POROSITY AND PERMEABILITY

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Purpose

This exercise is done in order to demonstrate how any fluid flows through the underground. If you understand porosity and permeability, you can visualize how oil can accumulate in the subsurface, why a water well provides water, and why environmental pollution can affect the quality of our drinking water. In this exercise we will deal with groundwater.

Definitions

Aquifer – soil or rock from which one can pump water.
Groundwater - water in soil or rocks.
Permeability - the ability for a fluid to flow through a rock.
Porosity - the pore space, or holes, in a rock.

Teacher Information

Groundwater originates as surface water, melting snow, or rain water that infiltrates down into the ground. Groundwater accumulates in either sediments or bedrock, and flows slowly through the subsurface. An aquifer is a layer of rock or sediment that yields sufficient water for human use. The amount of groundwater present in an aquifer and the rate of groundwater flow are determined by several factors. The porosity of a given aquifer is the amount of empty or void space within the rocks or sediments. This void space can be fractures, joints, solution cavities, or the space between mineral grains. The degree to which these voids are connected is referred to as permeability, which determines how easily the groundwater can pass through the voids. Groundwater moves very slowly, with a maximum velocity of approximately one meter per day in the most permeable aquifers, and a minimum velocity of one meter per thousand years in less permeable units. This exercise uses soil and rock materials so is more realistic than the usual marbles-in-a-tube exercise. Yet, even these flow much too quickly.

Student Exercise

You will need clear cylinders, and three materials with different porosities to do this exercise. We suggest that the cylinders be 1,000 ml. graduated cylinders, but clear tubes would work as well. They should be of a similar capacity. For the sediments we buy a bag of marble chips at a garden center and dig up a bucket of sandy soil. Any rock chips and some mason's sand would do as well. Fill each of the cylinders halfway with one of the materials. Take about 500 ml. of water. Get ready with the stopwatch. Pour the water into each of the cylinders and time how long it takes for the water to get to the bottom. Record the results. This exercise can be done with one cylinder by emptying the cylinder into a waste bucket and repeating the process with each of the other materials.

Material

Sand and rock chips: 1 bucket of sand
1 bucket of sand and gravel
1 bucket of gravel

Several waste material buckets

For each work group: 3 1,000 ml graduated cylinders or clear tubes
1 500 ml graduated cylinder
1 Stopwatch

The sediments that we use are dug up locally. We have a nearby sand pit, but mason's sand would do as well. We buy the rock chips in a local garden store. You could also use river washed pebbles.

For an interesting experiment you might want to use clay, also. This can be dug up from a local source or bought at a craft or pottery supply store. Be aware that the permeability is very low and the water flow will be slow or not at all.

WORKSHEET

Measuring Permeability

1. Fill one graduated cylinder to the 500 ml mark with gravel, one with sand, and one with a gravel and sand mixture.

2. As one lab partner begins pouring water into a cylinder, another starts the stopwatch. When water reaches the bottom of the cylinder stop the watch and note the time.

3. Measure the height in centimeters of the cylinder from the bottom to the 500 ml mark. Use these figures to determine the flow rate in centimeters per second (cm/sec).

4. Repeat for the other two cylinders and record your data in the chart below.

Measuring Porosity

1. Empty the wet sediments from your graduated cylinders into the waste buckets and refill them with dry sediments as before (500 ml of sediment, one with sand, one with gravel and sand, and one with gravel).

2. Fill a 500 ml graduated cylinder with 500 ml of water. Slowly pour the water into the gravel-filled container, allowing time for water to seep through the sediments, until the water reaches the 500 ml mark of the sediment cylinder.

3. Determine how much water has been added to the sediment in order to fill up all of the pore spaces. (500 ml - remaining water = volume of pore space)

4. Calculate the porosity as a percentage of the total volume
(pore space / total volume) (x 100) = % porosity.

5. Repeat for the other two sediments and enter your data in the chart below.

	Flow Velocity			Porosity		
Sediment Size	Cylinder Height (cm)	Elapsed Time (sec)	Flow Velocity (cm/sec)	Remaining Water Volume (ml)	Volume of Pore Space (ml)	Porosity (%)

Questions

1. What effect does grain size have on groundwater flow velocity and sediment permeability?

2. Which of these sediments would make the best water source for a water well?

3. Imagine that a tanker truck carrying pesticide rolled over and spilled its contents on each of these three types of sediments. Describe how the three aquifers would be affected differently by the spill.