Bioresource Technology 102 (2011) 889–893

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Effect of impeller type and stirring frequency on the behavior of an AnSBBR in the treatment of low-strength wastewater

Selma A. Cubas [a,*], Eugenio Foresti [b], José Alberto D. Rodrigues [c], Suzana M. Ratusznei [c], Marcelo Zaiat [b]

[a] Universidade Positivo, Rua Professor Pedro Viriato Parigot de Souza, 5300, CEP 81280-330, Curitiba, PR, Brazil
[b] Laboratório de Processos Biológicos (LPB), Departamento de Hidráulica e Saneamento, Escola de Engenharia de São Carlos (EESC), Universidade de São Paulo (USP), Engenharia Ambiental-Bloco 4-F, Av. João Dagnone, 1100, Santa Angelina, 13.563-120, São Carlos, SP, Brazil
[c] Escola de Engenharia Mauá – Instituto Mauá de Tecnologia (IMT), Praça Mauá 1, CEP 09.580-900, São Caetano do Sul, SP, Brazil

A R T I C L E   I N F O

Article history:
Received 4 May 2010
Received in revised form 21 July 2010
Accepted 18 August 2010
Available online 21 September 2010

Keywords:
Anaerobic reactor
Batch reactor
Immobilized biomass
Mass transfer
Impellers

A B S T R A C T

The influence of impeller type and stirring frequency on the performance of a mechanically stirred anaerobic sequencing batch reactor containing immobilized biomass on an inert support (AnSBBR – Anaerobic Sequencing Batch Biofilm Reactor) was evaluated. The biomass was immobilized on polyurethane foam cubes placed in a stainless-steel basket inside a glass cylinder. Each 8-h batch run consisted of three stages: feed (10 min), reaction (460 min) and discharge (10 min) at 30 °C. Experiments were performed with four impeller types, i.e., helical, flat-blade, inclined-blade and curved-blade turbines, at stirring frequencies ranging from 100 to 1100 rpm. Synthetic wastewater was used in all experiments with an organic-matter concentration of 530 ± 37 mg/L measured as chemical oxygen demand (COD). The reactor achieved an organic-matter removal efficiency of around 87% under all investigated conditions. Analysis of the four impeller types and the investigated stirring frequencies showed that mass transfer in the liquid phase was affected not only by the applied stirring frequency but also by the agitation mode imposed by each impeller type. The best reactor performance at all stirring frequencies was obtained when agitation was provided by the flat-blade turbine impeller.

1. Introduction

Novel configurations of anaerobic reactors have been investigated for a variety of applications, such as the treatment of different industrial and domestic wastewaters, with a focus on the potential use of anaerobic processes and maximization of their practical application (Zaiat et al., 2001; Rodrigues et al., 2006). All modern configurations are designed to attempt to meet the requirements essential for achieving good treatment efficiency, practical applicability and operational simplicity. These requirements have been met by improving contact between the biomass and the material to be degraded and by retaining a large amount of the biomass in the system.

These configurations include discontinuous anaerobic reactors, or anaerobic sequencing batch reactors (AnSBR – Anaerobic Sequencing Batch Biofilm Reactor), which have been employed by researchers in several applications. This reactor configuration was designed as an alternative to continuous systems to provide improved solids retention, improved process control and easier operation (Canto et al., 2008).

The operation of anaerobic sequencing batch reactors comprises four stages: feed, reaction, decanting and discharge (Sung and Dague, 1995). However, despite the advantages over continuous reactors provided by the intrinsic characteristics of the system, many fundamental and operational aspects remain to be investigated to enable full-scale application, especially for the treatment of low-strength wastes, such as domestic wastewater. Some of the main drawbacks of this configuration include the long operation time required to accomplish autoimmobilization of the biomass in the form of granules or flocks and the decanting time of the autoimmobilized biomass, which further lengthens the total batch time and affects the final quality of the treated effluent.

To overcome some of these drawbacks, Ratusznei et al. (2000) proposed a new configuration for an anaerobic sequencing batch reactor that included immobilized biomass and mechanical stirring to treat low-strength wastewater (AnSBBR). In this reactor, the biomass adheres to an inert support, in this case a polyurethane foam, and mixing is promoted by mechanical stirrers to improve mass transfer, which is fundamental in anaerobic systems using inert material for biomass adherence. Moreover, the utilization of polyurethane foam as a support for immobilization of the biomass promoted good solids retention in the reactor and eliminated the decanting step, which reduced the cycle length and resulted in good organic-matter removal efficiency. However, the utilization

* Corresponding author. Tel.: +55 41 3317 3277; fax: +55 41 3317 3082.
E-mail address: selmacubas@up.edu.br (S.A. Cubas).

0960-8524/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biortech.2010.08.128

of immobilized biomass on an inert support evidenced the need for studies regarding aspects related to mass transfer (both solid and liquid phase), including investigations on the effect of agitation on the performance and stability of these bioreactors (Harnby et al., 1997; Nienow, 1998; Vrábel et al., 1998).

Cubas et al. (2007) assessed solid-phase mass transfer using polyurethane foam cubes ranging in size from 0.5 to 3.0 cm and concluded that effluent quality improved with decreasing bioparticle size as a consequence of the decrease in solid-phase mass-transfer resistance. Improvement in liquid-phase mass transfer through mechanical agitation was observed by Cubas et al. (2004), who concluded that the reactor performance and cycle length required for each batch were directly affected by liquid-phase mass transfer. Pinho et al. (2004) showed that stirring in sequencing batch reactors, in addition to promoting mixing in the reactor, increases solid-phase mass transfer and the solubilization of particulate organic matter. Damasceno et al. (2008) and Michelan et al. (2009) both noted that improvement in homogenization, liquid flow and solid–liquid mass transfer were directly related to the type of impeller used.

Although prior authors have evaluated the influence of impeller type in mechanically stirred AnSBBR (Pinho et al., 2006; Michelan et al., 2009; Novaes et al., 2010), no conclusive results have been obtained for low-strength wastewater, and fundamental studies in bench-scale reactors are still required for a deeper understanding of such influence.

In this context, this paper reports on the influence of four types of impellers providing axial and radial agitation at different stirring frequencies on the performance of a mechanically stirred anaerobic sequencing batch reactor containing immobilized biomass on an inert support (AnSBBR) applied to the treatment of a low-strength synthetic wastewater.

2. Methods

2.1. Experimental setup

The bench-scale AnSBBR (Fig. 1) consisted of a glass flask with a total capacity of 5 L. The biomass was immobilized on polyurethane foam particles arranged in an 18-cm high perforated basket with a diameter of 22 cm. Mixing was performed by three impellers, each with a diameter of 3 cm, that were vertically spaced 4 cm apart. The reactor was encased in a water jacket to maintain a constant temperature of 30 ± 1 °C throughout the experiment. Feed and discharge steps were performed with two diaphragm pumps equipped with automatic timers.

2.2. Inoculum and inert support

The sludge used as inoculum came from an upflow anaerobic sludge-blanket reactor that treated wastewater from a poultry slaughterhouse. The immobilization procedure was performed in accordance with the methodology proposed by Zaiat et al. (1994). Approximately 4 L of sludge and 45 g of dry foam were uniformly mixed and maintained for a period of about 12 h to promote adhesion of the biomass. The biomass was immobilized on 1-cm polyurethane foam cubes with an apparent density of 23 kg/m^3, a surface area of 43.8 g/m^2 and a porosity of 95%.

2.3. Synthetic wastewater

All experiments used a low-strength synthetic wastewater containing readily and barely degradable carbohydrates, which were composed of sucrose (35 mg/L), starch (114 mg/L), cellulose (34 mg/L), meat extract (208 mg/L), soybean oil (51 mg/L), NaCl (250 mg/L), $MgCl_2{\cdot}6H_2O$ (7 mg/L), $CaCl_2{\cdot}2H_2O$ (4.5 mg/L), $NaHCO_3$ (200 mg/L), and a commercial detergent for emulsification of soybean oil (three drops/L). Organic-matter concentration in unfiltered samples of the synthetic wastewater was 521 ± 36 mg/L measured as chemical oxygen demand (COD). The total volatile acid concentration was 34 ± 10 mg HAc/L, and the bicarbonate alkalinity was 124 ± 19 mg $CaCO_3$/L. Finally, the pH was between 6.5 and 7.5.

2.4. Experimental procedure

Four impeller types were used (Fig. 2): a helix with three blades, a turbine with four flat blades, a turbine with four inclined blades and a turbine with four curved blades. The agitation frequencies studied were 100, 300, 500, 700, 900 and 1100 rpm. Experiments

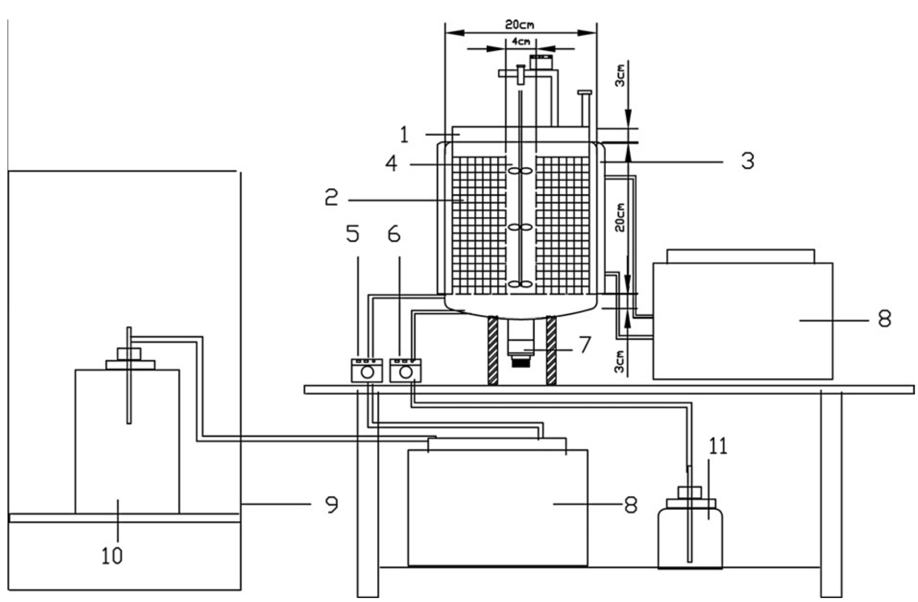

Fig. 1. Experimental setup. (1) Reaction vessel; (2) Basket containing immobilized biomass; (3) Heating jacket; (4) Mechanical stirrer; (5) Diaphragm feed pump; (6) Diaphragm discharge pump; (7) Sludge discharge; (8) BTC-9090 ultrathermostatic bath; (9) Refrigerator; (10) Substrate; (11) Effluent.