Bioelectrochemical Systems for the Treatment of Wastewater and Methane Production

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Background

Long term spaceflight will require technology that is self-sustaining, while minimizing volume and mass. Bioelectrochemical systems (BES) have the ability to recover valuable resources, process waste, and generate a small amount of electrical current, via microorganisms, while satisfying the above criteria (Rabaey et al., 2010). We are currently working on small scale BES reactors that will generate electricity from the breakdown of urine and utilize the electrical current to catalyze synthesis of products including water and methane.

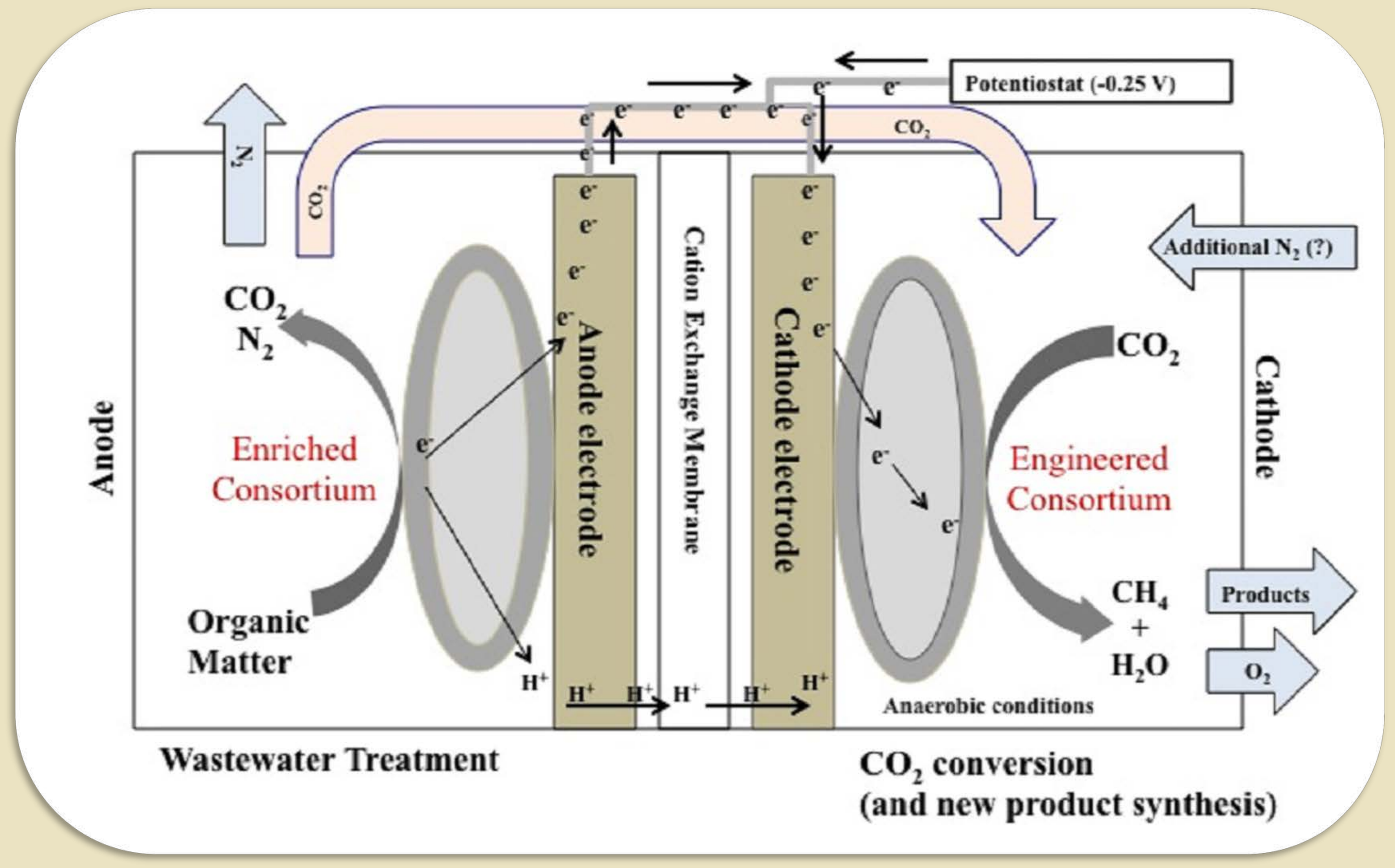


Figure 1: **BES Configuration for Wastewater Treatment (Grossi et al. , 2013)** *Electrogenic microorganisms in the anode chamber can oxidize available compounds in urine and reduce the electrode surface. The bacterial consortium in the anode chamber harvests electrons and creates CO2 and other compounds as byproducts that are used in the cathode chamber. Reduction of CO2 occurs in the cathode chamber which requires electricity, CO_2, and protons from the anode chamber.*

Methods

The small scale reactors contain three electrodes: two carbon fabric swatches comprising the cathode electrode, one carbon fabric swatch as the anode electrode, and a Ag/AgCl reference electrode in the cathode chamber. A cation exchange membrane separates each side and allows for the flux of protons and other positively charged ions from the anode chamber to the cathode chamber.

The consortium of microorganisms in the anode are isolated from sewage run off, while a a separate culture including methanogens exists in the cathode. Methanogenic bacteria are able to produce methane as a metabolic byproduct from hydrogen and carbon dioxide. Gas chromatography is used to quantify methane production in the BES. Multiple small scale reactors currently contain either human urine or synthetic urine (ersatz) in the anode and M120 growth media in the cathode. Total organic carbon (TOC), ammonium (NH_4), and pH levels will be consistently tested to determine the condition of the reactors.

Experimental Design

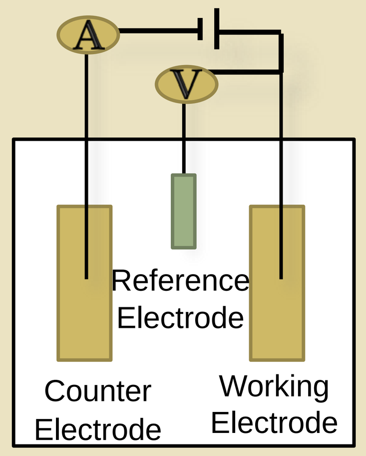


Figure 2: Small scale reactor with three electrode system.

- A potentiostat controls the voltage by using the counter electrode to apply the measured difference in potentials between the working and reference electrodes (Fig. 2). The potentiostat is used to confirm extracellular electron transport and current consumption by the microbes.

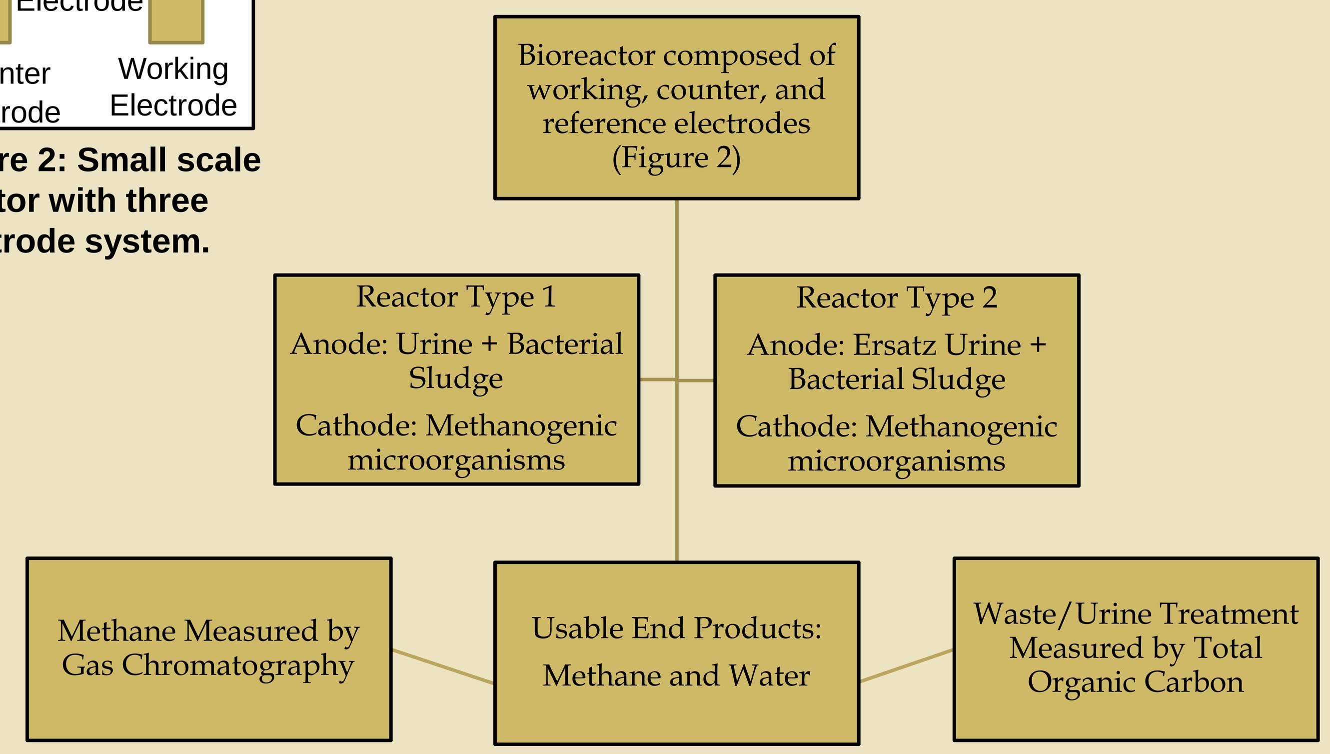


Figure 3: Products and Materials

Results

Total organic carbon (TOC) is an analytical method that measures the amount of organic carbon in an organic compound and is used to assess water quality.2 **Preliminary data suggests the microbial culture in the anode side is successfully metabolizing the carbon in the raw and ersatz urine.** A decrease in TOC (shown in figure 4) suggests improved water quality and confirms that the reactor is an effective means of treating wastewater.

Preliminary gas chromatography measurements of methane production in the cathode side of the reactors have shown promise but are not ready to be presented at this time.

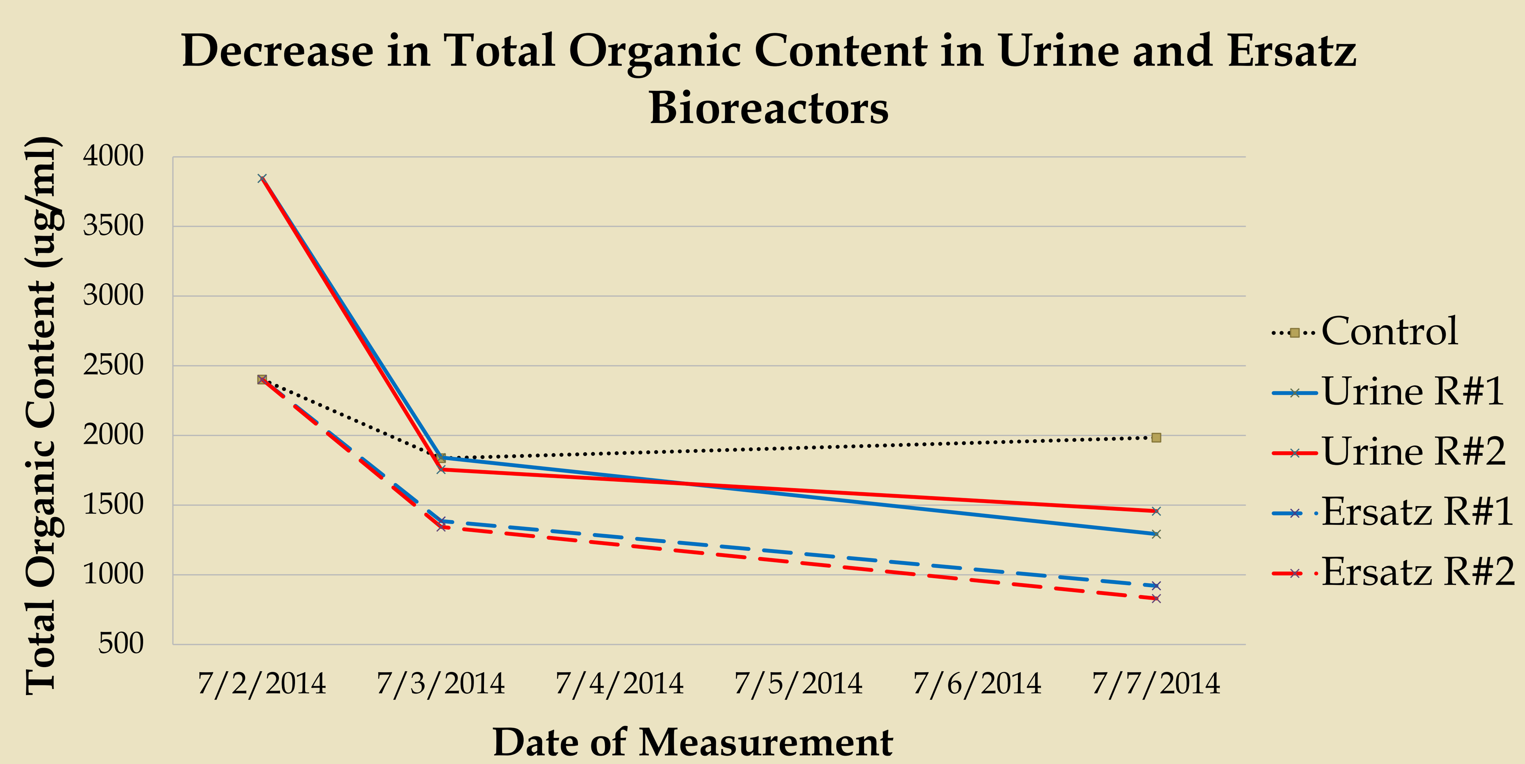


Figure 4: TOC measurements in urine and ersatz bioreactors. *Data from 7/2/2014 is the existing amount of TOC in raw urine and ersatz urine prior to inoculation in bioreactor.*

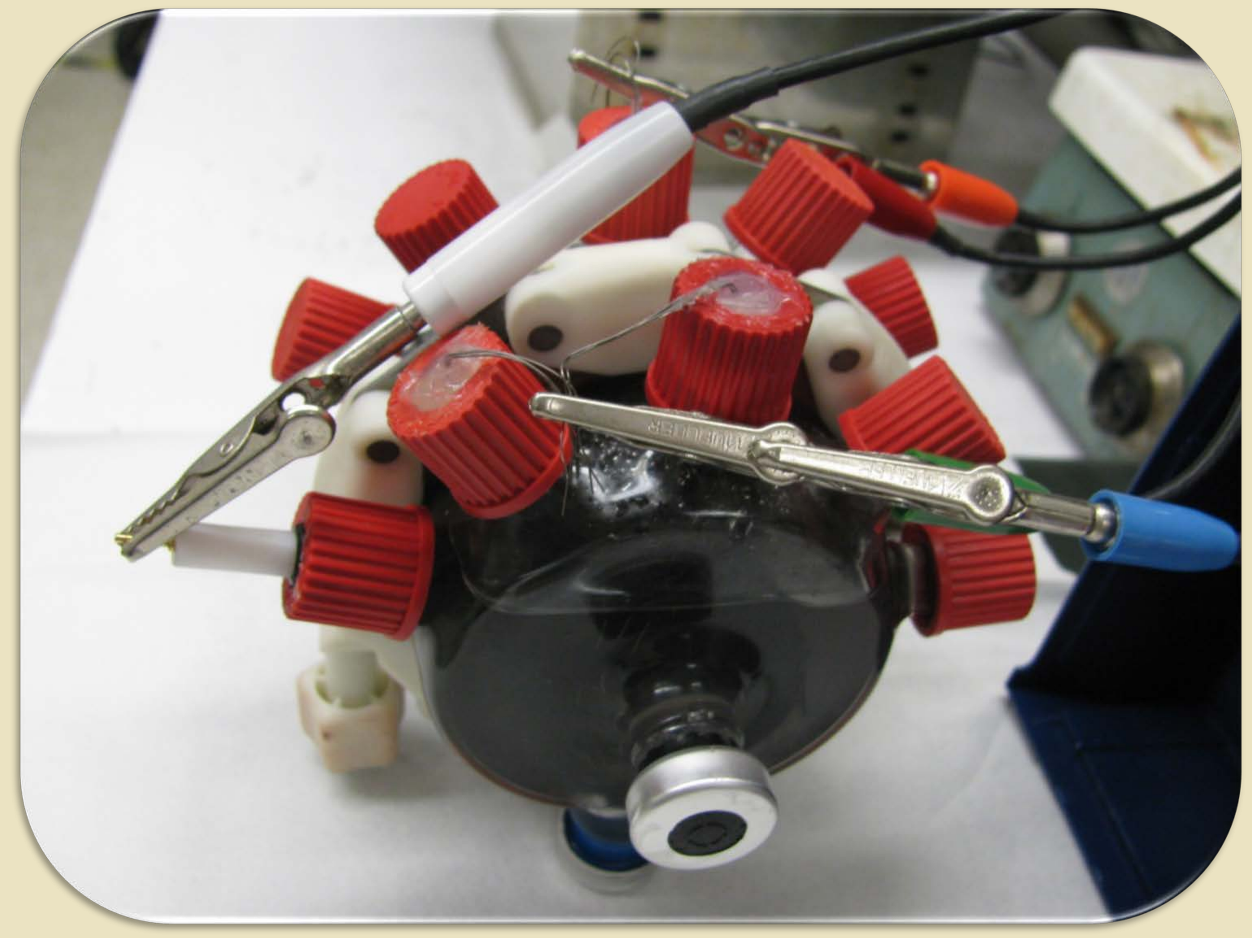
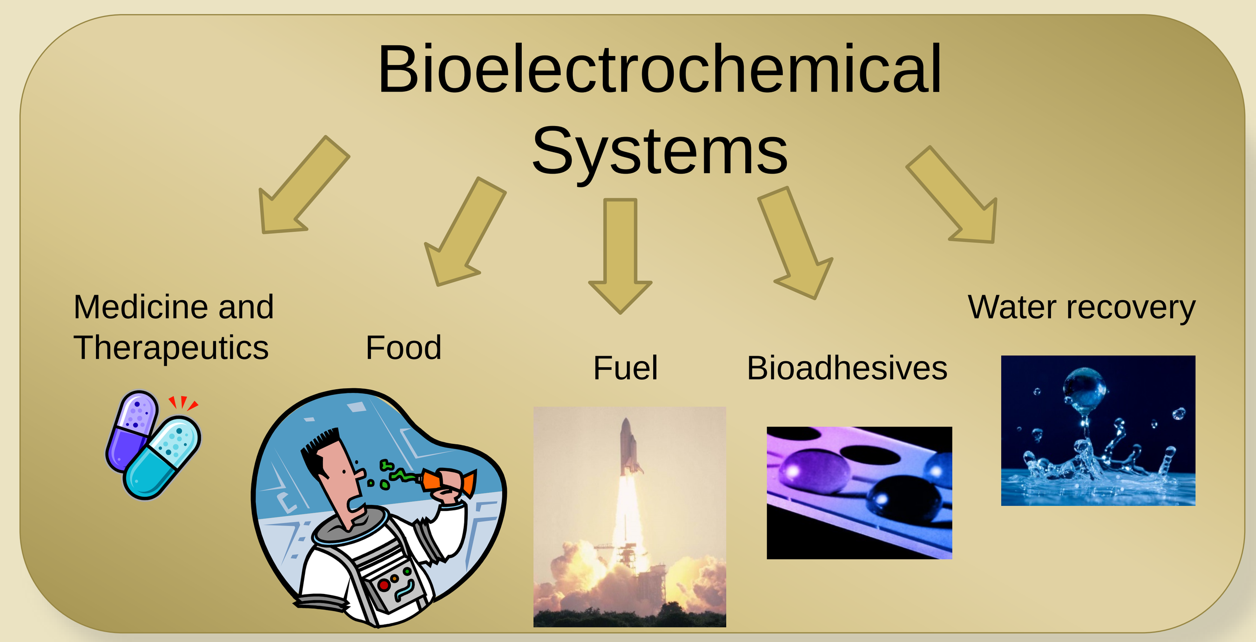


Figure 5: Small Scale Glass Reactor Connected to a Potentiostat

Conclusions and Future Work

Through experimental work with the small scale reactors, we have met conditions for wastewater treatment and production of methane, though further work will be needed to determine the true efficiency of the bioelectrochemical processes. With future research, experimentation will be done for optimizing the consortium of microbial cultures as well as membrane selection. Experimentation will be done with the goal of developing more efficient and sustainable wastewater treatment and resource recovery for manned space flights. BES's have a wide range of applications beyond that of wastewater treatment and methane production (see Figure 6). In the future, it may be possible to develop a BES to generate electricity or biofuels from the methane produced.



Citations and Acknowledgements

Grossi, E. N., Berliner, A. J., Cumbers, J., Kagawa, H., Modarressi, B., Hogan, J. A., and Flynn, M. "Potential applications for bioelectrical systems for space exploration," *43rd International Conference on Environmental Systems.* July 14-18, 2013, Vail, CO.

Rabaey, K., Angenent, L., Schröder, U., Keller, J., (Ed.), *Bioelectrochemical Systems: From Extracellular Electron Transfer to Biotechnological Application,* IWA, London, UK, 2010.

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