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Interaction effects of organic load and cycle time in an AsBr applied to a personal care industry wastewater treatment

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ABSTRACT

A mechanically stirred anaerobic sequencing batch reactor (ASBR) containing granular biomass was applied to the treatment of a wastewater simulating the effluent from a personal care industry. The ASBR was operated with cycle lengths (t_C) of 8, 12 and 24 h and applied volumetric organic loads (AVOL) of 0.75, 0.50 and 0.25 gCOD/L.d, treating 2.0 L liquid medium per cycle. Stirring frequency was 150 rpm and the reactor was kept in an isothermal chamber at 30 °C. Increase in t_C resulted in efficiency increase at constant AVOL, reaching 77% at t_C of 24 h versus 69% at t_C of 8 h. However, efficiency decreased when AVOL decreased as a function of increasing t_C, due to the lack of substrate in the reaction medium. Moreover, replacing part of the wastewater by a chemically balanced synthetic one did not yield the expected effect and system efficiency dropped.

1. Introduction

Anaerobic sequencing batch reactors were proposed as an alternative to continuous systems, because they promoted good solids retention in the system and improved process control (Dague et al., 1992). Despite the advances observed since the first works, complete utilization of these systems still depends on insight into fundamental and technological aspects (Zaiat et al., 2001).

One of the applications of anaerobic sequencing batch reactors is the treatment of wastewaters containing toxic or recalcitrant compounds, such as surfactants. The relationship between chemical structure, physicochemical properties, biodegradability and the impact caused by these substances has still not been very well elucidated. The role of these compounds in the environment seems to be ambiguous, since on one hand they may have toxic effects on living organisms and on the other hand may promote the decomposition of organic pollutants from the environment (Cserháti et al., 2002).

Baumann and Müller (1997) investigated the degradation of sodium lauryl sulfate, with no addition of any other compound, in an up-flow anaerobic continuous fixed-bed reactor. Media contained 350 mgCOD/L in addition to salts and were autoclaved at 121 °C. At a hydraulic retention time (HRT) of 1 h, methane production was only 15% of that which could be theoretically obtained. The justification of the authors was that sodium lauryl sulfate had been partially degraded to dodecanol by sulfate reducing bacteria and since consumption was very slow accumulation occurred in the reaction medium, which might have caused inhibition to the microorganisms.

Also using an up-flow anaerobic continuous fixed-bed reactor, Patel and Madamwar (1998) studied the effect of different surfactants in the treatment of cheese whey. Addition of 200 mg/L sodium lauryl sulfate resulted in a 70% increase in the production of biogas as well as an increase from 69% to 77% of methane molar fraction in the biogas. Moreover, under that condition total volatile acids concentration was at its lowest, confirming system stability during operation.

The treatment of different wastewaters has been on the agenda of many research groups including Feitkenhauer and Meyer (2002), Ndegwa et al. (2005), Li and Mulligan (2005), Mohan et al. (2005, 2007), Damasceno et al. (2007), Oliveira et al. (2008), Bezerra et al. (2007) and Canto et al. (2008). One of the explanations is that the compositions of these wastewaters interfere directly with

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reactor stability and efficiency and may alter previously established critical parameters for a specific effluent, even when operational conditions are maintained.

The surfactant present in the wastewater used in this study was sodium lauryl sulfate, commonly used in shampoos. Works on anaerobic treatment of this surfactant are scarce in the literature. Most papers encountered deal with the treatment of linear alkylbenzene sulfonate (LAS).

Within this context the focus of this work was to assess the application of a mechanically stirred anaerobic sequencing batch reactor, containing granular biomass, in the treatment of an effluent from a personal care industry, containing large amounts of the surfactant of sodium lauryl sulfate. Reactor stability and efficiency were analyzed as a function of applied organic load defined by influent concentration and cycle length.

2. Materials and methods

2.1. Experimental set-up

The ASBR consisted of a 200-mm high acrylic column with outer diameter of 200 mm and wall thickness of 3.5 mm. The agitation system comprised a mechanical stirrer (150 rpm), three-blade helix impeller with diameter of 60 mm (distant 60 mm of the reactor bottom) and timer to turn off the agitation during the sedimentation and discharge steps and turn on during the feed and reaction steps. Diaphragm pumps were used in the feed and discharge steps also with the aid of timers. The experimental set-up used is illustrated in Fig. 1.

2.2. Inoculum

The inoculum came from an Up-flow Anaerobic Sludge Blanket (UASB) reactor treating wastewater from a poultry slaughterhouse, with total solids and total volatile solids of 49 and 42 g/L, respectively. About one liter of this inoculum was used in the ASBR, which means that the reactor contained 42 g TVS, since the liquid medium of the system was 2.0 L and biomass concentration was 21.4 g TVS/L.

The inoculum used was already in the form of granules (2.5 ± 0.3 mm) when obtained from the UASB reactor. The sludge presented total solids of 49 g/L and total volatile solids of 42 g/L, i.e. a relation of 86%, showing pronounced organic characteristic.

2.3. Industrial wastewater

The surfactant present in the wastewater used in this study was sodium lauryl sulfate. The wastewater was prepared by diluting a commercial shampoo and sodium bicarbonate in tap water. While shampoo concentration varied from one condition to the other, bicarbonate concentration was maintained at 200 mg/L. The amount of organic matter in the shampoo was experimentally estimated at 0.5 gCOD/g shampoo. The intention of this preparation was to simulate wash water from the reactors of a shampoo production unit of a personal care industry. Sodium bicarbonate was used to guarantee buffering of the system. Shampoo name, brand and manufacturer have been preserved.

In one of the experimental conditions, part of the wastewater was replaced by a synthetic medium (Sousa and Foresti, 1996) of equal concentration, consisting of sucrose (35 mg/L), soluble starch (114 mg/L), cellulose (34 mg/L), meat extract (208 mg/L), soybean oil (51 mg/L), commercial detergent (3 drops/L), NaCl (250 mg/L), $MgCl_2 \cdot 6H_2O$ (7 mg/L), $CaCl_2 \cdot H_2O$ (4.5 mg/L) and $NaHCO_3$ (200 mg/L). After mixing, the percentage COD of the reactor influent, attributed to the solids in suspension, dropped from 21 ± 1% to 18 ± 1%.

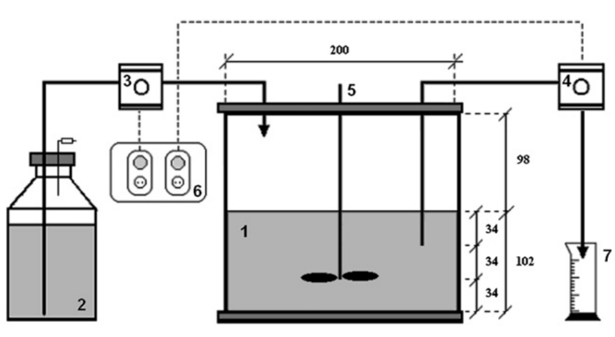

Fig. 1. Experimental set-up of the ASBR. Notation: 1. Reactor with granular biomass; 2. Wastewater reservoir; 3. Feed pump; 4. Discharge pump; 5. Mechanical stirrer; 6. Control unit; 7. Effluent outlet; 8. Biogas collect; — Hydraulic lines; ——— Power lines; dimensions in millimeters.

2.4. Experimental protocol

The ASBR was operated under six distinct batch conditions with cycles of 8 h (480 min), 12 h (720 min) and 24 h (1440 min), as listed in Table 1. Conditions 1, 2 and 3 were implemented with the same applied volumetric organic load (AVOL) of 0.75 gCOD/L.d, but varying influent concentration (C_I) and cycle length (t_C) as follows: 500 mgCOD/L and 8 h, 750 mgCOD/L and 12 h and 1500 mgCOD/L and 24 h. Under Conditions 4 and 5, AVOL was reduced to 0.50 and 0.25 gCOD/L.d, maintaining C_I at 500 mgCOD/L, but increasing t_C of 8–12 and 24 h, respectively. Finally, under Condition 6, AVOL of 0.75 gCOD/L.d was reset, with t_C of 8 h and C_I of 500 mgCOD/L and replacing 30% wastewater volume by synthetic medium.

At the beginning of each cycle the reactor was fed with a volume of 1.0 L wastewater in 10 min. The react step lasted 429, 669 and 1389 min, for the 8, 12 and 24-h cycle, respectively. Stirring frequency was 150 rpm and a three-blade helix impeller with diameter of 60 mm was used (Michelan et al., 2009), resulting in a negligible mixture time in relation to cycle length (Rodrigues et al., 2003). The stirring was performed during the whole react step. Biomass settling lasted 30 min. At the end of the cycle the effluent was discharged in 10 min. The total volume of reaction medium maintained in the reactor during each batch was 2.0 L. The reactor, as well as all experimental apparatus, was maintained in an isothermal chamber at 30 ± 1 °C. The sequential operation steps were controlled by timers: feed (turning on and off the feed pump), reaction, settle (turning on and off the agitation motor), and discharge (turning on and off the discharge pump).

2.5. Physicochemical analysis

Monitoring of the ASBR influent and effluent was performed in accordance with the Standard Methods for the Examination of Water and Wastewater (1995) and the following variables were determined: influent organic matter concentration (C_I) and organic

Table 1
Summary of the experimental conditions of the ASBR.

Condition	C_I (mgCOD/L)	AVOL (gCOD/L.d)	t_C (h)	Supplementation of synthetic medium
1	500	0.75	8	–
2	750	0.75	12	–
3	1500	0.75	24	–
4	500	0.50	12	–
5	500	0.25	24	–
6	500	0.75	8	0.30 v/v