Mitochondrial Dysfunction and Genotoxicity Provoked by Exposure of Human Lung Cells to Lunar Dust Simulants

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Lunar dust was reported during the Apollo missions as a potential threat to astronauts during future exploration of the Moon by humans. The planned lunar explorations starting in 2024 bring this problem to the forefront. Occupational dust exposure (e.g., in miners,) causes silicosis and related pulmonary disease, and increases the risk of lung cancer. Lunar regolith is composed of unique material found exclusively on the lunar surface, and this material appears to have physical and chemical properties that could exacerbate toxicity to humans compared to terrestrial dusts. Our previous work [1] demonstrated that grinding to reduce particle size and expose fresh surfaces strongly enhanced the cytotoxicity and genotoxicity (DNA-damaging) effects of NASA-generated lunar regolith simulants. That work also indicated that the capacity of various simulants to cause DNA damage or cell death was not well correlated with their oxidant-generating activity in aqueous solution. The grinding procedure mimics one aspect of “space weathering,” fragmentation due to micrometeorites.

Another important facet of space-weathering is exposure of the surface to solar wind. In preliminary studies, we mimicked this effect by treating ground simulants with hydrogen gas under heat. This procedure greatly enhanced the cytotoxicity of ground JSC-1A (Johnson Space Center 1) simulant both in neuronal cells (mouse CAD cells) and in human lung alveolar epithelial cells (the A549 cell line). We have now employed Lunar Mare Simulant-1 (LMS-1) and Lunar Highlands Simulant-1 (LHS-1), which more accurately mimic the actual lunar regolith. We have applied new assays that monitor mitochondrial dysfunction (MitoSOX Red, reporting oxidative stress in the organelle) and the comet assay to monitor the integrity of nuclear DNA. The preliminary results show a significant, dose-dependent increase in the MitoSOX Red signal after treatment with either LMS-1 or LHS-1. Likewise, the comet assay demonstrated significant DNA damage in the nucleus, which corroborates the measurements using our established polymerase chain reaction assays.

Our results underscore that complex materials such as regolith have complex cellular effects. Our work has begun to unravel the roles of specific forms of space weathering. These studies indicate not only the potential physiological effects of exposure to Moon dust, but they also point the way to possible biomarkers to assess such exposure in astronauts.


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