Comparison of Water Movement in Different Lunar Regolith Simulants in Lunar Gravity and Microgravity

Introduction

This is the second in a series of experiments comparing water movement in regolith simulants in reduced and microgravity environments. In the first set (flown in May 2022), students designed and tested equipment that could obtain data in a weightless environment in 20-second intervals. Results from 1-G, Mars-G, Lunar-G, and 0-g showed that reducing gravity (the resistant force) increased rate of water uptake in Mars regolith simulant and the VEGGIE growth medium used on board the International Space Station. However, little to no water movement was seen in the lunar regolith simulant (JSC-1A) in any of the tests. Students hypothesized this was due to the fine, powdery texture of lunar regolith.

In this set of experiments, students were supplied with multiple types of regolith simulant used in lunar research. Each simulant represents lunar chemistry from different locations on the moon, both mare and highlands.

The testing apparatus was used to compare water uptake in a variety of lunar regolith simulants at 1-g (Earth gravity), with and without the use of surfactant. The experiment was then flown on board G-Force One in lunar and microgravity to determine effect of reduced gravity on water movement through the regolith simulants.

Students gained valuable experience in data analysis, research and networking, engineering, experimental design, and critical thinking, even before the actual parabolic flight. These projects can be modified to suit any classroom.

Target Grade Level: 6th-12th
Suggested Time Frame: 5 days (50 minute class periods)

Standards:

NGSS-

MS-PS1-1: Develop models to describe the atomic composition of simple molecules and extended structures.

MS-PS2-2: Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Objectives

- To compare water uptake in a variety of lunar regolith simulants.
- To investigate methods of improving water uptake in lunar regolith simulants.
- To determine the effect of reduced gravity and microgravity on movement of water in lunar regolith simulants.
- To provide an authentic learning experience for students which deepen understanding of force and motion, lunar exploration, capillary action, engineering design process, and scientific inquiry.

Purpose

To investigate capillary movement of water in various lunar regolith simulants. How will reducing or eliminating gravity affect water transport in each type of regolith?

**Compare results at Earth gravity (1 G) to results in lunar gravity and microgravity environments after Zero-G flight.*

Materials

Four 10 cm capillary tubes
multiport T-irrigation reservoir
coffee filter
latex balloon
lunar regolith (simulant)
sponge
20 cc syringe
water
velcro
grid board
camera
Tween 20

Regolith / Substrate Types (used in various combinations):

JSC 1A (Lunar Mare regolith simulant)- Crushed basaltic ash, mined at Flagstaff, AZ. Similar chemistry to Apollo 14 and Apollo 17 landing sites.

NU-LHT (Lunar Highland regolith simulant)- Similar chemistry to Apollo 16 landing site.

OB-1 (Lunar Highland regolith simulant)- Similar chemistry to Apollo 16 landing site.

Exolith LHS-1 (Lunar Highland regolith simulant)- Similar chemistry to average lunar highlands.

VEGGIE (control)- Growth medium used for VEGGIE system on board the ISS (Sierra Space)

Lunar regolith is abrasive and can irritate lungs. You MUST wear a mask and goggles.

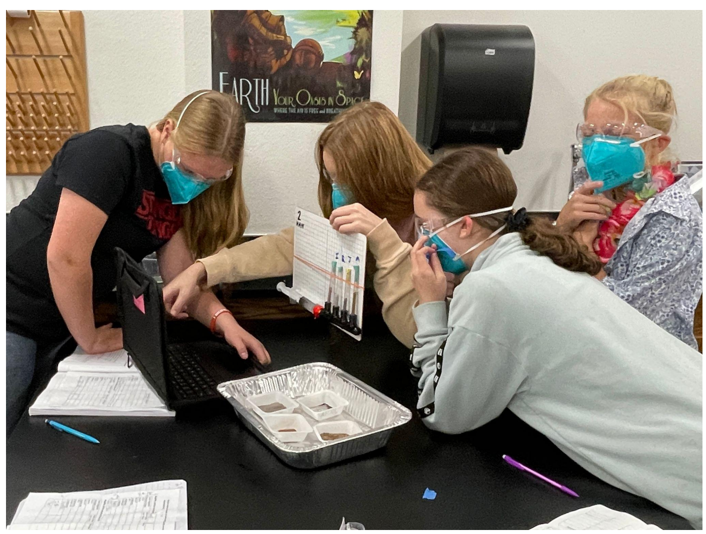
Procedure (classroom)

Build apparatus

1. Four 10 cm capillary tubes secured in multiport T-irrigation reservoir
2. Tape one layer of coffee filter at bottom of tube (painters tape)
3. Fill one tube with 4 cc of lunar regolith (simulant). Tap to settle regolith
4. Repeat in separate tubes with each type of regolith simulant
5. Insert sponge at top of each tube to hold soils intact and allow air diffusion

Testing water movement in regolith:

1. Insert syringe containing 20 ml water into reservoir, velcro to grid board.
2. Attach syringe and capillary apparatus to grid board
3. Set timer 20 seconds
4. Begin filming
5. On “Go” inject water into tube (5 second injection)
6. Continue filming to 20 seconds, say “20 seconds” then turn upside down.
7. Review video, record water uptake (darkened soil) for each soil type



Results

Regolith, without surfactant (fill in all that apply)

Lunar Regolith Simulant (type)	Description of Regolith	Water Uptake(cm) 20 sec.	Observations
JSC1A (mare)			
NU-LHT (highlands)			
OB-1 (highlands)			
Exolith LHS-1 (highlands)			
VEGGIE Substrate (control)			

Regolith, WITH surfactant (Tween-20)

Lunar Regolith Simulant (type)	Description of Regolith	Water Uptake (cm) 20 sec.	Observations
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NU-LHT (highlands)			
OB-1 (highlands)			
Exolith LHS-1 (highlands)			
VEGGIE Substrate (control)			

Assessment

1. Which lunar regolith (if any) had greatest upward transport of water?

2. Why do you believe water moved more easily?

3. What is the purpose of adding a SURFACTANT (wetting agent) in water?

4. Did adding the surfactant affect water movement in lunar regolith?

5. Explain the force of capillary action in water movement:

6. Do you think the rate of water movement in lunar regolith will change in lunar gravity? Explain using Newton's second law of motion.

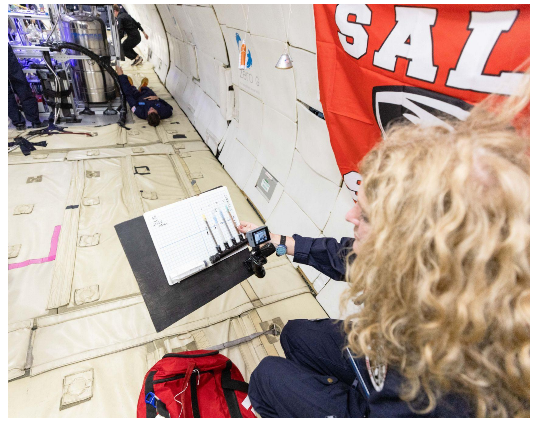
7. Do you think the rate of water movement in lunar regolith will change in microgravity? Explain using Newton's second law of motion.

8. Why is understanding how water moves in lunar regolith important?

9. What other experiments would you like to see using lunar regoliths, and why?

10. Using a hand lens or stereoscope, illustrate and label Mars regolith. Predict and explain how well water will move through the regolith.

Procedure (In-Flight: Lunar-g, Microgravity)



- Use same apparatus and technique as classroom experiment
- Apparatus pre-filled, placed in secondary containment (2 Gallon Ziplock) and taken on board Zero-G parabolic plane.
- In class, watch video of results in lunar and microgravity environments and record data and observations.

Regolith, without surfactant (fill in all that apply)

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Regolith, WITH surfactant (Tween-20)

Lunar Regolith Simulant (type)	Description of Regolith	Water Uptake (cm) 20 sec.	Observations
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Exolith LHS-1 (highlands)			
VEGGIE Substrate (control)			

Post-Flight Assessment

1. Discuss (in complete sentences) how water uptake in regolith is different in Earth gravity (1-g), lunar gravity, and weightless environments. Explain using Newton's Laws as a guide.

2. Explain differences in water uptake between regoliths. Which allowed for the greatest water movement? Least water movement?

3. Explain differences in water movement through regolith when a surfactant is added to water.

4. Why is this information important to space science and earth science?

5. Brainstorm other ways to increase water movement in lunar regolith

How would you improve the experiment/design for sub-orbital flight aboard a rocket?

*It must be fully automated! Include labeled drawings

Additional Resources

- Video: Regolith simulants
  https://twitter.com/seeker/status/1597266568575995904?s=51&t=9Q7kSjT8fhHY2Ys4mRNfjw

- Surface Tension Paperclip and Boat activity (Teach Engineering)
  https://www.teachengineering.org/activities/view/cub_earth_lesson2_activity4

- Capillary Action in Plants
  https://docs.google.com/document/d/1LPy4lr_AUhKetAnQL9fvAovjwvZwjsbwncCw1JOKW6c/edit

- Break the Tension (Teach Engineering)

  https://docs.google.com/document/d/1-tPWeiAyI3pZuOXiOk5y-uIGRTyjer6VzdWAJCUZpKU/edit?usp=sharing