Microbial Fuel Cell

The American Society of Agricultural and Biological Engineers (ASABE) needs your help in designing a microbial fuel cell for generating electricity to run a water sewage treatment plant. The goal of this initial stage of the project is to generate enough electricity to illuminate an LED using pond sludge as the microbial fuel.

DESIGN REQUIREMENTS

- Maximum fuel container size: 4 liters
- System must be housed in a sealed container

TESTING EQUIPMENT

- Vernier Interface
- Differential Voltage Probe
- Current Sensor

DELIVERABLES

- Prototype
- Detailed design specifications (so the unit be replicated exactly)
- Maximum power output
- Sources for all materials
- Impact statement on the benefit of your design to the environment

CONSTRAINTS

- Construction materials must be readily available locally or online
- Budget limited to $50

JUDGING CRITERIA

- Ease of construction
- Power output

Teacher Tips

OBJECTIVE

Students will build a microbial fuel cell capable of illuminating an LED using pond sludge.

BACKGROUND

A microbial fuel cell (MFC) is a bio-electrochemical system that converts chemical energy to electrical energy by the bacterial interaction of microorganisms. MFCs are a very clean and efficient method of energy production. Though a relatively new form of alternative energy, MFCs are being investigated as potential power sources for sewage treatment plants. Wastewater treatment in the US (including pumping, filtering, etc) accounts for approximately 1.5% of total energy costs.

A typical fuel cell consists of a cathode compartment and an oxygen-free anode compartment separated by a salt bridge. Electrons and protons are generated when organic waste (the “fuel”) is oxidized by microorganisms in the anode compartment. The protons move to the cathode compartment through the salt bridge; however, because there is no oxygen in the anode compartment, the electrons attach to an electrode and travel through an external electric circuit to the cathode compartment. The electrons and protons are exposed to oxygen in the cathode compartment and combine to form water. Some MFCs use a mediator (such as thionine, methyl viologen, methyl blue, humic acid, etc) to transfer electrons to the electrode, but mediators tend to be toxic and expensive. Mediator-free fuel cells use the active bacteria in wastewater or mud to transfer electrons to the electrode.

During metabolism, bacteria stick to the surface of the electrode forming a bacterial community called a *biofilm*. The sticky biofilm is made up of extracellular proteins, sugars, and bacterial cells that form an electrical potential gradient allowing the transport of electrons. As the electric potential increases, the rate of bacterial metabolism increases. Bacteria will continue to grow as long as there is an abundant supply of nutrients. Maximum power output is dependent upon the thickness of the biofilm. If it is too thick, the electrons must travel too far to get to the electrode; if it is too thin, there are not enough electrons produced.

TEACHER PROCEDURE

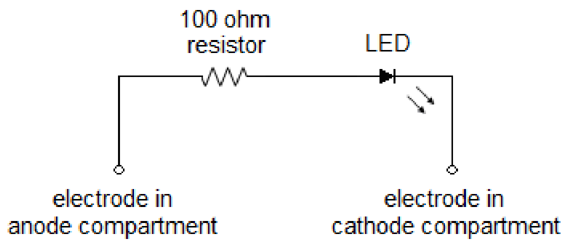
1. Instruct the class on the definition of a microbial fuel cell. Students should be able to discuss the bio-electrochemical interactions that occur as the microorganisms oxidize organic waste.

2. Construct the electrodes from carbon cloth.

3. Build the salt bridge.

4. Wire the LED in series with a 100 ohm resistor, and connect to the electrodes.

Tip: *LEDs have polarity. The positive lead (long wire) should be connected to the electrode in the anode compartment. The negative lead (short wire) should be connected to the electrode in the cathode compartment.*



5. If you want to include a measurement of the power the cell produces you can measure it with the Vernier Differential Voltage probe and the Vernier Current probe. The students will be tempted to measure the open circuit voltage or the short circuit current. Neither are good indicators of the useful power the cell can produce. Put a resistor across the electrodes of the cell. Measure the voltage across the resistor and the current in series with it using Logger *Pro*. Create a calculated column to take the product of the voltage in volts and the current in amps. This will be the power in watts. The value of the load resistor will affect the maximum power that can be delivered, thus the students will need to try an assortment of them to find the power maximum.

6. Obtain pond sludge. For best results, the sludge should be taken from the bottom of the pond and should be fairly thick and heavy (about the consistency of peanut butter).

7. Assemble the microbial fuel cell. Fill the anode chamber with pond sludge taking care to pack down the material so there are no air pockets. Fill the cathode chamber with a conducting solution such as salt water.

Tip*: You can bubble additional oxygen through the cathode chamber with an inexpensive aquarium pump.*

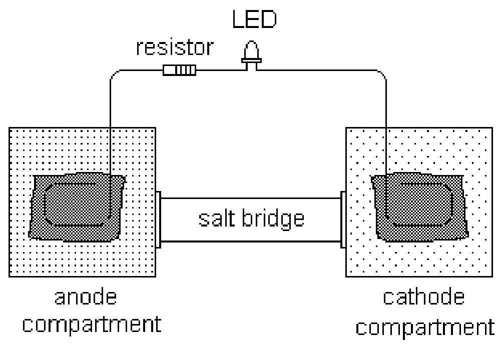
TIME ALLOTMENT

This is a moderate activity and will require 2-5 class periods

This activity requires 1 class period to build the electrodes and 1-3 class periods to assemble the fuel cell. Time spent retrieving pond sludge is not included in this estimate.

CONSTRUCTION TIPS

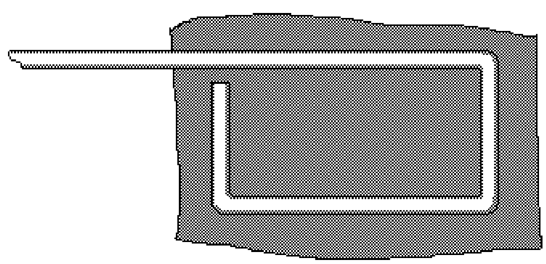
An MFC is basically two compartments (an anode and a cathode) connected by a gelatinous conductor called a *salt bridge*. Any storage containers or jars will work well for the two compartments. If they are made from plastic, it will be easy to cut holes in the sides to connect them. A compression fitting works well for the salt bridge, because the two end caps at the end of the tube allow a simple connection to the anode and cathode containers.



***Tip**: Compression fittings can be found in the plumbing section of the hardware store.*

To build the salt bridge, dissolve 100 grams of agar in 1 liter of boiling water. Add salt (NaCl, KCl, KNO^3, etc) until the mixture is saturated. Seal one end of the tube on the compression fitting with some plastic wrap and a rubber band. Stand the tube vertically and pour the salt/agar mixture into the open end. Allow the mixture to cool and solidify. You can transfer the tube to the refrigerator for faster setting.

The trickiest part of this project is building the electrodes. Normally, you could use lead from an old pencil as the carbon electrode in a homemade battery application; however, MFCs require electrodes with a large surface area. Carbon cloth with a high gas-permeability and conductivity is one material that works well. Carbon cloth can be attached to copper wire with epoxy, which also helps protect the wire from corrosion. To give the electrode some extra stability, form the wire into a large loop.



***Tip**: As an alternative to building your own device, you can purchase the MudWatt™ from Keego Technologies.*

RESOURCES

- http://www.engr.psu.edu/ce/enve/logan/bioenergy/mfc_guide.htm
- http://www.keegotech.com/ScienceKits/MudWatt
- http://www.microbialfuelcell.org/www/
- http://www.sciencedaily.com/releases/2008/01/080103101137.htm