TEACHER LESSON PLAN
Go with the Flow: Permeability Demonstration

Standards:

Elementary TEKS (K- 5th)	Middle School TEKS (6th – 8th)	ESS TEKS	Enviro. Sys. TEKS	AP Enviro. Sci	NGSS
K – 1.A, 1.C, 1.D, 1.E, 1.F, 2.B, 2.C, 3.A, 3.B, 3.C, 5.A, 5.B, 5.C, 6, 10.A, 11 1st – 1.A, 1.C, 1.D, 1.E, 1.F, 2.B, 2.C, 3A., 3.B, 3.C, 5.A, 5.B, 5.C, 6.A, 10.A, 10.B 2nd – 1.A, 1.C, 1.D, 1.E, 1.F, 2.B, 2.C, 3.A, 3.B, 3.C, 5.A, 5.B, 5.C, 10.A 3rd – 1.A, 1.C, 1.D, 1.E, 1.F, 2.B, 2.C, 3.A, 3.B, 3.C, 5.A, 5.B, 10.B, 11.B 4th – 1.A, 1.C, 1.D, 1.E, 1.F, 2.B, 2.C, 3.A, 3.B, 3.C, 5.A, 5.B, 5.C, 10.A, 11.A, 11.B, 11.C 5th – 1.A, 1.C, 1.D, 1.E, 1.F, 2.B, 2.C, 3.A, 3.B, 3.C, 5.A, 5.B, 5.C, 10.B, 11	6th – 1.A, 1.C, 1.D, 1.E, 2.A, 2.C, 3.A, 3.B, 3.C, 10.A, 10.C, 11.A, 11.B 7th – 1.A, 1.C, 1.D, 1.E, 2.A, 2.C, 3.A, 3.B, 3.C, 10.A, 11.A, 11.B	1.A 1.C 1.E 1.F 2.B 2.C 3.A 3.B 9.B 9.C 9.D 13.A 13.B	1.A 1.B 1.C 1.D 1.E 1.F 1.G 2.B 2.C 3.B 3.C 7.A 7.B 12.A 12.B 12.C	4.2 4.3 4.6 6.3 6.4 6.5	K-2-ETS1-2 2-ESS1-1 2-PS1-1 4-ESS1-1 5-ESS2-1 MS-ESS2-1 MS-ESS2-2 MS-ESS3-1 HS-ESS2-1 HS-ESS2-2 HS-ESS2-5

Level: K-12

Objective: This demonstration provides students the opportunity to directly observe permeability and calculate different rates of permeability by using different grain sizes. The demonstration also allows students to practice using scientific equipment and engage in the scientific method as they make predictions based on the grain sizes. Students follow steps in the scientific method by completing a hands-on exercise to confirm or refute their hypothesis. Students will also collaborate and utilize critical thinking skills to understand how grain size affects the flow of fluids in the subsurface.

Background Information:

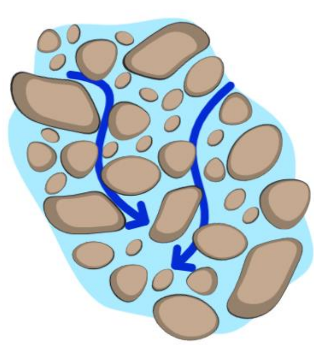


Fig. 1 Less compact soil allows water to move easily, therefore demonstrating high permeability.

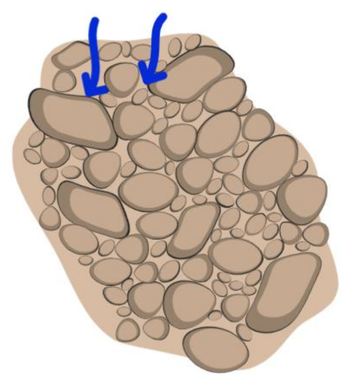


Fig. 2 More compact soil does not allow water to move easily, therefore demonstrating low permeability.

Images by Sabrina Ewald

In nature, the ability of the soil to store water is controlled by the porosity of the soil. Permeability is influenced by the sizes of the soil particles and particle compaction.

If the soil particles are loose (Fig. 1), water can move more easily through the soil. However, if the soil is compact (Fig. 2), water cannot move as well through the soil.

We can observe how fast it rains and how soil particles affect whether water collects on top of the surface and runs off to comprise surface water (to the closest creek, and then off to a larger river and away from the area) or infiltrates into the subsurface to comprise ground water (Fig. 3).

Soil is still much more permeable than rocks (or any type of man-made pavement). As we go deeper under the surface, rock layers have a smaller and smaller ability to transport water (or any other fluids, such as oil and gas) through them. As water moves into the subsurface, it becomes trapped by these less permeable rock layers.

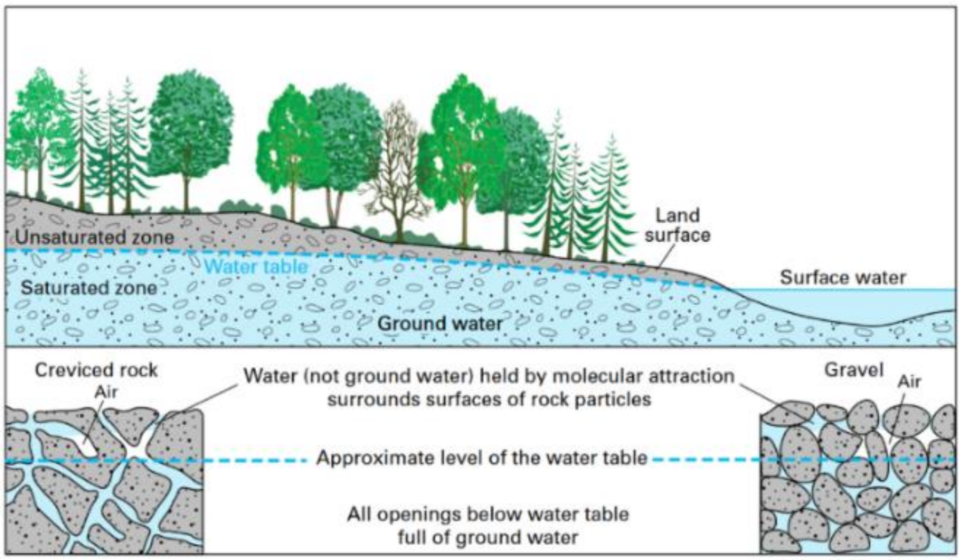


Fig. 3 Diagram of water being stored in porous and permeable layers in the subsurface.
Source: https://commons.wikimedia.org/wiki/File:Groundwater_flow.svg

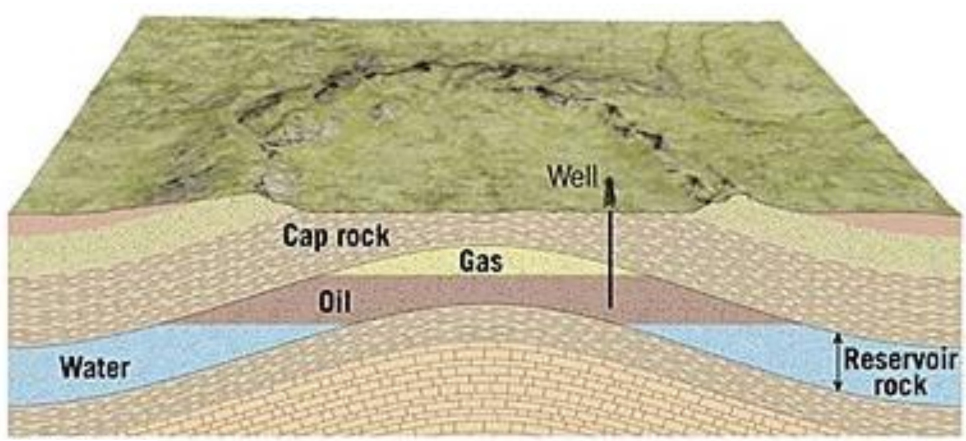


Fig.4 Oil, natural gas and brine water are similarly trapped in between impermeable rock layers in an anticline structural fold.
Source: https://commons.wikimedia.org/wiki/File:Different_Trapping_Mechanisms.jpg

<u>Time Requirements</u>: 45 - 55 minutes

Teacher Preparation:

Materials:

2 syringes with stoppers	mesh (cheese gauze)	4 100ml beakers
ring stand	stand holder for syringes	2 sizes of glass beads
graduated cylinder	water	timer

Procedure:

Set-up the following for each group of students you have in your class. See the images below.

1. You will need 2 plastic syringes. Remove the stopper from each syringe, place a small mesh (cheese gauze works well) at the bottom.

2. Fill each syringe with a unique size of glass beads (one smaller beads, the other larger beads). The syringes need to be secured in a stand (see photo). Place the stopper until you are ready to pour water.

3. Place a beaker beneath each plastic syringe to collect water.

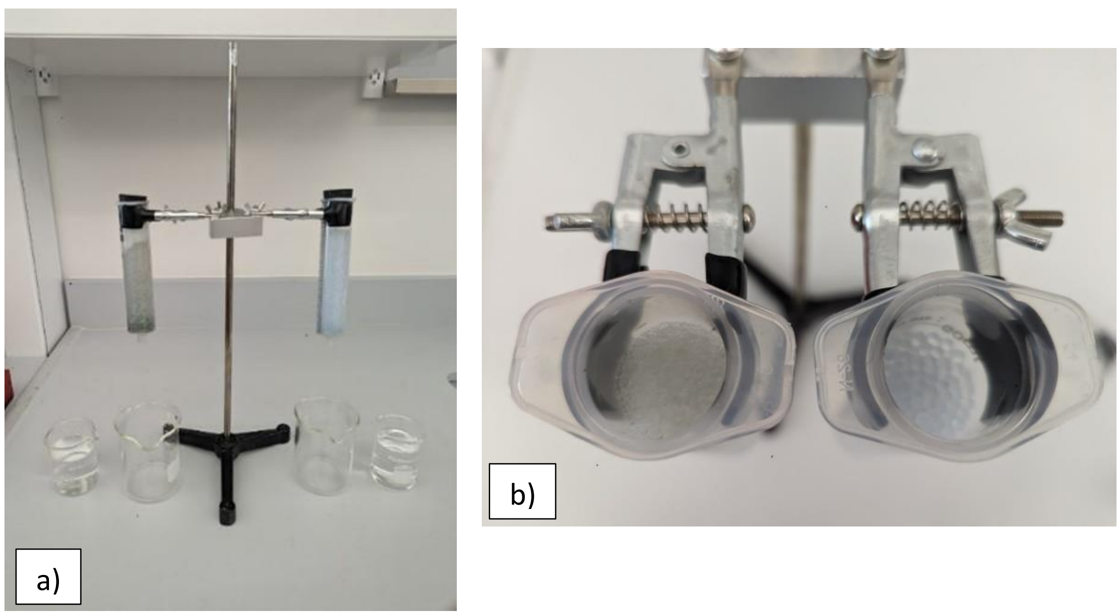


Fig. 5. a) Two syringes, each filled with a unique glass-bead size, fastened to a metal stand. b) Close-up of the open syringes and bead sizes (smaller on left, larger on right) before pouring water through the two mediums. Photo Credit: Masa Prodanović

Students will be able to quickly complete this demonstration if this set-up is completed before class. The following procedure is included on the student handout. The steps are outlined below so that teachers can prepare for the demonstration.

Student Directions

1. Check to ensure there is a beaker under each syringe at your lab station.

2. Fill 2 beakers each with 100ml of water. Set aside for now. Record 100ml of water in the data table under the column "Starting Volume".

3. Observe the beads and predict which beads you expect the water to move through most easily (fastest) and which you expect the water to move through less easily (slowest). Write down your hypothesis on your handout in the section titled "Hypothesis".

4. Group members will have specific roles – 2 water pourers, 2 timers, 1 recorder. Each group member needs to be responsible for one role. *See image below*.
   - There are 2 syringes present at your lab station. Assign 1 pourer and 1 timer to each syringe. These individuals are responsible for collecting data for their syringe.
   - The recorder is writing down the data for both syringes and will share with the other group members.

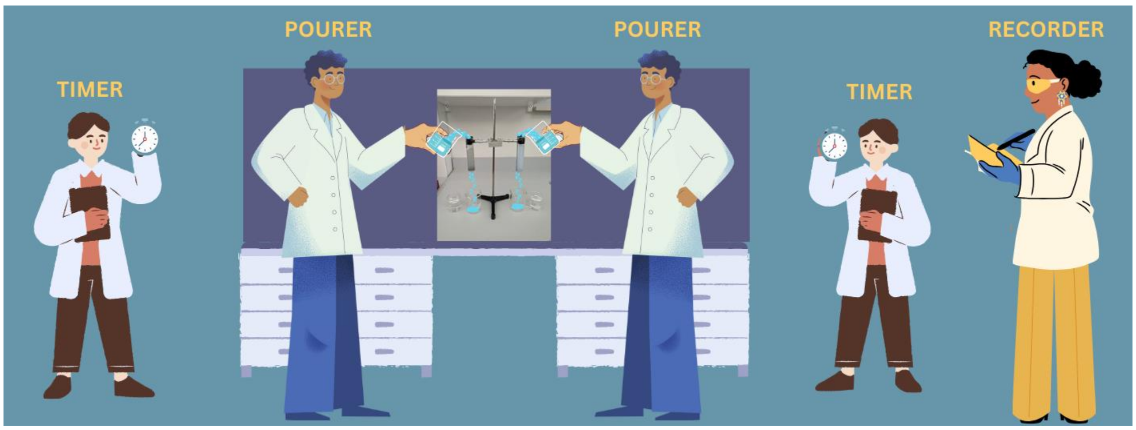


Fig. 6 Example procedure for the activity with numerous participants. Image Credit: Sabrina Ewald

READ THESE STEPS CAREFULLY SO YOU ARE PREPARED TO COMPLETE THE DEMONSTRATION.

5. 2 group members who are the water pourers will remove the stoppers. When the timers are ready, pour the water from the 100ml beaker into the top of each syringe. The timer stops timing when the water stops flowing out of the syringe.

6. Everyone in the group - observe the water as it travels through the beads, noting the time it takes water to move through the glass beads in the two syringes. In the section titled "Observations" explain the speed the water moves through each syringe.

7. Measure the amount of water in the beaker beneath each syringe by pouring the water into the graduated cylinder provided. Record the volume in the data table in the column titled "Final Volume".

8. Record your group's data and then data from other groups in the class and answer the Analysis and Conclusion Questions.

Where to learn more? You can find more about porosity and permeability of rocks and soil in (Peters, 2012). If you are interested about rocks in the context of geology see (Murck et. al., 2008) for a wonderful visual introduction.

Murck, B. W., Skinner, B. J., & Mackenzie, D. (with National Geographic Society (U.S.)). (2008). *Visualizing geology*. Wiley.

Peters, E. J. (2012). *Advanced petrophysics*. Live Oak Book Company.

Formative Assessment:

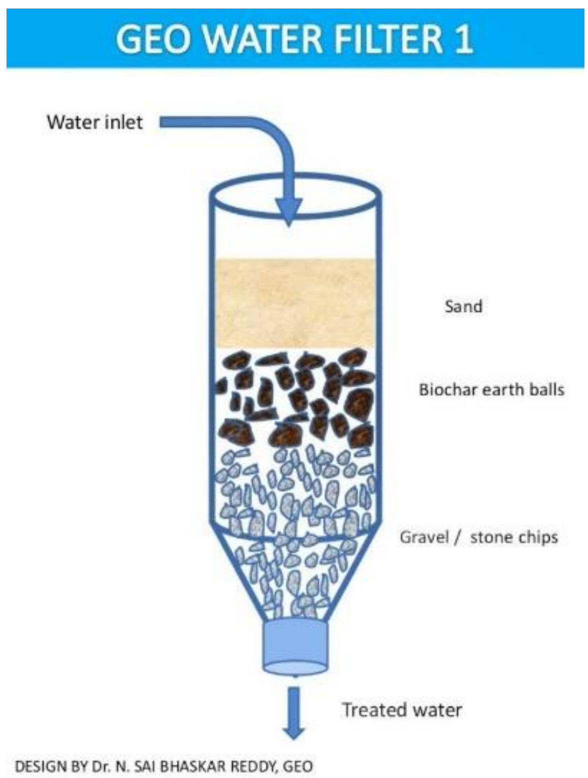
How does the bead diameter, D, control porosity? Because the two mediums display a somewhat ordered packing of beads, the larger bead diameter creates a larger pore space. The total porosity will be the same between the two mediums. However, the passageway between the pores (the pore throat) in the smaller-bead medium will be significantly smaller than in the larger-bead medium, and thus, constrict the flow through the bead packing medium.

Extension:

We are analyzing packings of spheres (bead-packs) as a model of soil or rock. However, there are many other applications for the concepts of porosity and permeability. For instance, water filters are typically packings of spheres or close-to-spherical grains. Additionally, they might have an active surface that attracts other materials and particles, cleaning water in the process (Fig. 7). In many chemical engineering applications, the surface of spheres is coated with catalysts that facilitate a reaction.

a)

b)



c)

Fig. 7. a) Typical household water filter and its insert shown in b). c) Design of a low-cost water filter by Dr. Bhaskar Reddy that can be created with materials common in rural areas such as sand, coarse aggregate, cotton, rice husk, powdered charcoal and placed into a cut plastic water bottle. Design of such a filter could also be a classroom activity. Photo Credits (a & b): Sabrina Ewald

Supporting Documents:

Student Worksheet (when you click on the link, the file will automatically download to your computer)

*This activity can be further adapted for different grade levels.

K – 5th grades can include how permeability of soil influences water available to plants as they learn about how organisms depend on resources available in their ecosystems. This concept can also be related to water conservation and why it is important for humans to conserve water.

5th – 8th grades and Environmental Science courses can use this concept to further explore implications of human water use and water pollution, related to rate of aquifer recharge and surface water recharge.

Earth and Space Science and Environmental Science courses can further explore the implications of pore space and permeability and how it relates to the extraction of fossil fuels (oil and natural gas) from the subsurface.

REFERENCES:

Image and Diagram Credits found on Student Worksheet:

1 – Permeability Diagrams Credit: Sabrina Ewald

2 – Aquifer Diagram Credit: https://commons.wikimedia.org/wiki/File:Groundwater_flow.svg

3 – Oil Trap Diagram Credit: https://commons.wikimedia.org/wiki/File:Different_Trapping_Mechanisms.jpg

4 – Lab Set-Up Diagram Credit: Sabrina Ewald