Settleability assessment protocol for anaerobic granular sludge and its application

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Abstract

A simple method for settleability assessment of anaerobic granular sludge was proposed and its applicability as an operating parameter was evaluated in a lab-scale UASB reactor treating brewery wastewater. Based on the settleability protocol, the OLR was increased up to 28 kg COD·m^{-3}·d^{-1} (67 kg COD·m^{-3} of granular bed volume·d^{-1}) which corresponds to an HRT of 1 h. The results revealed that the protocol was sufficiently sensitive to define the settleability of the sludge samples and to accurately determine their allowable upflow velocities, resultant organic loading rates, and recycling ratios according to the settleability of the granular bed. Also, a series of graphical procedures with settling tests which are very easy to apply for settleability monitoring was improvised, capable of direct use as an operational and monitoring parameter of the granular bed with laboratory and full-scale reactors, without need for additional sludge bed control such as dosing of chemicals. In addition, this method was also found to be applicable to improve and monitor system performance according to high or low-strength wastewater characteristics. Image analysis of the granular biomass supported the suitability of this graphical method.

Keywords: brewery wastewater, granular sludge, recycling, settleability, UASB, upflow velocity

Introduction

During the past two decades anaerobic wastewater treatment biotechnology was extensively advanced by the development of the innovative upflow sludge bed (USB) type reactor concepts such as upflow anaerobic sludge bed (UASB), anaerobic baffled reactor (ABR), upflow anaerobic solids removal (UASR), hydrolysis upflow sludge bed (HUSB), upflow acidogenic substrate precipitating (UASP), elutriated phased reactor (EPR) as well as expanded granular sludge bed (EGSB) (Bachman et al., 1985; Kim et al., 2001; Lettinga et al., 1997; Zeeman et al., 1997). The success of these anaerobic systems is related to their capacity for accumulation of good settling biomass without the need of a biomass carrier, allowing high solids retention time and process stability with simple and low-cost equipment.

There is a need for an improved settleability monitoring technique that is simple, requires low labour, and is economical, which can directly be used as an operational and monitoring parameter for laboratory and full-scale research. In addition, an assessment of settleability to evaluate the adequate operating upflow velocity as well as the stability of the sludge bed is needed. Restocking granules to replenish those lost due to excessive granular sludge washout is a common problem in higher rate UASB systems (Stover, 2000). The application of a technique to measure operating upflow velocity, particularly in higher rate conditions, would result in production and maintenance of well-defined and densely structured granular sludge as well as enhancement of system performance.

Various direct and indirect methods to quantify the physical characteristics of the anaerobic granular sludge in terms of the size, density, strength and settleability have been presented. Direct granular particle size analysis was performed manually with a portion graticule/lattice ruler (Hulshoff Pol, 1989) or wet sieving using phosphate buffer solution or tap water (Laguna et al., 1999), by automatically using image analysis and computerised data processing (Dudley et al., 1993) and by particle size analysis using a laser (Yan and Tay, 1997). The strength of granules was measured in several studies by examining the effects of shear force, sonication, shaking of the granules, or turbidity (Teo et al., 2000; Quarmby and Forster, 1995; Tramper et al., 1984). Indirect granular sludge density analysis was performed by the measurement of the settling velocities of a sludge sample to extrapolate the corresponding diameters (Hulshoff Pol, 1989; Grotenhuis et al., 1991) or sludge volume index (SVI) (Ahn, 2000; Cuervo-López et al., 1999; Yan and Tay, 1997), and by a settleability profile analysis using an upflow-type settling column (Ahn, 2000; Andras et al., 1989; Moosbrugger, 1994). Unfortunately these methods have several disadvantages in application and cost requirement. Also these methods can only be used to test the sludge particle size distribution and sludge settleability. None can be used directly as an operational parameter in laboratory or full-scale systems to determine the allowable upflow velocity of the anaerobic granular sludge in USB-type reactors.

The purpose of this research is to introduce a settleability assessment protocol for determining the allowable operating upflow velocities of high-rate UASB reactors, and to evaluate its applicability as an operational parameter in laboratory-scale reactors. To assess the suitability of this method, image analysis of each sample was performed, using computerised data processing.

Materials and methods

Settleability assessment protocol

Settling test apparatus

Figure 1 depicts the settling device with a vertical glass tube (effective size: 20 mm diameter and 300 mm height) followed by

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