The Use of Dwarf Pennywort to Generate Electricity within a Plant Microbial Fuel Cell (p-MFC)

Gigianna Santiago and Dr. Margaret Larrousse

Background

In recent years, attention has been drawn to the fact that the Earth's climate is rapidly changing. Sea levels have risen along with the global temperature according to NASA[1]. Oceans are warming and undergoing acidification while the ice sheets are decreasing in size.[1] Oceans have warmed by 0.302 °F since 1969 and due to the carbon dioxide content increasing within the oceans the pH of the water has continued to decrease, becoming more acidic.[1] Greenland has lost 150-250 cubic kilometers of ice per year in a four year time span from 2002 to 2006.[1] Although such things seem trivial on a small scale, these changes are occurring faster that they should be occurring. On a small scale a temperature change of 0.302 degrees is nothing but when whole ecosystems are looked at where animals are given no time to adapt to the rapid climate change it becomes an entirely different story.[2] The most likely result for most species of animal, plants, and even microorganisms is the threat of extinction which is more likely to occur if this trend continues without enough time for these organisms to adapt.[2] With the polar regions decreasing in size more and more breeding grounds of certain animals have been destroyeed.[2] Even for those animals that inhabitant the Arctic, for example, resources are depleting for them as the land shrinks.[2] This crisis is a global one and one that has scientists driven to find an alternative to fossil fuels.

*Adapted from climate.nasa.gov

Human activity is a major cause of this growing crisis. On Earth a phenomenon occurs called the Greenhouse Effect.[1] When the sun's rays hit the Earth, specific gases in the atmosphere trap the heat from the sun on the Earth.[1] These gases, appropriately called the greenhouse gases, are water vapor, carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons(synthetic compounds used for various purposes).[1] Chlorofluorocarbons, nitrous oxide, methane, and carbon dioxide have increased within the atmosphere due to a number of human activities such as deforestation, agricultural activities, burning of biomass and fossil fuels as well as the production of nitric acid and certain organic fertilizers.[1] To curb these products from increasing evermore scientists have looked towards fuel cells as possible saviors.

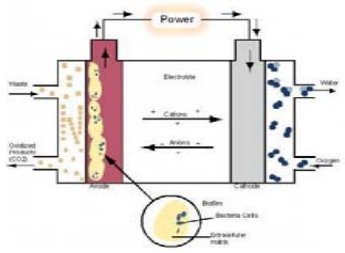
Introduction

A fuel cell is a device in which chemical energy is converted into electrical energy.[3] Generally fuel cells consist of an anode compartment and a cathode compartment connected by a salt bridge which allows for the cations and anions to pass through from one side to another.[4] Fuel cells rely on redox reactions to function. Therefore, in the cell you have an anode where oxidation occurs and the cathode where reduction occurs.[4] The following table lists some types of fuel cells and their fuel source:

Table 1.1: Types of Fuels Cells and their Electron Source

Fuel Cell Types	Source of Energy
Hydrogen Fuel Cell[6]	Hydrogen
Direct Methanol Fuel Cell[5]	Methanol and water
Microbial Fuel Cell[6]	Microorganisms (bacteria) Substrate (sugar)
Alkaline Fuel Cell[5]	Potassium Hydroxide

In particular we are interested in the microbial fuel cell and its variation the plant microbial fuel cell. In a Microbial fuel cell (MFC) the anode holds the bacteria and sugar while the cathode contains oxygen to accept the electrons.[7] Since the bacteria are kept in the anode where the environment within is anaerobic (without oxygen) the electrons that would normally transfer to oxygen get transferred to the electrode within the cell.[7] These electrons then travel from the electrode in the anode side to the electrode in the cathode side through a wire.[7] At the cathode the electrons are combined with oxygen and protons to form water within the chamber.[7]



*Adapted from science daily article Fuel Cell That Uses Bacteria to Generate Electricity.

Plant microbial fuel cells run on the same concept as the microbial fuel cells. However, there are slight differences. One difference and the most significant different is that the anode where the bacteria are kept in the microbial fuel cell contains a plant instead of just bacteria and sugar.[9]

*Adapted from www.glastuinbouw,wur.nl

According to a study by Schamphelaire et al, a plant that produces rhizodepostis such as the rice plant is the ideal plant for this type of fuel cell.[10] Rhizodeposits are located in the roots and provide a substrate for the bacteria within the soil to consume.[10] One such plant is the Dwarf Pennywort.[11] The Dwarf Pennywort is a perennial plant can grow to be 4-12" tall.[11] These plants have stems with the ability to float on water.[11] It is this plant that will be used to conduct experiments with the p-MFC.

*Adapted from http://www.illinoiswildflowers.info

Procedure

The fuel cell was constructed using PVC piping purchased in a local home improvement store. Before all the pieces, except for the 1 ½" coupling, were placed together they were primed to remove impurities and clean the piping. Glue was spread on one of the two pieces meant to be placed together. The pieces were then placed aside and dried for 24 hours. Starting with the anode of the fuel cell, a 4" by 2" step down was placed within a 1 ½" by 3" step down. A J coupling was then attached to the 1 ½" by 3" step down. At the end of the J coupling another step down (smaller in size to fit snuggly into the J coupling) was attached. Next a piece of PVC pipe 5.5 cm in length was placed within the step down. The cathode was assembled using another J coupling placed within a step down similar in size to the previous smaller one. As for the anode that was constructed before, the smaller step down had another 5.5 cm in length PVC pipe. A cap was placed on top of the vertical part of the J coupling. The open ends of the cathode and anode consisting of the 5.5 cm PVC piping were then connected using a 1 ½" coupling that allows for easy removal to allow for the replacement agar serving as the salt bridge.

Future Experiments

Future Experiments are as follows:

- The Dwarf Pennywort will be grown in the anode compartment of the fuel cell
- Voltage and Current measurements will be taken over several weeks
- Other species of water plants will be tested and compared with the Pennywort

Works cited

1) Global Climate Change. http://climate.nasa.gov (09/05/2010)
2) Climate Change-Health and Environmental Effects. http://www.epa.gov (07/12/2010)
3) Fuel Cell Basics. http://americanhistory.si.edu/fuelcells/basics.htm (7/12/2010)
4) Kotz, John C.; Treichel, Paul M.; Townsend, John R.. *Chemistry & Chemical Reactivity*; Enhanced Edition; Brooks/Cole; Canada, 2010; 905
5) Types of Fuel Cells. http://www1.eere.energy.gov (07/19/2010)
6) Harper, Gavin D.J. Fuel Cell Projects for the Evil Genius; McGraw Hill: New York, 2008; 57,95,107-113
7) General Principles of MFCs. http://www.microbialfuelcell.org (0712/2010)
8) Arizona State University. Science Daily. http://www,sciencedaily.com (07/12/2010), article name is Fuel Cell That Uses Bacteria To Generate Electricity
9) Jan Snel. Living Plants Produce Energy. http://www.glastuinbouw.wur.nl (07/12/2010)
10) Schamphelaire, Lieslie De; Bossche, Leen Van Den; Hofte, Monica; Dang, Hai Song; Boon, Nico; Rabaey, Korneel; Verstraete. Microbial Fuel Cells Generating Electricity From Rhizodeposits of Rice Plants, *Environmental Science & Technology*, 2008
11) Water pennywort. http://www.illinoiswildflowers.info(07/12/2010)