Developing Biological ISRU: Implications for Life Support and Space Exploration

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Introduction: Our ultimate goal in space is to be able to go anywhere, at any time with whatever capabilities to accomplish any task or job we choose to undertake. We are light-years away from achieving such a goal, largely because we must drag everything we need in space with us from the bottom of a very deep gravity well – the Earth's surface. As long as this paradigm prevails, we will remain mass- and power-limited in space and thus, capability-limited as well.

In-situ production of consumables (In-Situ Resource Utilization-ISRU) will significantly facilitate current plans for human exploration and colonization of the solar system, especially by reducing the logistical overhead such as recurring launch mass. The production of oxygen from local materials is generally recognized as the highest priority process for lunar and Martian ISRU, for both human metabolic and fuel oxidation needs. The most challenging technology developments for future lunar settlements may lie in the extraction of elements (O, Fe, Mn, Ti, Si, etc) from local rocks and soils for life support systems [LSS], including extraterrestrial greenhouses, and the production of propellants.

However, while the majority of physico-chemical methods proposed for O2 extraction from lunar/Martian regolith [1] are intended to supply LSS only with oxygen, they are not able to contribute to other important processes such as CO2 sequestration and/or food production..

On the other hand Biological Life Support System as the European Micro-Ecological Life Support System Alternative (MELiSSA) [2]. is a net consumer of ISRU products without a net return to in-situ technologies, e.g. to extract elements, as a result of complete closure of MELiSSA. That is why the investigation of more efficient air bioregeneration techniques based on the metabolism of lower order photosynthetic organisms with ability to dissolve (weather) in situ rocks appears to be very timely and relevant. Cyanobacteria (CB) are known as effective producers of O_2, proteins, vitamins, and immunomodulators [3] and some of those possess litholitic capabilities [4]

Method: We have been using several species of siderophilic CB isolated from iron-depositing hot springs in Yellowstone National Park [5] and grown in a special photoreactor to dissolve (weather) stimulants of lunar regolith. Such parameters as elements released from stimulants, their accumulation in cells, biomass production and oxygen evolution are continuously monitored.

Main findings: 1) supplementing very dilute media for cultivation of CB with analogs of lunar or Martian regolith effectively supported the proliferation of CB; 2) O2 evolution by siderophilic cyanobacteria cultivated in diluted media but supplemented with iron-rich rocks was higher than O2 evolution by same strain in undiluted medium; 3) preliminary data suggest that organic acids produced by CB are involved in iron-rich mineral dissolution; 4) the CB studied can accumulate iron on and in their cells; 4) sequencing of the cyanobacterium JSC-1 genome revealed that this strain possesses molecular features which make it applicable for the cultivation in special photoreactors on Moon and Mars.

Conclusion: As a result of pilot studies, we propose, to develop a concept for semi-closed integrated system that uses CB to extract useful elements to revitalize air and produce valuable biomolecules. Such a system could be the foundation of a self-sustaining extraterrestrial outpost (Hendrickx, De Wever et al., 2005; Handford, 2006). A potential advantage of a cyanobacterial photoreactor placed between LSS and ISRU loops is the possibility of supplying these systems with extracted elements and compounds from the regolith. In addition, waste regolith may be transformed into additional products such as methane, biomass, and organic and inorganic soil enrichment for the cultivation of higher plants.

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