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Digestion and dewatering characteristics of waste activated sludge treated by an anaerobic biofilm system

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HIGHLIGHTS

- Filler enhance conversion rates of sludge digestion.
- Pre-incubated filler improve dewaterability of digested sludge.
- Filler alone do not improve dewaterability of digested sludge.

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ABSTRACT

Immobilization of microorganisms for sludge anaerobic digestion was investigated in this study. The effects of filler properties on anaerobic digestion and dewaterability of waste activated sludge were assessed at mesophilic temperature in batch mode. The results showed that the duration of the methanogenic stage of reactors without filler, with only filler, and with pre-incubated filler was 39 days, 19 days and 13 days, respectively, during which time the protein was degraded by 45.0%, 29.4% and 30.0%, and the corresponding methane yield was 193.9, 107.2 and 108.2 mL/g volatile suspended solids added, respectively. On day 39, the final protein degradation efficiency of the three reactors was 45.0%, 40.9% and 42.0%, respectively. The results of normalized capillary suction time and specific resistance to filtration suggested that the reactor incorporating pre-incubated filler could improve the dewaterability of digested sludge, while the effect of the reactor incorporating only filler on sludge dewaterability was uncertain.

1. Introduction

Owing to the high content of water and putrescible organic matter, waste activated sludge (WAS) generated from wastewater treatment plants must undergo some treatment to enhance its stability and reduce its corresponding volumes prior to final disposal.

WAS treatment via anaerobic digestion (AD) results in a reduction of the sludge solids amount and a decrease in odor while produce methane (Duan et al., 2012; Young et al., 2013). Nevertheless, a long hydraulic retention time (HRT) is needed for sludge anaerobic digestion.

Immobilization of microorganism can decrease the possibility of microbe losses, prolong solids retention times (SRT), benefit the formation and maintenance of preponderant organism morphology, since large amounts of high-activity biomass are intercepted in biological treatment systems (Wang et al., 2010). Until recently, microorganism immobilization in anaerobic digester has mainly focused on liquid wastewater with low content of suspended solids (Ozgun et al., 2013). Anaerobic granulation and anaerobic filler biofilms are the main methods for microorganism immobilization (Wang et al., 2010). Comparatively, microorganism immobilization has seldom been investigated and applied to waste with high content of suspended solids owing to strict operating and separating condition.

Wang et al. (2010) incorporated polyurethane foam matrices into an anaerobic sequencing batch reactor for the treatment of thermally hydrolyzed municipal biowaste (food waste, fruit–vegetable waste and dewatered sewage sludge), expecting to provide an adequate environment for microbe growth and retention, and to increase the possibility of high-efficiency anaerobic conversion. Gong et al. (2011) incorporated activated carbon fiber into an anaerobic reactor for treatment of cattle manure and obtained higher biogas and methane production than a control blank reactor

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over the long term. Romano and Zhang (2008) incorporated polyethylene cylinders into an anaerobic mixed biofilm reactor for treatment of mixture of onion juice and wastewater sludge and obtained efficient volatile solid reduction.

These studies focused on the biowastes that were easily biodegradable or had been prehydrolyzed. In contrast, sludge organics were mainly distributed in the solid phase, which was generally unsuitable for application of the method of microorganism immobilization. Few relevant studies for sludge digestion by this method have been conducted. Nevertheless, since microorganism immobilization can enhance the degradation rate of dissolved organics and the degradation efficiency of total organics, it is possible to improve the dewaterability of digested sludge, which deserves detailed research.

In this study, three identical reactors, one without filler, one with only filler, and one with pre-incubated filler, were used to anaerobically digest WAS. Dissolved organic matter (DOM), methane yield, particle size, extracellular polymeric substances (EPS), normalized capillary suction time (CST) and specific resistance to filtration (SRF) were used to investigate the effects of polyester nonwoven fabric as the filler on anaerobic digestion and dewatering characteristics of the digested WAS.

2. Methods

2.1. Sewage sludge

WAS was obtained from the sludge thickener of a local domestic wastewater treatment plant in Shanghai, China. The capacity of the plant was 75,000 m^3/day and it used an anaerobic–anoxic–oxic process. The service population of the waste water treatment plant was about 200,000. The total suspended solids (TSS), volatile suspended solids (VSS) and protein in the WAS were 29,217 ± 20 mg/L, 20,219 ± 20 mg/L and 11,348.0 ± 15.7 mg/L respectively.

2.2. Experimental setup

2.2.1. Anaerobic reactors

Three identical reactors were constructed of cylindrical plexiglass columns (Fig. 1), each having an internal dimension of 150 mm, a total height of 1500 mm, and a working volume of 15 L, one without filler (R1), one with only filler (R2), and one with filler that had been pre-incubated over 60 days (R3). During the pre-incubation period, R3 reactor was fed with glucose and sodium acetate with an organic loading rate (OLR) of 1 g COD/(L·d) and an HRT of 15 day and continuously produced methane over 15 days. Its methane production was near zero before sludge digestion. Three reactors were operated at temperatures of 35 ± 1 °C with 15 L WAS respectively, while keep the sludge suspension recycled internally in reactors by a peristaltic pump at a downward flow rate of 1.2 L/min.

2.2.2. Filler characteristics

The filler in anaerobic reactors was wear-resistant and corrosion-resistant polyester nonwoven fabric that had been prewashed with distilled water until the concentration of dissolved organic carbon in (DOC) its eluate was below 1 mg/L by submerging 2.0 g filler in 100 mL distilled water and shaking at 120 rpm for 12 h. The dimensions of filler were about 5 mm × 15 mm × 15 mm, with a porosity of 96.8 ± 0.2% and BET surface area of 0.2063 m^2/g. The total quantity of filler in R2 and R3 was 140.9 and 138.7 g respectively.

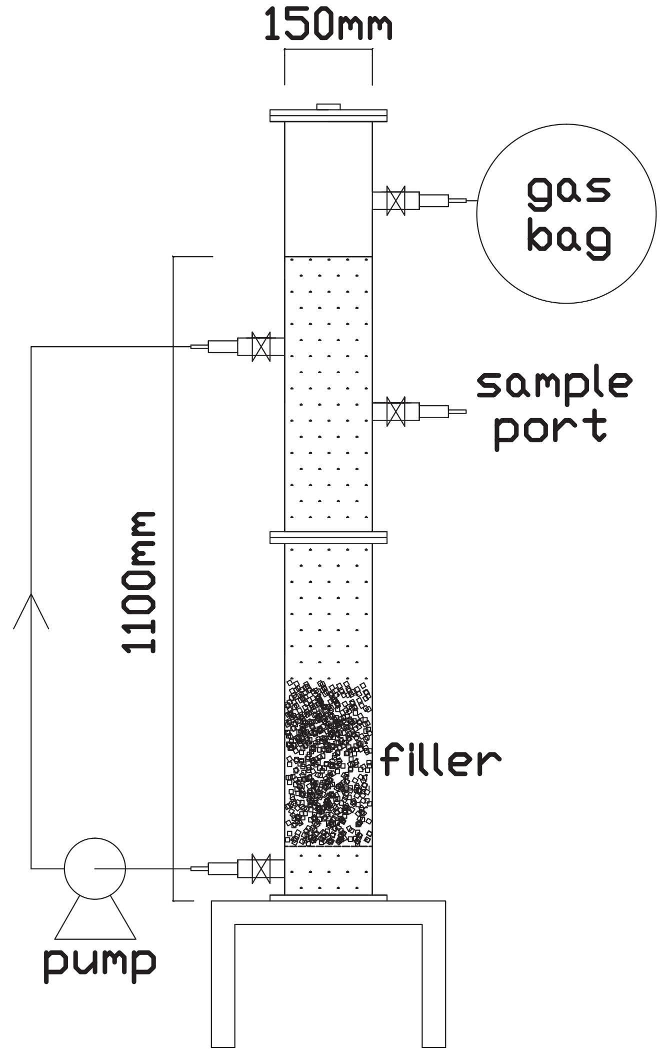

Fig. 1. Sketch of down-flow non-woven biofilm reactor.

2.3. Analytical methods

The sludge samples were collected from the sampling port (on the top of reactors) using a peristaltic pump. The sludge samples were first centrifuged at 2000×g for 10 min after which the supernatant was filtered through a 0.45 μm microfiber filter. The filtrate corresponded to the liquid samples in this study.

2.3.1. EPS extraction

The sludge samples were subjected to ultrasound at 20 kHz and 480 W for 10 min in an ice bath. Following ultrasound, the suspensions were centrifuged at 12,000×g for 10 min. The bulk solution was then collected as the EPS. The EPS was filtered through a 0.45 μm microfiber filter before analysis.

2.3.2. Physico-chemical analysis

DOC, inorganic carbon (IC) and total nitrogen (TN) of liquid samples were analyzed using a TC/TN analyzer (TOC-V CPN, TNM-1, Shimadzu, Japan). Kjeldahl nitrogen (KN) and ammonia nitrogen (AN) were analyzed using an auto Kjeldahl determination system (8400, FOSS, Sweden) for sludge samples and liquid samples. Protein of sludge, EPS and liquid sample were calculated by 6.25 multiplying the concentration of organic nitrogen (ON), which determined by subtracting AN from KN. Polysaccharide of EPS and liquid sample were measured by the anthrone method using