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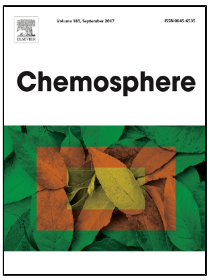

Ozone-Cathode Microbial Desalination Cell; an Innovative Option to Bioelectricity Generation and Water Desalination

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Highlights:

- A new type of electron acceptors, ozone, was evaluated in MDCs.
- 16S rRNA gene sequencing and SEM images used to observe microbial community.
- Salinity removal efficiency above 74% was observed in the O_3-MDC.
- O_3-MDC produced power density of 11 times higher than O_2-MDC.
- *Proteobacteria* are from the dominant microbial communities in anode biofilm.

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Abstract

Microbial desalination cell (MDC) is a new approach of water desalination methods, which is based on ionic species removal from water in proportion to the electric current generated by bacteria. However, the low current generation and insufficient deionization in this technology have created challenges to improve the process. Here, the performance of MDC using ozone as a new electron acceptor (O_3-MDC) was evaluated versus another operated independently with oxygen (O_2-MDC). Results showed the maximum open-circuit voltages of 628 and 1331 mV for 20 g L^{-1} NaCl desalination in O_2-MDC and O_3-MDC, respectively. The O_3-MDC produced a maximum power density of 4.06 W m^{-2} (about 11 times higher than O_2-MDC) while at the same time was able to remove about 74% of salt (55.58% in the O_2-MDC). Each cycle of O_2-MDC and O_3-MDC operation lasted about 66 and 94 h, respectively, indicating a more stable current profile in the O_3-MDC. Moreover, sequencing test based on 16S rRNA gene showed that the anode biofilm had more diverse microbial community than anolyte sample. Proteobacteria, Firmicutes and Acidobacteria were from dominant microbial communities in anode biofilm sample. Accordingly, the results revealed that ozone can enhance MDC performance either as a desalination process or as a pre-treatment reactor for downstream desalination processes.

Key words: Ozonation; Microbial desalination cell (MDC); Electricity generation

1. Introduction

Safe drinking water is an essential for humans and other living beings. As the population grows, the scarcity of fresh water resources and the demand for additional water supplies will be critical in many arid regions around the world (Kim and Logan, 2013; Sevda et al., 2015). To overcome these problems, the need for water desalination has increased recently, especially in the areas where the freshwater resources are limited and brine/sea water is available (Sevda et al., 2015; Gholizadeh et al., 2017).

There are a number of commercial techniques for water desalination such as reverse osmosis (RO), Nanofiltration (NF), electrodialysis (ED), ion-exchange resins, and etc., (Burn et al., 2015). However, one of the drawbacks attributed to the current desalination technologies is their high-energy consumption, resulted in high operating and water cost. For example, RO in a large scale is considered as one of the most conventional desalination technologies which requires 3−7 kWh of energy to produce 1 m^3 of fresh water (Ping et al., 2014; Burn et al., 2015).

Recently, the bio-electrochemical systems (BESs) have emerged as the new technology for water and wastewater treatment because of their relatively lower cost and environmental impacts (Logan et al., 2006; Sevda et al., 2015; Sevda et al., 2017). A new BES for partial or complete water desalination is the microbial desalination cell (MDC), which integrates microbial fuel cell (MFC) and electrodialysis (ED) processes to treat wastewater, desalinate saline waters, and simultaneously produce electricity in a single reactor (Cao et al., 2009; Qu et al., 2012; Cheng et al., 2017; Koók et al., 2017).

A typical MDC is fabricated from three chambers, anode, middle and cathode chambers, separated by cation exchange membranes (CEM) and anion exchange membrane (AEM). In the anode chamber, bacteria catalyze the oxidation of organic matter, release electrons from cell respiration, where they flow towards the cathode through an external electrical circuit (Mehanna et al., 2010; An et al., 2014b). The middle chamber contains an ion solution, and cathode chamber accepts the electrons received from anode chamber (Cao et al., 2009; Saeed et al., 2015; Sevda et al., 2015). The potential difference between the

anode and cathode generates electricity, providing the driving force for water deionization (Jacobson et al., 2011; Qu et al., 2012). Thus, loss of ionic species from the middle chamber results in desalination of water without any external feed pressure, additional waste, and external electricity requirements.

In an MDC, the ion removal rate is affected by many factors, such as salt concentration, reactor volume, retention time of wastewater and ion solution, membrane surface area, microbial oxidation rate, and the ultimate electron acceptor used in cathode chamber (Luo et al., 2012b; Brastad and He, 2013; Meng et al., 2014). So far, many catholytes or electron acceptors have been investigated in BESs. Cao et al. (2009) used ferricyanide as the catholyte of MDC to desalinate water, and the maximum power density of 2 W m^{-2} (31 W m^{-3}) was produced in their reactor. Although ferricyanide is an excellent catholyte in terms of power density, it requires chemical regeneration and cannot be used for large-scale systems (Logan et al., 2006). In other similar studies, the synthetic Cu(II) and Cr(VI)-containing wastewaters were chosen as the cathodic electron acceptor, in which these compounds were rather competent in terms of current density and desalination (An et al., 2014b, a). However, these cannot be used for desalination everywhere.

Mehanna et al. (2010) introduced air as an electron acceptor in a cathode chamber of a BES. Air-cathode MDC reduced the conductivity of 5 g L^{-1} and 20 g L^{-1} NaCl solutions only by 43±6% and 50±7%, respectively. Zamanpour et al. (2017) used microalgae of *Chlorella vulgaris* as an oxygen generator in MDC cathode chamber and observed the maximum power density of 20.25 mW m^{-2} in the system. Nevertheless, there are still some ambiguities to be addressed; how to use certain oxidants with the ability to accept electrons and which processes can be selected to improve the MDC performance.

According to what mentioned above, if the compounds with high redox potentials such as ozone are used in the cathode chamber, it is expected to produce a more electrical current between cathode and anode, which will increase the ion removal efficiency. So, this study aimed to evaluate the ozone capability as a new cathodic electron acceptor in the MDC. The cell half-reactions and standard reduction potentials (E^o) of ozone and oxygen in the bio-electrochemical systems are given in Eq. (1) and (2), respectively:

$$O_3 + 2H^+ + 2e^- \longrightarrow O_2 + H_2O \qquad E^o = 2.07\ V \qquad (1)$$

$$O_2 + 4H^+ + 4e^- \longrightarrow 2\ H_2O \qquad E^o = 1.23\ V \qquad (2)$$

The obtained results in terms of salinity removal and electricity generation were compared with those of another MDC operated with oxygen, O_2-MDC. Moreover, changes in morphology of anode surface created by biofilm formation and microbial community existing in the reactors were investigated by scanning electron microscopy (SEM) and 16S rRNA gene-sequencing techniques, respectively.

2. Material and methods

2.1 MDC configuration

All experiments on O_2-MDC and O_3-MDC were conducted independently in a 3-cell MDC, as shown in Fig. 1. The reactor was constructed from polycarbonate blocks with a 5 cm diameter hole. The three chambers were clamped together and separated by placing an AEM (AR204SXR412, Ionics, MA, USA) between the anode and middle desalination chambers and a CEM (CR67, MK111, Ionics, MA, USA) between the middle and cathode chambers. The anode electrode was a porous graphite (width × length = 25 mm × 30 mm) (Fuel Cell Store, Texas, USA) heated at 450 °C for 30 min and connected to a graphite rod. Carbon cloth coated with 0.50 g cm^{-2} Pt were used as the cathode electrode. After inserting the electrodes, the volumes of anode, middle, and cathode chambers were 70, 38, and 70 mL, respectively.

The graphite electrode was washed using HCl (1 M) and subsequently with distilled water. The anode was connected to the cathode by a piece of copper wire (10 cm). Also, membranes were pretreated to expel their impurities and stabilize them. For this purpose, AEM and CEM were dipped in NaOH (1 M) and HCl (1 M) solutions, respectively for 2 h. They were then rinsed thoroughly with distilled water.

Fig. 1

2.2 MDC start-up and operation

Before conducting desalination experiments, the reactor operated as a microbial fuel cell (MFC) for two months with only one CEM between the anode and cathode chambers to form a satisfactory biofilm on the anode surface. Then, the reactor was configured as microbial desalination cell. Anaerobic sludge harvested from digestion tank of wastewater treatment plant (Yazd, Iran) was used to inoculate the anode chamber. This chamber was also fed by a solution of Peptone water (25 g L^{-1}) and nutrients, including (per liter in deionized water): 1.6 g $C_6H_{12}O_6$, 4.4 g KH_2PO_4, 3.4 g $K_2HPO_4 \cdot 3H_2O$, 1.5 g NH_4Cl, 0.1 g $MgCl_2 \cdot 6H_2O$, 0.1 g $CaCl_2 \cdot 2H_2O$, and 0.1 g KCl (all from Merck). The anode solution (anolyte) from an external feed reservoir (100 mL) was continuously recirculated through the anode chamber at a rate of 0.05 mL min^{-1} (HRT = 24 h) using two peristaltic pumps (M-RV Tygon, Etatron, Italy). In order to maintain anaerobic condition, the anode chamber was purged with N_2 gas (40 mL min^{-1}) for 10 min and sealed when the anode medium was injected into the chamber during the inoculation. The anolyte in the feed bottle was replaced every 48 h to ensure the sufficient substrate is provided for the bacteria, and avoid pH drop.

The middle chamber was filled with artificial salt water containing a NaCl solution (20 g L^{-1}), representing a reasonable average salt concentration of seawater. The pre-treatment of NaCl solution was carried out in an ultrasonic bath (model Transonic TI-H5, Elma, Germany) at the frequency of 22 kHz for 15 min.

The cathode chamber was filled with phosphate buffer as catholyte. To assess the ozone capability to improve the efficacy of MDC, the catholyte was continuously diffused by ozone at the rate of 8.36 mg min^{-1}. The achieved results in terms of salinity removal and electricity generation were compared with those of O_2-MDC, which operated at the same condition. The ozone was generated in an ozone generator (Ned Gas MK940, Netherlands) using oxygen (purity>95%) as input gas, and the ozone-laden flow was

diffused into the solution using diffuser installed at the bottom of the reactor. The operation of O_2-MDC and O_3-MDC with salt solution in the middle chamber continued until the voltage across the external resistance fell to 50 mV, and this was considered as one feeding cycle. The experiments were conducted at room temperature with normal atmospheric pressure and humidity. The O_2-MDC operated under open circuit voltage was used as control.

2.3 Analyses and calculation

Desalination efficiency was measured by monitoring the solution conductivity using a conductivity meter (HQ40d, HACH Co., USA), and results were then confirmed by a flame photometer (model CL378, Elico, India). The concentration of ozone in the inlet gas and off-gas streams was determined by sparging gas into a 2% KI solution and analyzing the solution by iodometric titration (APHA, 2005). Voltage (E, V) generated between anode and cathode as well as across the external resistance (R_{ex}=200 Ω) was recorded every 5 min by a precision multimeter (Model 109N, APPA, Taiwan). The current (I, A) was also determined from the measured voltage according to Ohm's law ($I = E/R_{ex}$). Since the biological reactions take place in the anode chamber, the power density (P_{An}, W m^{-2}) was calculated based on the cross-sectional area of anode electrode ($A_{An,}$ m^2) as follows (Logan et al., 2006; Logan, 2008):

$$P_{An} = \frac{E^2}{A_{An} R_{ex}} \quad (3)$$

Furthermore, the polarization curves were measured by changing the external resistance from 10 Ω to 1 MΩ (10 min per each resistor) with a resistance box (Rayannik, Ltd, Iran). The pH of solutions was determined by a Benchtop pH meter (HQd, HACH, USA). The total desalination rate (TDR, mg h^{-1}) was calculated by:

$$TDR = \frac{(C_0 - C_t)V_d}{t} \quad (4)$$

where C_0 and C_t are the initial and final concentrations of NaCl, respectively; V_d (L) is the liquid volume within the desalination chamber, and t (h) is the time of desalination period.

154

155 2.3.1 SEM analysis

156 The morphology of biofilms formed on the anode electrode surface was analyzed by a scanning electron
157 microscopy (SEM, SUPRA 55VP - Carl Zeiss AG, Germany). Moisture had to be removed from the
158 biological samples by complete drying.

159

160 2.3.2 Bacterial Community Analysis

161 Bacterial community growth in the O_3-MDC was monitored by PCR-amplification of 16S rRNA genes
162 fragments. The samples were taken from anolyte and middle section of anode electrode. The thermal
163 shock method was used to extract DNA through following procedure: the anode samples were initially
164 placed at 100 °C for 10 min and then they were frozen for 10 min at -20 °C. This procedure was repeated
165 twice. Subsequently, samples were centrifuged (12000 rpm) for 10 min. The 16S rRNA genes of
166 extracted DNA were amplified by using the universal primer 338F (ACTCCTACGGGAGGCAGCA) and
167 806R (GGACTACHVGGGTWTCTAAT).

168 The substances final concentrations in 16S rRNA gene PCR reactions were 5 µl of sterile distilled water,
169 2 µl of each of the primers, 10 µl of Master Mix (Amplicon, Denmark), and 3 µl of extracted DNA. The
170 DNA qualities of the samples were evaluated with 1% agarose gel and TBE 0.5X electrophoresis beside
171 50bp Ladder.

172 The PCR thermal cycling scheme of 16S rRNA consisted of initial denaturation at 94 °C for 5 min,
173 followed by 35 cycles of denaturing at 94 °C for 45 s, annealing at 53 °C for 45 s, extending at 72 °C for
174 45 s, and a final extension for 5 min at 72 °C. PCR products of interest were then sent to the Macrogen
175 Company in South Korea for sequencing. The 16S rRNA sequences were analyzed and compared using

the Basic Local Alignment Search Tool (BLAST) in the NCBI GenBank database (http://www.ncbi.nlm.nih.gov/BLAST/).

3. Results and discussion

3.1 Electricity generation and internal resistance

Fig. 2a and b shows the electrical profiles of MDCs operation. The open-circuit voltages (OCV) for 20 g L^{-1} NaCl desalination in O_2-MDC and O_3-MDC were 628 and 1331 mV, whereas the maximum closed circuit voltages (200 Ω external resistor) were 178 and 793 mV, respectively. Each cycle of O_2-MDC and O_3-MDC operation lasted about 66 and 94 h, respectively, indicating a more stable current profile in the O_3-MDC. The maximum current density observed in the O_2-MDC was 1.16 A m^{-2}; however, it increased to 5.27 A m^{-2} when ozone was used in the MDC. The current densities of O_3-MDC were higher than O_2-MDC in all operation times. Also, this parameter increased in both reactors during the lag phase of operation, then, declined after rising to peak value. However, the initial declining slope was greater in O_3-MDC. Such electrical trend is almost observed in MDC studies because the internal resistance gradually increases because of conductivity drop during desalination and substrate consumption (Luo et al., 2012a; Yuan et al., 2016; Sevda et al., 2017). Furthermore, the consequent higher salt concentration in the anolyte could inhibit microbial activity (Sevda et al., 2017).

Fig. 2

In MFCs and MDCs, many important information and conditions of reactors, such as internal resistance, can be derived from polarization curve, which represents the voltage versus the current (density). Internal resistance is an important factor controlling the power generation of BESs. In a microbial desalination cell, the slope of the polarization curve gives the internal resistance of reactor. Also, the maximum power density is achieved when the internal and external resistances are equal (Logan et al., 2006; Logan, 2008).

As shown in Fig. 3, the power density improved by the increase of current density and reached to the highest level. After this point, because of increasing in electrons resistance passing through the electrodes as well as in interconnections and over-sizing the potential of electrodes, the power density decreased. A maximum power density of 4.06 W m^{-2} was observed in the O_3-MDC, which was about 11 times higher than that obtained in O_2-MDC (0.369 W m^{-2}). The higher redox potential of ozone (2.07 V) than oxygen (1.23 V) can significantly justify such findings. In practical phase, ozone diffusion into catholyte would be ecologically sound, leaves no dangerous trace, and maintains its efficacy in a wide range of pH. In a BES, ozone breaks down into oxygen within a short time; this oxygen will again participate in the reaction. In addition, in the next applications of O_3-MDC, industrial wastewater containing ionic pollutant can enter into the middle chamber instead of saline water, the ions transferred from middle chamber would be rapidly oxidized by the ozone, which reduced its toxicity further.

The internal resistances of 305 and 71 Ω were estimated, respectively for O_2-MDC and O_3-MDC. In practice, the internal resistance of a BES influences strongly the electric current output and depends on many factors, such as the material used for anode and cathode electrode, reactor size, chemical properties, temperature, electrolyte conductivity, ion mobility, and electrode surface area (Heijne et al., 2010; Saeed et al., 2015; Sevda et al., 2017). Liang et al. (2008) used carbon nanotube, flexible graphite and activated carbon as anode material of MFC, and found that the internal resistances were 263, 301 and 381 Ω, respectively. Min and Angelidaki (2008) constructed an MFC in which an anode electrode and a cathode chamber were immersed in the anaerobic reactor; they found that the internal resistance was 35 Ω. Kim et al. (2007) found that the membrane type can influence the maximum power densities, and internal resistances of air-cathode cube MFCs (84-91 Ω) were lower than aqueous-cathode bottle MFCs (1230-1272 Ω). However, in this study, the use of O_3-MDC for desalination resulted in a reduction in internal resistance as compared with O_2-MDC. Employing narrower middle chambers would reduce the internal resistance and improve the power generation and ion removal (Kim and Logan, 2013). These

223 results demonstrate higher efficiency of ozone in terms of power production compared to oxygen as
224 electron acceptors in the reactor.

225

226 **Fig. 3**

227

228 3.2 The desalination performance of MDCs

229 In terms of salt removal in O_3-MDC, it was determined that the desalination efficiency is a function of
230 current generation in different stages; accordingly, a faster desalination was achieved under higher current
231 generation (Fig. 4). The O_2-MDC and O_3-MDC had the average TDR of 2.02±0.21 and 2.58±0.34 mg
232 TDS h^{-1}, respectively. In the initial 24 h of operation, the O_2-MDC and O_3-MDC removed more than
233 18.99% and 35.80% of the salt from the middle chamber and their TDRs were 3.69±0.4 and 5.00±0.45
234 mg TDS h^{-1}, respectively. However, TDR reduced by the increase of the operation time due to the
235 reduction of active ions in the middle chamber. Moreover, the gradual increase in the anolyte conductivity
236 is detrimental to the microorganisms and can hinder microbial activity. As a result, the desalination rate is
237 reduced (Luo et al., 2012a). O_2-MDC produced an average current of 0.42±0.02 mA and removed
238 55.58±0.2% of salt from middle chamber solution during operation time. The performance of O_2-MDC
239 was similar to other previous MDC systems operated using air (Mehanna et al., 2010) or ferricyanide
240 (Luo et al., 2012b). However, when ozone was used in the MDC, the average current of 1.41±0.3 mA and
241 74.08±3.1% of desalination were obtained. This indicates about 18% enhancement in desalination
242 performance.

243 The conductivity of anolyte increased from 8.4 to 14.6 mS cm^{-1} during one desalination cycle. This
244 increase was most probably due to the movement of anions available in middle solution toward anode
245 chamber during desalination. In the open circuit control, O_2-MDC and O_3-MDC eliminated only up to

19% and 21% of salt, respectively, indicating desalination was mainly due to the generation of electric current, and other factors such as natural osmosis, ion exchange, and scale formation had minor involvement.

However, the obtained desalination efficiencies in O_3-MDC are higher than many of the values observed in previous studies. For example, in a study in which ferricyanide was used as the electron acceptor, the MDC removed about 66% of the salt from the middle chamber during 400 h of operation, and in long-term operation, the current density and desalination rate decreased by 47% and 27%, respectively (Luo et al., 2012a). In another study, Sevda et al. (2017) obtained the maximum desalination efficiency of 19.9% in an MDC operated with real seawater and phosphate buffer solution as catholyte. This indicates that using MDCs with ozone as an electron acceptor in the catholyte chamber can provide sufficient energy for downstream desalination processes, e.g., reverse osmosis.

Fig. 4

3.3 Biofilm Formation on Anode Surface

Micrographs of anode surface before and after the experiment were recorded by a software-controlled digital SEM to observe the biofilm formation. A close inspection of Fig. 5a and b displays a significant change in morphology of anode electrode, so that the fresh anode electrode had a clear surface, while the SEM images of the used anode indicated occupation of microbes on the electrode surface. The anode biofilm had a complex dense structure distributed on the whole surface of graphite.

Fig. 5

3.4 Microbial Community Analysis

16S rRNA gene-based high-throughput sequencing, which is known as an effective method to analyze microbial community structures and functions in MFCs and MDCs was used to illustrate the dependence of bacterial communities and their relationships (Zhi et al., 2014; Liu et al., 2015). Both anode electrode and anolyte solution of O_3-MDC were sampled and sequenced in this study. Table 1 summarizes the identified names of bacterial families present in the anode biofilm and anolyte. The anode biofilm had more diverse microbial community than anolyte sample. Proteobacteria were from dominated microbial communities both in the anode biofilm and anolyte sample. Firmicutes and Acidobacteria were other microbial communities detected in BLAST results of anode biofilm sample, while were not identified in the anolyte. The Proteobacteria of anode biofilm belonged to betaproteobacteria and gammaproteobacteria classes. However, epsilonproteobacteria and Bacteroidia were only classes existed in anolyte sample. Proteobacteria species were widely reported in previous MFC and MDC studies and were considered as the dominant exoelectrogenic bacteria presumably due to competitive advantages in extracellular electron transfer (Luo et al., 2012a; Luo et al., 2012b; Liu et al., 2015; Zhang et al., 2016). Bacteroidetes are gram-negative, anaerobic or aerobic, and rod-shaped bacteria that were widely reported in the anode of BESs and seawater (Lu et al., 2012; Gao et al., 2014). The presence of Acidobacteria may be a result of low pH of the O_3-MDC anolyte, because these species were reported capable of withstanding acidic, metal-contaminated, and other extreme environments (Barns et al., 2007). Firmicutes are obligate anaerobic bacteria, which can consume glucose and convert it to acetate, lactate, butyrate, ethanol, CO_2 and H_2 (Ludwig et al., 2009; Karluvalı et al., 2015). Rabaey and Verstraete (2005) suggested some species of gammaproteobacteria and Firmicutes poses capacity to generate electricity. The anode biofilm also contained uncultured marine bacterium, which may be attributed to the higher salinity in the MDC anode chamber.

Due to some limitations, this study only focused on the microbial community excised in anode and anolyte samples at the family level.it is recommended that in the subsequent studies, the sample is first

cultured in the special culture medium, and after taking the single typical colonies, more comprehensive characterizations be conducted using high throughput sequencing technologies such as pyrosequencing to observe the distribution and contribution of each species in the microbial community.

Table 1

4. Conclusion

Salinity removal and electricity generation were successfully accomplished in the MDC with ozone as a new cathode electron acceptor. The salinity removal and electricity generation data of O_3-MDC were compared with those achieved through O_2-MDCs. Results showed faster desalination was occurred under higher current generation. The O_2-MDC performance was similar to other MDCs operated previously. However, when ozone was used as an electron acceptor, the reactor had lower internal resistance, the desalination performance enhanced, and the current density and power density were several times higher than those obtained in O_2-MDC. The results recommend ozone cathode MDC as a promising technology, both for seawater desalination and bio-electricity generation during wastewater treatment, especially as a pre-treatment mechanism for membrane processes.

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Figure captions:

Fig. 1: Three-chamber MDC used for desalination tests: (a) schematic, and (b) actual image.

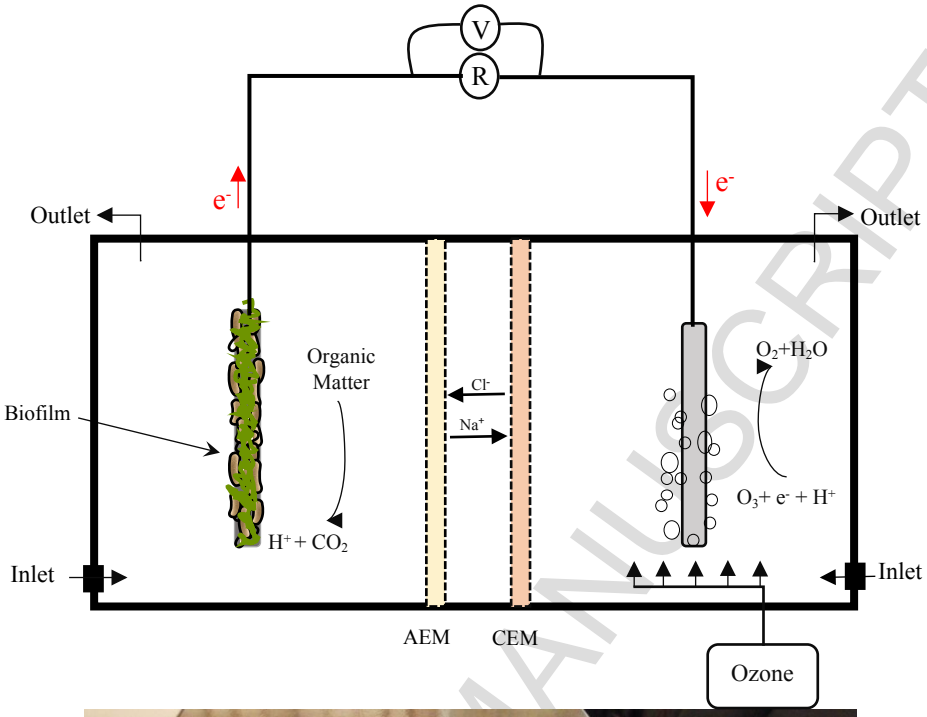
Fig. 2: Electrical profiles during operation: (a) O_2-MDC, and (b) O_3-MDC (salt water concentration of 20 g L^{-1}, and external resistor of 200 Ω).

Fig. 3: Polarization and power density curves of (a) O_2-MDC, and (b) O_3-MDC

Fig. 4: Desalination efficiency and TDR of O_2-MDC and O_3-MDC

Fig. 5: SEM image: (a) anode surface before the experiments (5000x), and (b) anode surface after the experiments (7500x)

a



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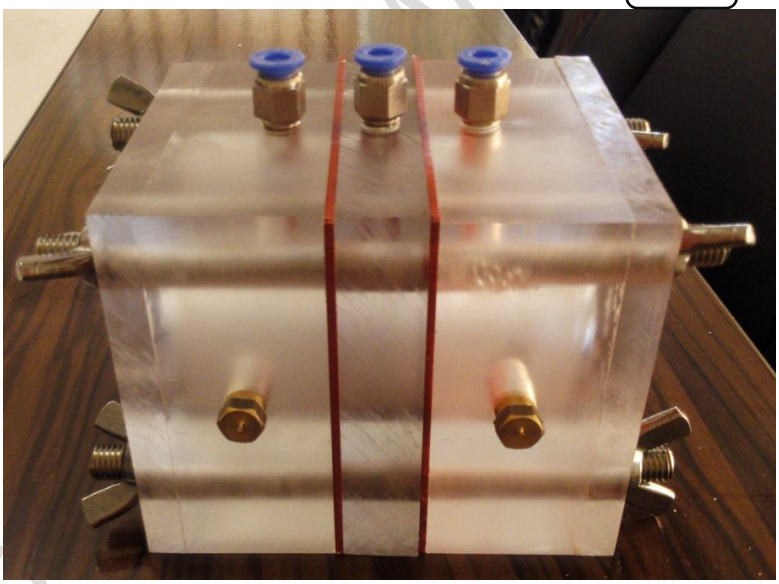

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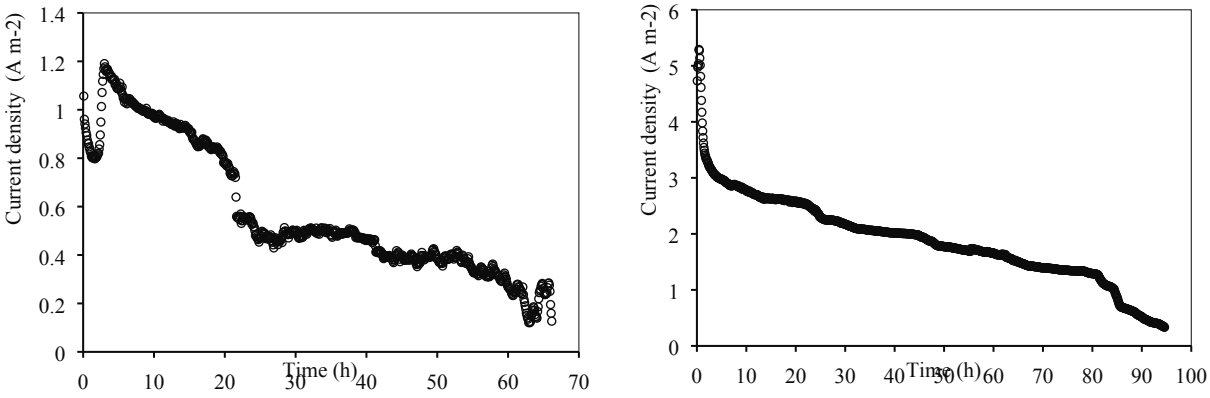
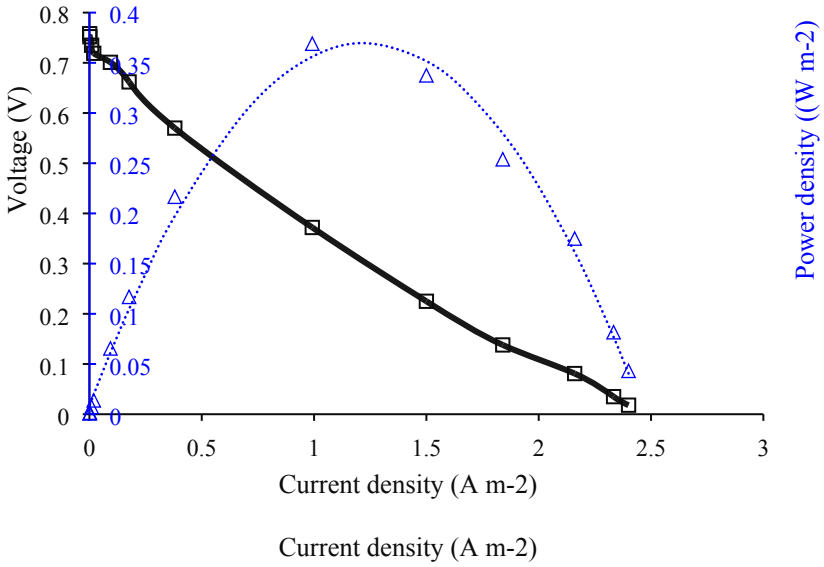


a b

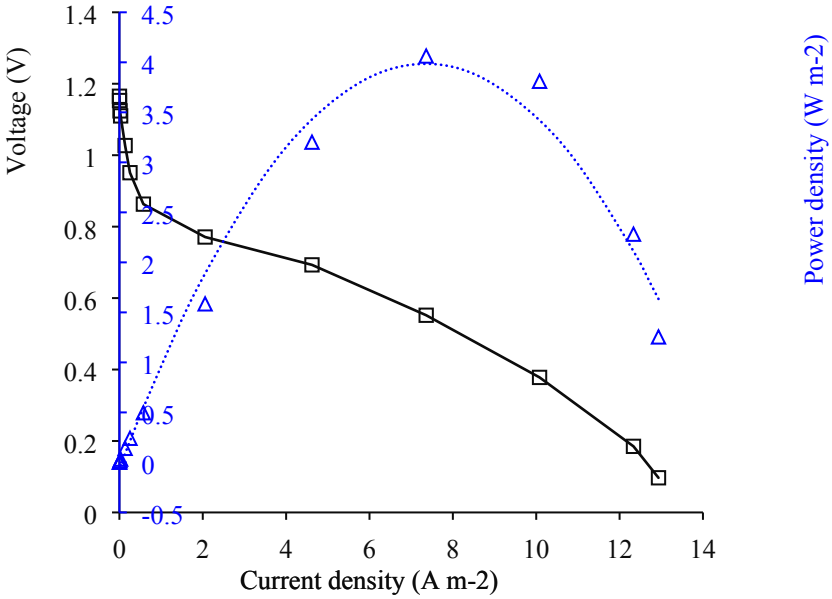
Fig. 2:

a



Current density (A m-2)

b



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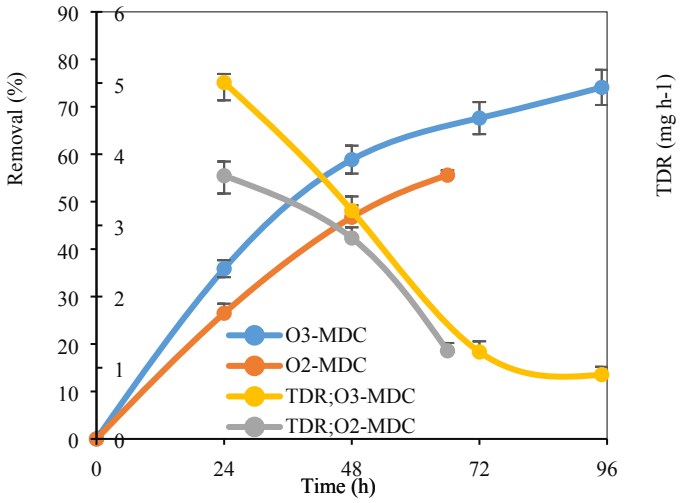
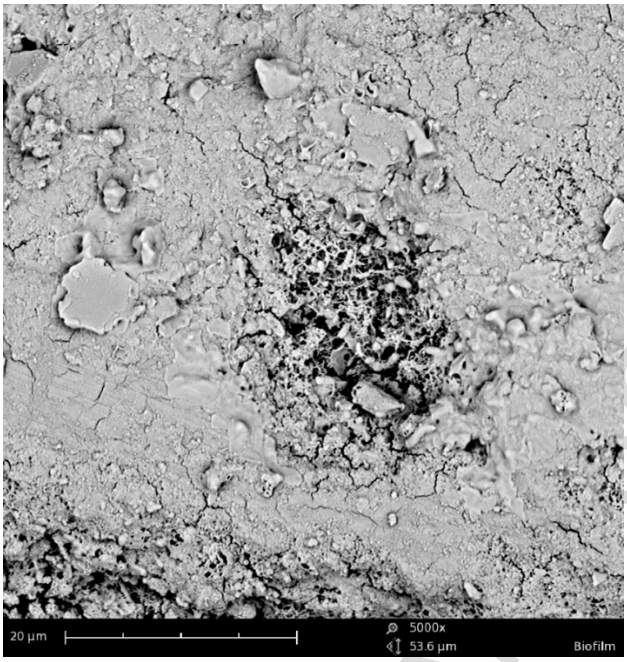


Fig. 4:

a



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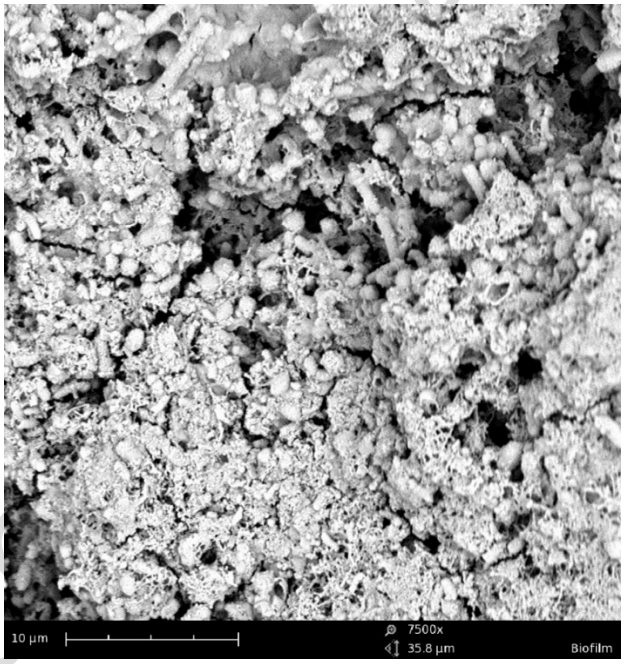

Fig. 5:

Table caption:

Table 1: Bacterial community of O_3-MDC's anode and anolyte samples.

Table 1:

Sequence ID	Family	Class	Phylum	Similarity (%)	GenBank accession No.
Anode biofilm					
MA1	Acidobacteriaceae	Acidobacteria	Acidobacteria	88	HG763957.1
MA2	Chromatiaceae	Gammaproteobacteria	Proteobacteria	91	HQ877094.1
MA3	Ectothiorhodospiraceae	Gammaproteobacteria	Proteobacteria	87	KC009941.1
MA4	Burkholderiaceae	Betaproteobacteria	Proteobacteria	87	KP772724.1
MA5	Clostridiaceae	Clostridia	Firmicutes	89	KU045501.1
Anolyte					
MS1	Campylobacteraceae	Epsilonproteobacteria	Proteobacteria	89	KF721645.1
MS2	Prevotellaceae	Bacteroidia	Bacteroidetes	86	GU955392.1