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Granule development and performance in sucrose fed anaerobic baffled reactors

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Abstract

Two 90 L anaerobic baffled reactors were used to study the granulation of sludge and the effect of the organic loading rate and $NaHCO_3$/COD ratios on reactor performance. Furthermore, it was determined whether an anaerobic baffled reactor would promote phase separation and if additive of bentonite or granular active carbon was capable of enhancing granule formation. In order to minimize feed variations, and have a totally biodegradable substrate, a synthetic sucrose substrate was used. Granulation was achieved in both reactors within 75 days. However, the granules from the granular active carbon amended reactor appeared earlier and were larger and more compact. The reactors were maintained at a hydraulic retention time of 20 h during performance study stage. The results showed that when organic loading rate were changed from 2.15 to 6.29 kg COD m^{-3} day^{-1}, chemical oxygen demand (COD) removal was not decreased (91–93%), but a slight increase in effluent COD was observed. It was found that the COD removals were generally good (87–92%) and had not obviously change with the decreasing $NaHCO_3$/COD ratios. From the bacterial distribution and the concentration of volatile fatty acids in four compartments, it was concluded that a separation of phases occurred within the anaerobic baffled reactors.

Keywords: Anaerobic baffled reactor; Granulation of sludge; Performance; Organic loading rate; $NaHCO_3$/COD ratios

1. Introduction

The anaerobic baffled reactor (ABR) is one of the many types of high-rate anaerobic reactors and able to separate hydraulic retention time (HRT) from solid retention time (SRT). This allows anaerobic microorganism to remain within the reactor and produces higher volumetric loads and significantly enhanced removal efficiencies.

The ABR was initially developed by McCarty and co-workers at Stanford University. In the ABR, a series of vertical baffles forces the wastewater to flow under and over them as it passes from inlet to outlet. This configuration has been shown to result in a high degree

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of chemical oxygen demand (COD) removal at high organic loading rate (OLR) (Grobicki and Stuckey, 1991; Uyanik et al., 2002). The main advantage of using an ABR comes from its compartmentalized structure. This leads to separating acidogenesis and methanogenesis longitudinally down the reactor, allowing the different bacterial groups to develop under most favorable conditions. This characteristic is similar to two-phase digestion process. A number of advantages of the two-phase digestion process have been summarized in the literature (Jeyaseelan and Matsuo, 1995; Bhattacharya et al., 1996; Ince, 1998).

Granulation is a complex process, in which suspended biomass agglutinates to form discrete macroscopic aggregates. This enhances the settleability of the biomass and leads to an effective retention of bacteria in the reactor. It is widely assumed that granular biomass have operational advantages over the use of flocculent biomass (Wirtz and Dague, 1996; Pereboom, 1997; Batstone and Keller, 2001). The most significant advantage of granulation is high biomass concentration in continuous reactors, and then high treatment efficiencies can be expected. Upflow anaerobic sludge blanket (UASB) reactors are generally considered to be the best design for promoting granulation. The ABR may be classified as a series of UASB reactors. So, the ABR has shown the potential to produce granular sludge (Barber and Stuckey, 1999).

The objectives of this study were: (1) to examine effects with addition of granular active carbon (GAC) or bentonite and polyacrylamide on the granulation of sludge in ABR; (2) to investigate the performance of ABR during various OLR and (3) to investigate the performance of ABR at different $NaHCO_3$/COD ratios in influent. In order to achieve these goals, two ABRs having identical dimensions and configurations were used.

2. Materials and methods

2.1. The reactors

The ABRs were made of clear acrylic plastic with total effective volume of 90 L. Every reactor contained three vertical standing baffles that divided it into four identical compartments (as shown schematically in Fig. 1). Within each compartment, downcomer and riser regions were created by a further slanted edge (45°) vertical baffle in order to direct the flow evenly through the riser. The width of the downcomer was 6 cm and the riser was 17 cm. Each compartment was equipped with sampling ports that allowed biological solids and liquid samples to be withdrawn. The influent was feed from troughs in higher position and rotameters were used to control the influent feed rate to the ABR. The temperature of influent water in the troughs was heated to about 50 °C in order to maintain the operating temperature of the first compartment at constant 34 °C. The produced gas was collected via portholes in the top of the reactors and was recorded by wet gas meters.

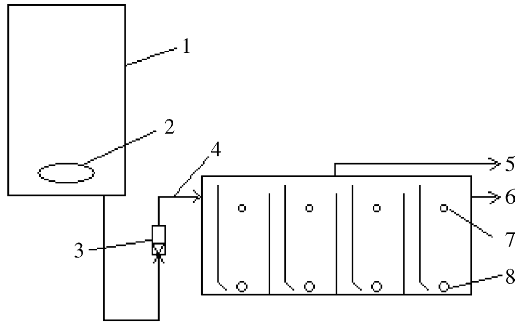

Fig. 1. Schematic diagram of ABR. 1, Feed tank; 2, heater; 3, rotameter; 4, influent; 5, gas collection; 6, effluent; 7, supernatant sampling port; 8, sludge sampling port.

2.2. Sampling and analyses

Supernatant liquor and sludge samples were taken separately from each compartment for analysis to characterise the behaviour of the reactors. Analysis of supernatant liquor included COD, pH, temperature, alkalinity and volatile fatty acids (VFA). COD, pH and temperature were monitored every day. Alkalinity and VFA were analysed weekly. COD and pH of the influent and effluent were analysed every day, too. Analysis of sludge samples included suspended solids (SS), volatile suspended solids (VSS) and particle size distribution at the end of every stage. COD, SS, VSS, pH, VFA and alkalinity were determined as described in *Standard Methods for Examination of Water and Wastewater* published by American Public Health Association (1995).