EXPERIMENTAL STUDY TO INVESTIGATE NEAR-SURFACE WATER CYCLE ON MARS.

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Introduction: Liquid water is the most fundamental requirement for habitability of Martian surface. There has been observational evidence by previous landed missions for frost formation on the Martian surface. Viking 2 lander observed the first frost formation at Utopia Planitia [1], and the Phoenix lander showed observational and theoretical evidence for liquid brines in disturbed and undisturbed areas at the landing site [2]. Numerous studies suggest that sulfates, perchlorate, and chloride salts in regolith can absorb water from the atmosphere under current conditions, forming hydrates via absorption and hydration, and then liquid brines via deliquescence [3,4,5,6,7]. In this state, there can be an exchange of water between the regolith and the atmosphere under present-day conditions due to the diurnal and seasonal variations of temperature and relative humidity. Understanding the present-day processes on Mars that relate the atmosphere-regolith interaction are critical to revealing its aqueous and climate history, which is relevant to determining its implications for present-day habitability [8]. Here we present the experimental results of thermal cycles and their effect on water vapor diffusion and interactions with salts in a shallow regolith column similar to [9] but at lower temperatures simulating a diurnal thermal cycle.

Methodology:

The objective of this work is to

(i) Understand the effect of diurnal cycle and dynamic temperature variations on the diffusion of water vapor in the regolith

(ii) Understand conditions leading to liquid formation in the Martian surface

This abstract focuses on the initial experimental results conducted using the Ares Mars simulation chamber in the W.M. Keck Laboratory for Space and Planetary Simulations at the University of Arkansas. In this experiment the sample was prepared with JSC Mars-1 regolith simulant mixed with 5 wt.% concentration of $Ca(ClO_4)_2$ with a 2 cm depth in an aluminum container and placed inside the chamber. A Martian atmosphere is created by vacuuming the chamber and filling it with pure carbon dioxide (CO_2) gas until the pressure reaches 1 bar, then decrease it down to Mars' pressure (6 mbar). A stainless-steel syringe connected to the chamber is used to increase the relative humidity (RH) inside the chamber by injecting 25 mL of liquid water in minute amounts until the RH reaches the desired initial value. The vacuum pump is connected to a controller to maintain the total pressure between 6-10 mbar. Next, the chiller is turned ON to simulate the 'night part' till the temperature reaches 250K and the chiller is turned OFF which allows the temperatures to increase to 280 K as the external walls of the chamber is in contact with the lab conditions thus simulating the diurnal cycle. The experiments were run for a total of 31 hours. Temperature and relative humidity sensors are placed at 2 different locations (i) ~ 30 cm above the sample (ii) inside the sample. Throughout the experiment, temperature and relative humidity values are logged every 1 minute. The sample is placed on a weighing scale inside the chamber and the change in weight of the sample is recorded in real time.

Results and Discussion: We simulated a plausible Martian near surface diurnal thermal cycle with pure carbon dioxide gas and water vapor at total pressure ranging from 6-10 mbar. The regolith sample was tested for deliquescence by change in mass and water darkening or regolith color change (Figure 1).

Figure 1: Images of the regolith sample before and after the experiment. Visual observations (marked in red) of deliquescence (water darkening the soil and regolith color change) of $Ca(ClO_4)_2$ salt can be seen after the experiment.

The environmental parameters recorded during the experiment are shown in Figure 2. As the experiment progressed, we could observe the change in mass of the regolith sample. Initially it decreased when it was subjected to vacuum and a sharp increase when liquid water was injected into the chamber (Figure 3).

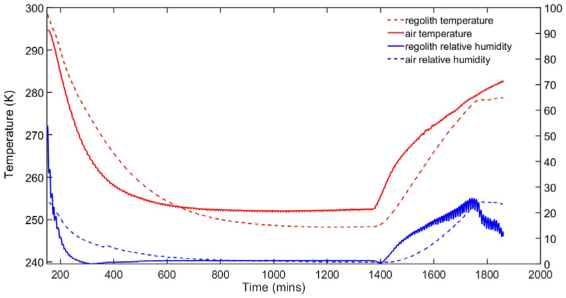

Figure 2: Diurnal cycle showing the temperature and relative humidity variations of air and regolith sample.

As the experiment progressed the temperature reached a stable and constant value at 250 K, up to 1400 min, when the chiller was switched OFF to allow the temperature to increase to observe the water release back to the atmosphere from the regolith, thus simulating a near-surface water cycle. We could clearly observe deliquescence by changes in mass (Figure 3) and the darkening of the sample surface. It is important to note that the water vapor inside the chamber was quite high compared to the measured values on the surface of Mars (0.1 mbar [8]).

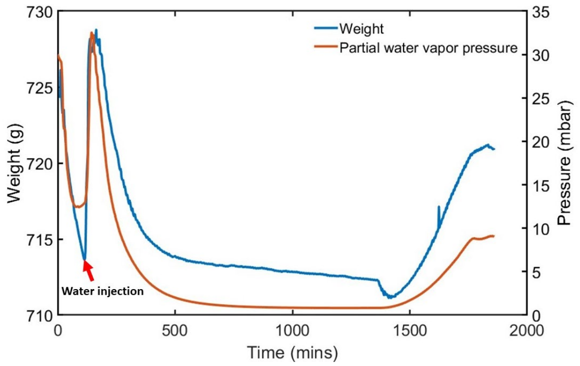

Figure 3: Effect of mass along with change the derived partial pressure of water inside the chamber.

Conclusion: The regolith sample with a depth of 2 cm mixed with $Ca(ClO_4)_2$ salt was subjected to diurnal thermal cycle for 31 hours. We observed deliquescence by increase in mass of the regolith sample and the darkening of the sample surface. We find that as the temperature is lowered the mass loss of the regolith may be due to desorption of adsorbed water on the regolith sample. Future, experiments will be conducted at temperatures closer to 200 K and will focus on using a secondary chamber as a water vapor source which will ensure a relatively constant pressure of water and therefore that the relative humidity follows the thermal diurnal cycle imposed in the primary chamber ideal to actual Martian conditions. This will help us understand the conditions leading to liquid formation in the Martian surface which will have implications for its habitability.

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References:

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