

Microbial Fuel Cells: Looking Inside the Black Box

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Global climate change and the impending water crisis are motivating researchers to develop more efficient methods for treating wastewater. The traditional treatment process consumes a significant amount of energy to treat high energy waste. One alternative to the conventional method would be a Microbial Fuel Cell (MFC). Microbial Fuel Cells use the native microbes to harness the energy stored in the organic bonds of the wastewater. Ideally the energy produced by the MFC could power the treatment plant and possibly produce a surplus of energy as well. Acquiring essentially “free” energy from the process seems like a great way to treat wastewater, however there is a flaw in the idea preventing MFCs from already being utilized in treatment plants.

There is a ‘black box’ around the MFCs. The ‘black box’ represents what actually goes on in the MFC. The microbial processes and relations to the fuel cell are not well understood. The idea of putting in wastewater and getting clean water and energy out of the ‘black box’ are clear. However, without looking inside the ‘black box’ and understanding the thermodynamic and kinetic theory behind why and how an MFC works, MFCs cannot be engineered to work effectively on a large scale to be able to compete with current treatment methods.

One aspect that was investigated was the pH of the catholyte chamber. The catholyte used was a 100 mM phosphate buffer solution. The buffering solution had two purposes. The high conductivity allowed for a higher electron transfer rate and the solution was also supposed to maintain a stable pH for an extended period of time. However during the initial testing of the effects of a neutral pH on MFC performance, the catholyte kept becoming very basic.

Through monitoring the catholyte pH, the whole cell voltage and the cathode potential, some very interesting relationships were discovered. The first relationship was that the catholyte at neutral to basic pH values had no effect on MFC performance. This was determined based on the cell voltage, which continued to reach approximately the same peak despite the fluctuation of pH. The next result found was that the cathode potential could be considered constant. This result can be seen in the graph below of the Voltage Profile of Reactors vs Time. The cathode potential is represented by the green line and remains relatively constant. This result means that any change in MFC overall voltage production (blue) must be driven by the anode potential (orange).

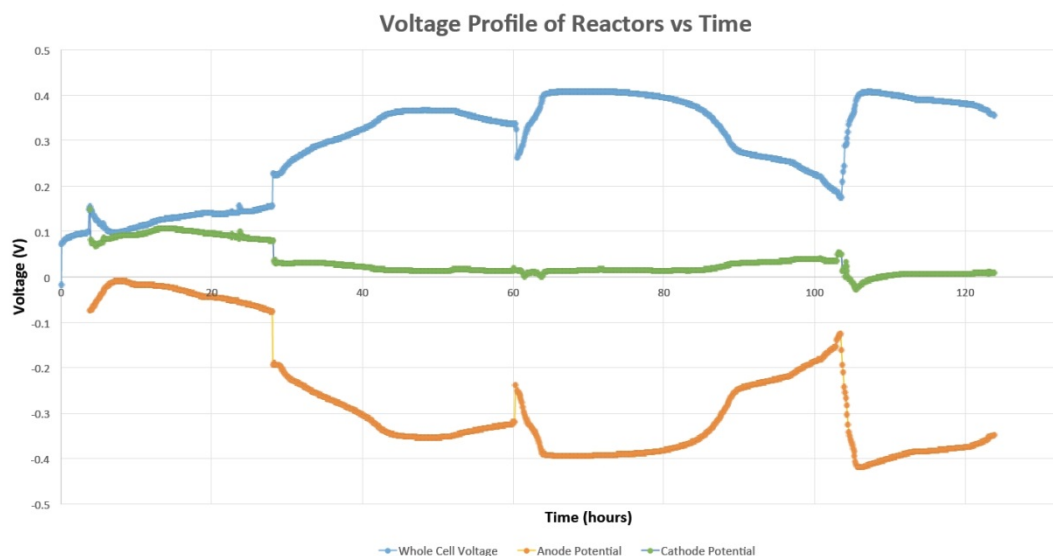


Figure 1: Graph of Voltage Profile of Reactors vs Time

The conclusions drawn above led to a new start up procedure in attempt to develop a microbial community that could compete with current wastewater treatment. The new batch of MFCs was initially hooked up to an external power supply to help speed up the acclimation process and select for a specific community. The image below shows the startup set-up for the improved microbial fuel cells. Wastewater is used as the anolyte to inoculate the carbon brush with a microbial community and help develop the biofilm. The catholyte is composed of a 10 gram per liter sodium chloride solution. Since the phosphate buffer was not effective at maintaining a constant pH and the earlier experiment showed that the catholyte being neutral or basic had negligible effect on the performance of the MFC, it was replaced to cut down on the cost of operation.

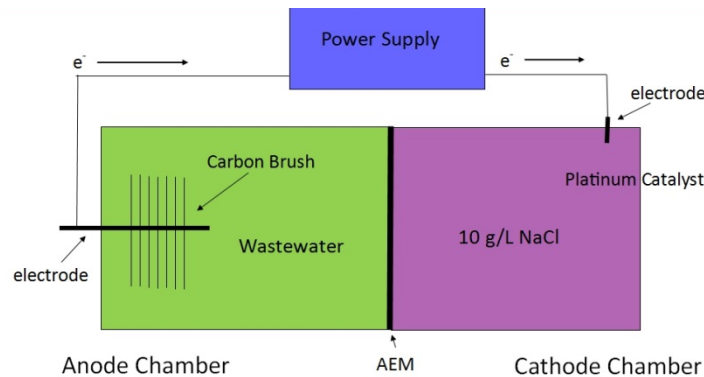


Figure 2: Diagram of MFC Startup Set-Up

The power supply was set to maintain an optimal anode potential of -200 mV versus an Ag/AgCl reference electrode and adjusted periodically to maintain that potential. The purpose of adding in the external was to pull electrons from the anode thus helping the microbes adjust to sending the electrons they produce through the electrode more quickly. The next major change in the MFC design was using an anion exchange membrane (AEM) in place of a cation exchange membrane (CEM). Using an AEM allows for negative hydroxide ions to pass through the membrane to balance out the electron being transferred to the cathode chamber. This is a better option than the CEM because there is a higher concentration of hydroxide and the CEM doesn't preferentially select for hydrogen ion transfer. Instead, sodium and calcium ions dominate the cation movement.

Once the MFCs had been run on the power supply for a start-up period, the power supply was removed and replaced with a resistor. Two resistors (1 and 470 ohm) were initially tested but led to decreasing fuel cell voltage. However, use of a 1000 ohm resistor resulted in an increasing fuel cell voltage indicating a favorable environment for the microbes. The MFCs were then monitored and fed as needed to continue acclimation of the microbial community until consistent voltage profiles were established.

This research has shown that changes in the voltage production of the MFC are driven solely by the anode potential. The anode potential is easy to measure and is directly related to and driven by the microbial metabolism. The microbial metabolism is difficult to measure and difficult to understand. However, using this relationship we can make changes to the microbial fuel cell and monitor the response via the anode potential to determine any effects on the microbial metabolism. This method can be used to look inside the 'black box' to gain a better understanding of how to engineer the MFCs so that they can compete with current methods of wastewater treatment.