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Sustainable water desalination and electricity generation in a separator coupled stacked microbial desalination cell with buffer free electrolyte circulation

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HIGHLIGHTS

- ▶ A separator coupled circulation stacked MDC (c-SMDC-S) was constructed.
- ▶ Electrolyte circulation between the anode and cathode could remove pH imbalance.
- ▶ Separator prevented the biofilm directly growing on the air cathode.
- ▶ The c-SMDC-S achieved stable current producing and desalination performance.

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ABSTRACT

A separator coupled circulation stacked microbial desalination cell (c-SMDC-S) was constructed to stabilize the pH imbalances in MDCs without buffer solution and achieved the stable desalination. The long-term operation of c-SMDC-S, regular stacked MDC (SMDC) and no separator coupled circulation SMDC (c-SMDC) were tested. The SMDC and c-SMDC could only stably operate for 1 week and 1 month owing to dramatic anolyte pH decrease and serious biofilm growth on the air cathode, respectively. The c-SMDC-S gained in anolyte alkalinity and operated stably for about 60 days without the thick biofilm growth on cathode. Besides, the chemical oxygen demand removal and coulombic efficiency were 64 ± 6% and 30 ± 2%, higher than that of SMDC and c-SMDC, respectively. It was concluded that the circulation of alkalinity could remove pH imbalance while the separator could expand the operation period and promote the conversion of organic matter to electricity.

1. Introduction

With increasing concern on global challenge for water shortage problem, desalination of salt water is considered as an important approach to produce freshwater (Khawaji et al., 2008; Shannon et al., 2008), but the commercial desalination technologies such as electrodialysis, reverse osmosis (RO) require a considerable energy (Zhou and Tol, 2005). As a modified microbial fuel cell (MFC), microbial desalination cell (MDC) is a recent discovery for low-cost water desalination. The typical MDC consists of three chambers: anode, desalination and cathode chambers (Cao et al., 2009). The desalination chamber constructed with a pair of anion exchange membrane (AEM) and cation exchange membrane (CEM) is inserted between the anode and cathode chamber. The ions in salt water held in the desalination chamber are migrated into the cathode and anode chambers through the respective CEM and AEM membranes. MDCs can desalinate salt water and generate electricity power by using electrochemically active bacteria from the degradation of organic substrates. It has been a hot spot in the field of water treatment owing to its advantages without the input of any external energy. Air–cathode MDC to pre-treat salt water prior to RO (Mehanna et al., 2010b), continuously operated up flow MDC (Jacobson et al., 2011a,b), stacked MDC (SMDC) to promote desalination performance (Chen et al., 2011; Kim and Logan, 2011), and simultaneous water desalination and hydrogen production (Mehanna et al., 2010a; Luo et al., 2011) have been successively reported.

One limitation to the performance of MDC is pH imbalance. Organic matter in wastewater is oxidized by electrochemically active bacteria while protons are released into solution and lower the pH of the anode chamber. Contrarily, the pH of the cathode chamber is elevated due to the consumption of protons. This pH imbalance phenomenon of MDC is dramatic compared with that of MFC, because the AEMs blocked the path of protons from the anode to the cathode and the CEMs blocked that of hydroxyls. The dramatic pH decrease of anode limits the electricity production and thus reduced the extent of desalination (Cao et al., 2009; Chen et al., 2011), and also inhibits the activity of electrochemically

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