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Nitrogen and sulfide removal from effluent of UASB reactor in a sequencing fed-batch biofilm reactor under intermittent aeration

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ABSTRACT

Simultaneous nitrification/denitrification (SND) coupled with sulfide oxidation may be suitable for the post treatment of effluents from anaerobic reactors. These effluents contain ammonium, which must be nitrified, and sulfide, which could be used as an endogenous electron donor for autotrophic denitrification. The SND process occurred in a sequencing fed-batch biofilm reactor of 8 h cycles, operated under intermittent aeration. The effect of the start-up period and the feeding strategy were evaluated. The previous establishment of nitrification process with subsequent application of sulfide in low concentrations was the best start-up strategy to enable the occurrence of SDN. The fed-batch mode with sulfide application in excess only in the anoxic periods was the best feeding strategy, providing average efficiencies of 85.7% and 53.0% for nitrification and denitrification, respectively. However, the low overall nitrogen removal efficiency and some operational constraints indicated that autotrophic denitrification using sulfide in a single SBR was not suitable for SND under the assayed conditions.

1. Introduction

Biological nitrogen removal in wastewater treatment plants is conventionally achieved in two separate steps: autotrophic nitrification followed by heterotrophic denitrification. However, some studies on single step nitrogen removal, called simultaneous nitrification/denitrification (SND), have been carried out in order to optimize treatment systems. Compared to conventional systems, the costs could also be reduced (Yoo et al., 1999; Canto et al., 2008). In this process, nitrification and denitrification occur concurrently in the same reactor. The advantages of this single step SND process over the conventional two steps process are already known. The space and aeration requirements, and the time necessary to complete nitrification and denitrification reactions are lower if SND is successfully applied (Münch et al., 1996; Yoo et al., 1999).

Sequencing batch reactors (SBR) are normally used to promote the SND process (Mace and Mata-Alvarez, 2002). Basically, they are operated in sequential cycles composed of four stages: feeding, reaction, settling and liquid withdrawal. However, some operational strategies have been studied in order to optimize the performance of these reactors, such as modifications in the feeding mode, the use of immobilized biomass and the application of intermittent aeration (Chen et al., 2000; Ratusznei et al., 2003; Canto et al., 2008). The fed-batch mode is an alternative to keep the substrate concentration in low levels inside the reactor, so that the feeding stage has a longer period than that conventionally adopted. This strategy can improve the electron donors' distribution and, because of dilution, it can also avoid inhibition by the substrate (Tilche et al., 1999; Poo et al., 2004). On the other hand, the use of immobilized biomass on inert support allows the elimination of the settling step and the reduction of the overall cycle time. Additionally, biomass losses are normally very low, resulting in high cellular retention times. According to Pochana and Keller (1999), the SND activity increases in reactors containing large sludge flocs. Thus, this technology seems to be especially advantageous in systems containing immobilized cells. Limitations of oxygen diffusion into the biofilm lead to anoxic conditions in its inner parts, favoring denitrification in this region, while nitrification occurs on the aerated surface of flocs.

Considering the occurrence of denitrification inside the flocs, the SBR for nitrogen removal can be operated under aerated conditions during all periods (Chen et al., 2000). However, the total nitrogen removal efficiency may not be acceptable. This way, the application of intermittent aeration can improve the nitrogen removal efficiency, by incorporating an anoxic period for denitrification. During the period of non-aeration, the reactor operates essentially as an anoxic reactor. In this period, a depletion of dissolved oxygen (DO) concentration occurs so that the concentration of oxidized forms of nitrogen decreases and the concentration of ammonium increases. In the subsequent aeration period, ammonium is oxidized to nitrate or nitrite. The specific times for aeration and

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non-aeration are essential to the performance of the treatment system.

By targeting the post treatment of effluents from anaerobic reactors, the use of conventional heterotrophic denitrification is disadvantageous due to the low concentration of organic matter in this type of wastewater. Therefore, the application of this process would require the addition of organic electron donors for denitrification. An innovative alternative is the use of sulfide as electron donor for autotrophic denitrification because this compound is commonly present in the effluent of anaerobic reactors. Moreover, such effluents contain ammonium that needs to be oxidized prior to the denitrification step. Thus, the SND process using sulfide for autotrophic denitrification seems to be a viable solution for nitrogen and sulfide removal of effluents from anaerobic reactors. Although there are promising studies on sulfide-oxidizing autotrophic denitrification, this process has not been well described and understood yet (Beristain-Cardoso et al., 2006; Mahmood et al., 2007a; Cervantes et al., 2009; Moraes et al., 2011), especially when associated with SND (Pérez et al., 2007).

According to Moraes et al. (2011), the final products of autotrophic denitrification are influenced by sulfide concentration in the wastewater. When sulfide concentration is in excess to the stoichiometrically required (N/S molar ratio of 1.6 for denitrification via nitrate, and 2.7 for denitrification via nitrite), sulfide oxidation tends to occur partially with the formation of elemental sulfur. In contrast, when sulfide concentration is equivalent to the stoichiometric requirement, complete oxidation to sulfate takes place. Other authors also observed this behavior (Krishnakumar and Manilal, 1999; Beristain-Cardoso et al., 2006; Moraes et al., 2011). Regarding sulfide concentration in effluents from anaerobic reactors, it is dependent on wastewater characteristics. Therefore, the amount of sulfide generated in the anaerobic treatment of domestic sewage is expected to vary according to the composition of this type of wastewater, which is variable according to the socio-economic habits of the contributor population. Thus, the range of sulfide concentration present in the influent may drive different behaviors inside reactors applied to autotrophic denitrification.

This study investigated the feasibility of SND coupled to sulfide oxidation in a sequencing fed-batch biofilm reactor intermittently aerated for the post treatment of effluent from an upflow anaerobic sludge blanket (UASB) reactor. The main objective of the investigation was to evaluate two start-up alternatives and feeding strategies for the establishment of nitrification and denitrification.

2. Methods

2.1. Sequencing fed-batch biofilm reactor

The nitrifying/denitrifying reactor, with a total volume of 7.5 L, was made of borosilicate glass and equipped with a mechanical stirrer composed of two radial flow-impeller turbines of 3.0 cm diameter. A perforated stainless steel basket was allocated inside the reactor to support the biomass immobilized on cubic matrices of polyurethane foam. The basket was in the form of a hollow cylinder and its central region accommodated a shaft for the stirrer. At the top of the reactor, two perforated pipes with 2.0 cm internal diameter were allocated to support micro-sensors for dissolved oxygen (DO) and redox potential (ORP) measurements. These micro-sensors were constructed specifically for the use in the present reactor. They were composed of a sensitive tip of 10–30 μm in diameter, which was supported by a small glass bar (3 mm in diameter and 7 cm long). The micro-sensors were connected to a data acquisition block coupled to a computer. The monitoring data were obtained using software developed by T&S Electronic Equipments. At the bottom of the reactor, porous stones were placed for air dispersion. Aeration was provided by an aquarium air pump. Two pumps were used for filling and discharging the liquid: a peristaltic pump and a diaphragm pump, respectively. The experimental setup is presented in Fig. 1.

2.2. Feed composition and inoculum

The reactor was fed with effluent from an UASB reactor treating synthetic substrate simulating domestic sewage. This effluent was

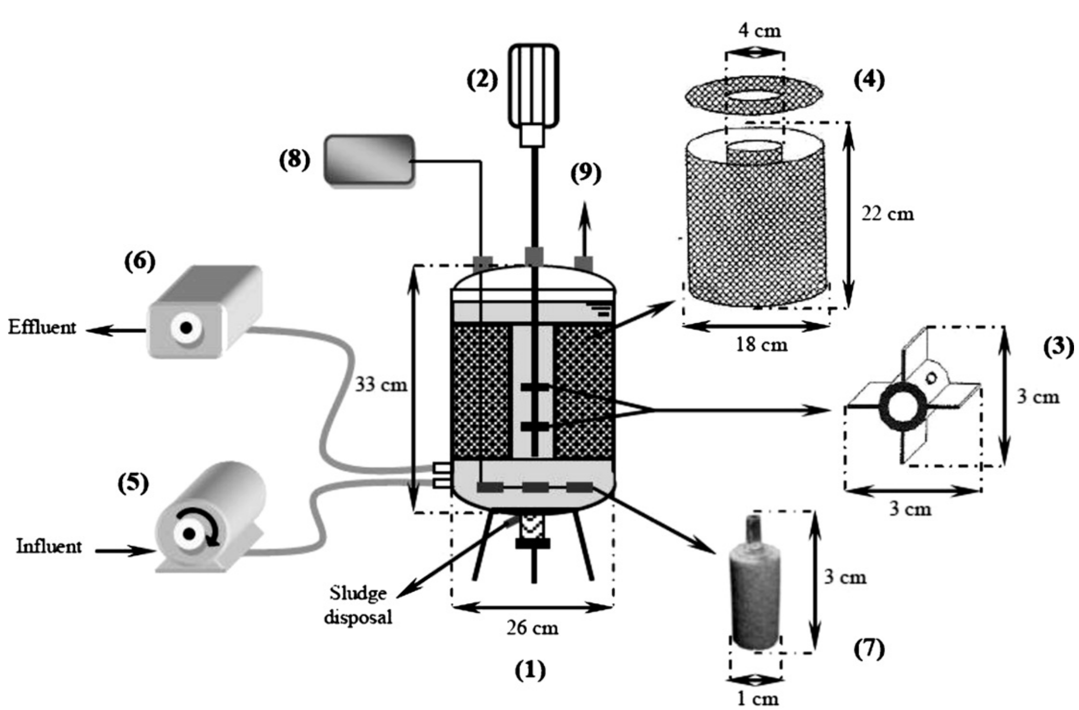

Fig. 1. Schematic representation of the experimental setup: (1) cross-sectional view of the nitrifying/denitrifying reactor operated in fed-batch mode; (2) mechanical stirrer; (3) turbine impeller; (4) stainless steel basket; (5) peristaltic pump-feeding; (6) diaphragm pump-discharge; (7) porous stone; (8) aquarium air pump; (9) entry for micro-sensors.