Middle School Laboratory Crash Course on Bioenergy

By

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Introduction

Remember your pre-college days when life was much simpler and perhaps less stressful? Remember your extracurricular activities and how they were not governed by responsibility and a regimented schedule? Remember your imagination, and how anything was possible if you just thought about it for a bit longer? This laboratory manual and experimental course seeks to recapture the imagination we all once had during our early years. By exposing young minds to proven scientific concepts, we hope to inspire creativity to pursue the impossible, challenge the status quo and lead society into a new frontier; in our particular case, sustainability.

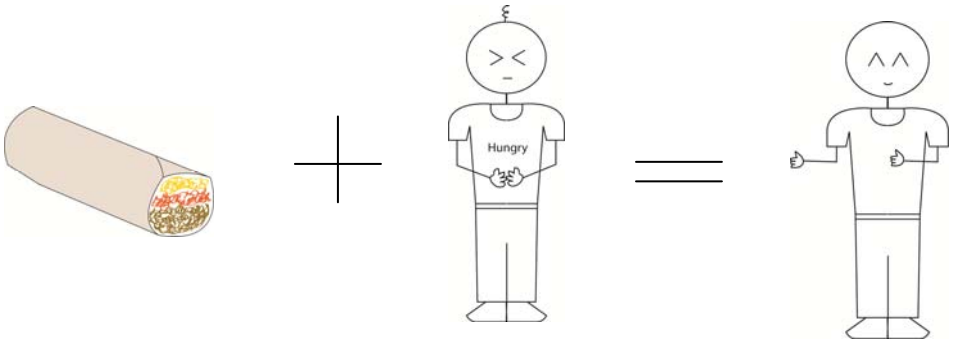
Having once been undergraduate college students (and lecturers) of sustainability topics at the university-level, one thing has become clear to us: we were too late. The typical university student has already developed his/her individual world-view, and there is very little less than an epiphany to convince him/her otherwise; even with scholarly evidence and research! Our intention here is to start younger than the university-level. We aim to provide younger, more malleable minds with knowledge and key concepts, and let them grow up and decide for themselves what is best for our society.

We rely heavily on you, the teachers to translate our excitement and hopes to the younger generation. ***As teachers, you have the most profound influence on every aspect of a student's life, and therefore hold the key for change in the near and long-term future***. It is truly a privilege to work with you, and we welcome any comments and or suggestions that you can offer to better get our message across to society's youth.

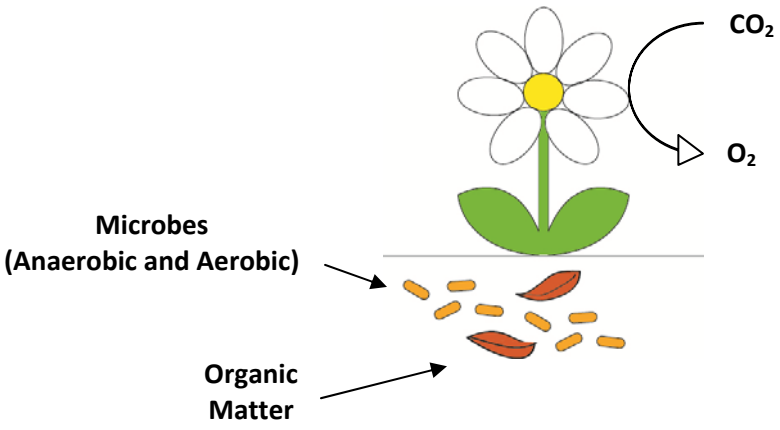
Experiment #1: Microbial Fuel Cell (MFC)

What is it?

All living organisms consume food (organic matter) to stay alive. (Think about that burrito that you had for lunch.) And all of the food that we eat contains energy, literally. As we digest our food, our bodies capture and use the energy contained in the food that we last ate. An MFC is essentially the same thing…sort of.

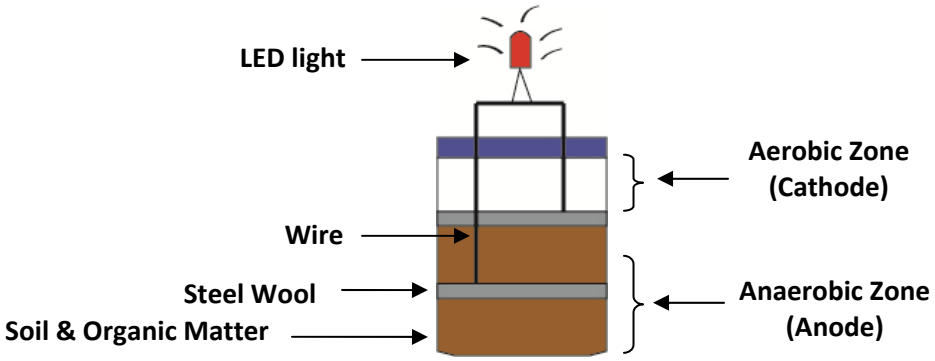


MFCs in our case use soil which contains a whole bunch of microorganisms that cannot be seen with the naked eye. Some of these microbes grow under anaerobic condition (without oxygen) and thrive by eating rotten leaves, branches, roots, and other organic matter present in the soil. Believe it or not, these microorganisms also clean up our environment.



Within the MFC, we trick the microbial community into thinking that it is still in its natural environment. We provide the microorganisms with food, and allow them to break the food down into usable energy. With strategically placed wires and electrodes, we can capture some of this energy in the form of a

small electrical current. In theory, MFCs can be used to power anything that runs on electricity.



How exactly does an MFC work?

An MFC is a device that directly converts the energy stored in organic matter into electricity. In MFCs, organic matter is broken down by microbes at the anaerobic anode surface. This releases charged atomic particles which travel through the wires in an attempt to reach their preferred neutral state.

More specifically, MFCs consist of an anode and cathode compartment separated by a cation permeable membrane as shown in Figure 1. The microbes in the anaerobic anode zone break down the organic matter to release electrons (e^-) and protons (H^+). Protons can selectively cross the cation membrane, but not electrons. Without a place to go in the crowded, negatively charged anode zone, the electrons are forced to travel through the wire we placed in the system to reunite with their positive counterparts (and attain their preferred neutral state). As they migrate to the cathode (via wire), we can force the electrons to do some work for us (e.g. spin a fan). Upon reaching the cathode, the electrons combine with molecular oxygen and protons (H^+) to make the end-product, water.

What is the difference between a battery and an MFC?

The main difference between a battery and an MFC is that a battery contains all of the energy that it will ever have upon leaving the factory. In other words, a battery is a ***storage device*** for energy and has a predetermined lifespan after which, it must be thrown away or recharged. In contrast, an MFC can theoretically produce electricity as long as the microbes have organic matter (food) to consume. Thus, you can keep your

MFC running for years if your microbes are supplied with enough food and stay healthy (and your wires and electrodes do not corrode).

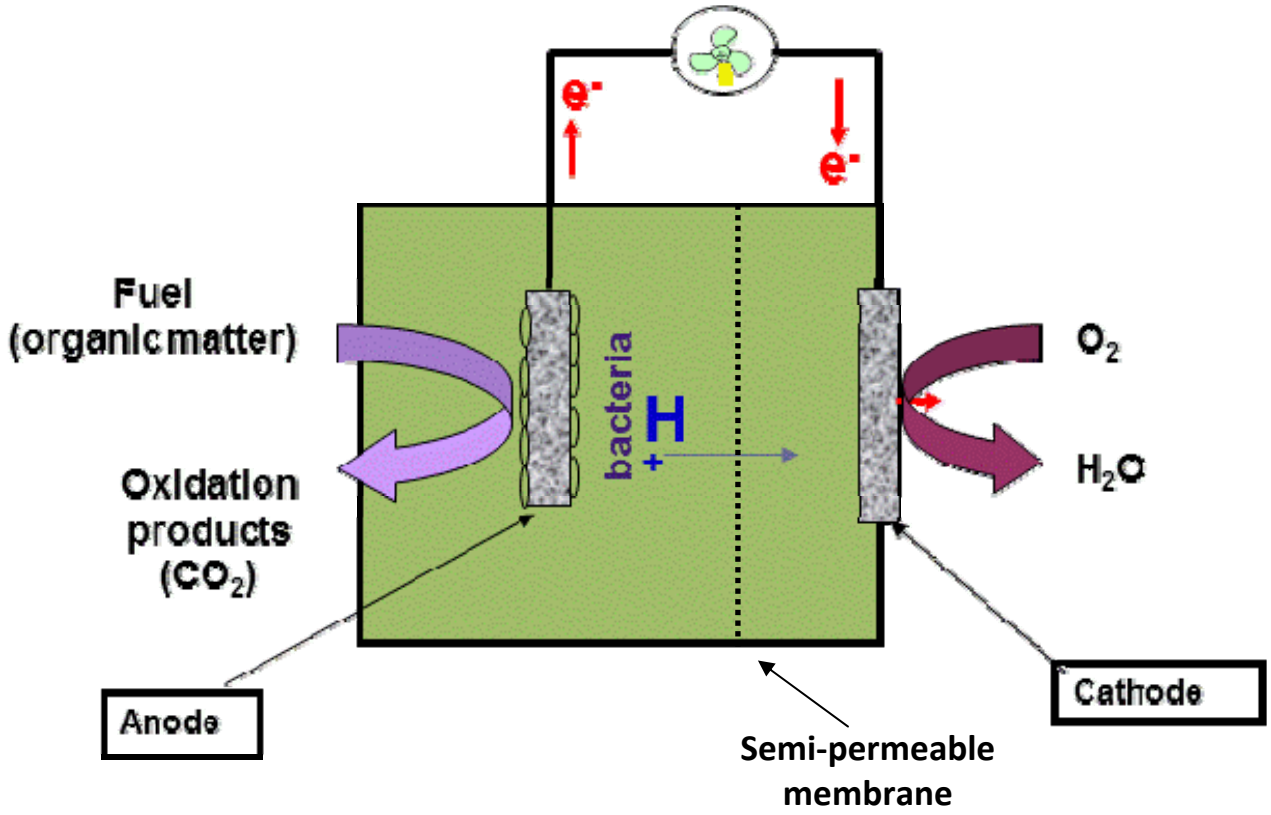


Figure 1 Schematics of microbial fuel cell

Experiment #2: Biogas

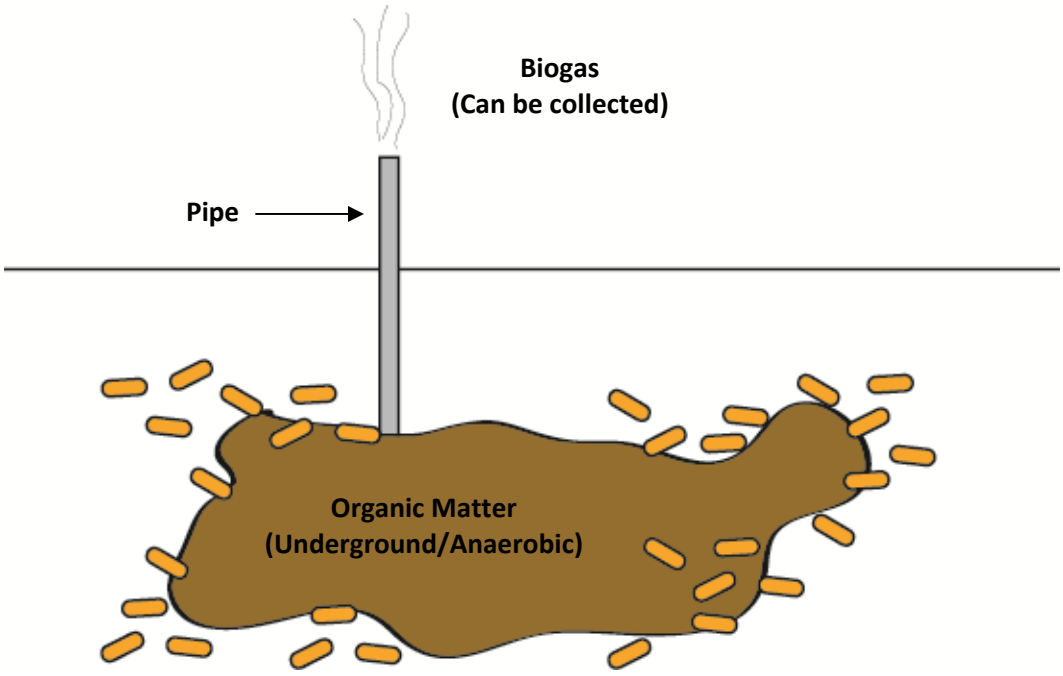
What is it?

Consider the burrito you had for lunch again. (And no, we aren't talking about *that* kind of gas.) As you digest your burrito, your body cannot help but exhale carbon dioxide. It is a natural byproduct of converting your food into energy and sustaining life. Similarly, under the right conditions (in absence of oxygen), certain microorganisms also produce gas. But unlike humans, these microorganisms can produce gas that can be used for producing usable energy. Carbon dioxide is still generated in the process, but the energy-containing gas known as methane (CH_4) is also generated. It is not necessary to get into too much detail here about the implications of this technology, but consider this: If you can burn methane, you can boil water and make steam. Steam can spin a turbine, and a spinning turbine

generates electricity. Interestingly enough, many power companies burn fossil fuel (instead of methane) to supply homes with electricity.

How do you make it?

You can produce biogas by feeding your anaerobic microbial community organic matter or food. (Yes, the same stuff from Experiment #1.) Although these microorganisms are of a different variety from the previous experiment, they like the same kind(s) of food. The biogas can be collected and used in a number of applications. Remote places in China, India and Nepal use this technique to convert food waste and feces into methane gas for cooking. This miracle gas has improved the lives of millions of people in these countries!



Experiment #3: Bioethanol

What is it?

Bioethanol is the same as drinkable liquor however, it is often found in extremely high concentrations (~100%), and is poisoned with 5% gasoline on purpose to prevent daredevils from drinking it. Under anaerobic conditions (no oxygen), you can force yeast (microbes) to produce bioethanol. This is called fermentation. Just like the microbes in the previous experiments, the yeast break down food (in this case sugar) to release energy and sustain life (You did the same thing to satisfy your hunger with that burrito you ate.) In the case of yeast, a byproduct of the metabolic process is alcohol which still contains a significant amount of usable energy. By rule of thumb, one pound of sugar generally produces ½ pound ethanol and ½ pound carbon dioxide.

Where does the sugar come from?

The sugar can come from anywhere and the fermentation process will generally remain the same. Currently the sugar for the 10% bioethanol found at gasoline stations is derived from corn grown in the United States. Do you know how much ethanol we produce annually? About 10 billion gallons! In contrast, do you know how much transportation fuel we consumed annually? Around 130 billion gallons!

There is a lot of public outcry over the competition of bioethanol with food-producing land (e.g. corn) within the United States. Researchers such as ourselves are working hard to find alternative sources of sugar that does not compete with prime farmlands, and we are even looking to produce another kind of alcohol that cannot be consumed, and has properties very similar to gasoline!