

Measuring Permeability

Summary

Subject(s)

ESS: Earth's Systems & Processes

Grade/Level

Grades 6-8

Activity Type

Constructing explanations & Designing solutions

MN Science Standard

6E.3.1.1.3

SEP / CCC

SEP: Developing and Using Models

CCC: Energy & Matter

Est. Lesson Time

45 Minutes

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Implementation

Introduction

Permeability is the degree to which water or other liquids are able to flow through a material. Materials that are more tightly packed (few or small pores) tend to have lower levels of permeability while loosely packed (many or large pores) materials tend to be more permeable. Surface runoff is generated when water is blocked from flowing through a material, and instead must flow across a material. The extent of runoff from precipitation is directly related to the permeability of the materials in the ground and the type of drainage system used. The concern with runoff is two fold. Unfiltered rainfall can potentially carry contaminants with it and free flowing rainfall can lead to flooding issues. If vegetation or other materials are used to interrupt the water's flow, the surface runoff and the amount of pollutants that can travel with the water can be significantly reduced. In urban areas, the quantity of impermeable surfaces can invite flooding since water cannot flow through the hard surfaces like concrete.. Therefore, it is important to create areas such as gardens, patios, wooden decks, or landscaping materials to improve permeability and reduce the likelihood of flooding. Engineers who work on major construction projects design drainage systems to handle the high volume of roof and parking lot runoff. If the use of nonpermeable materials is mistakenly used, the result will be increased stormwater runoff which can result in more flooding and pollution concentration.

Key Terms

- **Permeability:** The degree to which water or another liquid is able to flow through a material.
- **Porosity:** The ratio of the volume of gaps of a material to the volume of its mass. Simply, it is the amount of "holes" in a material.
- **Runoff:** The portion of precipitation on land that ultimately reaches streams, often carrying dissolved or suspended material.
- **Sediment:** Solid material moved and/or deposited by human travel, water, wind or glaciers.
- **Pollutants:** A substance that is abundant enough it becomes harmful to life and interferes with natural processes.

Objective

Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.

Essential Questions

- What is permeability? What is porosity?
- How are porosity and permeability related?
- Why does a liquid permeate through one substance more quickly and thoroughly than another?
- What effect does having more permeable materials/surfaces have on the health of a watershed?
- What effect does having more impermeable materials/surfaces have on the health of a watershed?

- How do impermeable surfaces cause runoff and can runoff be prevented?
- What types of material might an engineer use to reduce impermeable surfaces on a construction project?

Materials & Resources

Each group needs:

- 100 mL graduated cylinder
- Stopwatch or clock with a second hand
- 4 - 7 cm in diameter PVC pipes, cut to 10 cm lengths, open on both ends
- Dry Gravel - between 100 - 150 ml, 3 to 4 oz
- Dry fine sand - between 100 - 150 ml, 3 to 4 oz
- Dry soil - between 100 -150 ml, 3 to 4 oz
- Marbles - between 100-150 ml, 3 to 4 oz (~40 to 50 marbles)
- 4 pieces of cheesecloth, cut into squares 14 cm x 14 cm
- 4 large rubber bands (big enough to go around the PVC pipe)
- Medium size mixing bowl or small bucket to catch water - 1 L or greater
- **Optional:** Clay

Pre-Experiment

Show students a permeability demonstration. Prepare the PVC pipes ahead of time and pre-cut the cheesecloth. Prepare a holder for the pipe and attach it to the edge of a table with cheesecloth on the bottom, but no material in the pipe. On the floor under the pipe, place a bucket or tray to catch the water runoff. For the demonstration, pour the water through and have the students observe how the water flows. Discuss the connection to permeability. Is cheesecloth a good example of permeability?

Procedure

Before the Activity

- A. Gather materials: graduated cylinder, PVC pipes, gravel, sand, soil, marbles, cheesecloth, rubberbands, bowl and bucket.
- B. Cut the PVC pipe to the desired lengths.
- C. Cut out the cheesecloth pieces to the desired sizes.
- D. Organize the materials needed for each student group to pick up.

With the Students

- E. Divide the class into groups of four students each.
- F. Using the laid out materials, challenge the groups to design an experiment to determine the relative permeability of each substance (gravel, sand, soil and marbles). Following is an example of an experiment that students might design.

Example Experiment

- G. Use rubber bands to attach cheesecloth to one end of each of the pipes.
- H. Make sure the open end of the pipe (without cheesecloth) is facing up and the cheesecloth end is resting on the table.
- I. Fill each container with one of the four substances:
 - 100 - 150 ml of gravel
 - 100 - 150 ml of sand
 - 100 - 150 ml of soil
 - 100 - 150 ml of marbles
- J. Make sure each student in the group has their own pipe and substance.
- K. Hypothesize which material has the greatest permeability, and which has the least permeability.

Steps for Each Can

- L. Fill the graduated cylinder with 20 ml water.
- M. Hold the pipe over the empty bowl.
- N. Slowly pour the water (through the non-cheesecloth end) into the can (make sure the can is held over the bowl).
- O. Observe and record in the data table how quickly (in seconds) the water traveled through the substance.
- P. Measure the amount of water that permeated through the can and fell into the bowl (mL) in the data table. If there is still water draining, end drainage collection after 1 minute
- Q. Calculate and record the percentage of the water that permeated in milliliters (mL).

Small Group Discussion (10 Minutes): Pair off with another student and discuss the following topics:

- A. Organize the materials in order of least permeable to most permeable.
- B. Identify ways each material may be used in agriculture, urban, and natural settings.
- C. Describe how impermeable surfaces cause runoff and affect the health of local watersheds.

Large Group Discussion (15 Minutes): As a whole class, have some pairs share their answers with the group. The discuss the following questions/topics:

- D. What other natural and human-made materials are permeable?
- E. What other natural and human-made materials are impermeable?
- F. What do permeable materials have in common besides being permeable?
- G. What do impermeable materials have in common besides being impermeable?
- H. Why do humans use impermeable materials?

Wrap-up (5 Minutes): The Key Ideas from the lesson are:

- Natural and human-made materials vary in their ability to allow water to pass through them. This is referred to as permeability.
- The permeability of a material is due in large part to the size/number of pores in the materials. In other words, the amount/size of holes in the material determines how much water can pass through.
- Water that can pass through a material is less likely to collect anything resting on its surface (eg. pollution). Any substances on the material's surface that is carried away by the water is considered runoff, which runs unfiltered into natural waters.
- The permeability of surfaces has a large impact on water quality in natural and built environments.
- Built environments can be designed with materials that reduce runoff and increase the permeability, leading to better water quality. (eg Permeable Concrete)
- Impermeable materials are important for human use mainly to protect from water damage.

Permeability Lab Data Sheet

Materials	Gravel	Fine Sand	Soil	Marbles
Time for water to travel through material (s)				
Amount of Water Collected After Draining Through the Material (mL)				
Percent of Water Recovered After Draining Through the Material (%) [water collected/20mL]				
Observations				
Rate from Most Permeable (1) to Least Permeable (4)				