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Anaerobic sequencing batch biofilm reactor applied to automobile industry wastewater treatment: Volumetric loading rate and feed strategy effects

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Abstract

This paper presents a technological viability study of wastewater treatment in an automobile industry by an anaerobic sequencing batch biofilm reactor containing immobilized biomass (AnSBBR) with a draft tube. The reactor was operated in 8-h cycles, with agitation of 400 rpm, at 30 °C and treating 2.0 L wastewater per cycle. Initially the efficiency and stability of the reactor were studied when supplied with nutrients and alkalinity. Removal efficiency of 88% was obtained at volumetric loading rate (VLR) of 3.09 mg COD/L day. When VLR was increased to 6.19 mg COD/L day the system presented stable operation with reduction in efficiency of 71%. In a second stage the AnSBBR was operated treating wastewater *in natura*, i.e., without nutrients supplementation, only with alkalinity, thereby changing feed strategy. The first strategy consisted in feeding 2.0 L batch wise (10 min), the second in feeding 1.0 L of influent batch wise (10 min) and an additional 1.0 L fed-batch wise (4 h), both dewatering 2.0 L of the effluent in 10 min. The third one maintained 1.0 L of treated effluent in the reactor, without discharging, and 1.0 L of influent was fed fed-batch wise (4 h) with dewatering 1.0 L of the effluent in 10 min. For all implemented strategies (VLR of 1.40, 2.57 and 2.61 mg COD/L day) the system presented stability and removal efficiency of approximately 80%. These results show that the AnSBBR presents operational flexibility, as the influent can be fed according to industry availability. In industrial processes this is a considerable advantage, as the influent may be prone to variations. Moreover, for all the investigated conditions the kinetic parameters were obtained from fitting a first-order model to the profiles of organic matter, total volatile acids and methane concentrations. Analysis of the kinetic parameters showed that the best strategy is feeding 1.0 L of influent batchwise (10 min) and 1.0 L fed-batch wise (4 h) in 8-h cycle.

Keywords: Automobile industry; AnSBBR; Organic load; Nutrient supplementation; Anaerobic treatment

1. Introduction

The anaerobic sequencing batch reactor (ASBR) has received much attention in recent years, mainly in industrial wastewater treatment. Compared to similar continuous reactors a larger useful volume for the treatment is generally required; however it does away with the use of a separated sedimentation, [1,2].

Currently, this kind of reactor using granulated biomass is applied to the treatment of high strength wastewater, such as beverage and dairy industry effluents, landfill leachate and intensive swine breeding wastes. Li and Mulligan [3] treating beer wastewater in a 2-L ASBR, containing granulated biomass, obtained COD reduction between 80 and 90% for organic loads between 2 and 10 kg COD/m^3 day and below 80% for organic loads between 10 and 20 kg COD/m^3 day with improved efficiency at 35 °C. Timur and Özturk [4] treated landfill leachate using a 2-L ASBR at 35 °C. During the study assays were performed with volumetric loading rate (VLR) of 0.4–9.4 g COD/L day and specific organic loads of 0.2–1.9 g COD/g VSS day, and hydraulic retention times varied from 1.5 to 10 days for influent concentrations of 3.8–15.9 g COD/L. The COD conversion efficiency changes ranged from 64 to 85% depending on applied organic load. Massé et al. [5] used an ASBR, without agitation, for treating piggery wastewater at psychrophilic temperatures (20 °C), with organic loads of 0.7–1.2 g COD/L day. The reactor was efficient in retaining the biomass and attained 73% of total organic mat-

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ter removal (as COD). Ruiz et al. [6] on using ASBR in treating winery effluent and operating with VLR of 8.6 g COD/L day and SOL of 0.96 g COD/g TVS day reported organic matter removal efficiency exceeding 98% for a hydraulic retention time of 2.2 days. Ndegwa et al. [7] using a 12-L ASBR with sludge circulation (500 mL/min) to treat dilute swine slurries at temperatures of 20 and 35 °C, on investigating COD reduction and biogas production interaction, obtained COD reduction of 90 and 84% for hydraulic times of 7.2 and 9.1 days, respectively.

Another investigation theme currently encountered in the literature focuses on the type of biomass used, namely granular biomass (ASBR) and immobilized biomass (AnSBBR, anaerobic sequencing batch biofilm reactor) on inert support as a means to improve solids retention, but which may be detrimental to mass transfer in the system. Siman et al. [8] investigated the performance of a mechanically stirred AnSBBR kept at 30 °C which contained immobilized microorganisms on polyurethane foam cubes and was submitted to increasing organic load using wastewater based on lipid/carbohydrate/protein. VLRs used ranged from 1.5 to 6.0 g COD/L day on feeding a 5.4-L reactor with 2 L synthetic influent of 500–2000 mg COD/L in 8 and 12 h batches. The system presented total volatile acids accumulation when submitted to a VLR of 5.4 g COD/L day (2000 mg COD/L and 8-h batch) and filtered sample removal efficiency of 55%. For the remaining conditions filtered sample removal efficiencies were between 73 and 83%. Chebel et al. [9] studied the effect of increasing organic load on the behavior of a mechanically stirred ASBR, which contained granulated biomass and treated synthetic wastewater. The reactor was fed with 2 L synthetic wastewater with 500–4000 mg COD/L in 8 and 12-h cycles, and VLR varied from 0.6 to 3.2 g COD/L day. The reactor presented stability with filtered samples removal efficiencies between 84 and 88% at 500–2000 mg COD/L in 8 and 12-h cycles. System efficiency did not vary when the influent concentration was maintained and cycle time was increased. For concentration of 3000 mg COD/L the system presented total volatile acids accumulation and filtered samples removal efficiencies of 77%. Kennedy et al. [10] used an ASBR to treat wastewater containing sucrose, acetic acid, some salts and meat extract. On applying organic loads varying from 2.5 to 18.5 g COD/L day removal efficiencies in terms of COD were obtained from 35 to 97% depending on the strategy used, which consisted in varying the feed to reaction ratios (F/R) of the reactor. Low F/R ratios (0.2–0.5) significantly reduced efficiency at high organic loads (9 g COD/L day). The authors mentioned that the specific organic load, based on the feed period, might be a critical design parameter of an anaerobic sequencing batch reactor.

Nowadays application of the AnSBBR is increasing. Mohan et al. [11] studied the bioaugmentation of an AnSBBR with alginate-immobilized sulfate reducing bacteria applied to sulfate bearing treatment. The reactor with non-augmented biomass showed 35% of COD removal efficiency and 27% of sulfate reduction, and volatile acids accumulation occurred. After bioaugmentation the reactor performance improved and COD removal attained 78% and sulfate reduction 80% with concomitant increase in biogas and reduction in volatile acids. The microbial diversity distribution was also seen to improve with the presence of methanogenic, sulfate reduction and acetogenic bacteria. Mohan et al. [12] used an AnSBBR to treat hypersaline and low biodegradable wastewater to investigate the influence of recirculation on reactor performance. The reactor presented improvement in substrate removal efficiency with a maximum of 51% and after introducing recirculation to the system a biogas yield of 0.023 m/h, due to the improved mass transfer between the substrate present in the bulk liquid and the attached biofilm.

The way the reactor is fed, i.e., batch or fed-batch wise, has also been studied to make fill time more flexible as a function of variable influent availability, as well as optimization of reactor performance with high strength influents. Ratusznei et al. [13] studied the behavior of a fed-batch operated anaerobic reactor, which contained immobilized biomass on polyurethane foam and was kept at 30 °C with agitation to treat 0.5 L synthetic wastewater with 500 mg COD/L in 3-h cycles. The reactor was fed-batch wise for 3 min and fed-batch wise for 30, 60 and 180 min. In the batch assays filtered samples organic matter removal efficiency attained 86%. In the fed-batch systems, on the other hand, operational stability was only reached in the 30-min cycle; whereas in the other cycles a considerable amount of extracellular polymers (ECP) was formed which hindered efficient contact between biomass and substrate. The drop in efficiency drew the attention of the researchers to the fact that the biomass bed should always be kept immersed in the wastewater to prevent biopolymer formation. Orra et al. [14] also evaluated the influence of distinct feeding strategies on the performance of an anaerobic reactor operated in batch and fed-batch modes with external recirculation of the liquid phase, treating 890 mL of influent in 6-h cycles. The removal efficiency for filtered samples decreased from 85 to 81% when load time was increased from 6 to 360 min. Despite this fact, organic matter concentrations presented small modification throughout the operation with increasing feed time, indicating the fed-batch strategy renders stability to the system. Formation of biopolymers also occurred during reactor operation, however without compromising system stability and efficiency. Damasceno et al. [15], treating cheese whey in AnSBBR, evaluated the effect of VLR and feeding strategy on reactor stability and performance. The applied VLR were 2, 4, 8 and 12 g COD/L day for feeding times of 10, 120 and 240 min, while the supply of bicarbonate alkalinity (BA) remained 50% of the $NaHCO_3$/COD mass ratio. Best results were obtained when applied VLR was 2–4 g COD/L day at feeding time of 20 min. For VLR of 8 and 12 g COD/L day feeding time of 240 min presented the best results.

The objective of this paper was to investigate the technological viability of treating wastewater from an automobile industry in a mechanically stirred anaerobic sequencing batch reactor containing immobilized biomass (AnSBBR) and equipped with a draft tube. The experimental protocol investigated first the effect of increasing organic load in order to quantify the effect of influent concentration as well as the effect of nutrients and alkalinity supplementation on performance. Second, the effect of applying different feeding strategies was investigated, i.e., filling time, on system stability and efficiency in order to quantify system flexibility when influent availability fluctuates, as frequently occurs in the industry.