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# Performance of microbial desalination cell for salt removal and energy generation using different catholyte solutions

Atieh Ebrahimi[a,b], Ghasem D. Najafpour[c,*], Daryoush Yousefi Kebria[a]

[a] Environmental Engineering Department, Faculty of Civil Engineering, Babol Noshirvani University of Technology, Babol, Iran
[b] Department of Civil-Environmental Engineering, Mazandaran Institute of Technology, Babol, Iran
[c] Biotechnology Research Lab, Department of Chemical Engineering, Babol Noshirvani University of Technology, Babol, Iran

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ABSTRACT

Microbial desalination cell (MDC) is a bioelectrochemical process for simultaneous bioelectricity generation, wastewater treatment, and water desalination. The major drawback of MDC improvement is using toxic catholyte solutions which are normally employed in cathode chamber. In this study, the performance of microbial desalination cell using buffer saline solution was investigated for the first time. The obtained results were compared to several low-cost catholyte solutions, including low concentration of phosphate buffer solution (PBS), non-buffer saline solution, and bio-catholyte. All MDC reactors were fed with actual urban wastewater as fuel. Among all examined catholyte solutions, the MDC using bio-catholyte achieved the highest power density of 32.6 W $m^{-3}$, followed by the MDC using saline buffer catholyte with maximum power density of 29.4 W $m^{-3}$. Bio-catholyte had also lower internal resistance, and it improved current generation; maximum COD removal and desalination rate were 80% and 0.38 g NaCl $L^{-1}$ $h^{-1}$, respectively. On the other hand, in the MDC with buffer saline solution, the COD removal and desalination rate were 73.1% and 0.34 g NaCl $L^{-1}$ $h^{-1}$, respectively. In the MDCs using PBS and non-buffer saline solution, maximum power density was 11.1 and 16.3 W $m^{-3}$, respectively. Based on experimental data, Among the examined catholytes, wastewater as bio-catholyte and saline buffer solution were the desired candidates for MDC scale up, and the most promising point was their being inexpensive alternatives to supplant the costly MDCs catholytes.

## 1. Introduction

Over the last few years, there has been a great development in new fuel cells that use bacteria to create bioenergy in the form of electricity, hydrogen, and methane [1]. Microbial desalination cells (MDCs) are able to degrade organic matters and, consequently, generate electrons through microbial metabolism. This process is a newly developed technology for simultaneous wastewater treatment, salt removal, and sustainable energy generation from organic waste. Microbial desalination cell with different configurations were recently designed to develop process. Although the operational principles of MDCs are similar to those of microbial fuel cells (MFCs), MDCs have shown different performances compared to MFCs [2,3]. Thus, in spite of many works conducted on MFC field, there are still challenges which need to be further explored for MDC scale up and reduce process operation costs.

The most recent investigations have clearly demonstrated the important role of cathode chamber in the performance of microbial desalination cells [4]. The demand for a low cost, easy-to-use, safe, and effective catholyte has been growing with increasing the popularity and commercialization of MDCs. The application of some catholyte solutions yields a high performance, but these catholytes may not be commercially available and economically feasible. Mehanna et al. [5] employed a three chamber MDC fed with synthetic wastewater using air cathode with 0.5 mg $cm^{-2}$ platinum (Pt.) catalyst; they achieved 43–67% salt removal and 480 mW $m^{-2}$ power density. Air-cathodes usually require expensive catalysts, such as platinum, which are not economical in large scale applications. In addition, the air-cathode performance using cheap alternative catalysts would not be high because of slow reduction kinetics [6,7]. The use of air-cathode in MDC also significantly increases the catholyte pH which is due to the loss of protons for the formation of water molecules [8]. To keep a neutral pH, most studies used buffer solutions temporarily to mitigate the problem; however it is not applicable in large scale systems due to several restrictions [2]. Phosphate buffer solution (PBS) is one of the frequently used catholyte, which can decrease pH variation, enhance electrolyte conductivity, and minimize internal resistance in MDCs [9]. Qu et al. [10] found that increasing PBS concentration from 25 to 50 mM in a three chamber MDC fed with synthetic wastewater enhanced the power

* Corresponding author at: Department of Chemical Engineering, Babol Noshirvani University of Technology, Shariati Avenue, 47148-71167, Babol, Iran.
*E-mail address:* najafpour@nit.ac.ir (G.D. Najafpour).

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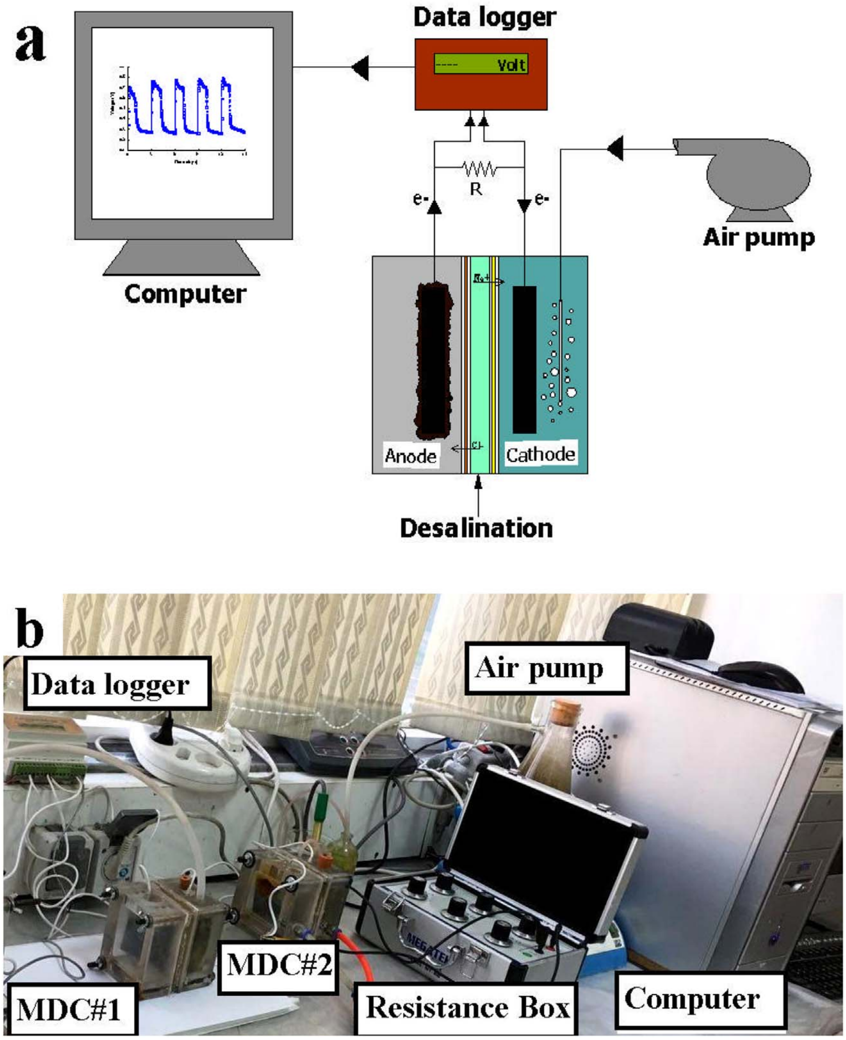


**Fig. 1.** a) Schematic diagram, b) actual image of fabricated MDCs.

density from 776 to 931 W m$^{-3}$, respectively. Although PBS has indicated a good performance in cathode of MDC reactor, the use of high concentration of PBS would be expensive and not practical because of limitation of phosphate release to the environment. The previously reported works indicated that solution conductivity is more important than using a specific buffer [11]. Hence, saline solution can be used as an effective alternative to supersede costly buffer solution. Microbial electrolysis cells have exhibited a good performance using non-buffer saline solution [12]. However, use of buffer and non-buffer saline solutions in MDC has not been well explored so far.

Use of ferricyanide, permanganate, persulfate or hexacyano ferrate as electron acceptor was also investigated in MDC or MFC to substitute oxygen with other electron acceptors having relatively faster oxygen reduction reaction and high redox potential [8]. Although these chemicals provide a stable and high cathode potential, they are not recommended to be used in large scale applications as they entail high cost and may also be harmful to the environment. Moreover, the cathodes used in previous works, comprising ferricyanide catholyte, are not a sustainable technology in spite of their positive impacts on energy production [13].

Recent studies have substituted these chemical electron accepters by bio-cathodes which use bacteria in cathode chamber to promote electron acceptance. Bacterial catalysts result in a low operational cost and environmentally friendly products [14]. Virdis et al. [15] investigated the performance of bio-cathode in MFC for the first time. Xie et al. [16] showed that using raw wastewater as catholyte produced maximum power density of 14 W m$^{-3}$ in MFC. Zuo et al. [17] employed continuous MDC coupled with anion exchange resin using synthetic wastewater as catholyte at HRT of 50 h, achieved 99% desalination efficiency and 17 W m$^{-3}$ power density. The high desalination efficiency most probably was due to use of anion exchange resin in their MDC chambers.

On the other hand, aeration in cathode has attracted extensive attention in fuel cell research owing to high redox potential of oxygen and relatively low supply costs. Crossover of oxygen from cathode compartment to the anode chamber was the main drawback of aerobic biocatholyte in MFCs. This is because oxygen diffusion to the anode chamber has an inhibitory effect on the activity of biofilm formed on the anode electrode. This problem is eliminated in MDC by inserting middle chamber between the anode and cathode chambers. Desalination chamber provides a buffer zone in MDC which minimizes the penetration of oxygen into the anode.

While many types of the mentioned catholytes were examined in microbial desalination cells, use of saline buffer solution in MDC has not been investigated to date. In addition, the comparative study of the low cost catholytes has not been well explored in microbial desalination cell so far. In order to make the final decision to select an efficient, inexpensive catholyte solution, a comprehensive comparison of economical catholytes is required. In this study, the performances of different economical catholyte solutions were evaluated to solve above challenges and also provide suggestions on optimal choices for sustainable wastewater treatment, bioelectricity generation, and