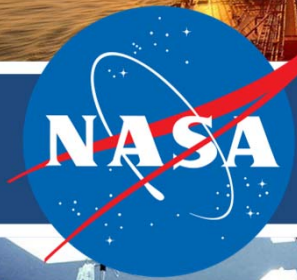


NASA Johnson Space Center



HTC Tech Connect - Water Reclamation Technology Development at Johnson Space Center



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NASA

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Water Hardware & Technology Development Group



Who We Are:

A staff of approximately 14 BS, MS, and PhD-Level Engineers and Scientists with experience in Aerospace, Civil, Environmental, and Mechanical Engineering, Chemistry, Physical Science and Water Pollution Microbiology.

Our Primary Objective:

To develop the next generation water recovery system technologies that will support NASA's long duration missions beyond low-earth orbit.



Advanced Water Recovery Systems Development Facilities



- A reconfigurable test area supporting the build-up, test and evaluation of water recovery technologies and integrated systems.
- The Water Analysis Laboratory provides a full service of analytical capabilities as well as services for technology development and flight certification purposes.
- The Biological Process Development Facility is a BL-2 laboratory that supports a wide range of microbiological services and procedures.
- A Waste Water Collection and Transportation System (WWCTS) that allows the collection of unique water blends for specific hardware testing.



Competencies



- Technical leadership in spacecraft water recovery systems.
- Development, test and analysis of in-house and vendor supplied water recovery system technologies , including integrated closed-loop systems.
- Investigation and troubleshooting of complex water recovery issues .
- Extensive knowledge of hardware, chemistry, microbiology, and laboratory processes.

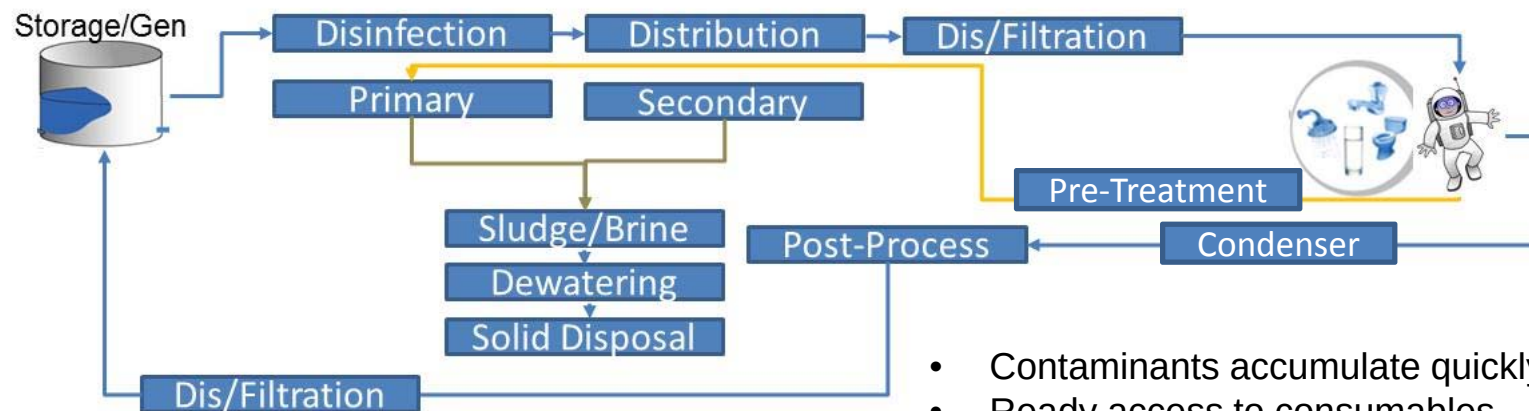
- Development of waste stream formulations to support R&D and flight hardware testing.
- Certification and processing of flight hardware for ISS and other NASA vehicles.
- Experience working with industry and universities through grants, Small Business Research Initiatives, contracts and collaborations.



Water Recovery on Earth and in Space



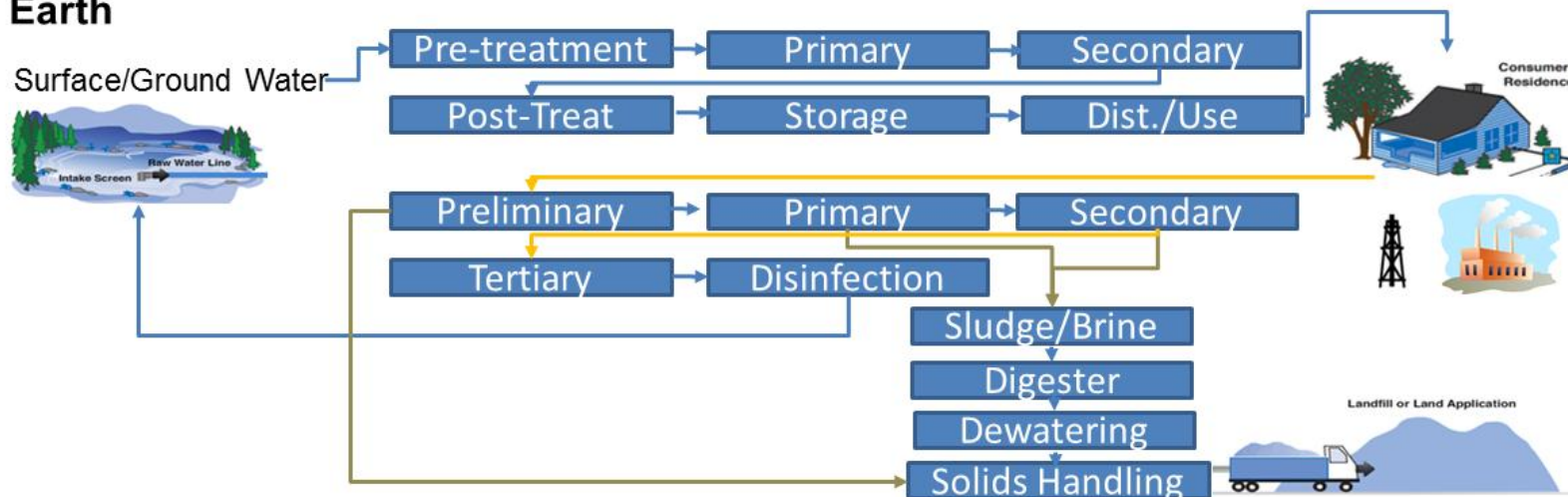
Spacecraft



- Average use per person per day: 4 - 12 liters
- Water Poor/Small Hold Up/Short Residence Time

- Contaminants accumulate quickly and be diluted
- Ready access to consumables – No
- Systems must be reliable and easy to maintain
- High water recovery critical

Earth



- Average use per person per day: 303 to 379 liters
- Water Rich/Large Hold Up/ Long Residence Time

- Contaminants accumulate slowly and can be diluted out
- Ready access to consumables – Yes

- Frack well can use up to 2.8 million gallons of water

Areas Water Technology Development at JSC



Brine Recovery Systems

Advanced Wastewater Stabilization

Disinfection Technologies

Biological Water Processing Development

Vacuum Rotary Distillation Technologies

Membrane Technology

Microbial Control Technologies

Post Processing Technologies

Process Control & Sensor Development



Waste Stabilization



Challenge:

- Biological activity “destabilizes” wastewater and affects processes and drinking water quality. Compounds used to control bio activity tend increase equivalent system mass and place stress on spacecraft environment, hardware and crew.

Need

- Low toxicity stabilization systems that control biological activity, prevent solid formation /precipitation, yet are relatively safe to crew and spacecraft systems.

Current Research

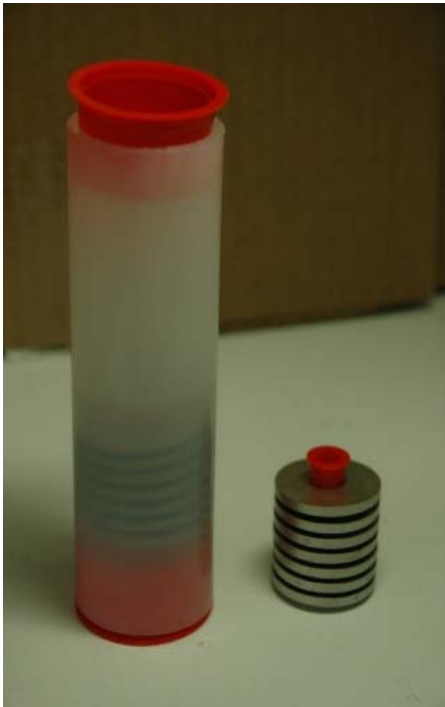
- Alternative Pretreatment
- “Greentreat”

Issues:

- Urea hydrolysis: $(\text{NH}_2)_2\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + 2\text{NH}_3$
- Bio and solids fouling
- pretreatment corrosion
- Precipitation prevention



Potable Water Disinfection



Challenge:

- Compounds used for microbial control in potable water storage and distribution systems can corrode hardware, quickly lose disinfection residuals, often require re-dosing and can be unfit for crew consumption.



Need

- Low toxicity disinfectant systems and secondary barriers that control biological activity through point of use and are safe to crew and spacecraft systems.

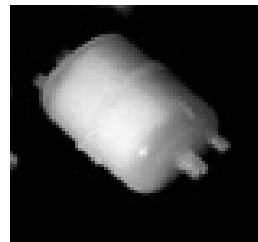


Current Research

- Silver Biocide
- Electrochemical Disinfection (ECD), e.g., ozone, peroxide, peracetic acid
- Point of use filters

Issues:

- Biofouling and disinfectant corrosion.
- Potable water contamination
- Reactive biocides have short disinfection residuals



Biological treatment systems



Challenge

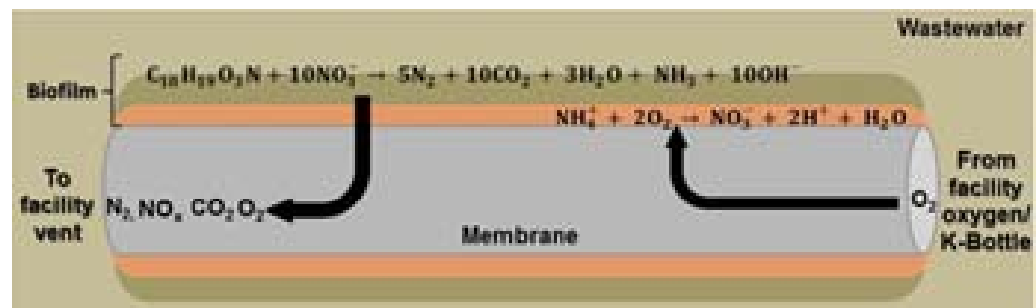
Developing efficient microgravity compatible biological water processors with low equivalent system mass.

Need

A highly efficient and regenerable means of organic contaminant reduction.

Current Research

Membrane Aerated Biological Reactors (MABRs) hollow gas permeable substrates used to create oxic and anoxic zones in same reactor vessel.



Issues:

- Efficient sizing
- Achieving simultaneous carbon oxidation and nitrification/de-nitrification.
- Slow start-up and recovery
- Incompatibility with current pretreatment chemicals



Membrane Technologies



Challenge

Identification of low fouling membranes and processes offering efficient contaminant rejection.

Need

Development of reliable membrane technology and processes for contaminant removal

Current Research

- Direct Contact Membrane Distillation
- Forward Osmosis/Reverse Osmosis
- Rotating Reverse Osmosis

Issues

- Membrane fouling
- System maintenance
- Salt Leakage across membrane, consumable
- Membrane incompatibility with low pH pretreatment
- Passage of specific contaminants, e.g., ammonia



Distillation Systems

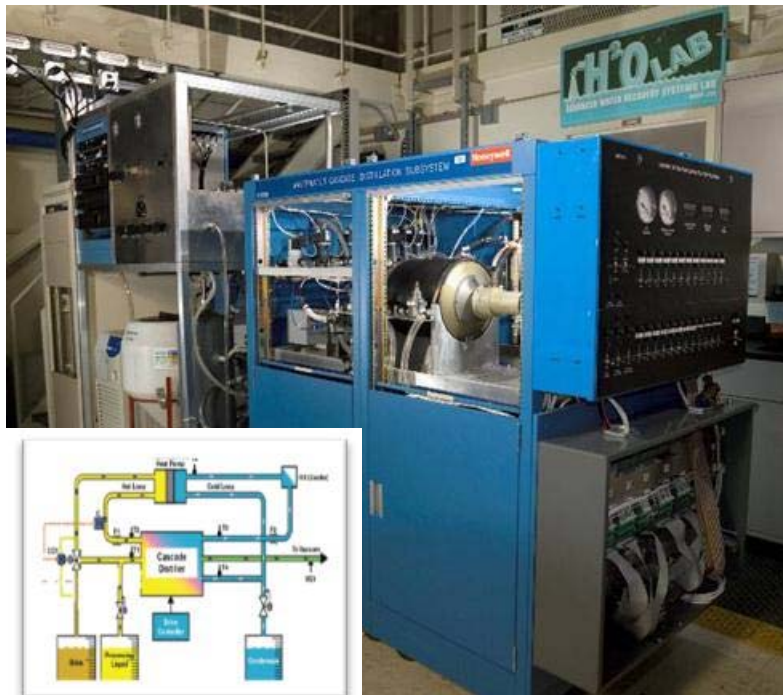
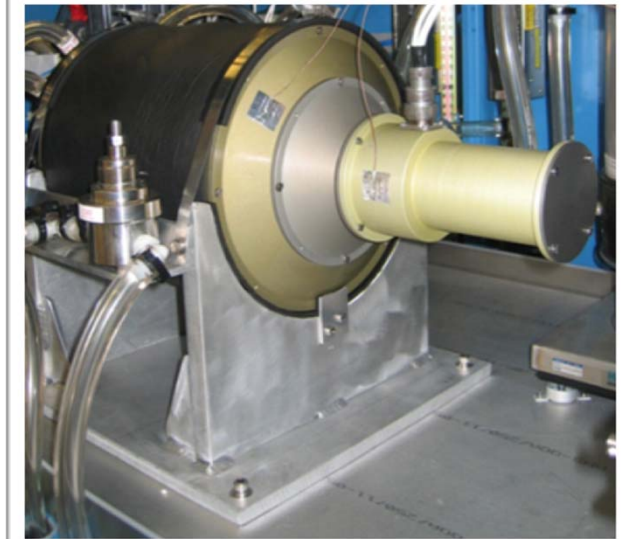


Challenge

Development maintainable low equivalent system mass systems, e.g., > 100 W-hr/kg of produced water with high reliability.

Need

Development of reliable high efficiency vacuum rotary distillation systems

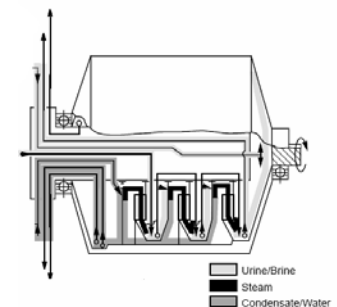


Current Research

Cascade Distillation Subsystem, a 5-stage vacuum rotary distiller driven by a thermoelectric heat pump. Vapor Compression Distillation.

Issues:

- Complex precipitation chemistry
- Compatibility with solids
- Material compatibility
- Phase separation



Water Recovery From Brine



Challenge

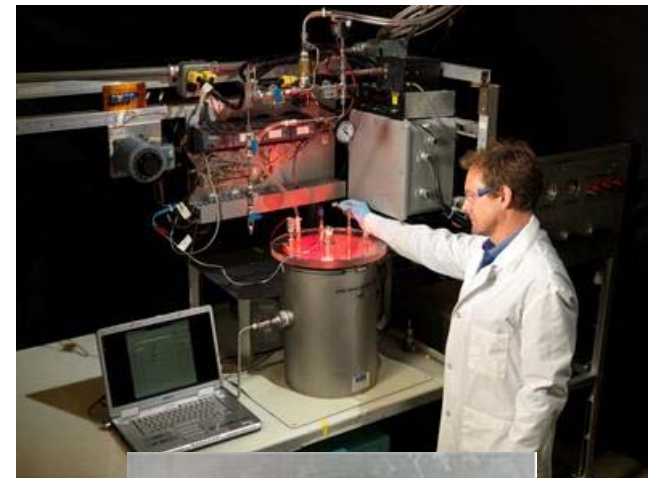
Brine dewatering technologies are needed to close the water loop. Long duration missions targeting 98% recovery.

Need

Robust, low maintenance, microgravity compatible brine dewatering systems that minimize crew time and contact with residual solids.

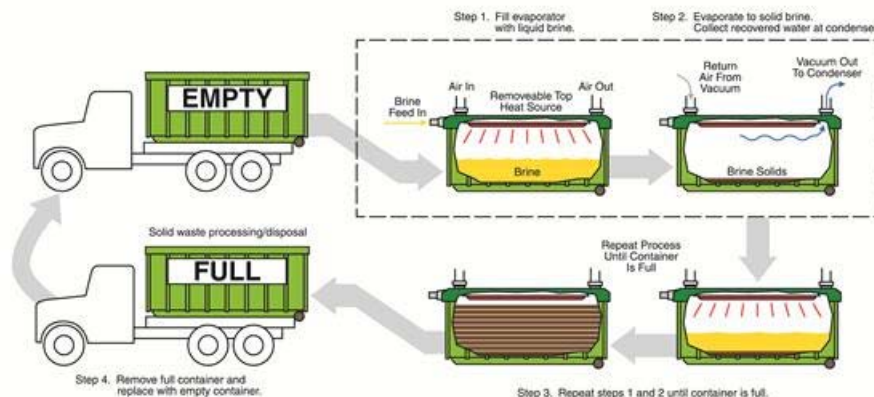
Current Research

- BRIC, “in-place” drying and disposal technologies
- EBDS, Enhanced Brine Dewatering System
- Wick and other capillary-based technologies



Issues:

- High contaminant loading
- Energy intensive process
- Brine streams and solids are typically corrosive, fouling and toxic
- Process optimization is critical to efficient and reliable operation.
- Needs phase separation and containment in microgravity.



Conceptual Scale-Up of BRIC Process for Industrial Applications

Sensor Development



Challenge

Development of robust sensors able to support process control in corrosive wastewater environments that will increase system reliability and process yields.

Need

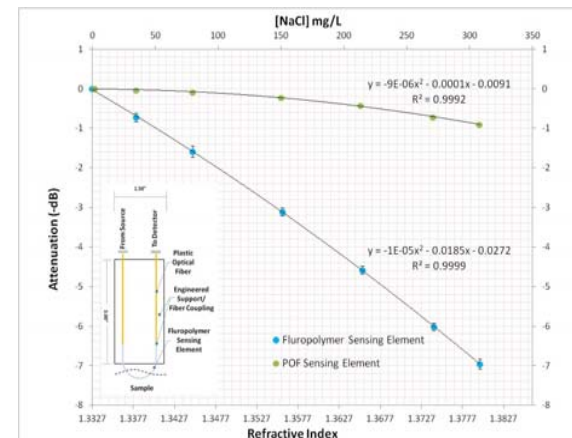
Reliable and accurate in-line sensors requiring low maintenance and offering stable calibration.

Current Research

Robust class of simple refractive index based optical sensors for measuring concentration factors in waste water process stream. Possible application in-situ sensor for monitoring ocean salinity.

Other Measurements of Interest:

- Oxidation potential
- Flow sensing
- Non-contact flow measurement
- Organic carbon
- Mass spectrometry



Fiber Optic Sensor Head (enlarged)



Fiber Optic Sensor Head (illuminated)



Post-Processing



Challenge:

Development of efficient reliable systems post-processing systems requiring little to no consumable mass.

Need:

Low consumable polishing technologies tailored to upstream treatment trains.

Current Technologies:

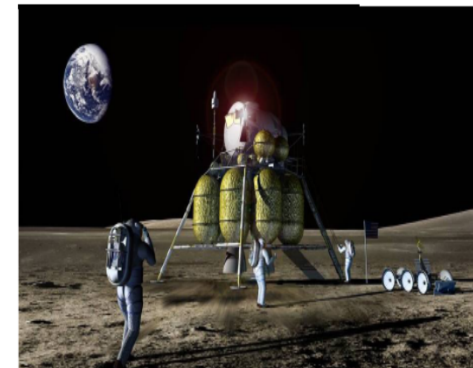
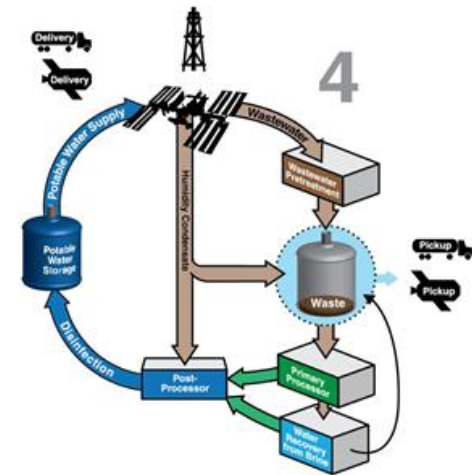
- Ion exchange
- UV oxidation
- Catalysts
- Carbon filtration
- APCO, Aqueous phase catalytic oxidation



Potential Areas of Collaboration



- Prevention of scaling in pipes
- Water recovery from urine, seawater, and brines
- Biological treatment of wastewater
- Reliable inline monitoring in remote locations
- Water reuse in remote habitats
- Capillary flow
- Reduction of equivalent system mass and equipment transport costs
- Elimination of consumables, resupply, and wastewater discharges
- Chemistry and recovery of water from brines
- Disinfection technologies and biofouling studies
- Science Technology Engineering and Math (STEM) Opportunities



“Science has not yet mastered prophecy. We predict too much for the next year and yet far too little for the next 10.”

Neil Armstrong

