Bioresource Technology 127 (2013) 138–142

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Comparison in performance of sediment microbial fuel cells according to depth of embedded anode

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HIGHLIGHTS

- We investigated the relation of anode-embedding depth with the power output of SMFC.
- As the anode depth was increased, the internal resistances of SMCs were increased.
- Nevertheless, the SMFC performances were increased as the anode depth was increased.
- The anode potential could be a primary parameter for determining the anode depth.

ARTICLE INFO

Article history:
Received 1 August 2012
Received in revised form 24 September 2012
Accepted 26 September 2012
Available online 12 October 2012

Keywords:
Sediment microbial fuel cell
Microbial fuel cell
Benthic MFC
Redox potential
Anode depth

ABSTRACT

Five rigid graphite plates were embedded in evenly divided sections of sediment, ranging from 2 cm (A1) to 10 cm (A5) below the top sediment layer. The maximum power and current of the MFCs increased in depth order; however, despite the increase in the internal resistance, the power and current density of the A5 MFC were 2.2 and 3.5 times higher, respectively, than those of the A1 MFC. In addition, the anode open circuit potentials (OCPs) of the sediment microbial fuel cells (SMFCs) became more negative with sediment depth. Based on these results, it could be then concluded that as the anode-embedding depth increases, that the anode environment is thermodynamically and kinetically favorable to anodophiles or electrophiles. Therefore, the anode-embedding depth should be considered an important parameter that determines the performance of SMFCs, and we posit that the anode potential could be one indicator for selecting the anode-embedding depth.

1. Introduction

A sediment microbial fuel cell (SMFC) is a device used to harvest electricity by locating the anode in sediment phase and placing the cathode in an oxygen-rich water phase (Lowy and Tender, 2008; Rezaei et al., 2007). In the SMFC anode, the family Geobacteraceae is a known anodophile that directly transfers electrons to the anode electrode (Holmes et al., 2004) and sulfur- or iron-reducing bacteria are classified as electrophiles that indirectly donate electrons to the anode via sulfur and iron redox cycles (Holmes et al., 2004). However, these anodic microbial reactions do not occur equally through all layers of the sediment. In general, the water/sediment boundary is under oxygen rich conditions; thus, oxygen diffuses into the sediment and organic matter in the sediment is aerobically consumed based on the aerobic respiration of heterotrophic microorganisms within a depth 0.5 cm below the sediment surface (Tsertova et al., 2011). Then, as oxygen levels are depleted relative to the sediment depth, a series of rather stable horizontal gradients can be established within the sediment, in which electron acceptors such as NO_3^-, NO_2^-, metal oxides, SO_4^{2-}, and CO_2 (for methanogenesis) are consumed (Nealson and Myers, 1992; Nealson and Stahl, 1997; Londry and Suflita, 1999; Kim et al., 1997).

To date, in order to make SMFC installation in the sediment of a natural environment as easy as possible, most sediment MFCs are installed using only anode and cathode electrodes without using chambers or membranes (Lowy and Tender, 2008; Rezaei et al., 2007; Tender et al., 2008). Accordingly, their performance can be affected by a number of factors inherently existing in the natural environment. In particular, embedding the anode at a depth at which O_2, NO_3^-, or NO_2^- exists would cause a partial loss of organics by microorganisms that prefer O_2, NO_3^-, or NO_2^- as thermodynamically more favorable electron acceptors in the sediment (Nealson and Myers, 1992; Londry and Suflita, 1999; DiChristina, 1992), resulting in a decline of the anode performance. Hence, if the anode

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0960-8524/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biortech.2012.09.095