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MICROBIAL DESALINATION CELL CASCADE

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***Abstract* - Microbial desalination cell (MDC) offers a decentralized wastewater treatment solution as well as an energy-efficient saline water desalination system, which also produces electricity. However, several factors need to be optimised such as: i) the membrane materials properties; ii) overall power density ouptup; and iii) increase of the desalination efficiency. This work focuses on the third part (iii). To enhance the desalination rate and improve the wastewater treatment, a system with 6 MDCs stacked in a cascade configuration has been tested. All three chambers had a volume of 33 mL with a cross-membrane area 25 cm^2. The results showed that by cascading the MDCs the total desalination efficiency was susbstantially increased over 20% compared to that achieved from a single stage MDC, which is an excellent initial demonstration of the benefits of sequential treatment. As shown in this work, the MDCs cascade can be effectively optimised to achieve the desired desalination level whilst generating power. To the best of the Authors' knowledge, this is the first report in open literature that described the MDC cascade principles.**

***Index Terms* – Microbial fuel cell, cascade effect, desalination, wastewater treatment.**

I. Introduction

MDC is a newly developed environmentally friendly technology, which integrates the microbial fuel cell (MFC) process and electrodialysis for wastewater treatment, water desalination and production of renewable energy [1]. It offers a great alternative to the energy demanding conventional methods, which only achieve 50 % recovery [2]. Higher amounts of electricity and improved wastewater treatment have been reported through MFC cascades [3], and so the objective in this study was to apply the cascade effect on desalination.

II. Materials and Methods

In order to increase the desalination rate of a saline solution of 30 g L^{-1}, a total of 6 MDCs were assembled and set up in a cascade configuration, as that shown in Fig 1. Each MDC consisted of three chambers with an empty volume of 33 mL: anodic, middle (desalination) and cathodic chamber.

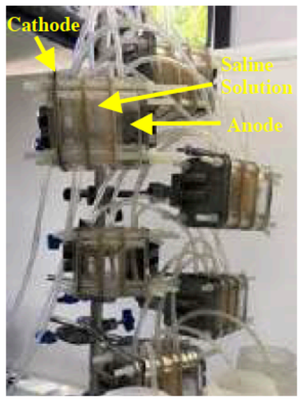

Fig. 1. Picture of the MDC cascade.

Anode and desalination chambers were separated by a cation exchange membrane (CEM, CMI-7000, Membrane International Inc, USA), whereas an anion exchange membrane (AEM, FumaTech FAA-3-50 50 μm, Germany) separated the desalination and cathode chambers. The anode electrode consisted of carbon veil (20 g cm^{-2}) of 270 cm^2 area folded. Fe-N-C catalyst was prepared using nicarbazin (NCB) as organic precursor by sacrificial support method (SSM) as previously reported [4]. The anodic chamber was fed 20 mM sodium acetate in wastewater, whereas the cathodic chamber contained sodium phosphate buffer (25 mM). The anolyte solution was replenished every day in order to maintain measurable amounts of power generation. The saline and catholyte solutions were replenished every second day for 12 days (6 cycles). The pH and conductivity of all the solutions were measured before and after each MDC. The power generated from the MDCs was calculated from the cell voltage, which was continuously monitored. All MDCs were running under 500 ohms load.

III. Results and Discussion

The changes in conductivity of the solutions used are shown in Fig. 2. A decrease in conductivity of 11.2 mS cm^{-1} was obtained after the first cycle. The desalination rate decreased to 4.8 mS cm^{-1} after the second cycle. The conductivity barely changed during the third cycle, probably due to the underperforming operation of that MDC. After that, the decrease in conductivity was constant 2.61 mS cm^{-1} per cycle, reaching 19.9 mS cm^{-1} at the end of the sixth cycle.

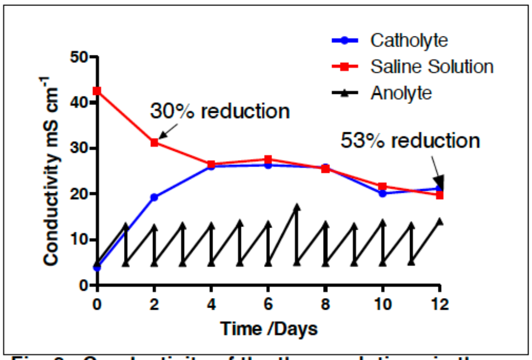

Fig. 2. Conductivity of the three solutions in the MDCs changes along the cascade

The conductivity of the catholyte solution increased from 3.91 to a maximum of 26.3 mS cm^{-1}. The anolyte solution also became more conductive, following the same pattern on a daily basis. The pH values of the saline solution and the catholyte increased from 6.7 and 8 to 8.1 and 9.1, respectively. On the contrary, the anolyte solution pH decreased by a factor of 0.5.

A total desalination of 53 % was achieved in this work. In theory and considering that the pattern followed after the third cycle would remain constant, the desalination could be complete by adding 8 MDCs to the cascade. However, that number could potentially be reduced by increasing the power output, decreasing the ohmic losses and improving the design.

Cao et al. reported 90% desalination in the first ever reported MDC [5] for a system in batch with anode, desalination and cathode chambers of 27, 3 and 27 mL capacity, respectively, part of a 100 mL recirculation system on either side, with the cathode consisting of ferricyanide. Although very high percentage of desalination was achieved with a salinity removal as high as 30 g L^{-1}, the volume of clean water obtained was very low (3 mL) and the absolute removal was approximately 0.09 g NaCl per batch. In the present study, the volume of all three chambers was equal (33 mL), achieving a total of 20 g L^{-1} salinity removal, with 0.65 g NaCl absolute removal. Despite desalinating a larger volume of water, the design of the MDCs must be further improved to achieve higher water volumes and higher desalination rates before it can be utilized at large scale.

IV. Conclusion

For the first time, a cascade of MDCs has been tested showing promising results. The desalination achieved increased from 30 % to 53 % by cascading the MDCs. Moreover, the wastewater treatment was also increased whilst electricity was generated. The power generated per MDCs was approximately 100 μW and that could be multiplied by electrically connecting the MDCs. The number of MDCs in cascade could be further increased to obtain an enhanced desalination.

Acknowledgment

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