Study of Different Membranes in Microbial Fuel Cell Through Different Cathodes

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Abstract
The two chambered Microbial Fuel Cell (MFC) was designed and used for studying efficiency of different membranes for the real wastewater treatment from a non-steroidal anti-inflammatory pharmaceutical plant. The removal of the contaminants was expressed in terms of Chemical Oxygen Demand (COD) removal, as measured by spectrophotometry experiments. Experiments were divided into two sections. First phase of experiments was performed using Pt-coated Ti as the cathode and Stainless Steel as the anode, using NAFION® 324 membrane while in the second phase PTFE membrane was replaced with NAFION. The results indicate that using NAFION membrane could increase the maximum power density and COD removal rate to 20.5w/m³ and 92 % respectively.

Keywords: Microbial Fuel Cell; Non-Steroidal Anti-Inflammatory Drug Wastewater; Electricity Generation; COD Removal, Nafion Membrane, PTFE Membrane.

1. Introduction
The presence of different pharmaceuticals in various water bodies has turned into a serious environmental issue [1–3]. A major part of the pollution caused by these compounds can be traced back to effluents from pharmaceutical plants. Due to their peculiar bioactive chemical structures, their treatment through common wastewater treatment methods is still a significant [3]. Diclofenac Sodium-containing nonsteroidal inflammatory compounds are one of the common pharmaceuticals, which also happen to be found in alarmingly high levels in the environment [1]. Poor degradation of DS (3-70%) has been reported by conventional wastewater treatment methods [4]. So far, numerous chemical, physical and biological treatment methods have been used for degradation of compounds in pharmaceutical wastewater. Despite their high resistance to conventional biological methods, several research is directed toward more effective forms of biological methods as well as their combination with physical and chemical methods [5–10].

Use of Microbial Fuel Cells (MFCs) is a biological method which has drawn considerable attention. Known as a promising form of biotechnology, MFCs offer electricity generation through anaerobic digestion of organic matter [11–13]. Recently different kinds of wastewaters from domestic to industrial effluents have been used as a feed in MFCs and have been treated [14,15]. Many researches are done on the treatment of industrial wastewaters including brewery, cheese wastewater and other types of food industry

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but just few studies are carried out on pharmaceutical wastewater treatment using MFCs[17]. Among recent studies of the treatment of pharmaceutical wastewaters by MFC technology, the major focus is mainly on steroidal and antibiotic drug industrial effluent [18]. In the present study, a tow chambered MFC was designed and made to investigate the effect of the type membranes on the performance of non-steroidal anti-inflammatory pharmaceutical wastewater treatment by using two different membrane as well as power generation for the first time.

2. Methods

2.1. Wastewater and inoculation
Real wastewater was obtained from non-steroidal anti-inflammatory drug factory (Ramofarmin, Karaj, Iran). The effluent had an initial COD of 7440 mg/l while its pH (pH-240L, Isteck, Korean) and conductivity (EC-470L, Isteck, Korean) were 9.2 and 8.3 ms/cm, respectively. Granular anaerobic activated sludge was obtained from wastewater treatment unit of Pegah Dairy factory and was isolated at 4°C to maintain the anaerobic condition of the sludge.

2.2. Reactor configuration and operation
Two similar dual-chamber MFC reactors were made of 5mm-thick Plexiglas sheets. The chambers each having an internal volume of 120 ml and a working volume of 100 ml were separated by a membrane (Sigma Aldrich, Germany). Two small circular holes were designed at the top of each chamber to purge Nitrogen and Oxygen into the anodic and cathodic chambers, respectively. Pt-coated Ti was used as the cathode and Stainless Steel as the anode (with a surface area of 4 cm²). Experiments were divided into two sections. First phase of experiments was performed using Pt-coated Ti as the cathode and Stainless Steel as the anode, using NAFION® 324 membrane and in the second phase PTFE membrane was replaced with NAFION. Fig 1 shows the picture of working MFCs. Prior to each run, the electrodes were first cleansed with acetone and washed repeatedly with distilled water. Then, they were autoclaved at 121 °C for 15 min. The electrodes were connected to external resistance (R) with a titanium wire. 50% of the working volume of the anodic chamber was inoculated with granular sludge and the other half was filled with 50 mM Phosphate buffer solution. Trace mineral and vitamins were added to anolyte, followed by purge of nitrogen to maintain anaerobic conditions. The cathodic chamber was filled with 100 ml of 50 mM Phosphate buffer solution. After the biofilm formed on the anode, the anolyte solution was replaced with 50 ml of buffer solution containing vitamins and minerals plus 50 ml of real wastewater for the first and second phase of experiments, respectively.

2.3. Electrochemical measurements
Voltage (V) was measured by a data logger system (myPCLab, Novus, Brazil). Current (I) and power (P) were calculated from $I=V/R$ and $P=IV$, respectively. Current and Power density were obtained from $I_s=I/V$ and $P_s=P/V$, where V is the working volume of the anode. Columbic Efficiency (CE) was calculated by integrating the measured current relative to the theoretical current based on the consumed chemical oxygen demand (COD). The polarization curves were obtained by changing external resistance from 1041 to 21 Ω during the steady state conditions. The data were recorded at a time interval of 10 minutes. The slope of V–I curve indicated the internal resistance ($R_{in}$) of the cell.

2.4. Chemical analysis
The closed reflux, colorimetric analysis (ASTM 5220 D) was employed as a standard technique to determine chemical oxygen demand (COD). Before measurement, the solution was filtered through a micro-porous membrane to remove the impurities.

3. Results and discussion

3.1. Electricity generation characteristics in the MFC
As it is clear in Fig 2, the amount and the stability period of the obtained voltage of MFC is higher in the case of using Nafion membrane (0.51v). On the other hand, the maximum power density was 20.5w/m³ and 16.13w/m³ for the Nafion and PTFE systems respectively (Fig 3). Although using membrane in the MFCs would increase the internal
resistance of the reactor, applying appropriate membrane would increase the final current characteristics. As it can be seen NAFION membrane is a more compatible membrane for MFC reactor. One reason that NAFION membrane showed better performance was because of the high porosity of this membrane. This property would not let Hydrogen ions, which were the result of anodic reactions, accumulate behind the membrane and pass them as fast as it can and this reduce internal resistance of the system. Another reason is that the thickness of NAFION membrane is 0.015cm and the thickness of PTFE membrane is 0.019cm. Rahiminezhad at 2010 compared two different kind of NAFION membranes with different thickness and proved that the increase in the membrane thickness can lead to increase in internal resistance of an MFC [19].

Figure 2. Voltage (v) changes during the time (h) for two different membranes.

Figure 3. Polarization and power density curves across the current density.

3.2. MFC efficiency in wastewater treatment
The COD removal rate was 92% and 86% for the systems using NAFION and PTFE membrane respectively. As previously mentioned, as the NAFION is a thinner membrane, the Hydrogen ion accumulation in anodic chamber in this system is much lower than PTFE membrane system, so the rate of oxidation reduction reaction would increase automatically and the rate of wastewater decomposition would also increase as well.

Figure 4. COD removal trend across the time.

4. Conclusion
This study demonstrates the use of a two chambered MFC to produce electricity from a nonsteroidal anti-inflammatory pharmaceutical effluent as a real wastewater. The experiments were done in two separate phases. First phase of experiments was performed using Pt-coated Ti as the cathode and Stainless Steel as the anode, using NAFION® 324 membrane while in the second phase PTFE membrane was replaced with NAFION. The maximum $P_{\text{max}}$ and the maximum COD removal was 20.5 W.m$^{-3}$ and 92% (during 30 hours) respectively and belonged to the first phase of experiments for the MFC using real wastewater.

References


