Waste Not, Want Not: Use a Microbial Fuel Cell to Create Electricity from Waste

https://www.sciencebuddies.org/science-fair-projects/project-ideas/Energy_p026/energy-power/use-a-microbial-fuel-cell-to-create-electricity-from-waste (https://www.sciencebuddies.org/science-fair-projects/project-ideas/Energy_p026/energy-power/use-a-microbial-fuel-cell-to-create-electricity-from-waste)

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Experimental Procedure

Microbial Fuel Cells in Science Fairs

Working with microbial fuel cells involves growing soil bacteria. Because of this, many science fairs, including those associated with the International Science and Engineering Fair (ISEF) have requirements which need to be met *before* you start your project. We recommend you:

- Check with your teacher or science fair coordinator about any requirements
- Read the Science Buddies Microorganisms Safety Guide (http://www.sciencebuddies.org/science-fair-projects/references/microorganisms-safety) to learn how to safely handle bacteria

The goal of this science fair project is to determine if an MFC using a benthic mud sample can create electrons or electricity. You can either do this by building your own two-chambered microbial fuel cells as described in the procedure below or you can use one-chambered microbial fuel cells that are available for purchase from the Science Buddies Store (https://www.homesciencetools.com/product/mudwatt-classic-kit//?aff=SB1). If you are using the microbial fuel cell kit, you can follow the setup instructions found in the procedure of this science project: Powered by Pee: Using Urine in a Microbial Fuel Cell (http://www.sciencebuddies.org/science-fair-projects/project-ideas/EnvSci_p061/environmental-science/microbial-fuel-cell-urine). The following experimental procedure states to perform actions several times, which means that you will build three identical microbial fuel cells in total. Keep this in mind as you go through the procedure, and also keep in mind that you will be asked to perform three parallel trials. All strong science fair projects are replicated at least three times.

The procedure is broken into six sections: Building the Anode and Cathode Chambers, Making the Electrodes, Making the Salt Bridges, Obtaining the Benthic Mud Sample, Assembling the Microbial Fuel Cells, and Testing the Microbial Fuel Cells.

Note: Once you collect the mud samples, you will need to use them within 24 hours. Make sure you have everything you need to assemble the microbial fuel cells and start your experiment *before* collecting the samples. Since you don't want to take too many trips to your local stream, get enough of a benthic sample to use for three parallel trials.

Building the Anode and Cathode Chambers

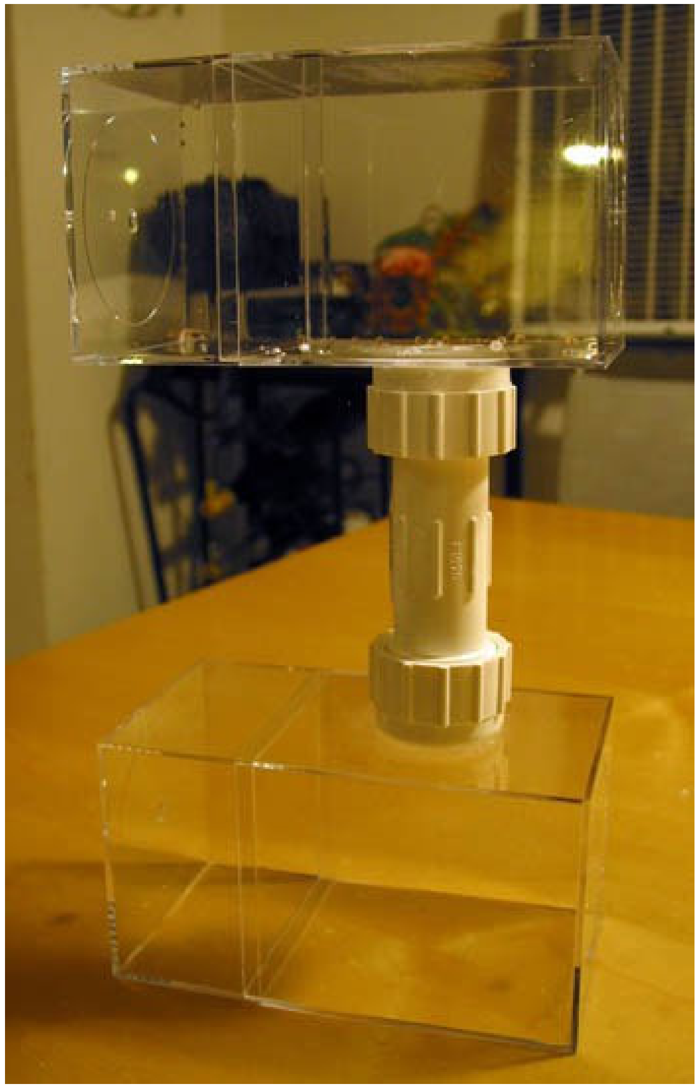
1. Unscrew the two ends of the compression fitting and discard the rubber fitting. Using the sandpaper, roughen the endcaps of the compression fitting as shown in Figure 2.

Figure 2. Roughening one of the endcaps.

2. Take the sandpaper and roughen two opposing sides of two of the plastic containers. Just roughen two 1-inch by 1-inch patches across from each other. Making a rough patch will help join all of the parts together.
3. Using the permanent marker, make a mark in the center of the roughened side of one of the plastic containers. Use the ruler to measure the location of the mark and then make a mark at exactly the same location on one of the roughened sides of a second plastic container. Make sure that the marks are exactly opposite of and facing each other.
4. Using the ruler, measure the outer diameter of the aquarium air pump tubing. Record this number in your lab notebook.
5. Put on the safety goggles. Carefully drill a hole 2 millimeters (mm) in diameter on top of two of the plastic container lids. Brush off any plastic debris from the lids. In one of those lids, drill another hole the same diameter as the plastic tubing of the aquarium air pump next to the first hole.
6. Using the 3/4-inch spade drill bit, drill a hole on the permanent marker marks on the sides of both plastic containers. *Note:* Drill slowly or the acrylic might crack. Brush off any plastic debris. You should now have two plastic containers that each have a hole in one side as shown in Figure 3.

Figure 3. Plastic container with a hole drilled into the side.

7. Read the safety recommendations on the acrylic cement. Squeeze acrylic cement around one of the 3/4-inch spade drill bit holes. The acrylic cement is watery so be careful not to get it in the hole or on your fingers. Now squeeze acrylic cement around the flat part of one compression fitting endcap. Center the endcap over the hole on one of the plastic containers that you just squeezed cement around. Fit the two pieces together. Hold the two together for 30 seconds. Squeeze some additional cement around the outside of the endcap where it joins with the container. This is to ensure that you minimize liquid leaks. Let the assembly dry for 10 hours.
8. After 10 hours, screw in the tube as tightly as possible. Hold the endcap firmly and just screw in the tube.
9. Now screw the second roughened endcap into the tube. Make sure to tighten the endcap firmly.
10. Lay the second container on its side with the 3/4-inch spade drill bit hole face up. Squeeze acrylic cement around the hole, making sure not to get any in the hole or on your fingers. Squeeze some acrylic cement on the second endcap on the assembly. Position the endcap and assembly over the 3/4-inch spade drill bit hole in the second container. Make sure that it is centered. Use the ruler to make sure that the containers are straight and level. Make adjustments as necessary. *You need to make sure that the containers can sit flat on the table when all the parts are dry.* Hold the entire assembly together for 30 seconds. Squeeze some acrylic cement around the outside of the endcap where it joins with the second container. Let the entire assembly (the two containers with connecting compression fitting), dry for 10 hours. See Figure 4 for a completed assembly.



The plastic tube is attached over a hole drilled into the side of each plastic container. Acrylic cement is used to secure the plastic tube so that no liquids leak out.

Figure 4. Aligning and cementing the second endcap and container.

11. After 10 hours have elapsed, check to see if the two joints are watertight. Fill the containers with water past the holes/joints. Wait for 5 minutes. If there is no water leaking out, then proceed to the next section. If there is excess water coming out of a joint, empty the containers and dry them off completely with paper towels. Carefully squeeze acrylic cement around the endcap joint that leaked. Squeeze out enough cement that you make a seal, but not so much that it becomes messy or that you seal the tube. Wait for 10 hours and retest the watertightness. Try again if this doesn't work. If it still doesn't work, remake the assembly with fresh parts.
12. Once the parts are watertight, carefully unscrew the tube from the endcaps. Set the tube aside.
13. Repeat steps 1-12 two more times. You should end this section with three sets of an anode and cathode chamber, like the one shown in Figure 5.

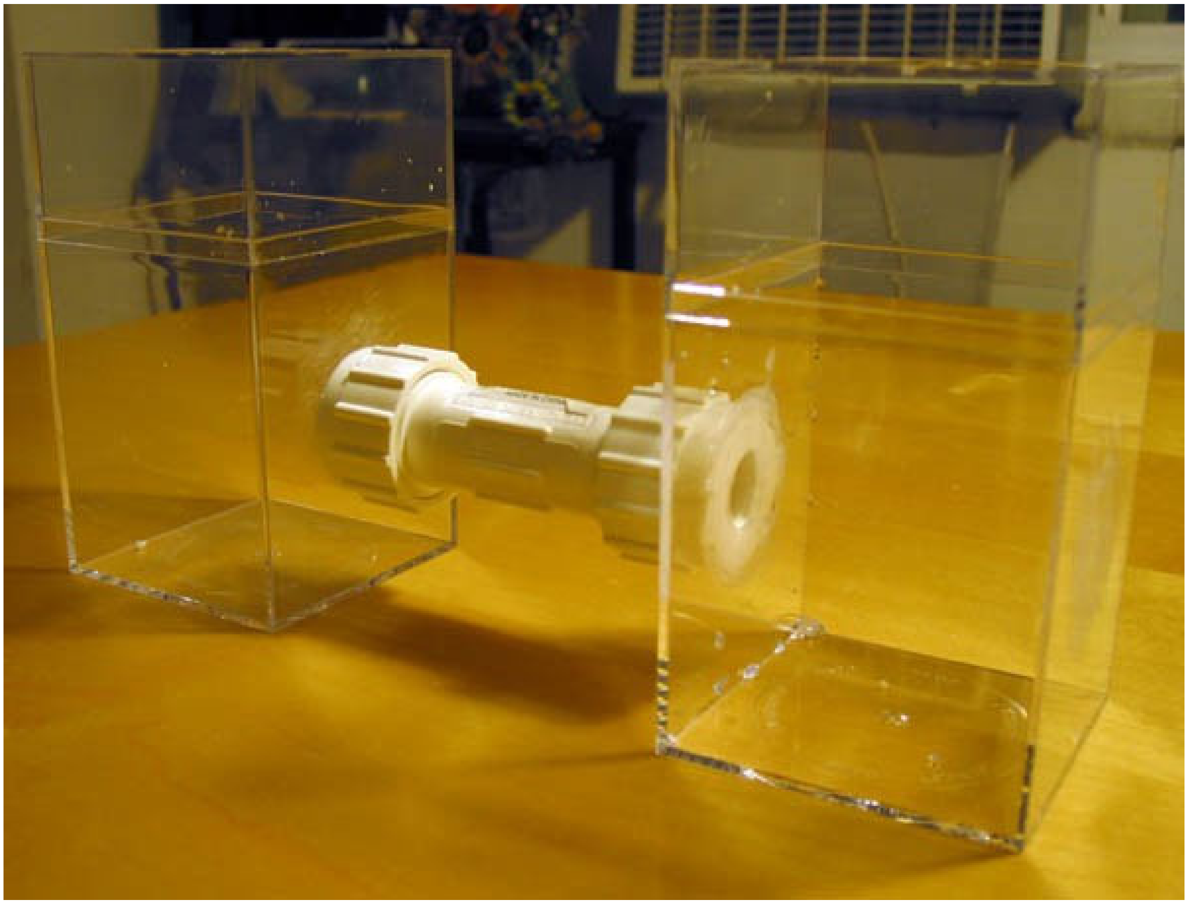


Figure 5. This is one set of a connected anode and cathode chamber.

Making the Electrodes

1. With the scissors, cut the carbon cloth into four equal squares. Each square should be 5 cm x 5 cm.
2. Take each of the four pieces of copper wire and with the wire strippers, strip off 6 inches of the insulator on one end of each piece. Strip off 1 centimeter (cm) from the other end of each wire.
3. Prepare the nickel epoxy according to its directions.
4. Epoxy the 6 inches of bare copper wire to the carbon cloth along the edges of the square. Repeat with the other three carbon cloths. Let the epoxy harden for 10 hours.

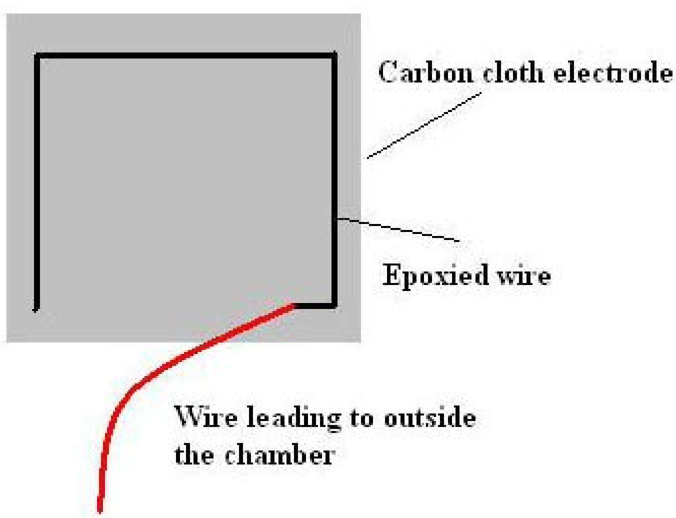


Figure 6. This is a visual of how the electrode should look.

5. Once the epoxy has hardened, test the connection between the carbon cloth square and the copper wire with the digital multimeter. If you need help using a multimeter, check out the Science Buddies reference How to Use a Multimeter (http://www.sciencebuddies.org/science-fair-projects/references/how-to-use-a-multimeter). Turn the digital multimeter to the resistor/resistance mode. Place one lead on the carbon cloth and the other lead on the free bare end of the copper wire. There should be no or very low resistance (1–3 ohms). If there is a large resistance, then remake the electrode.
6. Repeat steps 1–5 one more time. You need to make enough electrodes to make three anode-cathode pairs. In other words, you need to make six electrodes. At the end of this section, you will have eight electrodes. Set two of the electrodes aside and keep them as spares.

https://www.youtube.com/watch?v=ts0EVc9vXcs (https://www.youtube.com/watch?v=ts0EVc9vXcs)

Making the Salt Bridges

1. Place some plastic wrap along the bottom of a petri dish so that the ends of the plastic wrap are overlapping the edges of the petri dish. Set the covered dish aside.
2. Cover one end of the tube section (that you removed in step 12 of the Building the Anode and Cathode Chambers section) from the compression fitting securely with aluminum foil. Repeat with the tubes from all of the compression fittings. Place all tubes, open end up, vertically on the petri dish and then set it aside.
3. Measure 300 milliliters (mL) of water and pour it into the pot.
4. Using the scale, measure out 30 g of agar. Set the measured agar aside. Now measure out 6 g of salt.
5. Place the pot of water on the stove and bring it to a boil. When the water is boiling, add the agar and stir it with the glass rod until it is dissolved.
6. Once the agar is dissolved, take the pot off of the heat and add 6 g of salt. Stir with a spoon until the salt is dissolved.
7. While the solution is still warm, carefully pour the solution into the tubes in the petri dish. If the tubes leak, tighten the foil and refill them. Once the tubes are filled and stable (i.e. haven't fallen over, leaked liquid, etc.) for 10 minutes, carefully move the petri dish to the refrigerator. Let the tubes sit in the refrigerator overnight. These tubes are the salt bridges.
8. The next day, come back and place the salt bridges into a 1-qt. plastic baggie and seal it. This prevents the salt bridges from drying out. They should be a firm, jelly-like substance but not completely solid. Take the bridges out when you are ready to use them.

Obtaining the Benthic Mud Sample

1. Go to the location of your stream where you have found the richest riverbed. The sample you get should not be full of rocks or twigs, just rich mud.
2. Tie the nylon rope securely around the middle of the PVC tube.
3. Throw the tube into the stream or creek. Make sure that you keep a good hold onto the end of the rope! Try to scoop as much of the stream bed as you can.
4. When you think that you have gotten a large enough sample, drag the tube back to shore. Gently tap the pipe with the hammer and transfer the sample into the bucket. Cover the bucket with plastic wrap and set it aside. Make sure to get enough of the benthic sample to fill the anode chamber and remember to use the sample within 24 hours.
5. Collect some of the stream water in the cleaned 1-gallon jug. Be careful when retrieving this sample. Always exercise caution when you are near a stream or a creek, as the water current can be stronger than it looks.

Assembling the Microbial Fuel Cells

1. Retrieve the six containers built in section 1 and the salt bridges made in section 3. Remove the aluminum foil from the salt bridges. Connect a pair of containers with a salt bridge. Repeat two more times. You now have set up three microbial fuel cells containing an anode and cathode chamber each connected with a salt bridge.
2. Make a conductive salt solution using the water sample from the 1-gallon jug. Measure out 12 cups of stream water into the large bowl. Add 6 Tbsp. of salt to the bowl and stir with a spoon until the salt has been dissolved. Fill the cathode chambers of the three microbial fuel cells with the salt solution.
3. Take an electrode (this will be your cathode) and thread it through the smaller hole of one of the lids with two holes. Place the lid with the two holes and the connected cathode back onto the cathode chamber. Make sure the electrode is submerged. Repeat this step with another electrode and the other lids with the two holes. Seal each cathode chamber with a lid.
4. Connect the tubing to the outlet of the aquarium pump. Push the tubing into the cathode chambers through the larger hole in the lid. Be sure to submerge the end of the tubing.
5. Now, wearing gloves and safety goggles, fill half of the anode chamber of a microbial fuel cell with the benthic mud sample. Make sure that there are no bubbles in the mud. Push the mud sample down or gently tap to remove any

bubbles. Take one of the electrodes (this will be your anode) and bury it in the mud. Then place more of the benthic mud into the anode chamber, covering the anode. Push the free end of the electrode copper wire into the 2-mm holes in the container lids. Replace the lid onto the container to make sure that the electrode is hanging freely without hitting any of the walls or the bottom. You can use a little electrical tape on the outside top to hold the electrode in place. Repeat filling the anode chamber with your benthic mud sample and inserting the anode with the other two microbial fuel cells by repeating step 5 for the two additional trials. The microbial fuel cells are now complete and you should have three MFCs in total.

Testing the Microbial Fuel Cells

To evaluate the overall performance of your MFC, you can determine its **power output**. This is done by measuring the voltage across a fixed **resistor** that you attach to the MFC and from that, you can calculate power using a derivation of **Ohm's Law** as shown in Equation 1.

Equation 1:

$$P = \frac{V^2}{R}$$

- **P** is the power in watts (W),
- **V** is the voltage (V), and
- **R** is the resistance in ohms (Ω).

1. First, turn on the aquarium pump. This aerates the solution in the cathode chamber and creates more oxygen. Leave the pump on for the duration of your experiment.
2. Then connect the resistor and make the external circuit for the electrons to move through. Take one of the alligator clip cables and clip one end to the bare end of the electrode coming from the anode. Clip the other end of the cable to one end of the 220Ω resistor. Clip the end of the second alligator clip cable to the free end of the resistor. Clip the other end of the cable to the bare end of the electrode coming from the cathode.
3. Now test the voltage between the anode and the cathode with the digital multimeter. Test the first microbial fuel cell. Turn on the multimeter and put it in "voltage" mode. Measure the voltage reading across the resistor. Is there a voltage reading? You might have to adjust the sensitivity of your voltage setting on your multimeter (mV or μV) depending on your voltage readings. Note down your data in your lab notebook in a data table.
4. Take voltage readings twice a day at the same times, every day for 30 days.
5. Repeat steps 1–3 of this section for the other two microbial fuel cells. Always record your data in your lab notebook.

Analyzing Your Data

1. From your voltage readings each day calculate the power output for each microbial fuel cell using Equation 1.
2. Plot your results on a scatter plot showing the time on the x-axis and the calculated power output on the y-axis. Make three plots; one for each microbial fuel cell.
3. Did the microbial fuel cells produce electricity? If yes, did the MFCs start producing electricity right away? Did the electricity production ever peak? How did the electricity production vary over one day?