

LUNAR DUST BIOLOGICAL EFFECTS. L. Jones¹, S. Jacques¹, J. C. Rask², E. Tranfield², L. Taylor³, R. Kerschmann², D. J. Loftus². ¹Dermatology and Biomedical Engineering, Oregon Health & Sciences University, Portland, OR 97239, ²Space Biosciences Division, NASA Ames Research Center, Moffett Field, CA 94035, (jon.c.rask@nasa.gov), ³Planetary Geosciences Institute, University of Tennessee, Knoxville, TN 37996

Introduction: During the Apollo era, lunar regolith was commonly brought into the lunar module via dirty spacesuits and as a result, the cabin surfaces and the cabin atmosphere became contaminated. Based on detailed technical debriefs of the Apollo astronauts, it was apparent during the missions that respiratory effects, skin effects and potential ocular effects of lunar dust needed to be evaluated. Although these areas of concern were recognized, short mission duration and rapid mission succession prevented a detailed analysis of the medical problems associated with lunar dust.

We are investigating the biological effects of lunar dust to understand potential skin effects, inhalation toxicity, and ocular effects that may result from long duration human habitation of the Moon. These studies are designed to reveal a fundamental understanding of the exposure response of terrestrial life to lunar dust, provide insight into how dust in the lunar environment may affect surface operations, and influence designs for human exploration of the Moon. This work is being performed in cooperation with the Lunar Airborne Dust Toxicity Advisory Group (LADTAG), Johnson Space Center, and Oregon Health and Sciences University.

Skin Studies: Previous experience from the Apollo era indicates that skin irritation may be an issue, although the effect has never been studied in detail. Other effects may include skin sensitization (an immunological response to one or more components of lunar dust) as well as skin abrasion effects, which may have important ramifications for astronauts. One possible scenario that could lead to skin abrasion involves lunar dust entry into the space suit, where lunar dust could become trapped between the astronaut's skin and fabric materials immediately adjacent to the skin. The consequences of skin abrasion could include disruption of the barrier function of the skin with resultant increased water loss, risk of infection, and potential fouling of the suit.

In the studies reported here, lunar soil samples from Apollo 11, 16 and 17 missions, and the lunar soil simulant JSC-1A, were evaluated. All experiments were performed using freshly harvested pig skin, which is considered to be the best animal model of human skin. To perform abrasion studies, lunar soil or lunar simulant was embedded in cotton patches and used to abrade the pig skin samples. In order to measure abrasion effects, we carried out transcutaneous

impedance measurements, a sensitive method for detecting damage to the surface of the skin (Figure 1). As the skin surface is damaged, the electrical resistance

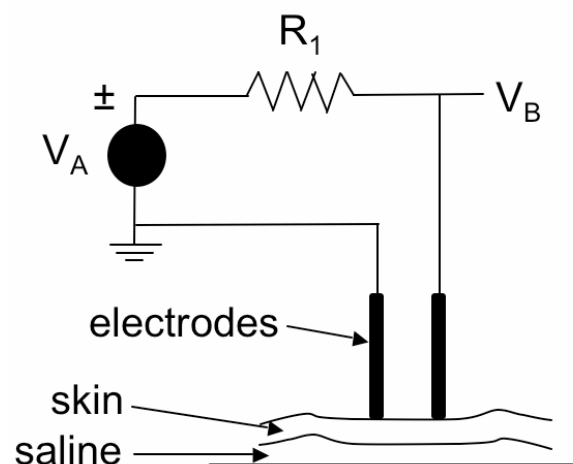


Figure 1. Experimental setup for measuring transcutaneous electrical resistance during abrasions of skin by cotton fabric with embedded lunar soil. As the abrasion damages the skin, the resistance across the skin drops.

drops from the M- Ω range to the k- Ω range. Our results show, that in the absence of lunar dust, little to no drop in the transcutaneous impedance was observed. When a small amount of lunar simulant was added to the fabric, skin abrasion occurred more rapidly, as expected. In order to provide a quantitative comparison of lunar soil vs. lunar soil simulant, we used a 10 stroke protocol that showed dependence of the resistance change on the amount of abrasive material added to the fabric sample. Lunar soil samples from the 3 Apollo missions studied all exhibited a high degree of abrasivity that was comparable to that for lunar soil simulant (JSC1A). In our assay, the midpoint of this effect occurred at approximately 50-100 mg per fabric patch (4 cm x 4 cm). Based upon an analysis of lunar soil simulant alone, we have shown that the skin abrasion effect is strongly dependent on particle size, with larger particles exhibiting a higher degree of abrasivity. The preliminary findings of these skin abrasion studies have implications for the selection of materials for EVA suits. Future work with the lunar simulant and lunar regolith will continue to evaluate the abra-

sivity of actual lunar dust in preparation for the return of humans to the lunar surface.

Inhalation Toxicity: On Earth, inhalation of particulate matter air pollution is associated with increased cardiopulmonary morbidity and mortality [1], and inhalation of freshly ground silica is associated with an acute and lethal form of silicosis [2] (Figure 2).



Figure 2. Chest X-ray showing bilateral pulmonary fibrosis characteristic of silicosis. Photo credit Robert Wood Johnson Medical School.

While lunar dust is not the same type of crystalline silica known to cause such disease, about 20 percent of the lunar regolith by weight is smaller than $20\mu\text{m}$ —much of which is respirable. In addition, lunar dust has a very high surface to volume ratio and contains fully reduced (metallic) iron, present as nanometer-sized deposits within the lunar dust agglutinates, a form of iron not found in terrestrial soils. These features of lunar dust suggest that it could be toxic, although definitive toxicity studies are just now getting underway. In co-operation with colleagues at Johnson Space Center, NASA Ames Research Center is investigating the potential for lunar dust to generate inflammatory responses in the lungs. These studies involve chemical assays of lunar dust surface reactivity, cellular studies, and animal studies. Preliminary results suggest that lunar dust simulants do, in fact, generate reactive oxygen species and so could trigger pulmonary inflammation comparable to that of SiO_2 . Preparations for similar tests using real lunar dust are ongoing.

Ocular Concerns: Upon the completion of the classical skin toxicity work, ocular studies will begin. We will consider the potential for lunar dust to cause corneal abrasions, corneal ulcers, conjunctivitis, as well as damage to the lid margins and to the lacrimal system. These effects could cause short term visual

impairment of astronauts as well as long term ocular damage.

Summary: Since long term habitation of the Moon is a key aspect of NASA's Space Exploration Policy, a full understanding of the potential health effects of lunar dust is necessary. With the availability of archived lunar samples from the Apollo era, we have the opportunity to study the biological response prior to our return to the Moon. This strategy will allow NASA to anticipate and manage medical issues that may arise in the unique lunar environment.

References: [1] Pope C.A. (2007). *Inhal Toxicol.*, 19 Suppl 1:33-8. [2] Greenberg M.I. (2007). *Dis Mon.*, 53(8):394-416.