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Operation of a cylindrical bioelectrochemical reactor containing carbon fiber fabric for efficient methane fermentation from thickened sewage sludge

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HIGHLIGHTS

- ▶ A bioelectrochemical reactor containing carbon fiber fabric was constructed.
- ▶ Flexibility of the technology was investigated using thickened sewage sludge.
- ▶ Newly designed reactor maintained stable biogas production from actual waste.
- ▶ Composition and diversity of microbiota in this reactor were clarified.

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ABSTRACT

A bioelectrochemical reactor (BER) containing carbon fiber fabric (CFF) (BER + CFF) enabled efficient methane fermentation from thickened sewage sludge. A cylindrical BER + CFF was proposed and scaled-up to a volume of 4.0-L. Thickened sewage sludge was treated using three types of methanogenic reactors. The working electrode potential in the BER + CFF was regulated at −0.8 V (vs. Ag/AgCl). BER + CFF showed gas production of 3.57 L L^{-1} day^{-1} at a hydraulic retention time (HRT) of 4.0 days; however, non-BER + CFF showed a lower gas production rate (0.83 L L^{-1} day^{-1}) at this HRT, suggesting positive effects of electrochemical regulation. A stirred tank reactor (without CFF) deteriorated at an HRT of 10 days, suggesting positive effects of CFF. 16S rRNA gene analysis showed that the BER + CFF included 3 kinds of hydrogenotrophic methanogens and 1 aceticlastic methanogen. These results demonstrate the effectiveness of the BER + CFF for scale-up and flexibility of this technology.

1. Introduction

The amount of sewage sludge is increasing in the world (Duan et al., 2012; Silvestre et al., 2011). Transformation of sewage sludge into valuable resources is needed because areas for landfill and incinerator capacities are limited (Yoshida et al., 2009). Methanogenesis in an anaerobic digester is an effective option for producing biogas as a renewable energy source and reducing sludge production (Duan et al., 2012; Fountoulakis et al., 2010).

The thermophilic packed-bed methanogenic system (Sasaki et al., 2007; Ueno et al., 2007) retains microorganisms on packed supporting material to enable operation at a high organic loading rate (OLR) and short hydraulic retention time (HRT) (Sasaki et al., 2010a; Tatara et al., 2004). Carbon fiber fabric (CFF) has been used as one of the supporting materials (Sasaki et al., 2010a; Tatara et al., 2004; Zhang et al., 2012).

Bioelectrochemical systems that typically include a working electrode, counter electrode, and proton-exchange membrane can affect microbial metabolism by controlling electron flow (Thrash and Coates, 2008). In previous studies, the cathodic reaction of a bioelectrochemical reactor (BER) was applied to methane fermentation from artificial garbage slurry to prevent accumulation of volatile fatty acids (VFA) at a high OLR with an artificial electron mediator (Sasaki et al., 2010b). In addition, the above effect of the cathodic reaction was shown in a BER using artificial garbage slurry without an artificial electron mediator at a high OLR when the CFFs were directly attached onto the electrode (Sasaki et al., 2011a). Accordingly, BER containing CFF (BER + CFF) combines the characteristics of the packed-bed system and bioelectrochemical system. BERs have been conducted in small-scale systems (<500 mL), and had counter chambers with a volume similar to that of the working chambers (Aulenta et al., 2011; Sasaki et al.,

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