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HIGH-FIDELITY DUST SIMULANTS FOR LONG-TERM TOXICOLOGICAL ASSESSMENT OF LUNAR REGOLITH TO SUPPORT IN-SITU RESOURCE UTILIZATION (ISRU)

Abstract

NASA, ESA, and other space agencies are planning a new phase of Moon exploration, with the goal of establishing a permanent human presence on the Moon. One of the most alarming aspects of a prolonged interaction of humans with the lunar environment is the potential toxicity of lunar dust (LD), which poses a significant risk to human health. During the Apollo missions, in fact, astronauts reported about mild to severe upper respiratory tract symptoms and eye irritation, suggesting possible toxicity associated to LD exposure. This peculiar reactivity might be related to some unique physico-chemical features of LD, which result from space weathering processes, including comminution, cementation, and chemical modification due to micrometeorite bombardment, solar wind, and hard UV irradiation. The occurrence of nano-phase iron clusters in agglutinated silicate glass is the most common results of space weathering of lunar regolith. As the availability of real lunar dust samples is limited, research must rely on simulant earthly materials.

In this study, two modified zeolites were used to obtain a glassy matrix containing nano-agglomerates of metallic iron. To mimic lunar impacts in the oxygen– and water–free lunar atmosphere, the as-prepared Simulant Moon Agglutinates (SMA) were ball milled in argon atmosphere. The powders were characterized for morphology, size, chemical composition, and specific surface area. Two exposure scenarios were simulated by contacting particles with: i. an inert (oxygen/water-free) atmosphere and, ii. Earth air. Particle reactivity was assessed in both these environments. Specifically, the capacity to generate oxidative stress (e.g., free radicals) and iron release in simulated body fluids, and the ability to induce damage to biological membranes were assessed. The SMA samples stored in the inert atmosphere induced a higher amount of free radicals with respect to SMA stored in air. The higher chemical reactivity was due to the presence of iron in its reduced state and signaled a relevant oxidative potential when the dust comes in contact with body fluids. The samples did not damage biological membranes, suggesting that the LD mechanism of action might be different from similar earthly toxicant such as crystalline silica.