Microbial Desalination Cell Using Tempe Wastewater as Substrate with Phosphate Buffer Solution as Catholyte

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Abstract—In the next few years, Indonesia will experience a water crisis, because the needs for water continues to increase every year. The water crisis will affect the quality of life, especially in terms of sanitation and health, so it is necessary to find the solutions. Microbial Desalination Cell (MDC) is a good technology to desalinate salt water into fresh water because MDC at the same time can generating electricity. Tempe wastewater used as a substrate by using their source of microorganisms to efficiency the price of operations. To improve the performance of the MDC, the experiment focused on the use of phosphate buffer solution with varying concentrations of 0.025 M, 0.05 M, 0.1 M and 0.15 M in the anode and the cathode chamber. The use of buffer solutions to the MDC system will decrease the pH imbalance that occurs during experiment due to the formation of hydroxyl and proton from redox reactions in the anode and cathode chamber. The experiment shows that MDC using model tempe wastewater, with a concentration of 0.1 M phosphate buffer solution in anode and cathode chamber is the optimum buffer phosphate concentration with salt removal 9.87 % and average power density 1734.08 mW/m2.

Keywords—desalination; microbial desalination cells; phosphate buffer solution; tempe wastewater

I. INTRODUCTION

In the next few years, Indonesia will experience a water crisis, because the needs for water continues to increase every year. The water crisis will affect the quality of life, especially in terms of sanitation and health, so it is necessary to find the solutions. One of the solution is desalination. It is a process that separate the dissolved components in seawater into fresh water. Desalination selected because the availability of sea water is very abundant in Indonesia, where as an archipelagic country, Indonesia has 5.8 million km2 sea area which is dominating total territorial area.

Microbial Desalination Cell (MDC) is a good technology to desalinate salt water into fresh water because MDC at the same time can generating electricity. MDC can generate electricity by using the exoelectrogenic bacterium that produces electricity [1].

This experiment used liquid tempe wastewater as their substrate, because in addition as desalination technology, MDC can also be used as a wastewater treatment technology by taking the advantage of the presence of bacteria and organic material in wastewater.

To improve the performance of the MDC, the research focused on the use of a phosphate buffer solution instead of electrolyte solution and examine the effect of varying concentrations and pH phosphate buffer. The use of buffer solutions to the MDC system will certainly cut costs, because the cost of the electrolyte solution is more expensive than the buffer solution. pH imbalance in the anode and cathode chamber are also taken into consideration on the MDC system that uses electrolyte solution. A decrease in pH of the anode chamber can inhibit microbial activity, while high pH in the cathode chamber can cause significant potential loss of electrical voltage, and decreasing the rate of desalination and formation of electricity [2]. This occurs due to the presence of membrane AEM and CEM on the MDC reactor that blocking proton and hydroxyl that formed from redox reactions at the anode and cathode chamber to move. In the anode chamber, the protons that generated from the oxidation reaction cannot diffuse into the cathode chamber where the hydroxyl formed from reduction reaction. This is causing the pH imbalance in the chamber so that the pH will decrease in the anode chamber and increase in the cathode chamber. Therefore, phosphate buffer substitute the used of electrolyte solution with expectations of pH in the anode and cathode chamber did not change significantly.

Variations of the concentration and pH buffer solution were done to get the optimum performance of desalination. Variations of the concentration conducted to determine the optimum concentration because higher concentration not guarantee good results. Variations in pH value of buffer solution devoted only at the anode chamber. Performance of exoelectrogenic bacteria to produce electric current will decrease if the pH in the anode chamber is less than 5 [3]. Microbial sensitivity towards pH indicate that a decrease in pH at the anode chamber was one factor of decreasing MDC performance.
II. MATERIALS AND METHODS

A. Tools and materials

In this study, MDC reactor with three chambers separated by Anion Exchange Membrane (AEM) and Cation Exchange Membrane (CEM) was used for the experiment. The contact surface area of the membrane for AEM and CEM is 113.04 cm². Graphite rods used as the anode and cathode 10 x 6 x 0.8 cm dimensions with 145.6 cm² of surface area. The anode and cathode are connected with copper cable and fitted with a 10-ohm resistor as external barriers. The result of electric voltage is measured by multimeter APPA 109N and KRISBOW KW06-796 that connect to a computer, while the conductivity of saline solution measured by conductivity meter LUTRON CD-4301.

Model tempe wastewater was made from the boiled soybeans with a mass ratio of soybeans: volume of water 3:5 [4]. Tempe wastewater must be incubated for 65 hours before used as a substrate [5]. Buffer solution for this study is a phosphate buffer solution with varying concentrations. NaOH solution is used as a model saline water and membrane AEM and CEM preparation. For the preparation of electrodes before MDC experiment, electrodes soaked in HCl 0.1 M and NaOH 0.1 M respectively for 24 hours.

B. Reactor Construction

MDC reactor with three chamber was made from acrylic with a comparison between the volume of the anode chamber: saline water chamber: cathode chamber respectively was 4:1:2 [6]. The volume of the anode chamber, saline water chamber, and a cathode chamber in this study was 400 mL, 100 mL and 200 mL (Fig 1).

The anode chamber was filled with a mixture of model tempe wastewater and phosphate buffer solution, saline water chamber was filled with a solution of NaCl 30g / L while the cathode chamber was filled with phosphate buffer solution.

![Fig. 1. Microbial Desalination Cell Reactor](image)

C. Operation Condition

The first trial began by comparing the use of buffer solution as catholyte with electrolyte solution of potassium permanganate 0.1 M. The next stage is the concentration variation of phosphate buffer solution with concentration 0.025 M, 0.05 M, 0.1 M and 0.15 M. These experiments were analyzed based on the percentage of salt removal, the rate of desalination and power density. All experiments were performed at room conditions (37° C).

D. Calculations

Conductivity data will be used to know concentration of saline solution by using the standard curve equation that was created earlier. The data is then processed to obtain the value of % salt removal and desalination rate. Salt Removal (SR) is percentage of the moles of salt that are eliminated against initial moles [7].

$$SR = \frac{c_o - c_i}{c_o} \times 100\%$$ \hspace{1cm} (1)

With:
- SR: Salt removal (%)
- Co: Initial salt concentration (g / L)
- Ci: Concentration of salt after desalination (g/L)

The calculation of desalination rate is to determine the decline rate of moles of salt at one time.

$$DR = \frac{n_o - n_i}{t}$$ \hspace{1cm} (2)

With:
- DR : Desalination rate (mmol/hour)
- no : Initial salt moles (mmol)
- ni : moles of salt after desalination (mmol)
- t : Desalination time (hour)

From the electric voltage data measured on the multimeter, can be known the value of electric current (I) then can be used to determine the generating power density. Electric current shows how many electrons that flowing in the system.

$$I = \frac{V}{R_{ex}}$$ \hspace{1cm} (3)

With:
- I : Electric current (mA)
- V : Voltage (mV)
- Rex : External resistance (Ohm)

Power density is the power that is released per unit of surface area of the electrodes

$$P_d = \frac{I^2 R_{ex}}{A}$$ \hspace{1cm} (4)

With:
- Pd : Power density (mW/m2)
- Rex : External resistance (Ohm)
I : Electric current (mA)
A : Surface area of electrode (m²)

Those results of data processing shown how much production of electricity.

III. RESULT AND DISCUSSION

A. The Effect of Using Buffer Solution as Catholyte

In this experiment, the MDC that used buffer solution had salt removal 9.87% and average power density 1734.08 mW/m², while the MDC that used electrolyte solution such as KMnO₄ had salt removal 11.16% and average power density 2474.59 mW/m². The result of desalination of saline water by using electrolyte solution was greater than using a buffer solution even though the difference of the decreasing salt concentration not much different from the use of buffer solution. Electrolyte solution of salt removal only increase as much as 1.29%. The result of decreasing salinity and power density can be seen in Fig 2.

Based on the analysis of raw material prices on the catholyte that used buffer solution and electrolyte solution (Table 1). Prices of electrolytic solution was 2.05 times bigger than the price of buffer solution, but their value of salt removal was not much different from using a buffer solution. Therefore, a buffer solution without electrolyte will be used for the next step in this research, by considering the price.

B. Variation of Concentration of Phosphate Buffer Solution

MDC with concentration buffer solution 0.1 M was able to reduce the salinity with the largest result from 29.79 g/L to 26.85 g/L with salt removal 9.87% and an average power density 1734.08 mW/m². MDC with buffer solution 0.025 M was able to reduce salinity from 28.73 g/L to 26.54 g/L with salt removal 7.59 % and an average power density 27.01 mW/m². MDC with buffer solution 0.05 M was able to reduce salinity from 29.46 g/L to 27.01 g/L with salt removal 8.32 % and average power density 132.20 mW/m². MDC with buffer solution 0.15 M was able to reduce salinity from 29.96 g/L to 27.56 g/L with salt removal 8.0 % and average power density 53.52 mW/m².

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Table 1. The Difference of Catholyte Price with Their Salt Removal

<table>
<thead>
<tr>
<th>Variable</th>
<th>Price</th>
<th>Salt Removal (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrolyte Solution</td>
<td>Rp 9.655.37</td>
<td>11.15</td>
</tr>
<tr>
<td>Buffer Solution</td>
<td>Rp 4.687.25</td>
<td>9.87</td>
</tr>
</tbody>
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Fig. 2. The effect of using buffer solution as catholyte towards (A) decreasing salinity and (B) power density
Based on the Fig 3 (B), four types of buffer concentration variation curves had the same trend of curves. The curve has increased in the early operating time, and then continued to decline up to the end of MDC operation. The value of power density at concentration buffer solution 0.1 M is very much different from other concentration which generated smaller power density. This significant difference could be caused by the internal resistance in the MDC system during the displacement flow process that result decreasing voltage [8].

IV. CONCLUSION

Microbial desalination cell using tempe wastewater as substrate and phosphate buffer solution as catholyte is good technology to desalinate salt water. Even though the result of desalination of saline water by using electrolyte solution as catholyte gave the bigger result, phosphate buffer solution has the lower price and it would cut the operating cost of MDC that were quite expensive.

The optimum concentration of phosphate buffer to produce electricity and desalinate salt is 0.1 M, with salt removal 9.87% and an average power density 1734.08 mW/m2.

REFERENCES