Chemical Reactivity of In-Situ Lunar Dust

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Is in-situ lunar dust less, the same, or more chemically reactivity reactive than the Apollo samples currently stored in curation facilities here on Earth? This question has been debated extensively across the community of scientists that have focused on lunar dust biotoxicity. A definitive answer will further mitigate exploration risks to future human explorers on the Moon and will provide useful information for astrobiologists and space biologists as well.

Previous studies by the NASA Lunar Airborne Dust Toxicity Assessment Group (LADTAG) carried out biotoxicity studies on biologically and operationally relevant doses of respirable-sized lunar fines with mean diameters of approximately 2.5 μm from an Apollo 14 bulk sample 14,003,96. That particular sample was chosen because it contained enough material needed for the physiochemical characterization (McKay et al. 2015) of the samples and the extensive biological studies that utilized the same specimens, which included numerous cellular and animal studies. Intratracheal instillation (Rask et al. 2013) and inhalation studies in rats (Lam et al. 2013) both showed that the Apollo 14 samples were intermediate in toxicity when compared to low toxicity titanium dusts and high toxicity quartz dusts with similar particle sizes. The collective results from the biology studies were used in models (James et al. 2013) to establish a safe exposure limit for astronauts and was set at 0.3 mg/m3 (Scully et al. 2013). However, it should be noted that the samples used by LADTAG spent 40+ years on the Earth in a curation facility before they were used in the biotoxicity studies. While it is important to note that LADTAG took extensive steps to preserve what chemical reactivity may have existed in the samples stored in the curation facility, it is simply unknown if the samples used actually possessed the true in-situ chemical reactivity or if that chemical reactivity had decayed.

Because chemical reactivity of a mineral dust is known to influence its biotoxicity (Porter 2002), researchers investigating the chemical reactivity of lunar dust developed methods to "activate" lunar dust and lunar dust simulants (Wallace et al. 2009, 2010). The studies were carried out to model impact processes and radiation (Loftus et al. 2010) in the lunar environment that are hypothesized to render in situ lunar dust more chemically reactive than samples that have been exposed to an Earth-like atmosphere. Experimental results suggested that material freshly collected from the lunar surface may be more reactive than material that has been in contact with oxygen or water in storage facilities on Earth and that in situ measurements of lunar dust chemical reactivity are warranted (Rask 2009). Other studies have examined the hydroxyl generating capability of iron bearing mineral phases (Turci 2015) (Hendrix 2019) and further emphasize the role iron plays in chemical reactivity of lunar material, as well as decay of chemical reactivity in mineral dusts (Hendrix 2019). Since the lunar surface is heterogeneous, the biotoxicity of lunar dust is expected to vary from site to site and is due to particle size, minerology, physical characteristics, and chemical reactivity (Rask 2018). Dose, location, and nature of particle exposure and duration of exposure will also affect the biological response. In addition to mitigating risks to humans, measurements of in-situ chemical reactivity of lunar dust will also provide valuable information for other biological research at NASA. For example, in-situ chemical reactivity measurements will inform astrobiology studies examining regolith habitability and its ability to preserve biomarkers, as well as space biology investigations that examine regolith-microbe interactions relating to life support systems, plant growth, biomining, and development of synthetic biology technologies such as regolith biocomposites.

In summary, a series of in-situ measurements of lunar dust free radical chemistry at the Artemis landing site, 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.

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