System Analysis of a shared Water-Hydrogen-Oxygen Infrastructure for future Space Habitats

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1. Introduction

An essential resource to enable long-duration Lunar or Martian missions is water by building the basis of life for astronauts. The decomposition of water (H_2O) into hydrogen (H_2) and oxygen (O_2) provides breathable oxygen for the Environmental Control and Life Support System (ECLSS) as well as fuel for space vehicles by combining liquid hydrogen and liquid oxygen. Two practices are considered to meet the water demand in space habitats: Water recycling within the ECLSS and water extraction by space resource utilization (SRU). Thus, the key technology to exploit synergies between the ECLSS and SRU is the water treatment system. As a result, a shared H_2O-H_2-O_2 infrastructure minimizes the mass brought from Earth and contributes to a sustainable exploration of the solar system.
The following block diagram represents the elements of the shared infrastructure for future space habitats.

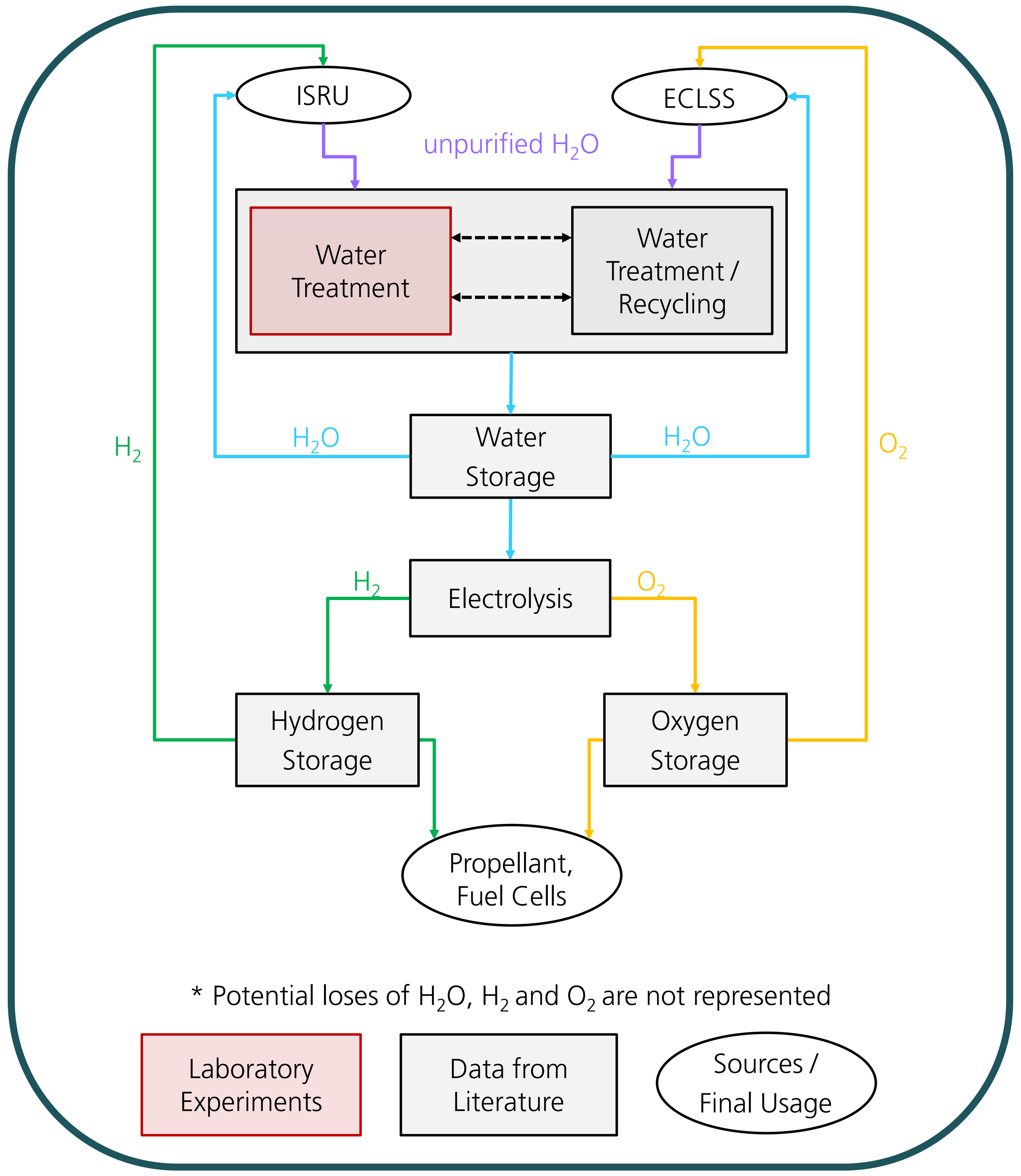

Figure 1: Shared H_2O-H_2-O_2 Infrastructure Block Diagramm.

2. Objectives

- Developing a lunar raw water simulant which contains impurities expected on the Moon.
- Exploiting the synergies between ECLSS and SRU water treatment technologies.
- Simulating the shared H_2O-H_2-O_2 infrastructure.
- Analyzing internal and external influences on the shared infrastructure.

3. Methodology

Lab Experiments Part I:
- Leaching lunar dust simulants in aqueous solutions.
- Varying dust to solution ratio, contact time, pH, and dissolved O_2 in solution.
- Preparing lunar raw water simulants.

Lab Experiments Part II:
- Installing a lunar raw water purification system.
- Testing the system with lunar raw water simulants.

Modeling:
- Developing the infrastructure by using results from the experiments and literature.
- Including the infrastructure into an existing ECLSS model.

4. Ongoing Research

Currently, the lab experiments partI are running, and thereof the first leaching experiments are completed. The experimental procedure is based on the guidelines of Kerschmann et al. [2020] and Stewart et al. [2013].

Ultrapure water + lunar LHS-1D dust simulant from *Exolith Lab*

Taking ~10 mL sample at specific time points, centrifuge at 6000 RPM for 10 min

Filtering through a PTFE 0.45µm syringe filter

Analyzing ion concentrations in solution with ICP-OES

[carlroth.com]

Table 1 summarizes the parameters of the dissolution experiments of lunar dust simulants in water.

Table 1: Test Batch Parameters of Dissolution Experiments.

Test Batch	Ratio of dust simulant in g to solution in mL	Dust Simulant Mass in g	pH initial	Use of pH Buffer
1	1:20	12.5	5.6	no
2	1:100	2.5	5.6	no
3	1:500	0.5	5.6	no
Aqueous solution	Ultrapure water, resistivity 18 mΩ·cm			
Volume of solution	250 mL			
Stirring rate	20 RPM			
Contact time	2 min, 15 min, 30 min, 1 h, 12 h, 1 d, 3 d			
Analyzed ions	Al, Ca, Fe, K, Mg, Mn, S, Si, Ti			
Temperature	20 °C			

5. First Results

- After 2 min of contact time, the pH and the concentrations of Al, Ca, K, Mg, S, and Si increased.
- After 1 h, the increase of the pH and the concentrations is less significant.
- Dissolution of Fe, Mn, and Ti is not observable.
- A contact time of 1 week shows no difference from a contact time of 3 days.
- Aluminum concentrations exceed the World Health Organization [2018] recommended drinking water standard of 0.2 mg L^{-1}.

6. Outlook

The aqueous solution will be adapted by using a buffer solution to resist the change in pH. Afterward, experiments with an O_2 outgassed solution in a nitrogen glove box will be conducted to mimic the lack of atmosphere on the Moon. These results feed into the laboratory set-up of a water treatment system considering the removal of aluminum.
Throughout the entire project, the exploitation of synergies between ECLSS and SRU is the main objective.

7. References

Kerschmann, R. L., Loftus, D. J., Damby, D., Scheiderich, K. and Winterhalte, D. Testing of Lunar Dust dissolution in aqueous environments, *NASA Engineering and Safety Center Lunar Dust Workshop Part II*, 2020.

Stewart, C., Horwell, C., Plumlee, G., Cronin, S., Delmelle, P., Baxter, P., Calkins, J., Damby, D., Morman, S., and Oppenheimer, C. Protocol for analysis of volcanic ash samples for assessment of hazards from leachable elements. Technical Report, 2013.

World Health Organization (WHO). A global overview of national regulations and standards for drinking-water quality. 2018.

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