NASA STTR 2019 Phase I Solicitation

T6.06 Spacecraft Water Sustainability through Nanotechnology

Lead Center: JSC

Participating Center(s): ARC, JSC, KSC, MSFC

Technology Area: TA6 Human Health, Life Support and Habitation Systems

Nanotechnology Innovations for Spacecraft Water Management ApplicationsÂ

Water recovery from wastewater sources is key to long duration human exploration missions. Without substantial water recovery, life support system launch weights are prohibitively large. Regenerative systems are utilized on the ISS to recycle water from humidity condensate and urine, but the Urine Processor and Water Processor Assemblies contain rotary systems and produce brines (Distillation Assembly), utilize non-regenerable consumables (Multi-Filtration Beds) and operate at high temperature and pressures (Catalytic Reactor). To stabilize urine and protect components from biofouling and precipitation, a toxic pretreatment formula is added to collected urine. Simple measurements of water composition are made during flight, including conductivity, total organic carbon and iodine concentration. For determination of ionic or organic species in water and wastewater, samples must be returned to earth.

This subtopic solicits improvements to reduce complexity, decrease consumable mass, improve safety and reliability, and to achieve a higher degree of autonomy are of interest. In the past decade, technology developers have used nanotechnology to improve capabilities of catalytic oxidation, microbial control, surface fouling, disinfection, water quality monitoring, nano-photonic heating and distillation, selective and reversible removal of trace contaminants, and transport and delivery of treatment systems using nano-carriers. This solicitation deliberately requests for â€œtechnology building blocksâ€ that demonstrate new nanotechnology capability which can favorably impact the NASA water recovery application. Because of the interconnected nature of water recovery systems, it is hard to insert new technology into an existing system. When key subsystem technologies are developed and demonstrated, new system level approaches can be implemented.

This solicitation targets three key aspects of water management for human spacecraft. These areas of scope are aligned with the three specific thrusts described within the white paper of the Nanotechnology Signature Initiative (NSI) "Water Sustainability through Nanotechnology".Â Please see references for additional information, including water quality requirements and guidelines.

Water Recovery from Wastewater: Increasing Water Availability Using Nanotechnology

- NASA is seeking nanotechnology based technologies capable of processing up to 10 liters/day urine, with >95% water recovery, system energy use <300 Watts, and contaminant levels in distillate less than 1.5 mg/l for organics, and less than 0.3 mg/l for ammonia.
- Technologies for water recovery from mixed streams of an exploration wastewater (containing hygiene,

clothes wash, etc.) are also of interest.
- Water reuse systems must be capable of operating for 6 months at a time with dormancy periods of up to 2 years in between operations.
- For potential future bioregenerative life support applications involving growth of crop plants for production of food, process water may include agricultural waste waters, and there may be interest in separation of sodium chloride, nitrogen, potassium, phosphorous and other nutrients from waste water for reuse in plant growth systems.

Stabilization of Water and Water Recovery System Hardware - Improving the Efficiency of Water Delivery and Use with Nanotechnology

Biological growth on condensing heat exchanger surfaces and in plumbing lines and tanks (for both potable water and wastewater) is a significant concern in water systems for future manned missions:

- NASA is seeking methods to maintain concentrations of biocidal silver (0.05 â€“ 0.4 mg/L) in potable water including surface treatments that may limit silver loss.
- Biofilm growth can obstruct flow paths in operational wastewater collection and processing systems, especially in tanks where stagnant conditions lead to consistent growth. A greater concern is missions beyond ISS that include dormant periods when the spacecraft is not tended by crew, during which biofilm growth would be even more significant. NASA is currently considering the concept of flushing the wastewater plumbing with potable water to reduce microbial and organic content before dormancy, though additional controls are required to insure biofilm growth does not impact operations once the crew returns to the vehicle. NASA seeks robust design solutions that mitigate (but not necessarily eliminate) biofilm growth in plumbing and tanks during nominal operations and to prepare a system for dormancy. Design solutions must be viable for implementation with minimal crew time (automated concepts are much preferred) and must be compatible with materials typically used in water plumbing (for example viton, Teflon, 316L SS, Inconel 718). Treatments that also reduce scale and solids build up are of interest.
- Alternative pretreatment methods are of interest for urine and wastewater, to inhibit microbial growth and to prevent precipitation of calcium salts and production/evolution of ammonia. Nanotechnology solutions may allow for the elimination of use of pretreatment chemicals classified as toxicity level 2 or higher.

Enabling Next-Generation Water Monitoring Systems with Nanotechnology

- Multi-species analyte measurement capability is of interest that would be competitive to standard water monitoring instruments such as ion-chromatography, inductively coupled plasma spectroscopy, and high-performance liquid chromatography. Components that enable the miniaturization of these monitoring systems, such as microfluidics and small-scale detectors, will be considered.
- NASA is seeking nano-sensors that measure pH, ionic silver (Continuous in-line measurement of ionic silver (range 10 to 1000 ppb), conductivity, TOC (minimum detection level 50 ppb) with >3-year service life and >50% size reduction compared to current SOA.
- Applications exist for monitoring species within regenerated potable water and/or wastewater (potential waste streams: urine, humidity condensate, Sabatier product water, waste hygiene, and waste laundry water).

While NASA is looking for innovative solutions to any aspect of water management as described above, several focused areas are of particular interest. Innovations that target improvements to delivery and maintenance of silver for use as a biocide in potable water, surface treatments and methods that suppress biofilm growth and support system dormancy, multi-analyte species monitoring capability and/or energy efficient distillation, are especially welcome. Expected TRL is from 2 to 4.

References:

- NASA is a collaborating agency with the NTSC Committee on Technology Subcommittee on Nanoscale Science, Engineering and Technology's Nanotechnology Signature Initiative (NSI): "Water Sustainability through Nanotechnology" (Water NSI).Â For a white paper on the NSI, see https://www.nano.gov/node/1580

- A high-level overview of NASA's spacecraft water management was presented at a webinar sponsored by the Water NSI: "Water Sustainability through Nanotechnology: A Federal Perspective, Oct. 19, 2016" https://www.nano.gov/publicwebinars
- A general overview of the state of the art of spacecraft water monitoring and technology needs was presented at a webinar sponsored by the Water NSI: "Water Sustainability through Nanotechnology: Enabling Next-Generation Water Monitoring Systems, Jan. 18, 2017" located at https://www.nano.gov/publicwebinars
- For a list of targeted contaminants and constituents for water monitoring, see "Spacecraft Water Exposure Guidelines for Selected Waterborne Contaminants" located at https://www.nasa.gov/feature/exposure-guidelines-smacs-swegs
- Technical papers on a wide variety of Environmental Control and Life Support System (ECLSS) topics are available at https://www.ices.space/conference-proceedings/