NASA STTR 2020 Phase I Solicitation

T6.07 Space Exploration Plant Growth

Lead Center: KSC

Participating Center(s): JSC

Technology Area: TA7 Human Exploration Destination Systems

Scope Title

Nutrient Recovery from Urine and Wastewater

Scope Description

Estimates for growing enough plants to support one human's food (dietary calories) suggest that 90-100 kg of fertilizer would be required per person per year. Even if plants were used only for partial life support (1/4 or 1/2 of the oxygen or food), this fertilizer mass would be substantial. NASA seeks methods and approaches for using *in situ* waste streams, such as urine and waste water to provide important nutrients and fertilizer for plants. Concepts should consider alternate approaches for how urine might be pre-treated to make it more amenable for fertilizer, and how the high levels of sodium typically found in urine might be separated or managed, since most plants are not tolerant to high levels of sodium.

References

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Lunn, G.M., G.W. Stutte, L.E. Spencer, M.E. Hummerick, L. Wong, R.M. Wheeler. 2017. Recovery on nutrients from inedible biomass of tomato and pepper to recycle fertilizer. Intl. Conf. on Environmental Systems ICES-2017-060.

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Muirhead, D. 2011. Urine stabilization for enhanced water recovery in closed-loop life support systems. ICES-2011. AIAA Technical Paper.

Macler, B.A. and R.D. MacElroy. 1989. Productivity and food value of Amaranthus cruentus under non-lethal salt stress. Adv. Space Res. 9(8):135-139.

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Expected TRL or TRL range at completion of the project: 3 to 5

Desired Deliverables of Phase II

Prototype, Hardware, Research

Desired Deliverables Description

Phase I proposals should at a minimum deliver proof of concept for retrieving useful plant nutrients and removal / partitioning sodium from urine or ersatz urine wastewater. By the completion of Phase II, we hope to have prototypic or engineering development unit hardware delivered to NASA for the technology. The potential for Phase III funding for spaceflight validation would then be explored.

State of the Art and Critical Gaps

Current approaches for fertilizing plants for space depend largely on time-release fertilizer pellets that are mixed in with a solid rooting media (used both in Veggie and APH). This approach is not sustainable for multiple crop cycles and requires that all the fertilizer be delivered from Earth. Hydroponic approaches have been suggested for space (e.g., AES NextSTEP AstroGarden) and will hopefully be tested soon on the International Space Station (ISS), and eventually on surface settings. In this case, fertilizer salts would be mixed with water to provide a nutrient solution for the plants. Growing plants in space would be more sustainable if the cost and amount of fertilizer salts could be reduced by using recycled wastes, including processed urine.

Relevance / Science Traceability

This technology would be relevant and science traceable to:

- Human Exploration and Operations Mission Directorate (HEOMD): Space Life and Physical Science (SLPSRA)
- HEOMD: Advanced Exploration Systems (AES)
- HEOMD: Human Research Program (HRP)
- Space Technology Mission Directorate (STMD): Game Changing Development (GCD)
- STMD: Space Technology Research Institute (STRI)

Scope Title

Ethylene Gas Sensor

Scope Description

Ethylene is a 2-carbon alkene gas that has growth regulating effects on plants. Plants can produce ethylene through natural metabolic processes, and this ethylene can accumulate in closed environments (such as closed plant growth chambers) and have undesirable effects on the plants. These effects can include reduced growth, impaired pollen development and/or fertilization, leaf epinasty, flower abortion, accelerated fruit ripening, and more (Abeles et al., 1992). Being hormonal in nature, ethylene can affect plants at very low concentrations, with levels as low as 25 ppb being reported to have subtle effects on some plants. More sophisticated plant growth chambers for space have included ethylene removal systems, such as $KMnO_4$ coated pellets, but this is a consumable material and adds resistance to air circulation in the chamber. Real time ethylene monitoring would allow more judicious use of ethylene removal for controlling plant growth, and save on consumables. NASA seeks a miniature, sensitive (25 ppb), real time or near-real time sensor to monitor ethylene in plant growth environments for space.

References

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Cushman, K.E. and T.W. Tibbitts. 1998. The role of ethylene in the development of constant-light injury of potato and tomato. J. Amer. Soc. Hort. Sci. 123:239-245.

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Klassen, S.P. and B. Bugbee. 2002. Sensitivity of wheat and rice to low levels of atmospheric ethylene. Crop Science 42:746-753.

Monje, O., J.T. Richards, I. Eraso, T. P. Griffin, K.C. Anderson, and J.C. Sager. 2005. Designing a reusable ethylene filter cartridge for plant flight hardware: Characterization of thermally desorbing compounds. SAE Tech. Paper 2005-01-2953.

Wheeler, R.M., B.V. Peterson, and G.W. Stutte. 2004. Ethylene production throughout growth and development of plants. HortScience 39 (7):1541-1545.

Expected TRL or TRL range at completion of the project: 4 to 7

Desired Deliverables of Phase II

Prototype, Hardware, Research

Desired Deliverables Description

Phase I proposals should at a minimum deliver proof of concept for a principle to detect ethylene real-time to a target level of 25 ppb. By the completion of Phase II, we hope to have prototypic or engineering development unit hardware delivered to NASA for the technology. The potential for Phase III funding for spaceflight validation with hardware like the Veggie or Advanced Plant Habitat chambers would then be explored.

State of the Art and Critical Gaps

Ethylene monitoring has traditionally been conducted using gas chromatography with either flame ionization or photo-ionization detection. However, gas chromatographs can be large instruments and require collection of gas samples, which are then analyzed. This limits their use in small spaces/volumes and their ability to analyze gases real-time.

Relevance / Science Traceability

This technology would be relevant and science traceable to:

- Human Exploration and Operations Mission Directorate (HEOMD): Space Life and Physical Science (SLPSRA)
- HEOMD: Advanced Exploration Systems (AES)
- HEOMD: Human Research Program (HRP)
- Space Technology Mission Directorate (STMD): Game Changing Development (GCD)

STMD: Space Technology Research Institute (STRI)