Understanding the Activation and Solution Properties of Lunar Dust for Future Lunar Habitation. W.T. Wallace[1] and A.S. Jeevarajan[2], [1]USRA/NASA Johnson Space Center, 2101 NASA Pkwy, Mail Code: SF, Houston, TX 77058 (william.wallace-1@nasa.gov), [2]NASA Johnson Space Center, Houston, TX (antony.s.jeevarajan@nasa.gov)

Introduction: The decision to return humans to the moon by 2020 makes it imperative to understand the effects of lunar dust on human and mechanical systems.[1-3] During the Apollo missions, dust was found to cause numerous problems for various instruments and systems. Additionally, the dust may have caused health issues for some of the astronauts.[2, 4] It is necessary, therefore, for studies to be carried out in a variety of disciplines in order to mitigate the effects of the dust as completely as possible.

Due to the lack of an atmosphere, there is nothing to protect the lunar soil from ultraviolet radiation, solar wind, and meteorite impacts. These processes could all serve to "activate" the soil, or produce reactive surface species. In order to understand the possible toxic effects of the reactive dust, it is necessary to "reactivate" the dust, as samples returned during the Apollo missions were exposed to the atmosphere of the Earth. We have used grinding and exposure to UV radiation in order to mimic some of the processes occurring on the lunar surface. To monitor the reactivity of the dust, we have measured the ability of the dust to produce hydroxyl radicals in solution. These radicals have been measured using a novel fluorescent technique developed in our laboratory,[5] as well as using electron paramagnetic resonance (EPR).

While a number of studies have been aimed at understanding the dissolution properties of lunar dust and lunar dust simulants under various conditions,[6-11] there has not been a consistent and systematic method applied over the various studies. For instance, the pH values, choice of acid, choice of simulant, or choice of soil were be different. Additionally, some of these studies also chose to observe the changes in surface morphology using electron microscopy after performing the dissolution studies. These changes could be important if they were to allow some particles to penetrate further into the respiratory system, where more damage could occur. We have undertaken a study aimed at understanding the changes in dissolution of lunar dust and lunar simulant at different pH and in solutions that more closely mimic the fluids likely to be encountered by dust in the body.

Results:

Activation: We have used hand grinding with a mortar and pestle as a means of activating quartz (Min-U-Sil 15), lunar dust simulant (JSC-1A-vf), and lunar soil returned by Apollo 16 (62241). As expected, samples that have not been activated do not produce a significant amount of radicals when placed in aqueous solution, and the emission spectrum is very small. Grinding the different materials under exactly the same conditions, however, leads to quite different emission intensities. As seen in **Figure 1**, the level of hydroxyl radical production increases in the order: quartz < lunar dust simulant < lunar dust.
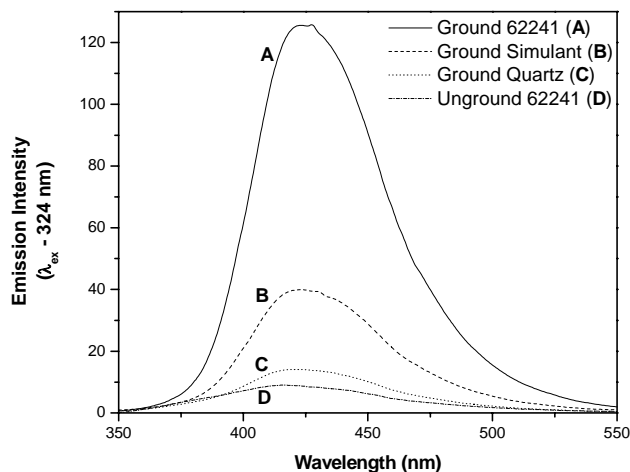

Figure1: Emission spectra comparing ground and unground Apollo 16 soil (62241) with ground JSC-1A-vf and ground Min-u-Sil 15. Increased emission represents increased hydroxyl radical production

In separate studies, we have also attempted to dismiss the idea that this increased activity is tied to the specific surface area of the ground materials. BET analysis has provided values for lunar dust (8.404 m^2/g), lunar simulant (5.369 m^2/g), and quartz (8.436 m^2/g), showing that the activity is not correlated with specific surface area. Additionally, we have monitored the time required to return the activity of its unactivated state. After grinding the dust, we have placed it in an environmental chamber set to a predetermined temperature and humidity. These experiments have shown the deactivation half-life of quartz to be ~ 2 hours, while that of lunar simulant is ~ 3 hours.

Dissolution: We have measured the solubility of JSC-1A-vf lunar dust simulant at three pH values: 4.0 (citrate buffer), 5.3 (citrate-phosphate buffer), and 6.7 (citrate-phosphate buffer). A variety of species were measured using ICP-MS. For all species, it was found that a lower pH results in a large increase in the

amount of material released into solution, as would be expected.[7, 8] Additionally, grinding of the materials prior to placing them in solution also leads to an increase in concentration. This is shown for iron in **Figure 2**. These tests have helped to develop a protocol for dissolution studies prior to testing with lunar dust returned during Apollo. Future tests will include solutions containing species found in the body, such as glycine[12] or phosphatidylcholine.[13]
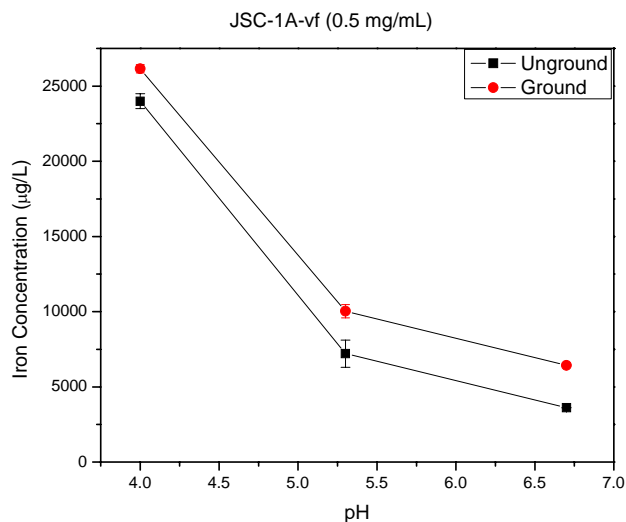
Figure 2: Changes in iron concentration upon placing JSC-1A-vf in buffers of different pH for 72 hours.

Conclusions: We have measured the reactivity of ground lunar dust, lunar simulant, and quartz using a fluorescent assay. The ability of the ground lunar dust to produce hydroxyl radicals is much greater than either lunar simulant or quartz. These results are important, as grinding can act as a surrogate for meteorite impacts on the lunar surface. Additionally, we have studied the dissolution of lunar simulant in buffer solutions of different pH. Lower pH causes a number of different ions to be leached into solution at much higher concentrations, as does grinding of the material. While these studies have not shown the presence of toxic materials or sufficient concentrations to be harmful, similar studies on lunar dust are necessary and will be performed soon.

References:

1.   President George W. Bush, (2004) http://www.whitehouse.gov/space/renewed_spirit
2.   J.R. Gaier, National Aeronautics and Space Administration (2005) NASA TM—2005-213610.
3.   W.W. Mendell, *Acta Astronaut.* **57** (2005) 676-683.
4.   W.J. Rowe, *JBIS* **60** (2007) 133-136.
5.   W.T. Wallace, et al., *Meteoritics Planet. Sci.* (2008) submitted.
6.   R.E. Beiersdorfer, et al., *Lunar Planet. Sci. XXVIII* (1997) 1271-1272.
7.   M.J. Eick, et al., *Geochem. Cosmochem. Acta* **60** (1996) 157-170.
8.   M.J. Eick, et al., *Geoderma* **74** (1996) 139-160.
9.   W.D. Keller and W.H. Huang, *Proc. Lunar Sci. Conf.* **1** (1971) 973-981.
10.   B. Mason, et al., *Science* **167** (1970) 656-659.
11.   V.I. Oyama, E.L. Merek, and M.P. Silverman. in *Apollo 11 Lunar Sci. Conf.* (1970) 1921-1927.
12.   G.M. Kanapilly, et al., *Health Phys.* **24** (1973) 497-507.
13.   X. Liu, et al., *Tox. Lett.* **96,97** (1998) 77-84.