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Using bacterial catalyst in the cathode of microbial desalination cell to improve wastewater treatment and desalination

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HIGHLIGHTS

- ► A biocathode was introduced into a microbial desalination cell (MDC).
- ► The maximum voltage produced by the biocathode MDC was higher than that of an air cathode MDC.
- ► The coulombic efficiency (CE) was higher than that of the air cathode MDC.
- ► The CE was higher than that of MDC with potassium ferricyanide catholyte.
- ► There was no oxygen transfer through the desalination chamber into the anode.

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ABSTRACT

A microbial desalination cell (MDC) is able to desalinate salt water without energy consumption whilst generating bioenergy. Previously MDCs used abiotic cathodes, which are restricted in application by high operating costs and low levels of sustainability whereas, in the present study, an aerobic biocathode consisting of carbon felt and bacterial catalysts was tested. The biocathode MDC produced a maximum voltage of 609 mV, the value of which was 136 mV higher than that of an air cathode MDC operated under the same conditions. The salinity of 39 mL of salt water (35 $g\,L^{-1}$ NaCl) was reduced by 92% using 0.441 L of anode solution (11.3:1), with a coulombic efficiency of 96.2 ± 3.8% and a total desalination rate of 2.83 $mg\,h^{-1}$. The biocathode MDC proved to be a promising approach for efficient desalination of salt water.

1. Introduction

Using the vast water resources of the oceans and the seas has long been a goal of water resource management. Over the years, water desalination techniques have developed rapidly, especially with a view to reducing energy requirements. For example, desalination of seawater by reverse osmosis (RO) requires an energy input of 3.7 $kWh\,m^{-3}$ (Semiat, 2008). However, with increasing energy costs and limited fuel resources, the range of desalination techniques currently in use tend to be considered intensive energy consumption technologies (Semiat, 2008). Efforts in finding less energy-intensive desalination methods have included microbial desalination cells (MDCs) (Cao et al., 2009). These cells are modified microbial fuel cells (MFCs) that can desalinate salt water using electricity generated by bacteria from organic matter in an anode solution (Cao et al., 2009).

Using a ferricyanide catholyte, Cao et al. (2009) were able to remove more than 90% of NaCl at an initial concentration of 35 $g\,L^{-1}$. Mehanna et al. (2010b) replaced the ferricyanide cathode with an air cathode using platinum (Pt) as catalysts. The air cathode MDC removed 43–67% of salinity from salt water using equal volumes of anode solution and salt water. Jacobson et al. (2011b) constructed a 1-L 'upflow MDC' (UMDC) for continuous operation (total volume of 2.75 L) and applied a Pt/carbon (Pt/C) with a Nafion solution mixture as catalysts to the air cathode. A total dissolved solids (TDS) removal rate of 11.61 ± 1.69 TDS $L^{-1}\,d^{-1}$ was achieved when the initial conductivity of the salt solution was 56.7 ± 1.4 $mS\,cm^{-1}$. Chen et al. (2011) developed a stacked MDC (SMDC), which used 1–2 cell pair(s) between the anode and air cathode. They concluded that due to the increasing internal resistance, the optimal cell pairs for the SMDC was 1.5. However, this conclusion

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