ADVANCED BIOELECTROCHEMICAL MODULE (BEM) FOR WASTE TO ELECTRICITY GENERATION DURING LONG TERM SPACE EXPLORATION

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Science PI: **Gadhamshetty Venkataramana**[1]
PI: **Edward Duke**[1]
Co-I: **R. Sani**[1], **R. Shende**[1], **A. Shende**[1], **J. Hoefelmeyer**[2], **Z. Gu**[3]
[1]SD School of Mines and Technology; [2]University of South Dakota; [1]SD State University

Long-term, manned space missions are challenged by waste-treatment and power requirements. The proposed project addresses these challenges through development of a bioelectrochemical module (BEM) that generates electricity as a product of treatment of complex solid wastes (SOWs) including synthetic polymers from space missions. The BEM is based on well-studied principles of microbial fuel cells but uses extreme temperatures (>65 deg. C) and photodegradative processes to breakdown recalcitrant wastes to more “palatable” compounds for microbial metabolism. The BEM project aligns with NASA’s Space Technology Roadmaps and Priorities related to Space Power and Energy Storage; In-Situ Resource Utilization and Human Exploration Destination Systems; and Human Health, Life Support, and Habitation Systems. The project addresses three prime focal areas identified for research and economic development in South Dakota (SD) jurisdiction (Energy and Environment, Value-Added Agriculture and Agribusiness, and Materials and Advanced Manufacturing). The BEM will use extremophiles isolated from the deep levels of the Sanford Underground Research Facility (SURF) in SD. The SURF is considered to be similar to extraterrestrial space in that it is seemingly uninhabitable, and its biosphere harbors an enormous range of extremophiles that thrive in the challenging subsurface environments. Our team has isolated Geobacillus sp. strain DUSELR7 from the SURF biosphere that synthesizes hydrolytic enzymes with remarkable properties; it shows optimum activity at >65□C, thermal stability (e.g., >50% of cellulase and xylanase activity was retained after 35 and 23 days of incubation at 60ºC, respectively), and can function in a broad pH range (pH 4-8). Compared to previous reports, the DUSELR7 cellulases and xylanases are among the most thermostable enzymes produced by Geobacillus spp. and other thermophilic microbes. Another SURF isolate, Enterobacter RC202, is a hydrocarbon degrading bacteria capable of utilizing a broad substrate repertoire including plastic degradation products. Preliminary results confirmed the electricity-producing (exoelectrogenic) capabilities of DUSELR7 and Enterobacter RC202. The RC202 was found to generate electricity from lignocellulosic polymers. The BEM project is also a unique scientific study that uses the monocultures of SURF extremophiles for treating the unprocessed solid organic and polymer wastes in space missions, inhibiting pathogens in human waste, and generating remote power. We will take advantage of nanotechnology (e.g., graphene electrodes), thermophilic fermentation, and design concepts to minimize BEM footprint in space, and use extraterrestrial UVB and UVC radiation for treating synthetic polymers. We will use TiO2/MnO2-graphene composites to develop a graphene supercapacitor for storing the charges from BEM, using a modified maximum power point circuit that integrates digitally controlled potentiometer with hysteresis-based energy converter and metal oxide semiconductor field effect transistor. The project will collaborate with experts at National Laboratories and industry to develop a stacked BEM that supports low-powered electronics including a Mars microrover.