

Fluids and Their Effect on Measurements of Lunar Soil Particle Size Distribution

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From the late 1960s until now, lunar soil particle size distributions have typically been determined by sieving—sometimes dry, and at other times with fluids such as water or Freon. Laser diffraction instruments allow rapid assessment of particle size distribution, and eventually may replace sieve measurements. However, when measuring lunar soils with laser diffraction instruments, care must be taken in choosing a carrier fluid that is compatible with lunar material.

Background

Distilled water is the fluid of choice for laser diffraction measurements of substances when there is no concern about adverse effects of water on the material being measured. When scientists at Johnson Space Center began the analyses of lunar soils using laser diffraction, the first measurements were made with distilled water. Although the medians measured were comparable to earlier sieve data, the means tended to be significantly larger than expected.

The effect of water vapor on lunar soil has been studied extensively. The particles interact strongly with water vapor, and subsequent adsorptions of nitrogen showed that the specific surface area increased as much as threefold after exposure to moisture. It was observed that significant porosity had been generated by this exposure to water vapor. The possibility of other physical changes in the surfaces of the grains was not studied.

Investigation

A dispersion test showed that the use of distilled water resulted in clumping of lunar soil (figure 1). When a size-fractionated sample from lunar soil 14003,96 was measured in water, the volumetric mean was 121.1 micrometers, and the median was 98.04 micrometers (figure 2). When another sample of the same material was measured with isopropanol, the volumetric mean was 59.63 micrometers, and the median was 57.30 micrometers. Variation in aliquots could not be invoked as the cause of this difference.

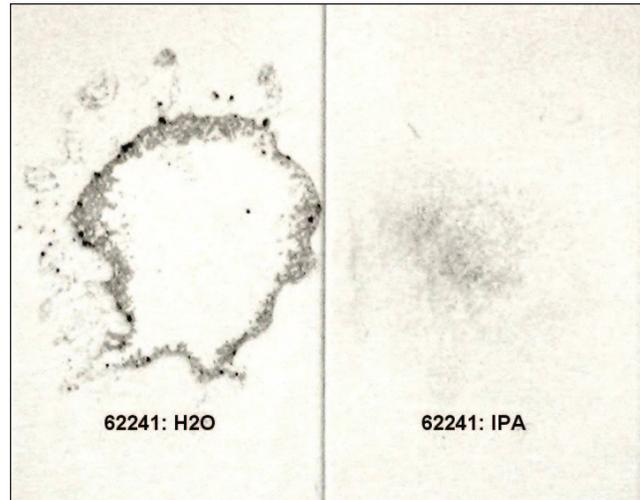


Fig. 1. Dispersion tests with drops of water (left) and isopropanol (right) on a microscope slide, followed by application of a few milligrams of lunar soil 62241.

A measurement of Apollo 11 soil 10084,2006 also showed significant variations related to the fluid that was used for measurement (figure 3). Moreover, when comparing three separate measurements of the sample in water, the standard error was seen to be significantly larger than the standard error produced when isopropanol was used.

It was found that the use of isopropyl alcohol resulted in little or no clumping. However, there was concern that the isopropyl alcohol might partially dissolve and disaggregate the agglutinates because of their high proportion of potentially reactive glass, and thus create smaller particles than would have occurred naturally. To address this concern, scientists at Johnson Space Center performed dissolution tests on lunar soil 14003,96 using isopropanol and water, and also using an acidic citrate phosphate buffer (pH 4). The solutions were analyzed with inductively coupled plasma mass spectroscopy. It was observed that neutral pH water had a strong tendency to dissolve the silicon, calcium, and aluminum in lunar soil, and that the isopropanol dissolved a negligible amount of these elements when corrected for the blank control (figure 4).

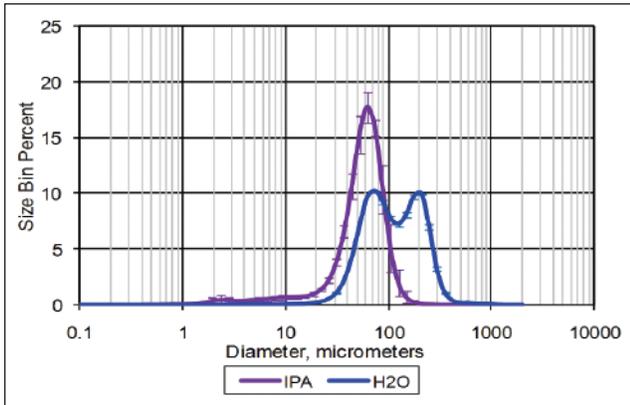


Fig 2. Measurements of a size-fractionated sample from Apollo 14 soil 14003,96 in water (blue) and in isopropanol (purple). Note the secondary peak at large (~200 micrometers) particle size in the histogram that was measured in water, and was thought to be caused by clumping.

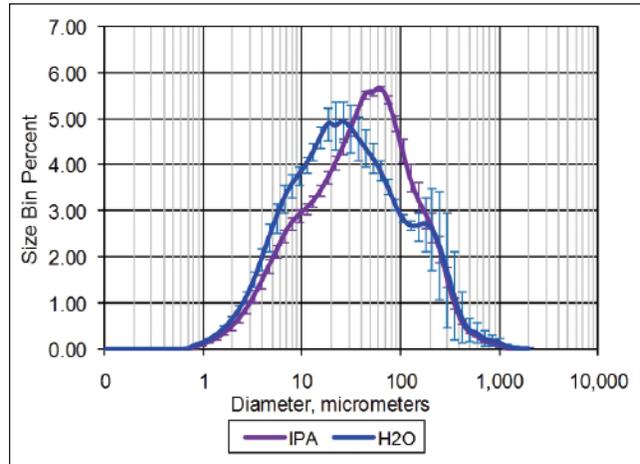


Fig. 3. Measurements of Apollo 11 soil 10084 in water (blue) and isopropanol (purple).

Discussion and Conclusion

During the studies of lunar soils 10084, 14003, 62241 and 61141, it was found that water tends to cause clumping in the soil particles that cannot be de-agglomerated by sonication or by dispersant. Dissolution also occurs when lunar soil samples are placed in water. The finest fraction of lunar soil is known to concentrate both glass particles and plagioclase-rich particles. The dissolution studies show that the major elements of plagioclase are the elements most affected by dissolution in water at neutral pH, but are not detectably dissolved by isopropyl alcohol. Dissolution and clumping can apparently create a spurious bimodal distribution in water-exposed lunar soil. Therefore, the use of alternative fluids of lesser polarity for particle size measurements is recommended. Isopropyl alcohol appears to have negligible chemical effect on lunar soil grains and its use avoids spurious grain size artifacts.

Element	Water	H ₂ O Control	Isopropanol (IPA)	IPA Control	pH 4 buffer Solution	pH 4 buffer Solution Control
Silicon	304.5	9	1280	1500	~35,000	~700
Calcium	0.53	0.14	0.1	0.2		
Aluminum	3	2	8	8	~22,500	~100
Magnesium	0.32	0.04	0.04	0.04		
Iron	5	8	20	20	~17,000	~100
Sulfur	0.7	0.7	1.6	1.6		
Titanium	1	1	4	4	~1700	~100

Fig. 4. Dissolution of lunar soil 14003 in water, isopropanol, and in a pH 4 buffer solution. Controls were water, isopropanol, and pH 4 buffer solution without soil or other solute.