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Optimizing a concentration of NaCl and $2Na_2CO_3 \cdot 3H_2O$ with microbial desalination cell from the usage of UI lake water

Putri Anggun Puspitarini[1], *Hidayati* Istiqomah[1], *Putty* Ekadewi[1], *Tania* Surya Utami[1], *Rita* Arbianti[1], and *Heri* Hermansyah[1]

[1]Department of Chemical Engineering, Faculty of Engineering Universitas Indonesia, Depok 16424, Indonesia.

Abstract. Microbial Desalination Cell (MDC) is one of a Bio Electrochemical technology and also modification technology of Microbial Fuel Cell (MFC), MDC is a method that desalinate a sea water. In the use of this MDC system, the bio electrode that use is from coconut shell charcoal. The use of charcoal as Bio Electrode because it has a low cost as well as environmentally friendly, and charcoal doesn't have some toxic properties. Another problem besides the use of bio electrode, is the imbalance between the pH and the chamber becomes another obstacle to the MDC system and the impact of some approaches leads to increased cost of capital and operational costs. In order to overcome these barriers by cost, Lake UI is used as the substrate and Sodium percarbonate (SP or $2Na_2CO_3 \cdot 3H_2O$) also used as a natural buffered electrolyte. Based on the results of variations of SP concentration, best concentration of SP was at 0.15 M (SR=15.14%), concentration NaCl at 35 g/L were able to reduce the mass of 3.626 g to 3.077 g with salinity 30.77 g/L.

1 Introduction

Water crisis and drought was one of the problems that occur almost every year, as well as being a crucial issue, there are 105 districts/cities, 715 sub districts, and 2,726 villages in Java and Nusa Tenggara Islands experiencing drought due to the normal dry season on 2017 [2]. Indonesia is currently estimated to have water availability of 15,000 m^3/capita/year, with potential water availability by 2020 estimated at 1200 m^3/capita/year and having 35% availability of water that can be managed economically, real 400 m^3/capita/year [7].

One method that has the potential to desalinate seawater without use energy, as well as utilize the metabolism of microorganisms is by using microbial Desalination Cell (MDC), MDC is one of the technologies developed from methods Microbial Fuel Cell (MFC), which has the ability in doing seawater desalination in order to generate electrical energy. In this research, the water of Lake UI will be used as substrate because has a high level of pollutant in it such as heavy metal content, organic compound, microorganism, turbidity level, taste, and odor coming from the water [13].

Coconut shell charcoal was used as bio electrode in this study. The coconut shell is an organic material consisting of several main components, in the form of cellulose, hemicellulose, lignin containing the atoms C, O, H, and N. With more and more cellulose, hemicellulose, and lignin content, the better the activated carbon produced [12] Chemical content of coconut shell is cellulose (34%), hemicellulose (21%) and lignin (27%) [1]

We optimized the MDC system with three chamber and 400:100:200 ml reactor volume, with catholyte of sodium percaronate ($2Na_2CO_3 \cdot 3H_2O$) (0.05 M, 0.1 M, 0.15 M and 0.2 M) and Models of sea water in the form of NaCl (20 g/L, 30 g/L and 35 g/L in distilled water).

2 Methods

2.1 MDC Reactor Design

Based on the below picture, the design showing for the three-chamber reactor design with the volume of the anode chamber: desalination: the cathode is 480 ml: 120 ml: 240 ml, and has an actual volume of 400 ml: 100 ml: 200 ml. In this study used obstacles of 10 ohm [10]. Where in the reactor there is an Anion Exchange Membrane (AEM) inserted between the anode chamber and the desalination chamber, and the Cation Exchange Membrane (CEM) inserted between the cathode chamber and the desalination chamber. In addition, there are also electrodes (A: anode, B: cathode).

2.2 Analysis

In this study was conducted by studying the effect of Sodium Percarbonate and NaCl concentration on Salt

* Corresponding author: nana@che.ui.ac.id

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Removal and Desalination Rate. The MDC system is done for 50 hours, while at optimum condition MDC system will be done until get the result of Salt removal and desalination rate stable (constant). For the conductivity value of salt solution measured by conduction. The retrieval of each conductance data is done twice (duplo). From the conductivity data, it can be seen that the concentration of NaCl solution showed decrease of salt concentration. In addition, the pH of the solution was measured using pH meters to analyze ionic displacements occurring during desalination. Each measurement of pH data is measured twice.

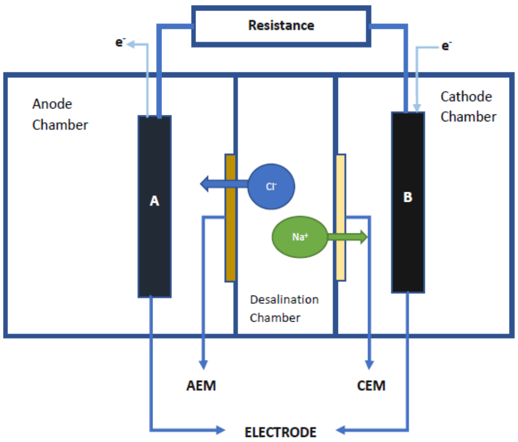

Fig 1. MDC Reactor Design

Fig 2. The three- chamber MDC Reactor

2.2.1 Salt Removal

Salt removal (SR) represents a percentage of the number of moles of salt lost to mole of initial salt. Calculation of Salt removal was obtained using Equation 1 [8].

$$SR = ((Co - Ci) / Co) \text{ x } 100 \text{ \%} \qquad (1)$$

where *SR* is the salt removal (% mol), *Co* is the initial moles of salt (g/L), *Ci* is the moles of salt after desalination (g/L).

2.2.1 Desalination Rate

Desalination rate (DR) is the rate of mole drop of salt at a given time unit. The desalination rate is expressed in Equation 2 [8].

$$DR = (no - ni) / t \qquad (2)$$

where *DR* is the rate of desalination (mol/hour), *no* is the mole of the initial salt (mol), *ni* is the mole of salt after desalination (mol) and *t* is the desalination time (hr).

3 Result and Discussion

3.1 Variation Concentration of Sodium Perkarbonate in Cathode Chamber

Experiments on the concentration of sodium carbonate on cathode chamber were aimed at obtaining the best concentration of sodium percarbonate as catholyte used in reducing the salinity and desalination rate in MDC reactor system, with variation of sodium percarbonate concentration 0.05 M, 0.1 M, 0.15 M and 0.2 M.

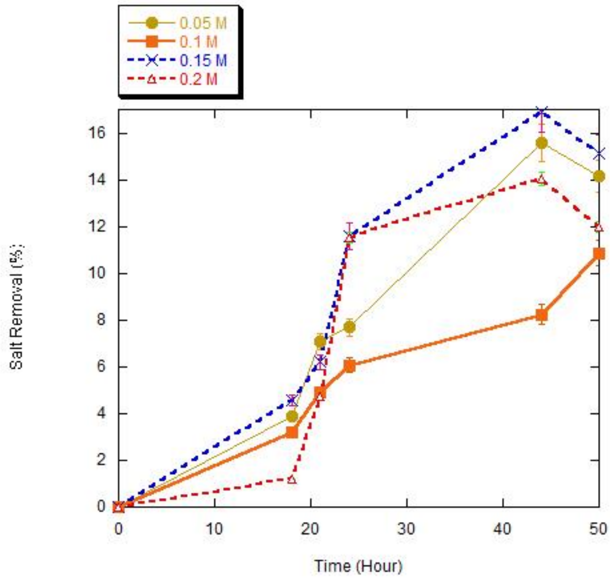

Fig 3. Sodium Percarbonate Concentration Variation Experimental Salt Removal Results During 50 Hours

The best result was obtained at variation of sodium percarbonate concentration 0.15 M with salt removal 15.14% and can decrease salinity from 3.626 g/L to 3.077 g/ L for 50 hours. The results show that it is not in accordance with the statement conveyed by Sang *et al.*, (2006) [16] that the best desalination performance can be obtained at the largest electrolyte but the result is close, so it can produce high electrolyte conductivity when compared with the lowest concentration. As well as in research Forrestal *et al.*, (2014) [5] found that the higher the concentration of sodium carbonate, the higher the buffer capacity produced. However, from the results obtained it is known that the value of SP concentration of 0.2 M has a salt removal results are lower than the concentration of SP of 0.05 M and 0.15 M it happens because of the influence of some things like water osmosis or particle diffusion. Water osmosis that occurs due to the displacement of a low salt solution will tend to migrate to a high salt solution.

From the results that have been obtained from this experiment is the concentration of SP of 0.15 M. The value will be used for the next experiment that is the variation of NaCl concentration and the performance of MDC at the optimum condition.

3.2 Variation Concentration of NaCl Concentration in Desalination Chamber

The purpose of experimentation of variation of NaCl concentration on salt chamber is to know how the effect of NaCl concentration as a sea water model to desalination performance in MDC system. The concentration of NaCl used was 20 g/L, 30 g/L and 35 g/L, and using the concentration of 0.15 M sodium percarbonate obtained from the previous experiment.

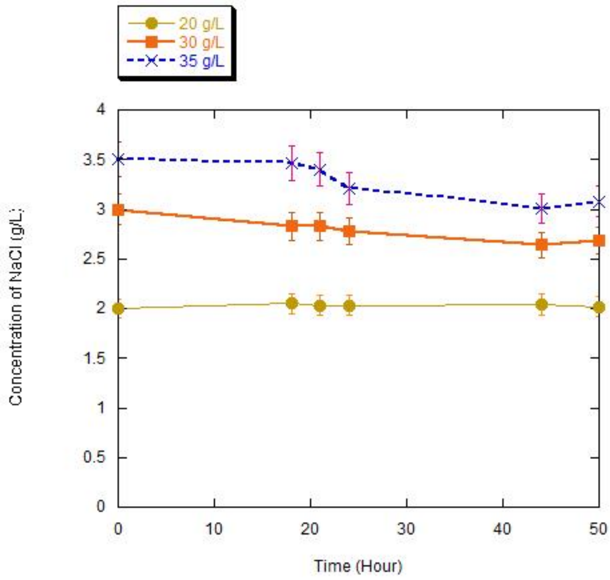

Fig 4. Concentration Decreace of NaCl Experimental Results Variation NaCl Concentration During 50 Hours

Based on the results obtained from the experiment variation of NaCl concentration conducted for 50 hours using SP concentration of 0,15 M obtained the best results at the concentration of NaCl 35 g/L. On that concentration can obtained the final mass of NaCl of 3.077 g from the initial mass of 3,.509 g and has a salinity value of 30.77 g/L. The results obtained at a concentration of NaCl 35 g/L has the best results than the concentrations 20 g/L and 30 g/L.

The presence of a decrease in salt water in the desalination chamber is due to the difference in concentration gradient between the salt chamber and the anode chamber and the cathode chamber. The results of this experiment are according to Cao *et al*., (2009) [3] which obtained the best results in reducing the salt water at a concentration of NaCl of 35 g/L. At that concentration the theoretical charge transfer (Qth) is at slightly higher concentration, so the process in reducing the salt water by the MDC method obtained can decrease 90% salt from the water through a single desalination cycle, and no need to press water or use an external power source. This process is effective for desalination of water even at salt concentrations as high as 35 g/L.

Can be seen from the results above that the best the concentration of NaCl used will be greater also in reducing salt water. Thus, the NaCl concentration of 35 g/L will then be used as the best concentration for experiment of optimum condition of MDC.

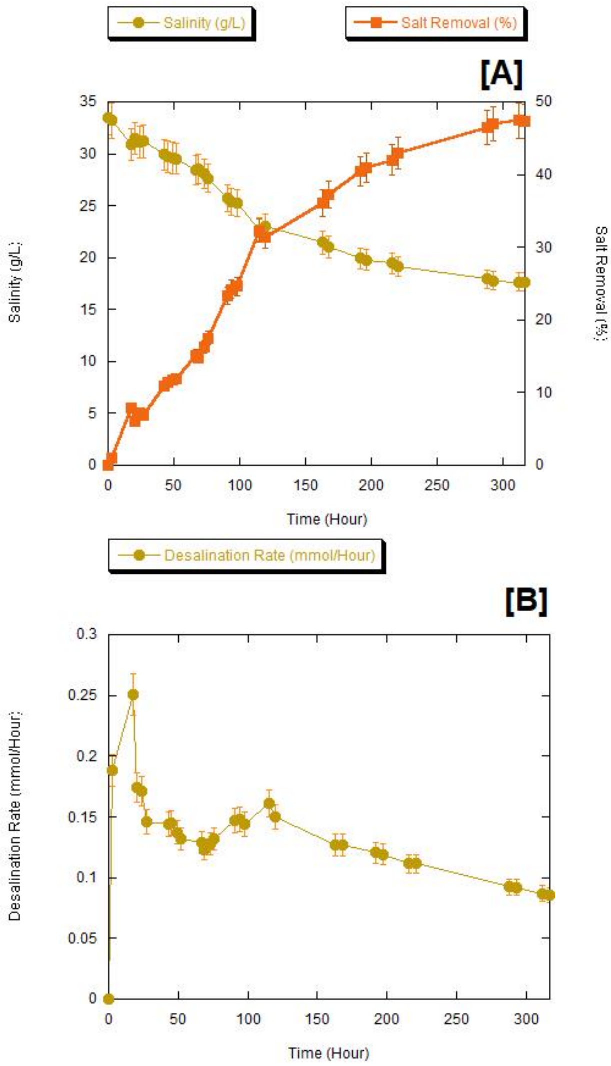

Fig 5. [A] Salinity and Salt Removal Result and [B] Desalination Rate Result in Experiment of Optimum Condition

3.3 Optimum Condition

The MDC experiment under optimum conditions using SP concentration of 0.15 M and NaCl 35 g/L was the best result of the previous experiment. This experiment is done until the condition gets stagnant or the condition is close to constant. From the results obtained on the experiment conducted for 317 hours (14 days), obtained salinity from 33.53 g/L to 17.66 g/L with salt removal of 47.33% and desalination rate of 0.0856 mmol/hour.

The desalination process is influenced by the presence of water osmosis from the cathode space to the desalination chamber as well as the production of the flow of electricity produced by bacteria on the substrate. Osmosis is a transfer of solvent through a semipermeable membrane from a high concentrated solution to a low concentration solution to equalize the dissolved concentration on both sides [6]. At the optimum condition performed for 317 hours it was found that there was a decrease in volume of cathode chamber containing catholyte of 74 ml sodium percarbonate from 200 ml, which is due to the influence of water osmosis occurring in MDC system and also influenced by flow factor electricity by bacteria.

3.4 pH

3.4.1 pH Anode Chamber

Table 1. Result of pH In the Anode Chamber

Experiment	Anode Chamber			
	pH day 1	pH day 2	pH day 3	ΔpH
Sodium Percarbonate (SP)				
0.05 M	6.65	8.37	7.35	**+ 0.70**
0.1 M	6.65	8.22	7.63	**+ 0.98**
0.15 M	6.25	8.61	8.05	**+ 1.80**
0.2 M	6.45	8.90	7.92	**+ 1.48**
NaCl				
20 g/L	6.35	9.18	8.05	**+ 1.70**
30 g/L	6.50	7.30	7.20	**+ 0.70**
35 g/L	6.25	8.61	8.05	**+ 1.80**
Optimum Condition		pH before	pH after	ΔpH
		7.40	6.87	**-0.52**

The pH decrease in the anode chamber occurs due to the accumulation of proton from bacterial metabolism [3]. Changes in pH can be caused by the inclusion of organic or inorganic compounds into water [14]. Based on the experimental results obtained on the anode chamber, the results are in accordance with previous studies, the experimental optimum condition conducted for 317 hours (14 days) obtained pH data that decreased not significant by 0.52; while in the experiment SP and NaCl obtained an increased pH. An increase in pH may occur because the pH of water fluctuates following dissolved CO_2 and has an inverse relationship pattern, the lower the CO_2 content of the water, the pH will increase [4]. CO_2 levels are the result of bacterial metabolism found on the substrate [4].

The ideal pH for freshwater aquatic life is between 6.8 – 8.5. If the pH was very low, can causing the solubility of the metals in the water, which is toxic to aquatic organisms, where as a high pH can increase the concentration of ammonia in water which is also toxic to aquatic organisms [17].

3.4.2 pH Cathode Chamber

Table 2. Result of pH In the Cathode Chamber

Experiment	Cathode Chamber			
	pH day 1	pH day 2	pH day 3	ΔpH
Sodium Percarbonate (SP)				
0.05 M	13.15	13.13	13.10	**-0.05**
0.1 M	13.65	13.67	13.63	**-0.02**
0.15 M	12.95	13.81	13.75	**+ 0.80**
0.2 M	13.00	13.88	13.80	**+ 0.80**
NaCl				
20 g/L	13.20	13.71	13.25	**+ 0.05**
30 g/L	11.00	11.13	10.97	**-0.05**
35 g/L	12.95	13.81	13.75	**+ 0.80**
Optimum Condition		pH before	pH after	ΔpH
		10.9	10.6	**-0.30**

From the results obtained in the above data it can be seen that in the cathode chamber containing a solution of SP (sodium percarbonate) change the outcome of the overall pH change reduced experiment and also goes up but did not experience any significant changes. Based on the MDC study conducted by Lustiono (2017) [11] stated that in theory there is the best pH change ranges from 0 – 0.2. The results show that sodium percarbonate has natural buffering capability even without buffer [11].

The increase of pH as in the experiments of MDC with SP of 0.15 M, SP of 0.2 M, NaCl of 20 g / L and NaCl of 35 g/L, may occur due to cathode cathode which increases pH caused by consumption of proton in catholyte [15]. While the pH of SP 0.05 M, SP 0.1 M, and NaCl 30 g/L decreased due to reduced OH^- consumed by HCO_3^- to CO_3^{2-} [9]. While the pH decreases in optimum condition other than the change due to the decrease of OH^- content in the solution, also caused the occurrence of water osmosis events that occurred during 317 hours (14 days) so that the decrease of the concentration of sodium percarbonate in cathode chamber.

4 Conclusion

The conclusion obtained from this research are by using coconut shell charcoal bio electrode and UI lake water substrate obtained the best sodium percarbonate concentration of 0.15 M with salt removal 15.14%. In the NaCl concentration variations obtained the best results in reducing the salinity of 35 g/L of mass of 3.626 g to 3.077 g with salinity 30.77 g / L. And when the optimum conditions obtained salt removal 47.33%, desalination rate 0.0856 mmol/hour, and salinity from 33.53 g/L to 17.66 g/L for 317 hours (14 days).

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