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Carbon and nitrogen removal and enhanced methane production in a microbial electrolysis cell

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HIGHLIGHTS

- A two-chamber methane-producing microbial electrolysis cell (MEC) is investigated.
- 94% of the influent acetate was oxidized at the anode with 91% coulombic efficiency.
- Methane was microbially produced at the cathode with 79% electron capture efficiency.
- Low-strength wastewater treatment with good energy efficiency and low sludge production.
- Good potential to refine both liquid effluent and biogas from anaerobic digestors.

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ABSTRACT

The anode of a two-chamber methane-producing microbial electrolysis cell (MEC) was poised at +0.200 V *vs.* the standard hydrogen electrode (SHE) and continuously fed (1.08 gCOD/L d) with acetate in anaerobic mineral medium. A gas mixture (carbon dioxide 30 vol.% in N_2) was continuously added to the cathode for both pH control and carbonate supply. At the anode, 94% of the influent acetate was removed, mostly through anaerobic oxidation (91% coulombic efficiency); the resulting electric current was mainly recovered as methane (79% cathode capture efficiency). Low biomass growth was observed at the anode and ammonium was transferred through the cationic membrane and concentrated at the cathode. These findings suggest that the MEC can be used for the treatment of low-strength wastewater, with good energy efficiency and low sludge production.

1. Introduction

Harnessing (even only partially) the energy contained in waste streams would mitigate the burden and costs associated with wastewater treatment, while simultaneously generating clean and renewable energy (Heidrich et al., 2011; Angenent et al., 2004); however, in order to convert undefined and often diluted waste organic substrates into clean fuels and/or chemicals a platform of selective and energy-efficient (bio) catalytic routes needs to be developed, optimized, and properly integrated.

Anaerobic digestion (AD), the microbially catalyzed conversion of (waste) organic substrates into a gas mixture primarily consisting of methane and carbon dioxide, is one of the most attractive routes to sustainable bioenergy production from waste substrates (Rittmann, 2008; Kleerebezem and van Loosdrecht, 2007; Verstraete and Vandevivere, 1999). Unfortunately, the well-established AD technology is constrained by the susceptibility of methanogenic microorganisms to toxic compounds, the need to operate the bioprocess at temperatures generally at or above 35 °C which restricts its applicability to high-strength wastewater only, inefficient nutrient removal, and difficulty in removing the organic substrates down to low residual concentrations (Pham et al., 2006). For the latter reason, in order to meet stringent effluent discharge limits, AD systems require a "polishing" post-treatment step, that is typically achieved in energy-intensive activated sludge systems, where the residual organic matter is aerobically oxidized to carbon dioxide and water, with concomitant production of considerable amounts of sludge.

Bioelectrochemical systems such as microbial electrolysis cells (MECs), have emerged as another highly versatile technology which enables coupling wastewater treatment to the generation of energy carriers and chemicals (Pant et al., 2012). In a microbial electrolysis cell, "electro-active" microorganisms use a solid-state anode as terminal electron acceptor for the oxidation of organic waste substrates to carbon dioxide, while simultaneously releasing protons to the solution. Electrons flow from the anode to the cathode

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