Soils as Sponges: How Much Water Does Soil Hold?

Purpose

To introduce students to gravimetric measurements of water content through calculating the amount of water in sponge and soil samples by weighing the samples before and after drying

Overview

Students determine the moisture content of a sponge after squeezing the water out of the sponge, and allowing water to evaporate from the sponge. Students also measure the amount of water that has evaporated from the soil samples.

Student Outcomes

Students will understand that objects can hold a measurable amount of water.

Students will be able to transfer this concept to soil by weighing wet and dry soil samples and calculating the amount of water held by the soil.

Science Concepts

Earth and Space Science

Earth materials are solid rocks, soil, water, biota, and the gases of the atmosphere.
Soils have properties of color, texture, structure, consistence, density, pH, fertility; they support the growth of many types of plants.
The surface of Earth changes.

Soils are often found in layers, with each having a different chemical composition and texture.
Soils consist of minerals (less than 2 mm), organic material, air and water.
Water circulates through soil changing the properties of both the soil and the water.

Scientific Inquiry Abilities

Identify answerable questions.
Design and conduct an investigation.
Use appropriate tools and techniques including mathematics to gather, analyze, and interpret data.
Develop descriptions and explanations, predictions and models using evidence.
Communicate procedures and explanations.

Time

Approximately two class periods for the initial sponge and soil activities; then 10-15 minutes per day for about 3 days, as objects dry

Level

Middle and Secondary

Materials and Tools

Scale or balance
Several sponges with different properties (e.g. size, shape, thickness, pore size and number of pores)
Soil samples
Paper towels, paper plates, newspaper, or other surface to dry soils on
Tray to place wet sponges and soils on
Graph paper (for intermediate or advanced)

Prerequisites

Knowledge of fractions, decimals, and simple algebra

Background

Many objects hold water. For living beings, this water is essential for survival. On Earth, soil has the ability to store significant amounts of water that can then become available to plants and animals that live in and on the soil. Moisture in the soil also affects weather, climate, and land use. Scientists use soil moisture data to predict what will grow in an area, how climate will change, when floods or droughts may occur, and what the best use of the soil is at a given location.

One way to calculate soil moisture is to take a gravimetric measurement of a soil sample. Gravimetric means to find the weight, or the pull of gravity, upon an object. Mass is the amount of matter in an object (or an object's resistance to acceleration). For GLOBE soil protocols, you measure mass rather than weight. Here is a formula to illustrate the relationship between mass and weight:

GSM (Gravimetric Soil Moisture) =

$$\frac{\text{Weight of moisture}}{\text{Weight of dry soil}} = \frac{g \times \text{mass of moisture}}{g \times \text{mass of dry soil}} = \frac{\text{mass of moisture}}{\text{mass of dry soil}}$$

g = gravitational constant which is equal to 9.81 m/second ^{2} at the surface of Earth

Note that the g's cancel each other when gravity is the only force involved. The units associated with mass are kilograms and grams.

When calculating soil water content, we want to find the mass of the water contained in the soil. To get the absolute value of the mass of the soil, we measure the mass of a soil sample, dry it out, and then measure the mass of the dried soil. The difference in the mass between the wet and dry soil is the absolute value of the amount of water originally in the sample. Because soil samples have different properties and are at different initial water contents, we normalize this result to find the relative amount of soil moisture by dividing the absolute value by the mass of the dry sample.

For example, you might dig up a handful of soil and find that it has a mass of 100 grams. After the soil has dried, you weigh it again and find that it only weighs 90 grams. Ten grams of water have evaporated from the soil, but this must be normalized, to remove sample size bias, by the mass of the dry soil (90 - 30 = 60 g assuming a 30 g can mass). We can then calculate the fraction 10/60=0.167, which is a measure of how much water is in the soil (water content). Since we are using a balance, which depends upon gravity, this method of determining soil moisture is called the gravimetric water content.

Soil water content calculations are simple to do, as long as samples are measured accurately. When the air is dry, evaporation can happen quite rapidly. Think about how fast you dry off after getting out of the water on a hot, dry day. Soil samples will dry quickly in the air as well, if they are not placed in a sealed container as soon as they are removed from the ground.

Soil moisture is influenced by many environmental factors, such as temperature, precipitation and soil type, as well as topographic features, such as slope and elevation. Soil moisture is especially important for agriculture. Much of the hard work of farming, such as plowing and adding organic matter, is done to try to improve the soil-moisture related properties of the soil. Terracing (making ridges in a field) is done in some areas to prevent too much runoff, while fields are rounded in other places to keep the soil from staying too wet. Also, different crops require different amounts of water throughout their growing season. Understanding how the soil moisture changes throughout the year can help a farmer decide when and what to plant.

In this activity, students measure the moisture in sponges and soils. They do these experiments in stages of increasing difficulty:

Stage 1 — Squeezing water from sponges

Students weigh a wet sponge, squeeze it, then weigh the dry sponge and the water that was squeezed from the sponge. Doing this, they see that a wet sponge = dry sponge + water. Squeezing is a very visible and immediate way to release water.

Stage 2 — Evaporating water from sponges

Students do the same exercise as above, except that they let the sponge sit for several hours or a day to let the water evaporate. Students can compare the mass of the dry sponge measured after squeezing and after evaporating to determine how effective these 2 methods are in removing water from the sponge. Students can experiment by placing the wet sponge near a sunny window, in a cold area, or under different conditions to determine if these locations have an effect on the amount of water that evaporates.

Stage 3 — Measuring soil moisture

Students transfer the concept of evaporative drying to soil by letting moist soil samples dry for a day or two. They measure the mass of the soil before and after drying to determine the soil moisture. They compare several soil samples to get a sense of a typical range of values.

Stage 4 — Using GLOBE visualizations for worldwide soil moisture

Students use visualizations from the GLOBE Web site to study a map showing soil moisture in other parts of the world. They discuss why there are differences, and conduct further investigations.

What To Do and How To Do It

Preliminary Exercise

Be sure that students are familiar with using a scale or balance and have them practice weighing objects.

Stage 1 – Squeezing water from sponges

1. Soak a sponge in water. Weigh it and record the wet mass. Ask your students how much they think it will weigh when it is dry. Record the estimates.
2. Squeeze the sponge and weigh it. Record the dry mass. Discuss with students how their estimates compared with the actual value.
3. Ask your students how much water was in the sponge and how they might determine this. This amount of water = wet sponge mass minus dry sponge mass. For example, 120 grams of water = 200 grams wet mass minus 80 grams dry mass.
4. Repeat the measurements with a sponge that has different characteristics (e.g. different thickness, size of pores, larger size, etc.). Have your students estimate which sponge will hold the most water and discuss why.

In discussion with your students, make sure that they understand the concept of water-holding capacity, and that capacity can differ from one type of sponge to another.

5. The measurement of water content using this equation (wet sponge mass-dry sponge mass) is an absolute measure of the water content. To find the relative measure of water content in order to compare water contents in sponges of different types, divide the absolute value by the dry sponge mass using the equation:

$$\text{relative water content} = \frac{(\text{wet sponge mass - dry sponge mass})}{\text{dry sponge mass}}$$

6. To extend this activity, weigh an empty cup, collect the water that was squeezed from each sponge in the cup, and weigh the water and cup together. Determine the mass of the water by subtracting the mass of the water from the mass of the cup and water weighed together. Compare the actual mass of the water with the calculated mass obtained by the equation above.

Stage 2 – Evaporating water from sponges

1. Ask your students what will happen if you leave the wet sponge on a tray overnight instead of squeezing it. Discuss the concept of evaporation and the conditions under which it is most effective.
2. Have your students weigh the wet sponge, record the mass, and leave the sponge on a tray at a specific location in the room. To extend this activity, use different types of sponges in the same location, or use the same type of sponge in different locations (e.g. in a sunny window, in a dark corner, near a heater, etc.). Leave the sponges exposed until the next day.
3. After the sponges have been left out for a day, have your students weigh the sponges to determine if any water was evaporated.
4. Calculate the relative amount of water that evaporated from the sponges using the equation:

$$\text{relative water evaporated} = \frac{(\text{wet sponge mass - current sponge mass})}{\text{current sponge mass}}$$

Compare the results for each of the sponges and for each of the locations. Were these values different from the amount of water that was squeezed from the same sponges? Which was a more effective way of removing water? The evaporation experiment can be continued for another day with the same sponges to determine if additional water will be removed.

5. The difference in the amount of water contained in a completely wet sponge and in a completely dry sponge is the sponge's water holding capacity. Ask your students how sponges of different types vary in their water holding capacity and why a high water-holding capacity is important for a sponge or similar object.

Homework

Explain to your students that they will soon be measuring how much water soil can hold. Ask them to bring in a soil sample from home in a small plastic sandwich bag, and to seal the bag to retain the soil's moisture. (If soil is not readily available, bring in potting or other soil from a garden store.)

Stage 3 — Measuring the moisture of soil

1. After performing the sponge experiments, ask the students how they might determine the moisture of their soil samples. In their answers, the central concept to look for is that soil moisture can be measured in a

similar way by determining the mass of the wet soil, drying the soil, and determining the dry mass in the same way they did with the sponges.

2. Have each student or group of students open their sealed sample bag and weigh the wet soil sample. Be sure to account for the mass of the bag, or a container, piece of paper or other holder weighed with the soil by subtracting its mass from the total mass (of soil plus holder). After the mass of the wet soil is recorded, have the students spread their soil samples on a paper plate, newspaper, or other surface, and set it in a safe place to dry. Place the soil samples in a location where they will dry quickly or experiment with locations and conditions.
3. When the soil samples are dry (based on feeling the soil for dryness), have the students weigh each soil sample again and determine how much water was evaporated using the formula:
4. This is the formula used in the soil moisture protocol. For example, if the wet soil mass is 100 grams and the dry soil mass is 90 grams, then the absolute soil water content will be 10 grams. To obtain the relative water content in order to compare different samples, divide the wet soil mass minus dry soil mass by dry soil mass (as in the previous step and in Background). Have your students calculate the relative water content of their soil samples and compare the values. Correct any errors in their calculations. Discuss the range of values and why they think there is such variety. Have them examine the properties of the different soils (e.g. color, texture) to help them think about why there is such a range. How did the amount of water held by the soil compare to the amount held by sponges?

Intermediate and Advanced Students

In the previous activities, older students can weigh the soil every hour, and then graph the rate at which evaporation takes place and identify whether the resulting plot is constant (a straight line) or not. Students may also consider how other factors including weather (humidity, wind,

$$\text{relative water content} = \frac{(\text{mass of wet soil - mass of dry soil})}{\text{mass of dry soil}}$$

This is the soil moisture content.

rain, cloudiness, shadiness, sun intensity, etc.), vegetation, or land use may affect evaporation.

Brainstorm with your students about ways that soils can be dried and how they could speed up or slow down the process. Some ideas are: put the objects in direct sunlight; blow a fan over them; put them on a heater; put them in a microwave or oven; pour salt on them; cover them with a plastic container; point a light on them. The experiment can be repeated based on this discussion and results compared.

Stage 4 — Using GLOBE Visualizations for Worldwide Soil Moisture

Intermediate and Advanced Students

This activity is appropriate for intermediate and advanced students who have map-reading skills and a basic understanding of soil moisture concepts.

1. Use the GLOBE Web site to access and display a map showing soil water content around the world based on the most recent student measurements.
2. You can display the soil water content data either as values or as contours (with different colored bands corresponding to certain ranges of soil moisture values).
3. Have students compare their own soil water content measurements with the soil water content readings from other schools around the world.
4. There are many domains of investigation for your students. Here are some examples:
    - what is the range of soil water content values around the world?
    - where is it the lowest? the highest?
    - does this vary over time? (examine soil water content maps from other months)
    - what affects the soil water content at the different sites?
    - how do the soil properties at a site affect the soil moisture (e.g. sandy soils, clayey or silty soils, soils on steep areas and different landscape positions, etc.)?
    - how are soil water content values affected by recent weather conditions?
    - how do soil moisture contents from a desert, a rain forest and a farming area compare?
    - what areas have about the same level of soil water content as your site?
5. Encourage your students to pursue further investigations using the GLOBE soil moisture visualizations.

Student Assessment

Bring a set of soil samples to school. Have your students estimate, and then calculate, the soil water content on their own. Check for reasonableness in their estimates, and watch the process to make sure they do it correctly.