



Description: Students test the porosity and permeability of sand, gravel, and clay.

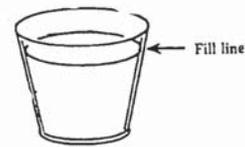
Objectives: Students will understand that:

All grades:

- water is stored underground in the spaces (pores) between grains of sediment; and
- the size of the grains of sediment affects how much water can be stored in the pore spaces.

Grades 5–8:

- the size of the grains of sediment affects how easily water can flow through sediment (permeability);
- sediment and sedimentary rocks that store water constitute an aquifer; and
- porosity and permeability are two characteristics that determine how much water is available in an aquifer.



Materials: Materials are per group of three or four students.

one small graduated cylinder

one dropper

five clear plastic cups—choose clear cups so that students can see the water filling pore spaces

gravel—should be as large as possible and preferably clean

sand—use playground-grade sand only; sand sold and used for mixing with cement (labeled silica sand) has too many fine particles that can harm the respiratory system

28. Porosity and Permeability



Grades: 5–12

Time: material preparation: 15–20 minutes
class time: 30–90 minutes, depending on how many sediment types are tested

Subject: science

Terms: pore space, porosity, permeability, aquifer, sediment



clay or very fine soil
sand/gravel mixture
nail
clock or watch with a second hand
four beakers (preferably plastic)
four large containers for holding sediment
four large containers for holding recycled sediment
water

Background: Water is vital to life. More than half of the world's human population uses ground water for survival; but until recently there has been little thought about the problems of depletion or contamination of ground water. More than 20% of the Earth's freshwater resources are in ground water reservoirs; and it is a vital resource, especially in arid areas.

Ground water is present in permeable rocks beneath many land areas; and is a replenishable resource. The problem in arid and semi-arid regions is that the rate of replenishment may be slow or periodic; and the resource can be depleted if ground water withdrawals exceed the local rates of replenishment. This is called ground water "mining." Ground water can actually be dated by the use of radioisotopes. Current work in the Rio Grande Valley indicates that in some areas the ground water we are mining is several thousand years old.

Ground water is created by precipitation. When rain falls, some is absorbed, some runs off into streams and rivers, some evaporates, and the remainder recharges the aquifer. Surface water and ground water are closely related. The water table often represents a reflection of the surface topography, and ground water provides much of the flow in streams and rivers during periods of low rainfall.

When the term ground water is used, many people visualize an underground cavern filled with water. But most ground water occurs in the interconnected pores between rock or sand particles or in fractures in rock. Gravity makes the water connect and flow toward an area where it can be discharged to the surface. Ground water occurs in the ground from the surface to almost 2,000 feet below the land surface and is divided into two zones. The zone where all of the voids in the sand and rock are filled with water is called the saturated zone and the water table marks the top of this zone. Above the water table is the unsaturated zone, where voids in the sand and rock are filled with either air or water.

Layers of rock, sand or gravel that are good ground water reservoirs are called aquifers, from the Latin words for "water" and "to bring." The best aquifers are loose sand and gravel. Sandstone is a



good aquifer, while clay, shale and slate are not good aquifers at all. You might be surprised to discover that lava flows can also be good aquifers. The properties that make a good aquifer are those that increase the storage of water (porosity) and increase the flow of water (permeability) within that layer. **Porosity** is the proportion of empty space in a rock. **Permeability** is a measure of the ease with which liquids and gases can pass through a rock. All rocks have pore spaces and fractures; the greater the percentage of pores or fractures and openings in the total volume of the rock, the greater the porosity. In unfractured granite, the porosity may be less than 1%; in loosely consolidated sand and gravel (such as the fill of the Rio Grande Rift), the porosity may be as great as 30%. But it is not enough to have pore spaces; the pores must also be connected so that the ground water can flow. Clay, shale and slate frequently have pores that are not connected and therefore it is difficult for water to enter or leave these rocks. Lava flows frequently have bedding planes and fractures that allow water to flow; springs or seeps are frequently found at the margins of layered lava flows. Fractured granite and metamorphic rock aquifers are the principal sources of water for mountain communities. Because the fractures in these rocks are irregular, the groundwater movement and concentration are also irregular, making exploration for water difficult in these areas.

A type of geologist called a hydrologist studies water resources.

Procedure:

Preparation:

1. Pour sediment into large containers and label accordingly ("sand," "gravel," "sand/gravel," "clay"). Sediment should be dry and free of clumps.
2. Label four more large containers for students to dump used sediment.
3. Using a beaker, determine how much sediment a plastic cup will hold. Write this number on the board. Students must be sure to use the same volume of sediment for each test.
4. Place a beaker in each large container of sediment.
5. Assemble the rest of the lab equipment and divide equipment for each group.

Doing the Activity:

1. Lead a short introductory discussion using the following questions. You may want to write down all student answers on the board. Students can then look back at their answers after the activity to assess how much they learned.

In New Mexico, where do we get most of our drinking water?



(Students may answer “the river.” You should explain that most communities get all or most of their drinking water from underground, although this will change for Albuquerque in 2009.)

From where do the trees and plants get their water? In the bosque, from where do the cottonwoods get their water? How can there be water underground? Where does it come from? How does the water get underground? Have you ever poured water on the soil? Where does it go? How do we (and plants) get the water out of the ground?

2. Develop the questions this lab will examine. Preferably, lead students to develop these questions instead of just giving them the questions. Students may write the questions on their data sheets or in lab notebooks.

Where is water stored underground?

Which types of sediment can hold the most water?

From which types of sediment is it easiest for people and plants to get water?

3. Have students hypothesize answers to the above questions. You may either write group answers on the board or have students write their own hypothesis on their data sheets or lab notebooks.
4. Demonstrate for students how to gather and test each type of sediment. Students will write data on their data sheets or in their lab books.
 - a. Use a beaker to fill a plastic cup to the proper volume with gravel.
 - b. Fill the graduated cylinder to the top. Record in the table how many ml of water are in the graduated cylinder.
 - c. Pour the water SLOWLY into the cup of gravel. Allow the water to soak in all the way. Use the dropper to remove any excess water on top of the gravel. Be sure to put any water removed from the cup back into the graduated cylinder.
 - d. Record how many ml of water are now in the graduated cylinder, then discard.
 - e. Complete the table to determine how many ml of water you poured into the cup.
 - f. Hold the cup of gravel over the extra cup.
 - g. Have someone ready to watch the clock.
 - h. VERY CAREFULLY, poke a hole at the bottom of the cup with the nail. (Note to teacher: sometimes the gravel you use may have lots of finer sediment mixed in. If you have not washed the gravel, your students will get better results

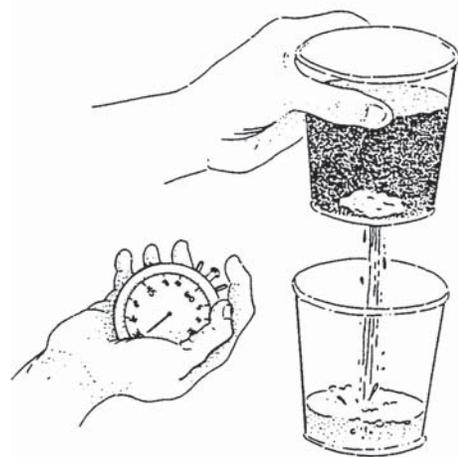


if they poke the hole on the side of the cup, about 3 cm from the bottom).

- i. Time for 30 seconds as the water drips from the first cup into the second cup.
- j. Pour the water into the graduated cylinder.
- k. Record in the table how much water is in the graduated cylinder.
- l. Empty the sediment in the cup into the appropriate container. Do not mix wet (used) sediment with the dry (unused) sediment.
- m. Repeat the above steps for the sand, clay, and the sand/gravel mixture. Use small cylinder for clay portion.

Note: The clay trial will take a long time.

5. Compile all class data. Make two charts on the board: one for porosity and the other for permeability. Have each group record their data for sand, gravel, sand/gravel mixture and clay. Calculate the means of each. Graph the means. This will give more accurate results and will illustrate experimental design and replication.
6. Use the following questions to lead a discussion about the data. Alternatively, you may wish to assign these questions for students to answer in written form.



Grades 3–5

- a. What is porosity?
- b. Which material above held the most water?
- c. Why does the mixture of gravel and sand hold less water than either the sand or gravel?
The sand is taking up the spaces between the gravel.
- d. What is permeability?
- e. Which cup of material would dry out faster? Why?

Grades 6–8: add the following questions

- f. What happens to the porosity when the particle size gets smaller?
You should see that porosity increases with smaller particle size. However, with the small volumes tested, the sand and gravel may show similar porosity values.
- g. Which material was most permeable? Why?
- h. What happens to permeability as particle size gets smaller?



You should see that permeability decreases with smaller particle size.

7. Re-examine the three questions from the beginning of the lab and the hypotheses. Did the data support the hypotheses? Have students develop a conclusion to these questions, based on their data. You may either write a group conclusion on the board or have students write their conclusions on their data sheets or in their lab notebooks.
8. Write the following question on the board. Have students develop an answer either as a group or as individuals.

What type of sediment would make the best aquifer? Why? (Think about which holds the most water AND which material is easiest to get the water out of).

Extensions: Have students bring in a sample of soil from their own home. Measure the porosity and permeability of these samples. Bring in two “mystery” samples to compare with the lab results. Are any results of the “mystery” samples similar to the lab results?

Related

Activities: This activity was adapted from similar activities in the following publications:

Gartrell, J. E, Jane Crowder, and Jeffrey Callister. *Earth: The Water Planet*. Arlington, VA: National Science Teachers Association, 1992.

Lind, K. K, (ed). *Water, Stones, & Fossil Bones*. Arlington, VA: National Science Teachers Association, 1991.

Proyecto Futuro, “Earth and Space Science Supplemental Curriculum.” New Mexico Museum of Natural History & Science, 1997.

- Assessment:**
1. Have students draw a picture showing where water is stored underground.
 2. Have students explain from where trees and plants get their water.

Thanks to Kristin Gunckel for this activity.

Drawings from the Earth & Space Science Supplemental Curriculum produced by the New Mexico Museum of Natural History & Science.

Porosity and Permeability

1. Use a beaker to fill a plastic cup to the proper volume with gravel.
 2. Fill the graduated cylinder to the top. Record in the table how many ml of water are in the graduated cylinder.
 3. Pour the water SLOWLY into the cup of gravel until the water reaches the top of the gravel. Allow the water to soak in all the way. Use the dropper to remove any excess water on top of the gravel. Be sure to put any water removed from the cup back into the graduated cylinder.
 4. Record in the data table how many ml of water are now in the graduated cylinder.
 5. Complete the table to determine how many ml of water you poured into the cup. Pour the water from the graduated cylinder into the sink.
 6. Hold the cup of gravel over an extra cup.
 7. Have someone ready to watch the clock.
 8. VERY CAREFULLY, poke a hole at the bottom of the cup with the nail.
 9. Time for 30 seconds as the water drips from the first cup into the second cup.
 10. Pour the water from the second cup into the graduated cylinder.
 11. Record how much water is in the graduated cylinder in the data table.
 12. Empty the sediment in the cup into the appropriate container. Do not mix wet (used) sediment with the dry (unused) sediment.
 13. Repeat the above steps for the sand, the sand/gravel mixture and the clay.
- Note: The clay trial will take a long time.

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Data Table					
	A. beginning ml of water	B. end ml of water	C. ml water used = A - B: porosity	D. ml in cylinder at end	E. ml water dripped out in 30 sec: permeability
gravel					
sand					
sand/gravel					
clay					