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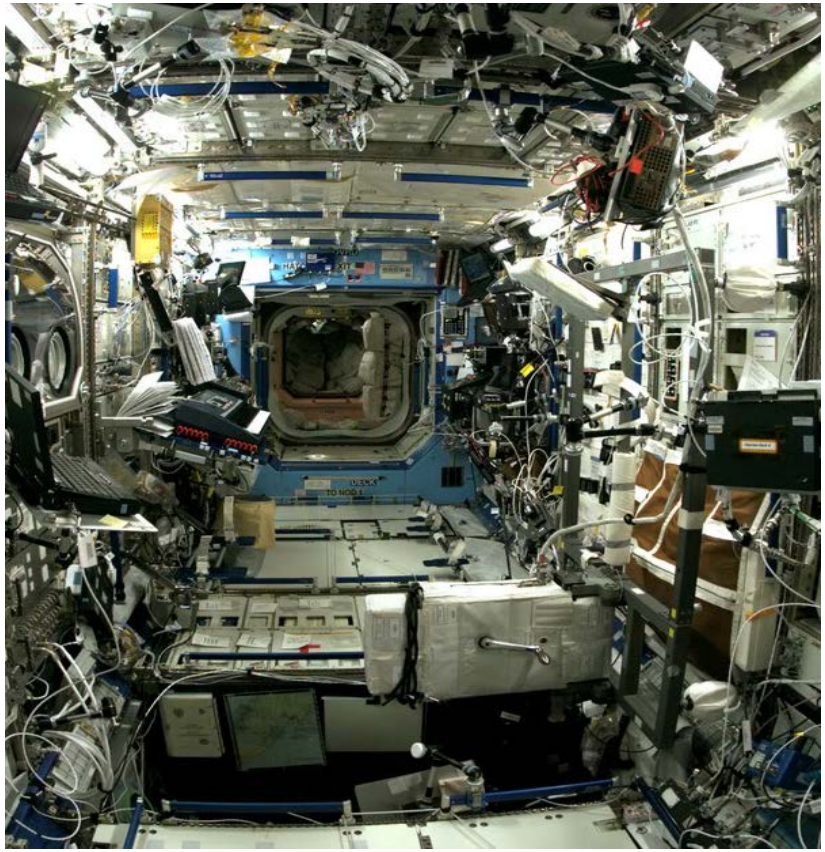
DEEP SPACE DEEP OCEAN

Aramco Technology and Operational Excellence Forum

NASA Advanced Life Support Water Recycling Technology Development Program – Produced Water Technology Transfer

Lessons Learned on ISS and Relevance to Produced Water Treatment

- ISS is a complex machine
- One of the most complex aspects of the Station is its life support system.
- Since 2009 NASA has learned a lot about the issues and problems associated with recycling human wastewater.
- Some of this information is relevant to produced water treatment



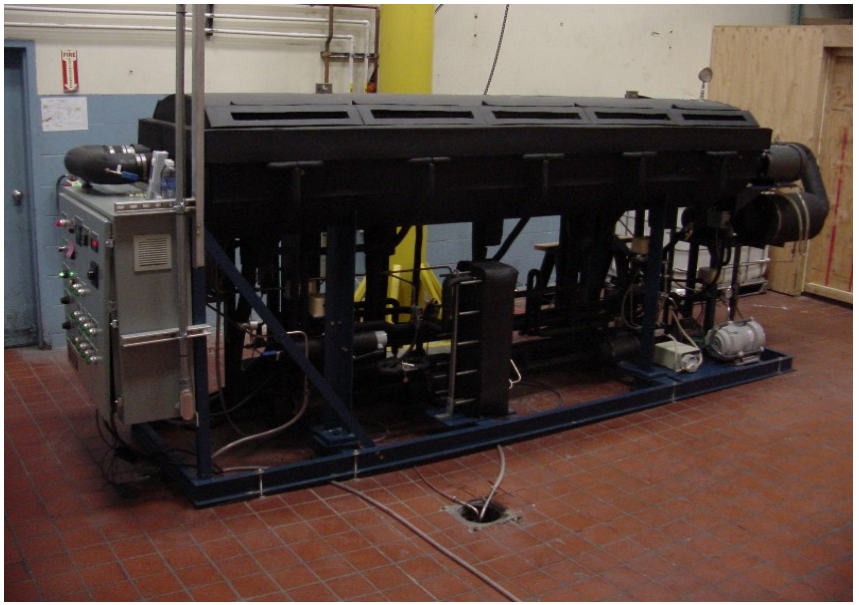
Example: Calcium Scale Formation

- One of the early problems on ISS is the formation of calcium scale.
- This scale originates from microgravity induced bone loss.
- NASA has investigated many mitigation approaches and has developed a unique know how on how to deal with this issue.

NASA Research Relevant to Produced Water Treatment

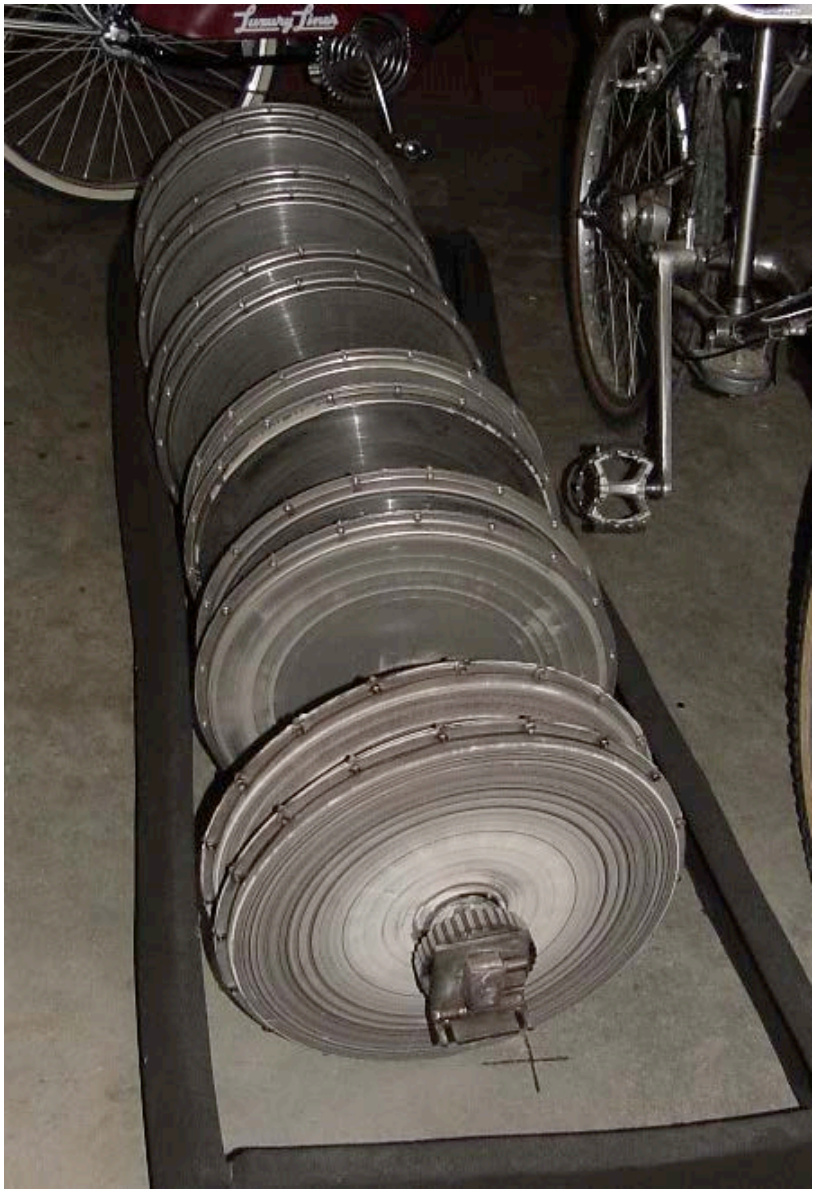
- Small scale, decentralize, and autonomous water and wastewater treatment systems
- Scale mitigation approaches
  - anti-scale chemicals
  - ion exchange resins and nucleation materials
  - electrodialysis
- Predictive modeling and operations
- Failure recovery
- Sensors, controls, and remote operations

Wiped-film Rotating-disk Evaporator



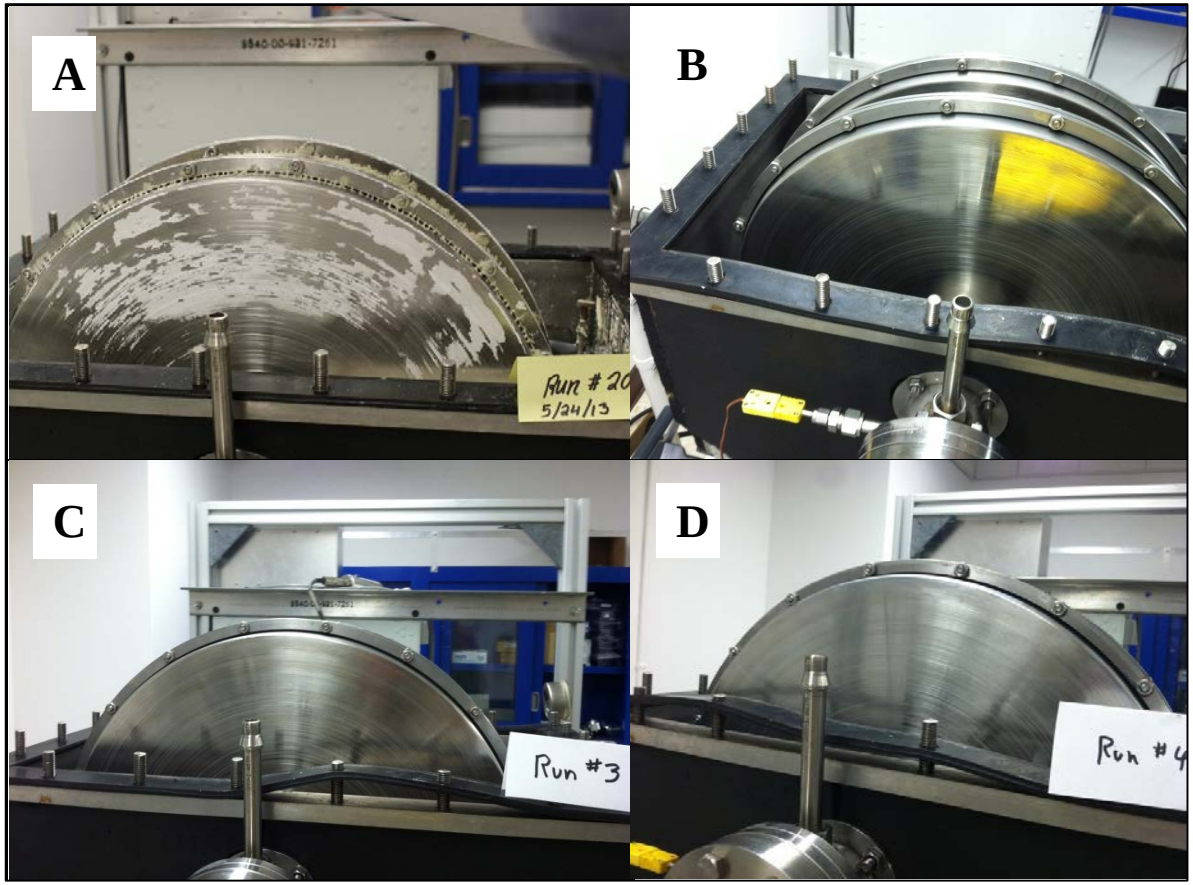
San Juan Produced Water (left), Recovered Water post WFRD Processing (center), and Brine (right)

Water Quality Parameter (ppm)	San Juan Produced Water	San Juan Brine	San Juan Recovered Water	Powder River Produced Water	Powder River Brine	Powder River Recovered Water
Aluminum (Al)	0.00	0.00	0.00	0.04	1.09	0.00
Ammonium (NH4)	0.00	17.40	1.66	0.68	15.4	0.89
Barium (Ba)	4.66	32.06	0.03	0.004	3.33	0.002
Boron (B)	4.24	38.11	0.05	0.13	3.87	0.02
Bromide (Br)	154.56	0.00	0.00	8.13	0.00	0.00
Cadmium (Cd)	0.00	0.000	0.000	0.00	0.000	0.000
Calcium (Ca)	212.58	1764.51	1.36	3.48	115.79	0.15
Chloride (Cl)	168.40	77,945.85	5.77	16.3	14,701.02	4.99
Chromium (Cr)	0.447	1.278	0.004	0.00	0.639	0.000
Copper (Cu)	0.00	0.00	0.02	0.00	0.45	0.00
Iron (Fe)	5.00	32.41	0.13	0.02	7.10	0.00
Magnesium (Mg)	56.22	466.99	1.36	0.96	39.57	0.03
Manganese (Mn)	0.93	6.24	0.00	0.02	0.24	0.00
Molybdenum (Mo)	0.24	1.67	0.00	0.00	0.63	0.01
Nitrate (NO3)	133.00	132.00	1.31	1.08	133.00	1.31
Nitrate (NO2)	0.00	5115.12	32.17	0.00	939.57	0.00
Phosphate (PO4)	36.12	226.37	0.11	0.2	46.69	0.02
Potassium (K)	211.23	2,066.62	0.28	3.72	138.38	0.1
Silica SiO2)	16.58	94.40	0.051	4.906	61.54	0.027
Sodium (Na)	7938.95	71303.00	5.11	434.50	7,780.92	2.4
Sulfate (SO4)	0.00	3,019.24	10.26	16.71	276.92	4.74
Sulfur (S)	0.00	1,006.41	3.42	5.57	92.3	1.58
Zinc	0.87	5.51	0.10	0.01	2.49	0.01
Alkalinity	958.77	-	41.53	469.88	-	22.52
Total Dissolved Solids (TDS)	23,680.00	218,880.00	89.6	1,068.8	2,1760.00	12.80
pH Value (in units)	5.78	6.72	4.55	7.8	9.21	6.77
Hardness	812.63	6,725.80	3.95	13.05	481.07	0.51
Total Organic Carbon (TOC)	4,590	39,400	641	19.8	2,380	6.1
pH Value (in units)	5.78	6.72	4.55	7.8	9.21	6.77
Electrical Conductivity (mmho cm-1)	37.00	342.00	0.14	1.67	34.00	0.02



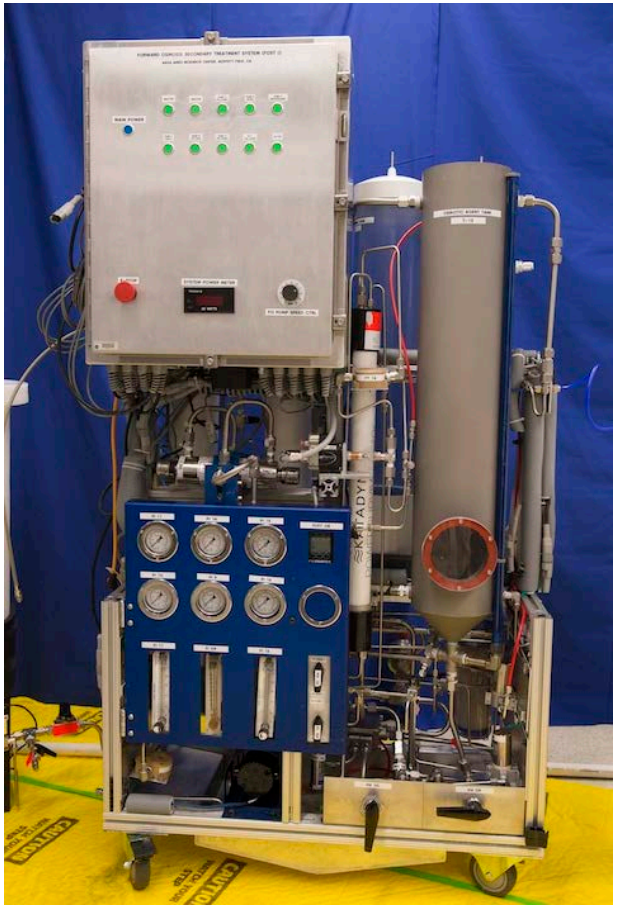
Electrodialysis Metathesis Scale Control

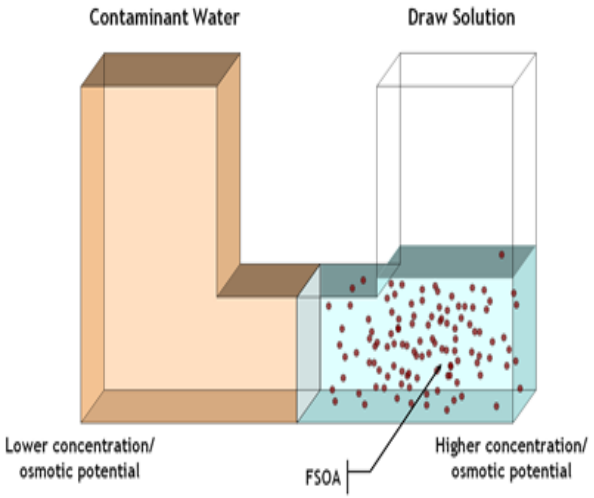
EDM test stand

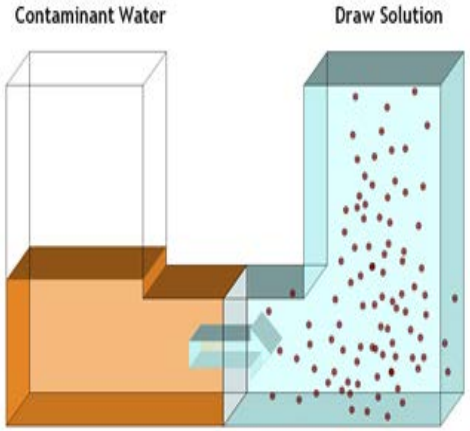


Testing Results

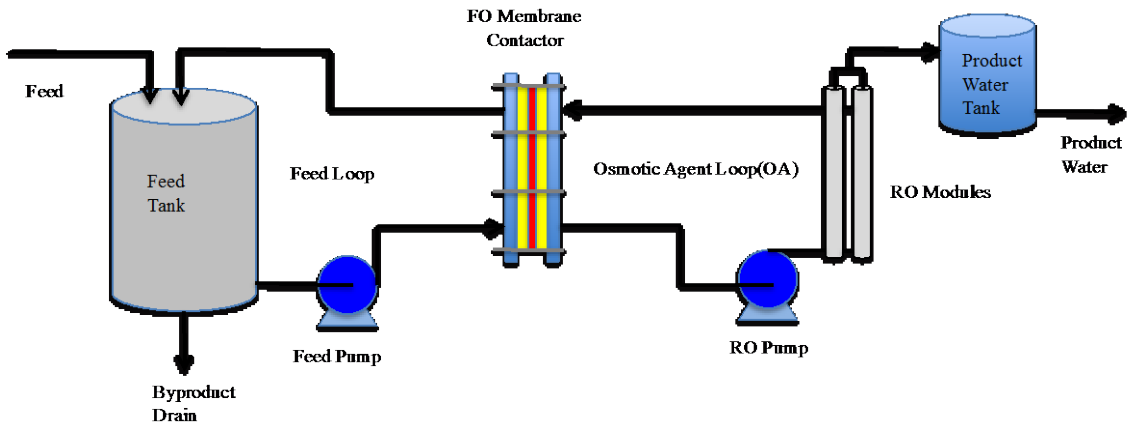
Forward Osmosis







Sustainability Base Gray Water Recycling System



Conclusions

There are similarities between the NASA mission and oil and gas produced water treatment.

- Brine treatment/disposal issues
- Need to get high water recovery ratios
- Scale mitigation
- Autonomous operations

The transfer of both knowledge and technologies is a two way street.