Planetary Surface Water Recycling Systems

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Abstract

Long-term planetary space missions present new and unique challenges in life-support systems. These missions will rely on the self-sustainability of the habitat, with water recycling being a key issue. Water constitutes the majority of the mass required to sustain human life in space, and it follows that efficient water recycling has the potential to lower overall launch mass, reducing mission costs. This trade study evaluates terrestrial water recycling technologies on the basis of applicability as a Mars base water recycling system. Various membrane reactors, filtration, and district water reclamation systems are investigated and rated based on several standardized parameters. A customer-oriented quality function deployment (QFD) is utilized to analyze the ratings of the technologies for the tasks required. The trade study aims to rank the various systems based on their Equivalent System Mass (ESM), Technology Readiness Level (TRL), scalability, crew time, overall logistics requirements, among others. The results of the study can serve as a basis for future inquiries and studies by NASA and other interested parties.

Overview of Technologies

Technology	Description
Aquacell S-Series	A unit that combines several technologies and is marketed as a "blackwater recycling solution." It facilitates aerobic screening, biological treatment, ultrafiltration, ultraviolet disinfection, and chlorination.
LEAP MBR	A modular membrane bioreactor system made by Suez Technologies (a subsidiary of General Electric).
BioBarrier Membrane Bioreactor	A membrane bioreactor system made by BioMicrobics Inc. It is used to treat winery process wastewater as well as wastewater produced by kitchens, sinks, and toilets at wineries.
Staged Anaerobic Fluidized Membrane Reactor (SAF-MBR)	A system that consists of two reactors in series: the Anaerobic Fluidized Bioreactor (AFBR), which partially treats wastewater, and the Anaerobic Fluidized Membrane Bioreactor (AFMBR), which finalizes wastewater treatment and suspends solids for their own treatment followed by disposal.
Orange County Water District (OCWD) Water Treatment System	A district industrial scale groundwater treatment system that supplies recycled water for over 2.4 million people in Orange County. It facilitates pre-purification, microfiltration, reverse osmosis, and ultraviolet light treatment.
Living Machine	A biological based wastewater treatment system that treats both gray and black water at schools and universities, municipal and government buildings, resorts and camps, and several other developments. Current models bring effluent water to standards that surpass secondary standards, which are primarily used for toilet flushing needs.
Janicki Omni Processor	A single unit that combines several solids processing technologies. It applies common underlying unit operations such as drying and combusting in order to dewater and burn biosolids.
Orenco Advantex AX15-RT3 with UV	A system that combines the primary sewage and secondary treatment tanks (of the AdvanTex Treatment System) into a single compact unit. The AdvanTex is "a multiple-pass, packed-bed aerobic wastewater treatment system specifically designed and engineered for long-term processing of residential strength wastewater."
siClaro Submerged Membrane Bioreactor (SMBR) BMA 10-75	A system that purifies wastewater such as grey water, black water, and laundry water. It contains a control cabinet, mechanical pre-treatment, a biological and scouring blower, a filtrate pump, a service area, and biological treatment with siClaro FM ultrafiltration.
Kuwait Water Recycling System:	A that consists of multi-media filtration, a pump, backwashing filtration and a storage tank.

Method

Initial Research	• Find potential gravity-based earth water treatment technologies to analyze in trade study
Survey	• Create survey for customers to determine important technology factors
Critical Parameters	• Create scales for parameters deemed important by customer input to survey and assign parameter scores to each technology
Initial QFD	• Aggregate initial parameter scores to perform initial cut on 10 technologies
Expanded Parameters	• Create scales for secondary parameters and assign parameter scores to remaining technologies
Final QFD	• Aggregate expanded parameter scores to finalize quantitative results

Results

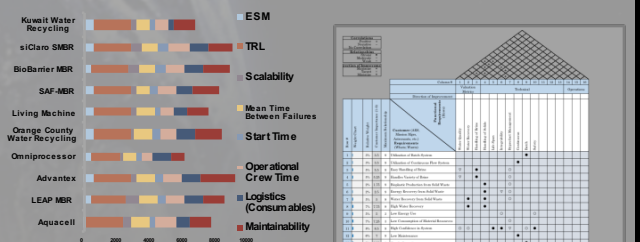

Figure 1. Results of first QFD (critical parameters)

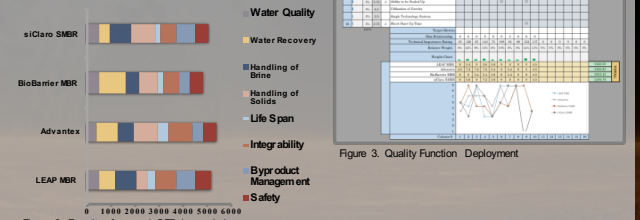

Figure 2. Results of second QFD (expanded parameters)

Figure 3. Quality Function Deployment

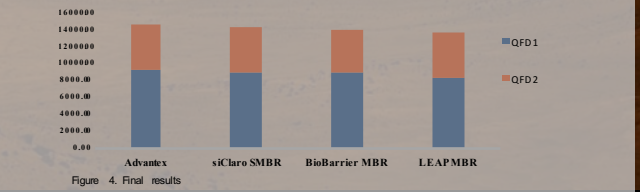

Figure 4. Final results

Final Technologies

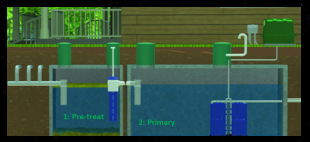

Figure 5. BioBarrier MBR

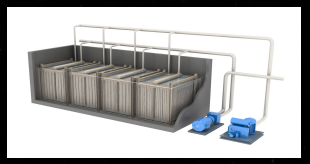

Figure 6. LEAP MBR by Suez Technologies

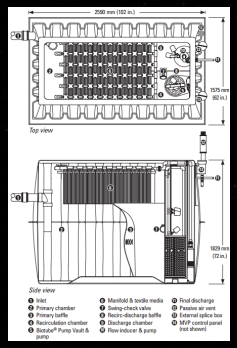

Figure 7. Advantex AX15-RT

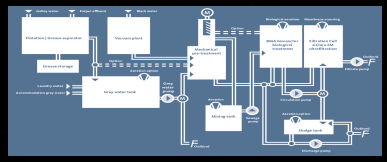

Figure 8. siClaro SMBR BMA 10-75

Conclusions

The group was able to successfully research ten separate technologies and determine the most suitable systems for use on a planetary space mission by rating each technology using a variety of parameters. By using quality function deployment and survey responses from industry experts, the group was able to assess the importance of each parameter and numerically rank each technology.

The most suitable technology in our trade study is the Advantex system. However, the remaining technologies from the second QFD also scored comparably, and as such the group would also recommend further research into the siClaro SMBR system.

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