A Thermodynamic Analysis of a Single Chamber Microbial Fuel Cell
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ABSTRACT
Microbial fuel cells (MFCs) are devices that utilize bacteria to generate renewable electricity directly from organic compounds. Most of the current research performed on MFCs is centered on improving the power density of the system, with respect to the peripheral anode surface area. This research has been done on determining the effects of voltage output, and second law thermodynamic efficiencies in comparison to varying fuel cell components and structures. Seven single chamber MFCs were fabricated and tested with primary effluent domestic wastewater sample via a permit from the City of Arcata, CA. The direct current (dc) voltage potential data obtained from these MFCs was used to compute second law thermodynamic efficiencies ranging from 7.27% to 33.6%. An environmental and economic analysis determined a theoretical large scale component capital cost as $31,250,000 with projection costs of 10, 20 and 30 years based on a 5% discount rate and a theoretical carbon emission offset of 841 kg C/year (based on a 2 mgd flow rate). Investigation concluded that a proper biofilm is needed to obtain desirable voltage results and further analysis will investigate double layer issues, internal resistance properties using an Electrochemical Impedance Spectrometry (EIS) technique, and SEM/TEM imagery of electrodes.

OBJECTIVE
Build 7 single chamber MFCs with dimensions of 25 m² and anode peripheral surface area to 1 m³ of inoculate volume. Inoculate each MFC repeating at varying conditions simultaneous to logging voltage data. Relate the theoretical electromotive force of a MFC to that of the measured voltage potential of each MFC by calculating second law thermodynamic efficiencies. Determine the economic and environmental significance of MFC technology.

BACKGROUND AND JUSTIFICATION
Renewable energy (RE) applications are becoming a popular means for power generation within our society. Microbial fuel cells (MFCs) represent a new form of renewable energy technology. Justification for this study includes:

- With population increase and energy demand on the rise across the nation, few forms of wastewater treatment and extensions of existing treatment will need to be developed which require less non-renewable electrical energy from petroleum or natural gas resources.
- A basic theoretical environmental and economic analysis is necessary to understand large scale feasibility of MFC technology for wastewater treatment.
- MFC technology contains many hurdles before it can be implemented as a form of wastewater treatment (i.e. cathode material costs, small power generation due to anode surface area, and internal resistance issues). Still, however, it is a worthwhile technological pursuit due to it’s proven ability to generate usable renewable energy.

METHOD AND MATERIALS

- Materials (carbon paper/cloth all hydrophobic less AvCarb P50)
- 50 m² and 25 m³ m² MFC ratios and component description
- PROCEDURE: Inoculate each MFC with primary effluent (about 20ml) with transfer bottle (washed) is conditioned by filling and refilling the bottle a few times with sample. Control MFCs utilized DI water.
- Performance on a routine basis (every day or every other day) until a biofilm developed on both the anode and cathode portion.
- Voltage was inspected by use of a Fluke 73-III multimeter after each re-inoculation.

RESULTS

- RESULTS (continued)

THEORY

<table>
<thead>
<tr>
<th>Anode Half-Reaction</th>
<th>Cathode Half-Reaction</th>
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</thead>
<tbody>
<tr>
<td>2HCO₃⁻ + 4H⁺ + 8e⁻ → CH₄ + 6CO₂ + 4H₂O</td>
<td>O₂ + 4H⁺ + 4e⁻ → 2H₂O</td>
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Conclusions:

- Second law thermodynamic efficiencies of a single chamber MFC will range from 7.27% to 33.6% depending on system performance or other conditions.
- A double layer effect is exhibited in an MFC having a 2 mgd flow rate due to a theoretical carbon emission offset of 841 kg C/year (based on a 2 mgd flow rate).
- Theoretical Cost:
  - Surface Area Required: 1500ft²
  - Theoretical Cost: $31,250,000

ENVIRONMENTAL AND ECONOMIC IMPACT

- ECONOMIC:
  - Cost Projections:
    - $31,250,000 + $7,250,000 (2 mgd) = $38,500,000
  - Environmental:
    - Carbon Offset Calculation
      - $3,820,000 (2 mgd) = 77,250,000 kg C/year

FURTHER INVESTIGATION

- Analysis on MFC internal resistance using an Electrochemical Impedance Spectrometry (EIS) technique (under controlled conditions)
- Investigation of double layer effects
- SEM and TEM imagery of electrode portions.

CONCLUSION

- A proper amount of biofilm is needed on the anode portion of the MFC to produce desirable voltage results.
- A double layer effect is exhibited in an MFC with dc voltage data.
- Second law thermodynamic efficiencies of a single chamber MFC will range from 7.27% to 33.6% depending on system performance or lack of.
- Both the economic and environmental analysis demonstrate large-scale usage of MFC technology for wastewater treatment in the near future.

REFERENCES


Note: Further references available: http://microbialfuelcell.wordpress.com/

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