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**In-Situ Materials Processing Systems and Bioregenerative Life Support Systems
Interrelationships**

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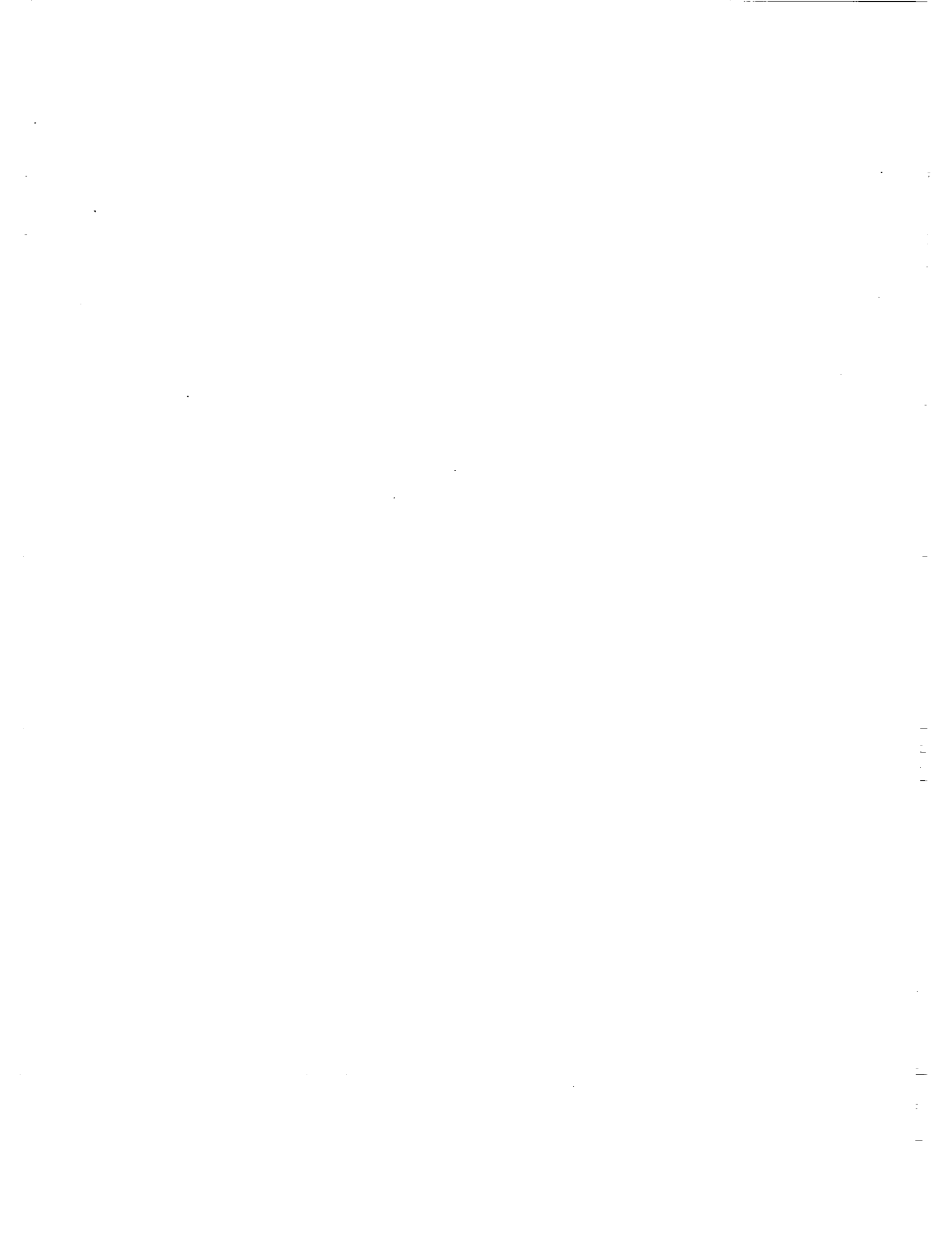
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Abstract

This project was to investigate the synergy and linkages between bioregenerative life support systems and the materials produced by in-situ materials processing systems. Such systems produce a broad spectrum of byproducts such as oxygen, hydrogen, processed soil material, ceramics, refractory, and other materials. Some of these materials may be utilized by bioregenerative systems either directly or with minor modifications. The main focus of this project was to investigate how these materials can be utilized to assist a bioregenerative life support system. Clearly the need to provide a sustainable bioregenerative life support system for long term human habitation of space is significant.



Approach

In order to narrow our investigation we chose a lunar mission scenario in which a fully functional bioregenerative life support system would be fully implemented at base maturity.

There are four basic functions that any life support system must achieve:

Atmospheric Regeneration

The atmosphere of any life support system needs to have contaminate gases such as CO₂, CO, HC, etc... removed and replenished with O₂. This is accomplished in a bioregenerative system by the interaction of micro-organisms and higher plants. A bioregenerative system will enable the complete recycling of these gases by utilization of CO₂ and production of O₂ by photosynthesis and the removal of contaminant gases by soil microorganisms residing in the substrate used for plant growth.

Water Purification

Water purification can be easily achieved by physicochemical means, however water recycling is not so easy. Within a bioregenerative system water is recycled and purified by the mechanism of plant evapo-transpiration and condensation on cooling coils. The only losses in this cycle would be due to leakage and export of water.

Waste Processing

The major waste to be processed is human waste. These wastes are really basic nutrients for growing plants and with proper treatment (composting, etc...) can be readily incorporated into a soil based bioregenerative system. Waste would be stored during base establishment and processed (for pathogen removal) via non-destructive methods. The waste material would then be latter utilized with lunar regolith to develop a living soil system. As organic matter is a limiting component of bioregenerative systems in space, all potentially usable forms of organic matter must be conserved for later re-use. The organic matter used to construct a soil from lunar regolith will provide the necessary cation exchange capacity and nutrient retention characteristics necessary to provide optimal microbial communities and thus higher plant growth. Re-use of human and other forms of organic material is a necessary component in closing the cycles of bioregenerative life support systems. The major thrust of our efforts has been to quantify the available nutrients which may be efficiently recycled.

Food Production and Processing

The fundamental function of a bioregenerative system is to facilitate the production of food through the support of higher plant growth and development. In the absence of energy and technology

intensive hydroponic culturing, soil microorganisms provide the nutrient regulation mechanism for food production. Under the proper conditions higher plants and soil microorganisms constitute an integrated system of high reliability and stability.

The basic elements required by a bioregenerative system are carbon, hydrogen, oxygen, nitrogen, and phosphorus. The first four are relatively abundant in organic matter and through correctly designed recycling systems can be conserved and continuously recycled. The other macro-nutrients required, potassium, magnesium, calcium, and sulfur are available in lunar regolith and would not be limiting. Micronutrients such as iron, manganese, zinc, copper, boron, molybdenum and chlorine can be supplied initially through terrestrial sources. A mature bioregenerative life support system will maintain these nutrients in adequate quantities and in useable forms.

The Moon, as far as we know, does not contain adequate quantities of water or nitrogen in any useable form. These two items may be the limiting factors in the productivity of a bioregenerative life support system. If local sources of water cannot be found or produced then all water must ultimately originate from terrestrial sources. Food production could provide one part of a water reuse system through transpiration and condensation. Nitrogen may ultimately be harvested from the atmosphere using nitrogen fixing microorganisms that form symbiotic relationships with higher plants.

The lunar regolith contains much of the essential materials necessary for a good agricultural soil. The availability of these nutrients will not be known until living soil systems can be constructed from reprocessed human waste, other transported organic matter and lunar regolith.

Conclusion

It is very apparent that some form of bioregenerative life support system will be required for long duration space missions such as a lunar base. The extent of closure will be determined by design trade off between cost of resupply and the first cost of establishment of the bioregenerative system. For a lunar base scenario it is also evident that there are really only two basic in situ materials of great benefit to a bioregenerative system; lunar oxygen and lunar soil. A detailed literature study has been conducted and citations compiled. The report, tabulates and summarizes the requirements for a bioregenerative life support system on a per person day basis and what materials can be provided by the proposed in situ processing schemes.