HUMAN SPACE ENDEAVOURS SYMPOSIUM (B3)
Enablers for the Future Human Missions (7)

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HYBRID LIFE SUPPORT AS INTEGRATED SYSTEM APPLYING FUEL CELL AND ALGAL PHOTOBIOREACTOR

Abstract

Human space exploration of distant destinations demands the application of synergetic and regenerative systems. A major part of required resources are consumed in the environmental control and life support system (ECLSS). It is mandatory for future ECLSS to regenerate main resources as oxygen, water and food-implemented carbon. An integrated hybrid ECLSS, comprising technologies based on physicochemical and biological processes is able to meet these demands. Utilizing an integrated system enables a flexible sharing of regenerated resources employing a joint infrastructure interfaced with all relevant subsystems. An integrated system approach permits an increase in redundancy and synergy while minimizing system and re-supply mass. Because of resource diversity, the ECLSS provides various options for resource sharing within the ECLSS itself and with other subsystems. This research focuses on the feasibility of hybrid ECLSS specifically investigating the integration of a proton exchange membrane (PEM) fuel cell and a microgravity (μg) suitable algal photobioreactor (PBR). Besides water, the PEM fuel cell provides also electrical energy supporting the power supply of the space system. The PBR utilizing algal photosynthesis supplies oxygen and edible biomass while consuming carbon dioxide. Due to their versatility, the application of both technologies is advantageous considering mass and energy budgets, as verified in hardware in the loop (HiL) simulations within various exploration scenarios. The anticipated system is applicable within a decade, provided several crucial issues are solved. In the scope of this paper, microgravity suitability and resource contamination are detailed. A functional μg-PBR design meeting space flight requirements is introduced. The design, appropriate for two-phase fluid flow in microgravity and reduced gravity, employs hydrodynamic mixing and avoids gas accumulation in the reactor. It affords maximum biomass production by optimizing illumination, carbon dioxide and nutrients supply as well as oxygen removal. A joint infrastructure requires contamination prevention of resources used by system components and crew. Although in low concentration, organic and inorganic compounds are found in PBR emitted oxygen as well as in fuel cell product water. The influence of oxygen impurities on fuel cell performance is analysed. Further, the effect of water contamination, induced by fuel cell degradation and by algae metabolic products, on algae cultivation and biomass quality is evaluated. Efficient countermeasures, filtration and purification methods are discussed. Results verify the feasibility of an integrated hybrid ECLSS at reasonable terms and demonstrate its benefits for future crewed space systems.