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Author: Mr. Talon Bullard
United States, james85@mail.usf.edu

THE ANAEROBIC MEMBRANE BIOREACTOR (ANMBR), A HYBRID BIOLOGICAL CREW-WASTE TREATMENT SYSTEM FOR SUSTAINABLE RESOURCE RECOVERY IN LONG-DURATION, DEEP-SPACE HUMAN EXPIRATION

Abstract

The requirements of NASA's Artemis program and future missions are significantly different than those for Low Earth Orbit (LEO) missions, namely the ISS, due to the dynamic environments inherent to the moon, Mars, and long duration space exploration. Conventional Environmental Control and Life Support System (ECLSS) technologies may not be appropriate or sustainable, as many utilize consumables that depend on frequent resupply missions. With an estimated price tag of $10,000/lb for payload costs, the long-term use of such technologies is not practical. Alternative technologies that create a shift to expand treatment capabilities towards resource recovery are necessary, but will need to provide the same degree of reliability and safety as conventional technologies. Biological treatment systems, which have been widely-used in terrestrial applications (including remote and isolated environments) and have minimal input requirements, are integral to the concept of Bioregenerative Life Support Systems (BLSS). Part of a larger BLSS architecture, a Technology Readiness Level (TRL) 3, two-stage Anaerobic Membrane Bioreactor (AnMBR) prototype was developed to treat food and fecal wastes to towards meeting the requirements of long duration space exploration. Food and fecal wastes represent lost opportunities, as they contain valuable resources such as nutrient fertilizers and water. The AnMBR design was developed over several iterations to be compact, easily accessible, and modular. The system performance was assessed using a synthetic feed stream representing fecal and food wastes associated with a crew of four. Major water quality parameters measured included Total Organic Carbon (TOC) and Chemical Oxygen Demand (COD). The system consistently achieved >90% removal of the influent TOC and COD and produced a effluent that can be treated in downstream processes for water and nutrient recovery. To investigate the robustness of the system and its assessment compared to existing technologies, Failure Mode & Effect Analysis (FMEA) and Reliability, Availability, Maintainability, and Safety (RAMS) analysis were conducted. Preliminary data was promising, as failures encountered had primarily low-level effects and resulted in manageable down times. Future investigations will progressively aim to asses the system's footprint and reliability against existing and competing ECLSS technologies in a trade study and create a more realistic treatment simulation by testing with real fecal waste. With its high organic removal and minimal failures and down time, the AnMBR prototype showed great promise for treating fecal and food waste for a crew of four and its integration into long-duration ECLSS.