Analysis of Bench Scale Dual-Chambered Microbial Fuel Cell

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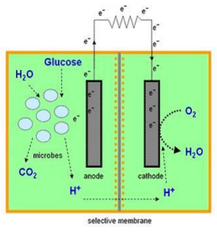
Introduction

A microbial fuel cell is a device that takes advantage of the natural metabolic processes of microorganisms to simultaneously generate electrical current and treat wastewater. For a single-chambered MFC, a batch reactor scenario is employed to contain the influent wastewater. This wastewater contains the crucial microorganisms, as well as organic matter, which serves as the microbial substrate. Microorganisms metabolize the organic substrate in the cell and release electrons. These electrons are conducted through an anode/cathode circuit, producing electrical current. As the wastewater is degraded, hydrogen ions are released and travel through a semi-permeable material to the air cathode chamber. Within this chamber, the hydrogen ions combine with ambient oxygen to produce pure water. Thus, the MFC produces electrical current, treats wastewater, and produces pure water.



$$C_6H_{12}O_6 + 6H_2O \rightarrow 6CO_2 + 24H^+ + 24e^-$$

Project Objective

The primary goal of this project was to investigate the output voltage potentials of a dual-chambered MFC by manipulating various initial nutrient concentrations. By changing these nutrient concentrations, and, invariably altering the initial BOD, COD, and total suspended solids (TSS), it was hypothesized that a trend would develop with respect to voltage outputs. MFC designs and materials were evaluated against feasibility and merit criteria in order to best meet this project goal. The secondary goal of this project was to compile and publish crucial data that was found lacking in the literature, such as a baseline for predicting electrical output potentials based on variable influent wastewater characteristics.

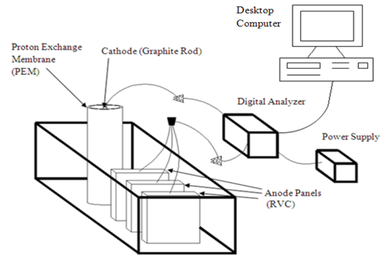
Procedure

Various standard water testing methods were employed throughout the term to assess the properties of the constructed MFC design. These testing methods included: Chemical Oxygen Demand (COD), Soluble Chemical Oxygen Demand (SCOD), Biological Oxygen Demand (BOD), and solids analyses.

In addition, electrical output was continuously monitored through the use of a digital analyzer. Data from the digital analyzer allowed electrical voltage to be plotted over time, as well as attribute electrical outputs to varying influent characteristics.

Peak voltages were recorded for each test and rationalized with initial volatile suspended solids (VSS) concentrations. Initial VSS concentrations were a reflection of the size of the microbial population at the beginning of each test. Initial SCOD concentrations were also recorded, which represented the concentrations of nutrients initially added. Trends were generated comparing the peak voltages per initial VSS concentration and initial SCOD concentrations.

Testing Solution
- 2 L MLSS (recycled after Test 1)
- 4 L Luria Broth (at 100% concentation)
  - 3 g/L Beef Extract
  - 5 g/L Peptone
  - 8 g/L Sodium Chloride
- Glucose (to contribute 200 mg/L SCOD)



Schematic of dual-chambered MFC design

Testing apparatus with MFC and components

Data and Analysis

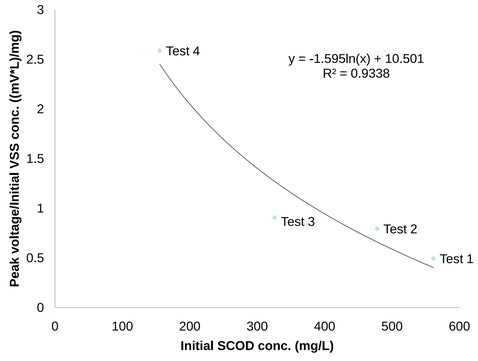
Initial SCOD concentrations were observed to decrease with increases in peak voltages. The trend established from the SCOD concentrations and peak voltages was contrary to the original hypothesis. Originally, it was hypothesized that an increase in organic substrate would lead to an increased output voltage; however, this was not observed. The microbial population that generated the highest peak voltage was given the lowest concentration of nutrients. It is believed that this trend was due to the initial manner of microbial sampling and the relative health of each microbial population. Because the microbial population used in Test 1 was sampled from MLSS, this population was initially composed of aerobes and facultative anaerobes (which, at the time of sampling, were oxidizing oxygen for metabolism). As the dissolved oxygen content was reduced to 0 mg/L, this aerobic population was replaced with anaerobic bacteria. Thus, at the end of Test 1, the MFC had become a completely anaerobic system.

Test 2 saw an increase in VSS concentration, indicating growth in the microbial population, despite a reduction of 50% in the nutrient solution (and thus initial SCOD). It is believed that a healthy anaerobic population existed, which led to both a quick peaking time and an increase in peak voltage. The nutrient solution for Test 3 was further reduced by 50%, yet the MFC yielded a similar peak voltage to Test 2. This test, did however, result in a much longer time to peak and a partial death phase of the microbial population due to exhausted nutrient resources. Test 4 initially had the lowest concentration of both microbes and nutrient solution. When exposed to new nutrient resources, the microbes recycled from Test 3 initiated a growth phase in Test 4. Similar to Test 2, this test had both a quick time to peak and a high peak voltage. It is difficult to explain this similarity, however, because Test 4 had a 75% less nutrient concentration than Test 2.

Broth Strength		Peak Voltages (mV)	Time to reach peak (min)	Initial TS (mg/L)	Final TS (mg/L)	Initial TSS (mg/L)	Final TSS (mg/L)
100 %	Test 1	431	7340	11892	3294	1150	1643
50 %	Test 2	540.9	220	13546	9696	947	1108
25 %	Test 3	549.6	840	7403	6575	763	652
12.5 %	Test 4	566.7	450	4729	4011	236	355
Broth Strength		Initial SCOD (mg/L)	Final SCOD (mg/L)	Initial VSS (mg/L)	Final VSS (mg/L)	Initial TVS (mg/L)	Final VSS (mg/L)
100%	Test 1	561.5	280.5	872	535	5322	1525
50 %	Test 2	478	224.5	681	739	5408	1923
25 %	Test 3	326	137	606	489	2534	1292
12.5 %	Test 4	155.5	101.5	219	310	1465	828

Further analyses of this comparison generated an unexpected trend. Comparisons showed that the stronger microbial populations required less and less amounts of nutrients. This was a very interesting trend that could be explained by the initial microbes implemented in Test 1. As previously stated, the majority of the microbial population in Test 1 was aerobic. As each test progressed, the microbial populations became more and more anaerobic and were better suited for their environment. When Test 4 was conducted the microbial population present was one that was completely anaerobic and very well suited for the environment present in the MFC. For these reasons, Test 4 produced the highest peak voltage with the lowest initial VSS concentration and lowest dose of nutrients. If the microbial population that was present in Test 4 was used in Test 1, results may have shown a much different trend than the one depicted in the figure.

Peak Voltage/Initial VSS vs. Initial SCOD



Conclusions

After analyzing the results of each test, a few theories have been proposed regarding dual-chambered MFC operation. Based on the graphs of voltage vs. time, each system reaches a pseudo-steady state condition. It is thought that this represents the stationary phase of the microbial growth curve and the relative upper limit of voltage output after peaking. As indicated in the graphs presented earlier, voltage outputs steadily increased despite the decrease in nutrient solution concentration. It appears as if a large, healthy anaerobic population has a more significant affect on voltage output than the initial nutrient concentration.

Acknowledgements

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