Bioresource Technology 120 (2012) 187–193

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

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

Long-term performance and characterization of microbial desalination cells in treating domestic wastewater

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HIGHLIGHTS

- ▶ Characterized the long-term performance of wastewater microbial desalination cells.
- ▶ Investigated the key factors affecting system performance.
- ▶ Characterized membrane fouling and scaling and their effects on MDCs.

ARTICLE INFO

Article history:
Received 28 December 2011
Received in revised form 15 June 2012
Accepted 17 June 2012
Available online 23 June 2012

Keywords:
Microbial desalination cell
Wastewater
Desalination
Electricity production
Membrane fouling

ABSTRACT

Microbial desalination cell represents a new technology for simultaneous wastewater treatment, water desalination, and energy production. This study characterized the long-term performance of MDC during wastewater treatment and identified the key factors that caused performance decline. The 8-month operation shows that MDC performance decreased over time, as indicated by a 47% decline in current density, a 46% drop in Columbic efficiency, and a 27% decrease in desalination efficiency. Advanced electrochemical, microscopy, and spectroscopy analyses all confirmed biofouling on the anion exchange membrane, which increased system resistance and reduced ionic transfer and energy conversion efficiency. Minor chemical scaling was found on the cation exchange membrane surface. Microbial communities became less diverse at the end of operation, and *Proteobacteria* spp. was dominant on both anode and AEM fouling layer surface. These results provide insights into the viability of long-term MDC operation on reactor performance and direct system development through membrane optimization.

1. Introduction

Bioelectrochemical systems (BESs) represent an array of processes capable of converting the chemical energy embedded in biodegradable materials including wastewater and sediments into direct electricity or biochemicals (Pant et al., 2012; Rozendal et al., 2008). Recently developed microbial desalination cell (MDC) is new bioelectrochemical process that offers simultaneous water desalination, renewable energy production, and wastewater treatment (Cao et al., 2009; Jacobson et al., 2011; Luo et al., 2011; Mehanna et al., 2010). MDCs use exoelectrogenic bacteria to convert biodegradable materials to electricity and use the potential gradient across the anode and cathode to drive desalination. MDCs can be either used as a stand-alone process for decentralized water treatment and reuse or combined with conventional desalination process, such as membrane-based reverse osmosis (RO) and thermal-based distillation, to reduce feed water salinity and energy demand (Jacobson et al., 2011; Mehanna et al., 2010).

MDC reactor architecture and performance have been significantly improved due to several years of substantial research (Forrestal et al., 2012; Kim and Logan, 2011; Luo et al., 2012b), but the knowledge and experience on long-term operation and using MDCs for wastewater treatment is very limited. Previous studies showed that power density and Coulombic efficiencies during long-term operating microbial fuel cells (MFCs) declined due to the changes of electrode performance (Yang et al., 2009) and variation of microbial communities (Kiely et al., 2011). MFCs share similar bioelectrochemical reactions with MDCs but have no desalination capability, so MFCs can be constructed without a membrane (i.e. single chamber MFCs). MDC is considered as a membrane-dependent technology, because it uses at least one anion exchange membrane (AEM) and one cation exchange membrane (CEM) to separate the desalination (middle) chamber from the anode and the cathode chamber, respectively (Fig. 1). As the key components in the MDC, the properties of membranes are very important to MDC's performance. It has been reported that the desalination efficiency of

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http://dx.doi.org/10.1016/j.biortech.2012.06.054