Prospective Study for Harvesting Solar Wind Particles via Lunar Regolith Capture. H. L. Hanks[1]
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Introduction: In the 1970s, experiments on Apollo lunar regolith samples demonstrated the existence of volatiles which could be released upon heating to approximately 700 °C.[1]

In 2009 data from lunar orbit-based detectors Chandrayaan-1 and LRO confirmed the existence of OH on the surface of the Moon[2] and even showed OH migration from equatorial regions to cold traps[3].

It is believed that water continues to accumulate on the Moon via comet impacts[4] and solar wind implantation of protons,[5] but questions remain about how much of it diffuses into the subsurface, escapes into space or hops into cold traps.

What is known is that some proportion of the solar wind ions have reacted with oxygen in the regolith over millennia to form around 150 ppm H_2O, CO, CO_2 and N_2 which can be extracted upon heating[6]. There is also evidence that these volatiles can be found at least 3m down, at the bottom of Apollo's core sample drills[6].

Non-PSR Regolith Mining: Much of the current Lunar ISRU research focusses on mining perennially shadowed regions (PSRs) where larger concentrations of water ice are believed to exist. However, there are some reasons to consider mining non-PSRs:

1) Only about 1% of the lunar surface consists of PSRs[7].
2) Mining operations can be executed during daylight hours with illumination and abundant solar energy.
3) Temperatures in the PSRs can be just a few degrees above absolute zero[8], so the risk to personnel and equipment is significant.
4) Mining in non-PSRs can be carried out on flat surfaces with well-mapped terrain. This provides more safety and operational certainty for volatiles mining activities.
5) Mining sites can be chosen to align with other mission objectives such as building settlements and landing and launching of spacecraft.

Process Engineering Approach: Previous studies of volatile extraction from lunar regolith noted that a useful gas pressure can be achieved but the expected heating requirements are daunting.[9] However, heat integration was not considered in the calculations.

The aim of the current research is to use standard process engineering techniques combined with available lunar environment information to design a Solar Wind Activated Material Processer (SWAMP) module.

The design is considering a range of possible technologies to achieve the following process steps:

1) Regolith extraction and loading
2) Heating and pyrolysis of the regolith
3) Cooling and heat recovery
4) Separation of volatile products
5) Purification and compression
6) Process integration to maximise heat recovery

As part of the process engineering project, legal, environmental, reliability, safety and infrastructure concerns will be considered in the prospective study.

References:

1. Gibson, E. K. & Johnson, S. M. Thermal analysis-inorganic gas release studies of lunar samples. in *Proceedings of the Second Lunar Science Conference* **2,** 1351–1366 (1971).
2. Pieters, C. M. *et al.* Character and Spatial Distribution of OH/H2O on the Surface of the Moon Seen by M3 on Chandrayaan-1. *Science (80-.).* **326,** 568–572 (2009).
3. Livengood, T. A. *et al.* Moonshine: Diurnally varying hydration through natural distillation on the Moon, detected by the Lunar Exploration Neutron Detector (LEND). *Icarus* **255,** 100–115 (2015).
4. Stewart, B. D., Pierazzo, E., Goldstein, D. B., Varghese, P. L. & Trafton, L. M. Simulations of a comet impact on the Moon and associated ice deposition in polar cold traps. *Icarus* **215,** 1–16 (2011).
5. Farrell, W. M., Hurley, D. M. & Zimmerman, M. I. Solar wind implantation into lunar regolith: Hydrogen retention in a surface with defects. *Icarus* **255,** 116–126 (2015).
6. Heiken, G., Vaniman, D. & French, B. M. *Lunar Sourcebook: a user's guide to the moon*. (Cambridge University Press, 1991).
7. Petrov, D. V., Shkuratov, Y. G., Stankevich, D. G., Shevchenko, V. V. & Kozlova, E. A. The Area of Cold Traps on the Lunar Surface. *Sol. Syst. Res.* **37,** 260–265 (2003).
8. Paige, D. A. *et al.* Diviner lunar radiometer observations of cold traps in the moon's south polar region. *Science (80-.).* **330,** 479–482 (2010).
9. Rapp, D. *Use of extraterrestrial resources for human space missions to moon or mars*. *Use of Extraterrestrial Resources for Human Space Missions to Moon or Mars* (Springer Berlin Heidelberg, 2013). doi:10.1007/978-3-642-32762-9