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ScienceDirect
Bioresource Technology 99 (2008) 3256–3266
BIORESOURCE TECHNOLOGY

Influence of organic shock loads in an ASBBR treating synthetic wastewater with different concentration levels

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Received 16 November 2005; received in revised form 9 July 2006; accepted 5 May 2007
Available online 31 July 2007

Abstract

Safe application of the anaerobic sequencing biofilm batch reactor (ASBBR) still depends on deeper insight into its behavior when faced with common operational problems in wastewater treatments such as tolerance to abrupt variations in influent concentration, so called shock loads. To this end the current work shows the effect of organic shock loads on the performance of an ASBBR, with a useful volume of 5 L, containing 0.5-cm polyurethane cubes and operating at 30 °C with mechanical stirring of 500 rpm. In the assays 2 L of two types of synthetic wastewater were treated in 8-h cycles. *Synthetic wastewater I* was based on sucrose–amide–cellulose with concentration of 500 mg COD/L and *synthetic wastewater II* was based on volatile acids with concentration ranging from 500 to 2000 mg COD/L. Organic shock loads of 2–4 times the operation concentration were applied during one and two cycles. System efficiency was monitored before and after application of the perturbation. When operating with concentrations from 500 to 1000 mg COD/L and shock loads of 2–4 times the influent concentration during one or two cycles the system was able to regain stability after one cycle and the values of organic matter, total and intermediate volatile acids, bicarbonate alkalinity and pH were similar to those prior to the perturbations. At a concentration of 2000 mg COD/L the reactor appeared to be robust, regaining removal efficiencies similar to those prior to perturbation at shock loads twice the operation concentration lasting one cycle and stability was recovered after two cycles. However, for shock loads twice the operation concentration during two cycles and shock loads four times the operation concentration during one or two cycles filtered sample removal efficiency decreased to levels different from those prior to perturbation, on an average of 90–80%, approximately, yet the system managed to attain stability within two cycles after shock application. Therefore, this investigation envisions the potential of full scale application of this type of bioreactor which showed robustness to organic shock loads, despite discontinuous operation and the short times available for treating total wastewater volume.

Keywords: Shock load; ASBBR; Synthetic wastewater; Organic load

1. Introduction

Wastewater characteristics usually fluctuate during operation, both qualitatively and quantitatively, i.e., in composition, flow rate and concentration, which may cause process destabilization, making operation of an anaerobic reactor vulnerable to feed and environmental perturbations. This is especially important in reactors operating with high organic load, where a perturbation may cause total failure of the system. It is important to determine when a process becomes overloaded and how this process behaves under this condition, i.e., when and how a perturbation may affect efficiency. Moreover, it is convenient to identify how the system can regain stable condition, before the negative effects become irreversible, since extended

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doi:10.1016/j.biortech.2007.05.068

Nomenclature

BA	bicarbonate alkalinity, mg $CaCO_3$/L
C_{ES}	filtered substrate concentration in the effluent, mg COD/L
C_{ET}	non-filtered substrate concentration in the effluent, mg COD/L
C_I	non-filtered substrate concentration in the influent, mg COD/L
C_X	biomass concentration in the bioreactor, g TVS/L
IVA	intermediate volatile acid concentration, mg/L
SOL	non-filtered specific organic loading, mg COD/g TVS h;
t_C	cycle time, h
TS	total solids concentration, mg TS/L
TSS	total suspended solids concentration, mg TSS/L
TVA	total volatile acid concentration, mg/L
TVS	total volatile solids concentration, mg TVS/L
V	medium volume in the bioreactor, L
VA	intermediary volatile acid concentration, mg/L
V_F	fed volume in the reactor per cycle, L
VOL	volumetric organic load, mg COD/L d
VSS	volatile suspended solids concentration, mg VSS/L
ε_S	filtered organic matter removal efficiency in the system, %
ε_T	non-filtered organic matter removal efficiency in the system, %
ASBBR	anaerobic sequencing biofilm batch reactor
COD	chemical oxygen demand

recovery periods may be necessary to regain process stability (Ruiz et al., 2002; Xing et al., 1997).

Bermúdez et al. (1988) when employing an anaerobic trickling filter (ATF) for treating fruit processing effluent and high-strength cheese whey wastewater obtained satisfactory results regarding stability when altering substrate, organic and hydraulic overload. These researchers obtained conversions above 60% in all cases and reported that reactor performance was strongly dependent on the ability to retain biomass inside the reactor. Caine et al. (1991) analyzed the effect of organic and hydraulic shock loads on the performance of a 5.28 m^3 anaerobic filter with recirculation of the effluent, treating ice-cream processing wastewater of 6000 mg COD/L. On applying 12000 mg COD/L shock load for 8 h effluent quality, removal efficiency and CH_4 production decreased (from 81% to 67%). Yet, after cessation of the shock load methane production regained initial values and volatile acids concentration in the effluent increased from 50 to 164 mg/L.

Borja et al. (1994) on employing an anaerobic downflow filter at 35 °C to treat 5050 mg COD/L slaughterhouse effluent obtained removal efficiency of 94.5% for an organic load of 10.1 kg COD/m^3 d and hydraulic detention time (HDT) of 12 h in steady state. On submitting the reactor to transient changes in temperature, pH, flow rate and influent concentration for periods of 5–10 h, effluent quality decreased during shock load application, regaining steady-state values within 6–15 h after which normal conditions were reestablished. Borja and Banks (1995) subsequently used a fluidized bed reactor at 35 °C to treat 5.2 g COD/L wastes from ice-cream processing industry. On submitting the reactor to transient changes in temperature, pH, flow rate and influent concentration for periods of 6–12 h, effluent quality decreased during shock load application, regaining steady-state values within 6–16 h after reestablishment of normal conditions.

Nachaiyasit and Stuckey (1997) on investigating the effect of both hydraulic and organic step shock loads in an anaerobic compartmentalized reactor found the reactor was very stable to transient shocks over long periods. Hydraulic shock loads with a residence time of 1 h (corresponding to an increase of 20 times the influent flow rate), 5 h and 10 h were applied to the reactors for 3 h, 2 weeks and 3.5 weeks, respectively. Removal efficiency decreased to 90% when HDT was reduced to 10 h and to only 52% when HDT was 5 h. Nadais et al. (2000) investigated the effect of organic and hydraulic loads on the performance of a 6-L UASB reactor operating intermittently at 35 °C and treating dairy wastewater. Initially, the reactor operated for 20 d at an organic load of 12 g COD/L d and HDT of 12 h, after which a shock load was applied for 21 d. Intermittent operation allowed 93% removal in terms of COD and a COD to methane conversion of 74% for an organic load of 12 g COD/L d with HDT of 12 h; values superior to those of continuous operation with the same HDT and organic load of 4.5 g COD/L d, at which similar COD removal was obtained, but with COD to methane conversion of only 40%.

Amorim et al. (2005) investigated the performance and stability of a 2-L horizontal anaerobic fixed bed reactor containing immobilized biomass on polyurethane foam, submitted to a progressive increase in organic load and organic shock loads. The reactor was initially fed with substrate composed mainly of carbohydrates with concentrations of 200, 1000 and 2000 mg COD/L. The carbohydrates were subsequently replaced by methanol and volatile acids at overall concentrations of 2000–5000 mg COD/L. Shock loads were applied in a way to triple influent concentration during a period equivalent to the HDT after which steady state was established. The system presented operational problems during the carbohydrate tests when submitted to 2000 mg COD/L and 8.77 kg COD/m^3 d. No operational problems were seen during the tests with substrate containing