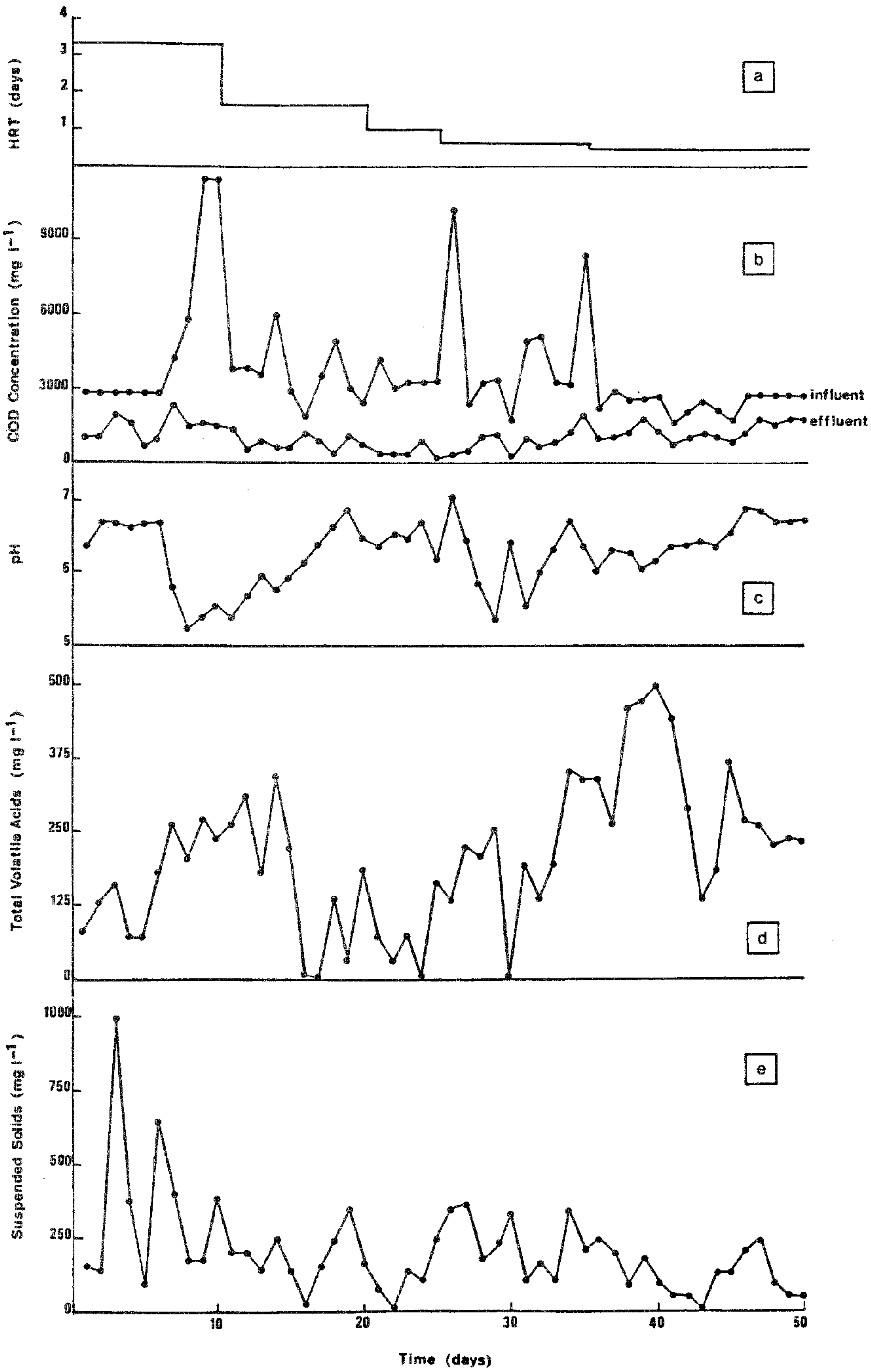

Figure 1 Effect of variable organic loading on effluent quality during start-up of an anaerobic fluidised bed reactor

increasing 6-10 fold, but returning to normal concentrations within 48 hours after overload. Kennedy and van den Berg (1982) reported 8 - 10 fold increases in acids concentrations after overloading at steady-state, with a return to normal concentrations within 12-16 hours; overloading during start-up thus appears to have a more protracted effect on reactor stability than overload in a steady-state system. The accumulation of TVA during periods of marked reactor instability was common, with COD removal decreasing rapidly from 80% to less than 50% at increased acids concentration, suggesting proliferation of acidogens at the expense of the methanogens and incomplete conversion of the substrate to biogas. Reactor pH decreased from 6.4 prior to shock loading to 5.9 under shock load conditions (Figure 1 (c)). When the COD loading was stabilised at day 45, a pH value of 6.9 was ultimately achieved.

Effluent SS concentration increased initially up to 1000 mgl^{-1} (Figure 1 (e)) then fluctuated within the range 350-375 mgl^{-1} during the first hydraulic retention period. However, after day 24, the effluent SS were low in comparison to the attached VS, suggesting good bacterial adhesion to the support matrix. The fluctuations observed in effluent SS concentration during start-up appeared to be more directly related to the variable nature of the influent (Figure 1 (b) and (e)) than to any inherent instabilty of the system itself. This was evident when the feed was returned to a constant strength on day 45 at the end of the stepped loading regime, at which point the effluent characteristics stabilised, indicating that steady state had been reached.

CONCLUSIONS

Variable organic loading during the start-up of an anaerobic fluidised bed reactor appears to have a more protracted effect on reactor stability than that normally associated with steady-state systems. A stepped-hydraulic regime aids recovery from transient shock organic loadings and the fluidised bed reactor configuration appears capable of sustaining sudden influent concentration variations. The final steady-state performance after start-up was poorer than may have been expected, however, hence variable organic loading during start-up would appear to be undesirable. The provision of balancing tanks for load equalisation is therefore necessary for rapid start-up.

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