Experiment: What Kind of Soil is Best To Power MFCs?

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Target age: High Schoolers and advanced Middle Schoolers
Subject Area: Biology and/or Physics

BACKGROUND

Recent research suggests that a soil's carbon composition, nitrogen composition, mineral composition, and bacterial community play a large role in determining how that soil will power microbial fuel cells (MFCs). Agricultural soil, which has higher rates of nitrogen, mineralization, and carbon respiration, can outperform forest soil by as much as 17%. In this experiment, students will test MFCs in different soils to empirically witness which kinds of soil will best power MFCs.

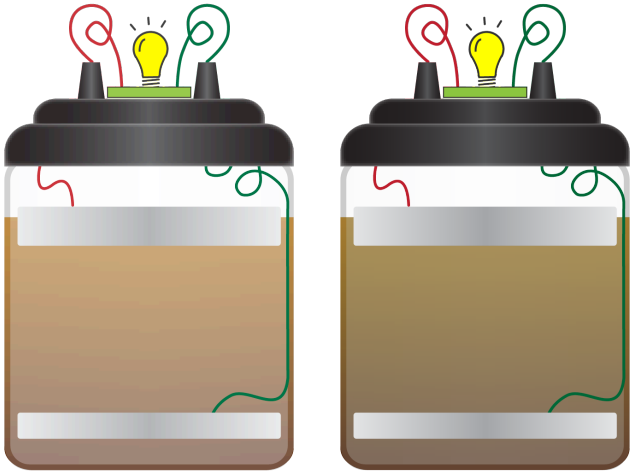
PREREQUISITES

- Understand how MudWatt MFCs work. Use the Teaching Material and Product Resources on http://www.keegotech.com/Community/Education.
- Understand how a Multimeter works. MudWatt Multimeters come with an instruction guide: http://www.keegotech.com/ScienceKits/Multimeter, or you can use Lady Ada's multimeter tutorial: http://www.ladyada.net/learn/multimeter/
- Understand how to collect (http://www.keegotech.com/Community/Hacker_Booklet) and record (http://www.keegotech.com/Community/DataLog_Booklet) data from a MudWatt.

Materials and Tools

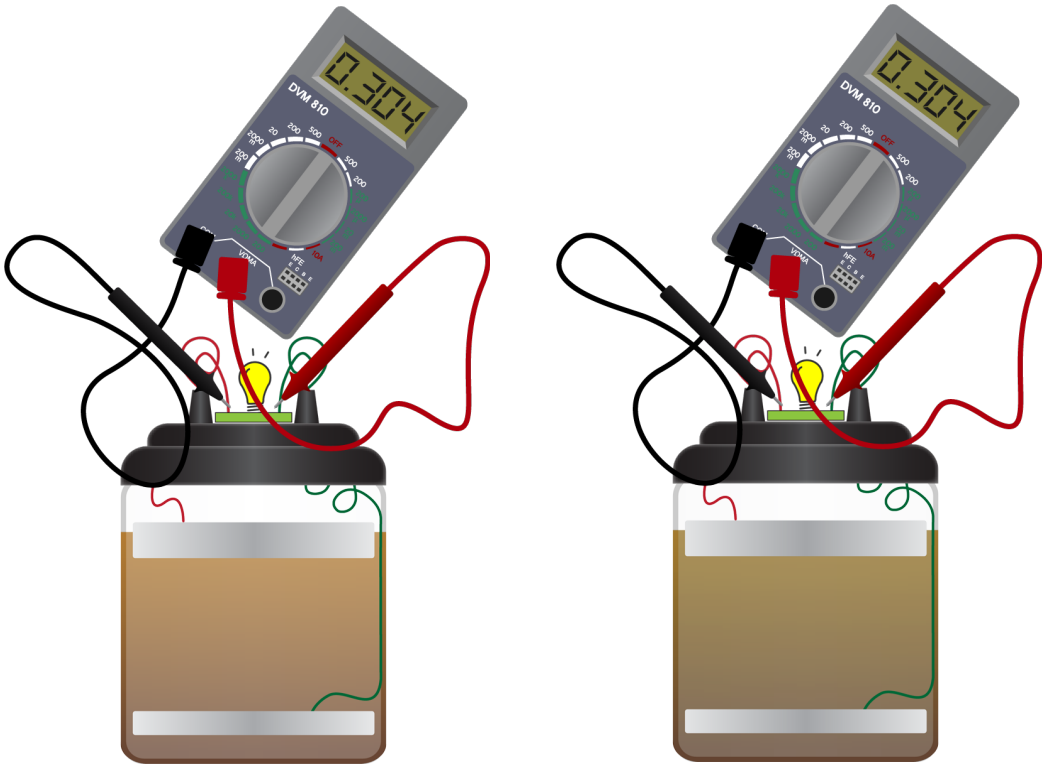
- 2 MudWatt MFC kits
- 1 farm soil sample*
- 1 forest soil sample*
- 1 multimeter

* Collect enough soil to fill a MudWatt Vessel.



PROCEDURE

1. Set up a MudWatt kit with the farm soil sample.
2. Set up a second MudWatt kit with the forest soil sample.
3. Discuss with students: which soil will better fuel ("light up") an MFC? Consider these questions in forming a hypothesis:
    - What grows in a forest? What grows on a farm?
    - At what rate do forest plants grow? At what rate do farm plants grow?
    - Which kind of plant, forest or farm, generally requires more daily energy?
4. Every week for two months, perform a "Sweep" on each MFC, as described in the MudWatt Hacker Booklet: http://www.keegotech.com/Community/Hacker_Booklet



5. Record voltage (V) and calculate power ($P=V^2/R$) for varying resistance (R). Refer to the MudWatt DataLog Booklet if needed: http://www.keegotech.com/Community/DataLog_Booklet If possible, record the results in a spreadsheet formatted like this:

Date	Temp	V (for R=100)	P (for R=100)	V (for R=500)	P (for R=500)	V (for R=1k)	P (for R=1k)	V (for R=5k)	P (for R=5k)	V (for R=10k)	P (for R=10k)

6. At the end of two months, convert each column in the table above to a series of graphs.

7. Discuss the the data findings.

   - Ask students to observe overall MFC patterns, such as if the MFC weakened over the course of time, and if so, in what way.

   - Ask students to compare and contrast patterns between the farm and forest MFCs. It may be useful to focus on just one resistance level for this part.

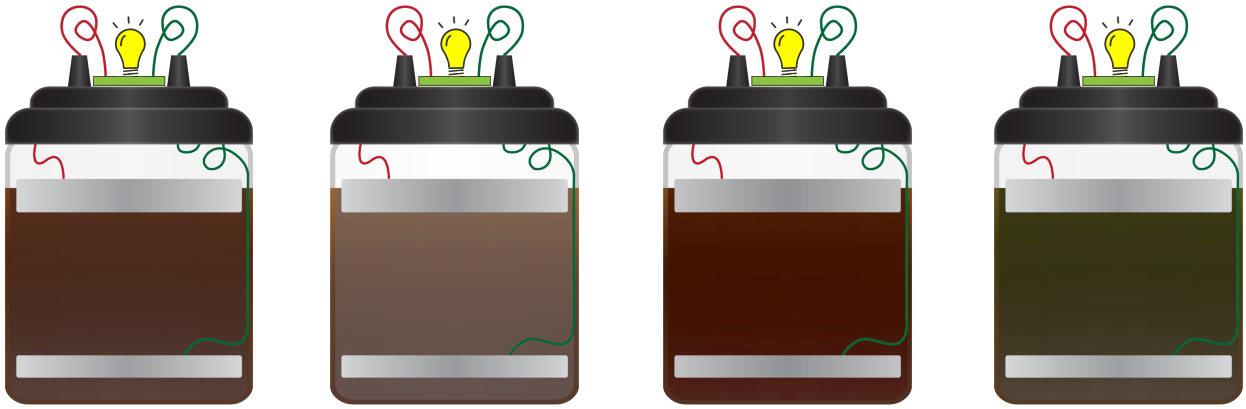
8. Ask students to compare their findings with the table below (simplified from the Dunaj article). What are some of the implications in using MFCs with certain soils?

	% organic carbon	Carbon-Nitrogen ratio	Nitrogen Mineralization Rate	Carbon Dioxide Respiration Rate	Peak Power Output
Farm MFC 2	4.1	16.4	38.3	0.29	44
Forest MFC 2	20.4	28.9	-10.6	0.033	4.21

9. Advanced Discussion: Take a closer look at carbon respiration in the table above. Considering that forestland is more likely than farmland to be a "carbon sink" that takes in more carbon than it outputs, what are the roles MFCs and different soils could play to curb carbon emissions and slow climate change? Diagram some of the roles/relationships between MFCs, farm soil, forest soil, carbon emissions, carbon sinks, and climate change. (Use the Murty and Paul articles for more information.)

ADVANCED EXPERIMENT TECHNIQUES

- Incorporate additional MFCs with additional soils: potting soil, backyard soil, beach soil, swamp mud, etc. Consider what grows in each of these soils and make a predictive list of how the soils will power MFCs. Conduct the two-month study and compare the results with the predictions!



- Set up an automated multimeter system with microcontrollers. These links can get you started. Voltmeter: http://arduinoprojects101.com/arduino-voltmeter/
  Ohm (resistance) meter: http://evilquark.com/blog/?p=49

REFERENCES

1. Danuse Murty, Miko U. F. Kirschbaum, Ross E. Mcmurtrie, Heather Mcgilvray. "Does conversion of forest to agricultural land change soil carbon and nitrogen? a review of the literature." Global Change Biology, Volume 8, Issue 2, pages 105–123, February 2002.

2. Sara J. Dunaj, Joseph J. Vallino, Mark E. Hines, Marcus Gay, Christine Kobyljanec, and Juliette N. Rooney-Varga. "Relationships between Soil Organic Matter, Nutrients, Bacterial Community Structure, And the Performance of Microbial Fuel Cells." Environmental Science & Technology 2012 46 (3), 1914-1922

3. K.l. Paul, P.J. Polglase, J.G. Nyakuengama, P.K. Khanna. "Change in soil carbon following afforestation." Forest Ecology and Management, Volume 168, Issues 1–3, 1 September 2002, Pages 241-257, ISSN 0378-1127, 10.1016/S0378-1127(01)00740-X. (http://www.sciencedirect.com/science/article/pii/S037811270100740X)