



Microbial electrolysis cell scale-up for combined wastewater treatment and hydrogen production



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HIGHLIGHTS

- We demonstrate microbial electrolysis cell scale-up from a 50 mL to a 10 L cell.
- MEC operation on domestic wastewater showed an energy consumption of 0.9 Wh/g-COD removed.
- Low wastewater strength led to low volumetric rate of hydrogen production.
- High rate of hydrogen production can be only achieved at high organic loads.

ARTICLE INFO

Article history:

Received 1 October 2012

Received in revised form 7 December 2012

Accepted 9 December 2012

Available online 20 December 2012

Keywords:

MEC
Hydrogen production
Scale-up
Domestic wastewater

ABSTRACT

This study demonstrates microbial electrolysis cell (MEC) scale-up from a 50 mL to a 10 L cell. Initially, a 50 mL membraneless MEC with a gas diffusion cathode was operated on synthetic wastewater at different organic loads. It was concluded that process scale-up might be best accomplished using a “reactor-in-series” concept. Consequently, 855 mL and 10 L MECs were built and operated. By optimizing the hydraulic retention time (HRT) of the 855 mL MEC and individually controlling the applied voltages of three anodic compartments with a real-time optimization algorithm, a COD removal of $5.7 \text{ g L}_R^{-1} \text{ d}^{-1}$ and a hydrogen production of $1.0\text{--}2.6 \text{ L L}_R^{-1} \text{ d}^{-1}$ was achieved. Furthermore, a two MECs in series 10 L setup was constructed and operated on municipal wastewater. This test showed a COD removal rate of $0.5 \text{ g L}_R^{-1} \text{ d}^{-1}$, a removal efficiency of 60–76%, and an energy consumption of 0.9 Wh per g of COD removed.

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1. Introduction

Microbial Electrolysis Cells (MECs) are bioelectrochemical devices that produce hydrogen by combining the hydrogen evolution reaction at the cathode with the ability of anodophilic bacteria to oxidize organic matter and transfer electrons to the anode. Although this process requires electricity to be supplied, the specific energy consumption is much lower than that consumed by water electrolysis for hydrogen production (Logan, 2004; Rozendal and Buisman, 2005; Rozendal et al., 2006, 2008). Furthermore, MECs can operate on a variety of carbon sources, including wastewaters, thus combining the chemical oxygen demand (COD) removal with the production of a valuable energy carrier (Cusick et al., 2011; Ditzig et al., 2007; Wagner et al., 2009).

Several laboratory studies evaluated the degradation of complex organic materials in a MEC. It was demonstrated that the mixed microbial consortium of the anodic compartment hydro-

lyzes and ferments the organic feed to volatile fatty acids and acetate, while the anodophilic bacteria predominantly utilize acetate as a source of carbon (Escapa et al., 2012; Wagner et al., 2009; Wang et al., 2011). Nevertheless, pure anodophilic strains were demonstrated to grow on other carbon sources (Chaudhuri and Lovley 2003).

Owing to the process novelty, MEC experiments are typically conducted in laboratory setups with an anodic compartment volume of several mL. Very few attempts at process scale-up have been reported so far. A pilot-scale 1000 L MEC operated on winery wastewater (Cusick et al., 2011) highlighted several difficulties of MEC scale-up, including low volumetric rates of H_2 production, H_2 losses to hydrogenotrophic methanogenesis, and a relatively low efficiency of chemical oxygen demand (COD) removal. A study of electricity production from brewery wastewater in a pilot-scale 1000 L microbial fuel cell (MFC) led to similar conclusions, as this test showed limited current generation and a low biochemical oxygen demand removal (Keller and Rabaey, 2008).

The study presented below was aimed at identifying main bottlenecks in MEC scale-up and demonstrating approaches for

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