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FEASIBILITY STUDY OF AN ALGAL-BASED LIFE SUPPORT SYSTEM

Abstract

For long-duration human spaceflight missions to the Moon, Mars, and beyond, new regenerative technologies are needed to develop life support systems that are sufficiently efficient and reliable to safely sustain human life in the hostile environment of space. Algal photobioreactors offer potential as a renewable technology that can combine the functionality of air revitalization, water recycling, and food production through photosynthesis. This paper conducts a first-order feasibility study to size an algal photobioreactor for a single crewmember in terms of air revitalization. Based on the maximum experimentally reported oxygen evolution and carbon dioxide absorption values for algae, a minimum cell culture volume of 15 litres is established. Based on data from previous studies, however, it is shown that the limiting factor in designing a mass and volume-efficient bioregenerative life support system is not the biology, rather the challenges of integrating the design into a spacecraft. Driven by the biological needs of this high-efficiency and high-density algal culture, critical photobioreactor design requirements for lighting, gas transfer, urine growth media, as well as continuous harvesting are established. Special consideration is given to constraints derived from a spacecraft implementation such as gravity, pre-existing mass streams, as well as resource efficiency. Based on these requirements, a conceptual implementation of an algal photobioreactor is presented. The necessary mass, power, volume, and consumables required for such a bioregenerative system are calculated based on International Space Station (ISS) environmental conditions and from commercially available products such as light-emitting diodes (LED) and gas transfer membranes. Even though the photobioreactor in this analysis is sized for air revitalization purposes only, the impact of this system on food supplementation and water recycling is also estimated. Finally, the design concept is compared to current state-of-the-art air revitalization and urine processing technologies and the feasibility to implement a sustainable photobioreactor into a spacecraft based on those functions alone is discussed. Potential mass savings are outlined, while implementation challenges and research gaps are identified.