Chemical Reactivity of In-Situ Lunar Dust for Biotoxicity Assessment.

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Introduction: How does the chemical reactivity of in-situ lunar dust compare to Apollo samples currently stored in curation facilities here on Earth? Essential investigations of this question will help us to further mitigate exploration risks for future human explorers on the Moon and will also provide critical information for astrobiologists and space biologists using the Moon for scientific inquiry.

Discussion: Apollo 14 dust biotoxicity studies, carried out by the NASA Lunar Airborne Dust Toxicity Assessment Group (LADTAG), included numerous physiochemical studies[1] and cellular and animal experiments. Intratracheal instillation [2] and inhalation studies [3] in rats both showed Apollo 14 dust to be intermediate in toxicity compared to low-tox titanium dusts and high-tox quartz dusts of similar particle sizes. The collective results were used in models [4] to establish a safe exposure limit for astronauts [5]. Although LADTAG took extensive steps to preserve what chemical reactivity may still have existed in the samples, it is simply unknown if they possessed true in-situ chemical reactivity or if that reactivity has decayed. Initial gas loss on collection and other alterations, and even intermittent exposure to Earth-normal conditions during subsequent decades of handling, obscure a forensic reconstruction of the initial state.

Because a mineral dust's chemical reactivity influences its biotoxicity [6], researchers have developed methods to "activate" lunar dust and simulants [7][8]. Past studies that modeled impact processes and radiation [9] in the lunar environment suggest that in-situ lunar dust is likely to be more chemically reactive than Earth-exposed samples. Because of these results, in-situ measurements are warranted [10]. Other studies have examined the hydroxyl generating capability of iron bearing mineral phases [11][12] and further emphasize the role iron plays in chemical reactivity of lunar material, as well as decay of chemical reactivity in mineral dusts [12]. Recent observations of the lunar surface reveal the presence of hematite [13], a finding that further supports the hypothesis that in-situ lunar dust is reactive. Since the lunar surface is heterogeneous, dust biotoxicity is expected to vary from site to site [14] due to particle size, mineralogy, physical characteristics, degree of space weathering, and chemical reactivity (Figure 1). This circumstance dictates dust assessments at a suite of lunar sites enabled by upcoming NASA and commercial lunar payload services (CLPS) opportunities. Dose, location, and duration of particle exposure will also affect biological responses. In-situ chemical reactivity measurements can inform cross-cutting collaborative research campaigns such as astrobiology studies examining regolith interactions with organisms and its ability to preserve chemical and structural biomarkers, as well as space biology investigations that examine regolith-microbe interactions relating to life support systems, plant growth, biomining, and development of regolith biocomposites.

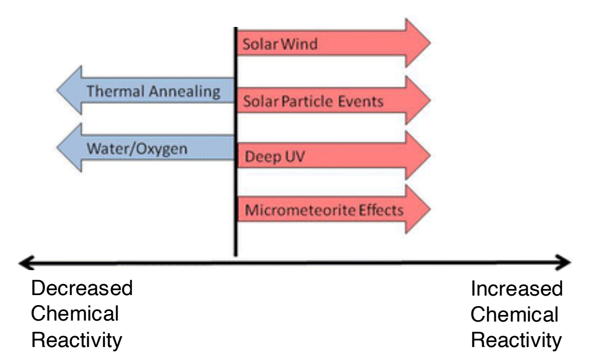

Figure 1: Environment conditions on the lunar surface that may alter regolith reactivity.

Summary A series of in-situ measurements of lunar dust free radical chemistry at future Artemis and CLPS landing sites, combined with LADTAG-like studies of freshly collected lunar dust specimens, will reveal the true chemical reactivity of in-situ lunar dust and generate scientific data that can be compared to the chemical reactivity and biotoxicity of samples from Apollo landing sites. Furthermore, results from in situ measurements and biotoxicity studies of freshly collected specimens can also be used to validate, or require revision of, the current astronaut permissible exposure limit [15].

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