American Association of Petroleum Geologists Foundation

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Designing Rain Gardens for Stormwater Solutions

Investigating Soil Texture and Infiltration

Objective: Students will explore soil texture and infiltration rates through hands-on testing to determine how different soil types affect water movement. These skills will help them analyze outdoor soils to assess if a location is suitable for a rain garden.

STANDARDS

NGSS: MS-ESS2-2, MS-ESS2-4, HS-ESS2-5, HS-ESS3-4
SDG 6: Clean water and sanitation
SDG 11: Sustainable cities and communities
SDG 13: Climate action

Learn more about the United Nation's Sustainable Development Goals (SDGs) and explore resources for educators from UNESCO.

MATERIALS

- two different soil samples, one mostly sandy and one mostly silt and clay, in labeled containers
  - soil samples can be created by combining specific proportions of sand, silt, and clay (such as is described here)
- sand
- water
- 2 clear containers with straight sides and lids, such as Mason Jars
- paper towels
- rulers
- clear plastic cups
- large mixing trays or plates
- block of wood, optional
- sledge or hammer – something to push the ring into the soil
- plastic wrap
- timer (phone)
- soil texturing flow chart and triangle
- 6-inch ring*, such as the Soil Infiltration Ring (Steel) from Conservation Demonstrations

* Another size ring will work, but you will need to calculate the amount of water that will correlate with 1" by measuring the diameter of your ring in inches, then halving that to get the ring's radius (r), which will be plugged into the following formula:

$$\text{Volume in inches} = 2\pi r^2 \times 1 \times 16.387\text{ml/in}^3$$

Table 1. Volume of water required based on ring size.

Ring diameter (in.)	Lesson Title
4	206 ml (7 oz.)
5	322 ml (11 oz.)
6	463 ml (16 oz.)
7	631 ml (21 oz.)
8	824 ml (28 oz.)
9	1043 ml (35 oz.)

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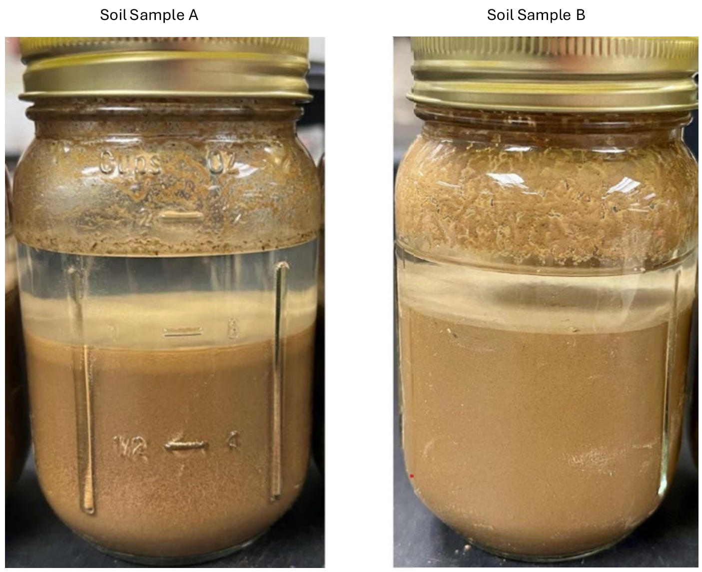
PREPARE

For the settling jar demonstration, label the lids of two clear jars with “sample 1” and “sample 2.” Fill each with about a cup of the respective soil sample. Add water until each jar is three-quarters full. Then add a few drops of dish soap and shake the jars. Allow the mixtures to settle for at least 24 hours.



Soil jars after they were shaken and have settled for 24+ hours. The sediment will be sorted by particle size at the bottom of the jar, with organics and very fine sediment (clay) floating on top.

Credit: L. Brase, AGI

Hands-on Investigation

Engage

1. Soil Texture Observation: Provide participants with two distinct soil samples. Lead a guided discussion:
   - How are these soils similar and different?
   - How do these soils feel (gritty, smooth, sticky)?
   - How might these soils behave differently when exposed to water?

2. Infiltration Demonstration:
   a. Place equal volumes of the two soil samples in identical containers with small drainage holes in the bottom. Set both containers on a tray.
   b. Pour a set amount of water (determined by container size) into each and time how long it takes for the water to infiltrate.
   c. Compare and discuss differences in infiltration rates.

Explore

Have students conduct hands-on soil texture assessments using the following methods, and then use the **USDA Soil Texturing Field Flow Chart**.

1. Initial Feel Test: For each soil sample, take a dry sample and rub it between fingers. Observe texture.
   - Gritty (sand-dominant)
   - Silky (silt-dominant)
   - Sticky and moldable (clay-dominant)

2. Moisture test:
   a. Add a small amount of water to the soil and knead until it holds together. Note the relative amounts of water required for each soil to hold together.

   b. Observe how the soil changes as water is added.

3. Ribbon test:
   a. Roll the moist soil into a ball and press it between the thumb and forefinger to form a ribbon.

   b. Measure the length of the ribbon before it breaks.

   c. Use the **Soil Texturing Flow Chart** to determine clay content.

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Explain

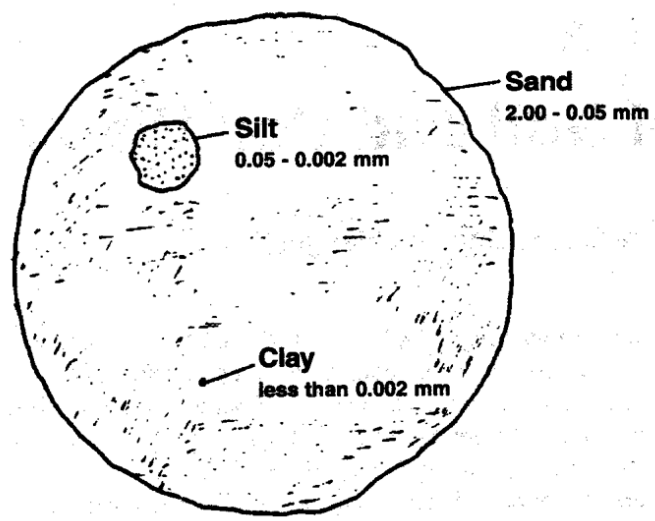
1. Elicit student ideas as to why the soils have different feels and ribbon lengths.

2. Introduce the concept that soil's interaction with water is influenced by multiple factors, including soil texture, which is determined by the relative proportions of sand, silt, and clay particles.

3. Explain that soil is made up of three primary particle sizes, each influencing soil properties in different ways:
   a. Sand – Largest particles (0.05–2.0 mm in diameter)
      - Feels gritty due to large, coarse particles.
      - Drains quickly because large spaces exist between grains.
      - Poor at retaining nutrients since water washes them away.

   b. Silt – Medium-sized particles (0.002–0.05 mm in diameter)
      - Feels soft and silky, like flour.
      - Holds more water than sand but still drains relatively well.
      - Provides better nutrient retention than sand.

   c. Clay – Smallest particles (less than 0.002 mm in diameter)
      - Feels sticky and smooth when wet, and hard when dry.
      - Drains very slowly due to tiny spaces between particles.
      - Holds onto nutrients effectively but can become compacted.



Relative size of sand, silt, and clay particles.

Credit: © University of Nebraska, originally published in 1999, accessed via https://passel2.unl.edu/view/lesson/0cff7943f577/2.

4. Use an image or diagram to compare the relative sizes of sand, silt, and clay, and discuss real-world examples, such as:
   - ► Sandy soils are common in deserts and along coastlines, where water quickly drains.
   - ► Silt-rich soils are often found in river valleys and floodplains, making them fertile for farming.
   - ► Clay soils are prevalent in wetland areas and tend to retain water for long periods.

5. Settling jar analysis:
   a. Guide students through analyzing their soil settling jars (prepared in Engage). Ask them to observe how the soil layers have settled (overnight, if possible). Explain:
      - Sand settles first (within minutes) because it is the heaviest and has the largest particles. This forms the bottom layer.
      - Silt settles second (within an hour), forming the middle layer.
      - Clay remains suspended the longest (up to 24 hours or more), eventually forming the top layer. However, some very fine clay particles may stay suspended indefinitely.
      - Organic material floats at the top, if present.

   b. Measure and classify the soil texture:
      i. Use a ruler to measure the thickness of each layer.
      ii. Calculate the percentage of each particle type by dividing each layer's height by the total height of the soil.
      iii. Use the Soil Texture Triangle to determine the soil texture of the sample based on the sand, silt, and clay percentages.

6. Infiltration and rain gardens:
   a. Elicit student ideas for why soil texture matters and what it might impact:
      - Why is infiltration important for preventing flooding and runoff?
      - What might happen if a rain garden is placed in an area with heavy clay soil?

   b. Guide students in a discussion that mimics components of CERR to connect their findings thus far to infiltration and rain garden suitability. Ask students to make a **claim** as to how soil texture affects infiltration. Have students provide specific **evidence** to back up their claim and provide their **reasoning**. Also, prompt students to come up with a potential **rebuttal** to their claim.

   c. Demonstrate the infiltration procedure using sand in the lab:
      i. Push a 6-inch diameter ring halfway into a container of sand.
      ii. Line the soil inside the ring with plastic wrap and pour 463 mL (1 inch) of water on top. (If your ring is a different size, calculate the amount of water that 1 inch would correlate to as described in the materials section.)
      iii. With a timer at the ready, carefully remove the plastic wrap to avoid disturbing the soil and start the timer.
      iv. Stop the timer when the water is gone and the surface of the soil just glistens. 5. Repeat steps 2-4. 6. Calculate infiltration rate using the equation below and the second time collected in step 5.

   d. Optionally, and if you have enough soil samples, have students carry out infiltration tests on the two samples.

   e. Discuss how real-world rain garden locations depend on infiltration tests. If soil drains too slowly, modifications such as amending the soil with compost or sand may be necessary.

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Elaborate

1. Using Web Soil Survey (WSS):
   a. Introduce WSS as a tool used by landowners to assess soil properties. WSS provides soil data based on a combination of remote sensing, field sampling, laboratory analysis, and historical records. While some locations have been directly analyzed in the field, much of the data is derived from broader soil mapping efforts and modeling, meaning site-specific conditions may vary. Soil interpretations in WSS are projections based on regional trends and known soil properties.

   b. Have students go through the **Digital Soil Analysis with Web Soil Survey** handout to assess the soil within your area of interest for a rain garden installation.

2. Discussion Questions:
   - How does the WSS data compare with hands-on observations?
   - What local soil types are best or worst for a rain garden?
   - Based on the data, would this site be a good location for a rain garden? Why or why not?

Evaluate

1. Conduct field tests at potential rain garden sites.
   a. Soil Texture Test: Collect a soil sample (at least 6 inches deep) and determine the soil texture.

   b. An infiltration test can be conducted if it hasn't rained in the last 24 hours. At the site, clear plant residue or trim vegetation to expose the soil surface. Use a wooden block and mallet to drive a 6-inch diameter metal ring into the soil about 2 inches deep. Follow the procedure described above to determine the infiltration rate. See the full procedure, **Measuring Infiltration Rate in the Field**.

2. Student reflection questions for each potential site:
   a. How did the field test results compare with classroom texture tests and Web Soil Survey (WSS) data? What similarities or differences did you notice?

   b. Based on your observations, is this site suitable for a rain garden? Why or why not?

   c. If the site is not ideal, what soil modifications (e.g., adding organic matter, aerating, amending with sand) could improve infiltration and rain garden performance?

3. Class Discussion:
   a. Which soil textures (or particle types) are best suited for a rain garden, and why?

   b. If a site has poor drainage, what modifications could be made to improve water infiltration?

   c. How does soil texture influence stormwater runoff and flooding in both urban and natural landscapes?

   d. In designing a community-wide stormwater management plan, how could soil data and infiltration rates help determine the best locations for rain gardens or other green infrastructure?

   e. How might climate, land use, and soil properties interact to affect water movement in different environments?

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