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Porosity and Permeability lab

Background

Mineral particle size is a major factor that influences both the amount of air in soil (aeration) and the capacity of soil to retain water. The volume of air and water that soil can hold is known as the soil pore size or ***porosity***. The larger the soil particle, the larger the pore size will be (see Figure 1). The reverse is also true-the smaller the soil particle size, the smaller the pore size (Figure 1).

The percent porosity of soil is measured using the following equation

Percent Porosity = (Pore space Volume/Total Volume of soil) X 100

Water tends to drain more rapidly through larger soil pore size than small pores. As water runs through any type of soil, it pulls small amounts of air along with it. When water enters soil that has a smaller pore size, the air fills the pores or voids in the soil. As the small pore spaces are filled, the soil holds or retains a greater amount of water. This is why it is important to have a good mixture of different types of soil for plant growth. A combination of large and small pores provides both better aeration and water retentions in soil.

Permeability is another key characteristic of soil. ***Permeability*** is the relative ease in which water and air can move through soil. Water flows through soils with high permeability very easily. Soils with low permeability allow much less water flow or drainage. Soils that have high permeability can be pictured as being loose and soils with low permeability can be thought of as being tight or compact.

Compaction of soil also plays a major role in the amount of water that is drained through soil. *Compaction* occurs when pressure is applied to a soil surface. As soil becomes compacted, the pores in the soil become smaller. The number of large pores decreases, which, lowers the aeration level of soil. Compacted soil also leads to a decrease in permeability.

Permeability also decreases when soil becomes saturated with water. Saturation of soil and high levels of introduced water (rainfall for example) lead to runoff of water. *Runoff* is water that is not absorbed by the soil and flows to lower ground, eventually draining into streams, lakes, rivers, and other bodies of water. Excessive amounts of water runoff can cause severe flooding which can lead to extensive property damage.

Materials

Cheesecloth, 2 pieces
Clear tubes, open ends, 2
Clear tubes, one end open, 3
Coarse gravel
Cup, plastic, 2
Fine gravel
Graduated cylinder
Rubber bands, 2
Pencil or wooden dowel
Sand
Soil
Stopwatch
Water

Safety Precautions

The components of this activity are considered relatively safe. Follow all laboratory guidelines. Wash hands after handling all materials.

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How does the soil composition change the drainage rates?

Activity One – Drainage Rate of Packed vs. Loose Soil

1. Obtain two clear tubes with open ends.
2. Rubber-band two pieces of cheesecloth to one end of each tube.
3. Place each tube upright, with cheesecloth end down, in a plastic cup.
4. Measure 40mL of soil using a graduated cylinder
5. Place the 40mL of loosely packed soil in tube #1
6. Place the same amount of soil (40mL) in tube #2. Pack the soil down, using a pencil
7. Hold tube #1 above the plastic cup and pour 40mL of water into the tube. Use a stopwatch to time the drainage of the water. *Start* timing as soon as all of the water has been poured into the tube. *Stop* timing when the water stops dripping from the bottom of tube #1. Record time under:
   Time of Drainage for the Loose Soil in Data Table 1.
8. Repeat step 7 for tube #2. Record the time of drainage of the water for tube #2 in:
   Seconds under Time of Drainage for Packed Soil in Data Table 1.
9. Using the amount of water placed into each tube and the time required for drainage, determine the drainage rate of the loosely and tightly packed soil in **mL per second** in *Data Table 1*.
10. Pour the water from each cup into the waste bucket. Save the tubes with the soil and the cups for activity 2.

Activity Two-Drainage Rate of Wet vs. Dry

11. Place each of the tubes with the wet soil in the cups once again
12. Hold tube #1 above the cup and once again fill the tube with 40mL of water. Start timing as soon as all the water has been poured into the tube. Stop timing when the water stops dripping from the tube. Record drainage time from the first tube in seconds under:
    Time of drainage of wet soil in Data Table 2.
13. Repeat step 12 for tube #2. Record the time for the second tube under:
    Wet Soil in the Data Table 2.
14. Calculate the drainage rate for tubes #1 and #2 using the procedure from in step 9.
15. Dispose of the soil and clean the tubes according to the instructor.

Activity Three-Permeability and Porosity of Varied Soil Types

1. Obtain a tube with one end closed
2. Using a graduated cylinder, measure out 100mL of fine gravel in the tube
3. Measure 100mL of water into a graduated cylinder. This will be the initial amount of water
4. Start a timer and slowly pour water from the graduated cylinder into the tube until the water hits the bottom of the tube for fine gravel. This is referencing the **permeability** of the soil. Record the amount of time in *Data Table 3 under initial time*.
5. Continue to fill the tube until water reaches the very tippy top of the soil, **Go Slow**. This is beginning to measure the **porosity** of the soil. Record the *Amount of Water Remaining in the Graduated Cylinder.*
6. Subtract the amount of water remaining in the graduated cylinder from the initial volume of water,100mL. This will give the *volume of the pore spaces* in the fine gravel. Record this in *Data Table 3.*
7. Empty the graduated cylinder
8. Pinch the tube and pour the water retained in the fine gravel from the tube into the empty graduated cylinder. **Be sure not to pour any of the fine gravel in to the graduated cylinder**. Record this amount of water *as Water Drained from the tube in Data Table 3.*
9. Pore space volume-water drained=water retained (still in the soil)
10. Repeat steps above with fine and coarse gravel.

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Student Data Tables

How does the soil porosity change the permeability?

Data Table 1 - Dry Soil Drainage (show all work)

	Time of Drainage	Drainage Rate (vol/time) (mL/s)
Tube 1 Loose soil		
Tube 2 Packed Soil		

Data Table 2 – Wet Soil Drainage (show all work)

	Time of Drainage	Drainage Rate (vol/time) (mL/s)
Tube 1 Loose soil		
Tube 2 Packed Soil		

Claim-

Evidence-

Reasoning-

How are porosity and permeability related?

Data Table 3 – Permeability and Porosity

Soil Type	Initial Time (s) #4	Amount of Water Remaining in Graduated Cylinder(mL) #5	Pore Space Volume #6 (100mL-#5)	Water Drained from tube (mL) #8	Water retained (mL) #9 (#6-#8)
Sand					
Fine Gravel					
Coarse Gravel					

Analyze trends in table for accuracy. Circle columns or rows that are incorrect and explain why.

Claim-

Evidence-

Reasoning-

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Conclusion:
Analysis: Activities 1 and 2

1. Given your results, would water-soaked soil be able to hold more or less water if a rainstorm occurred? Why?

2. Identify 2 factors (not tested in lab) that could effect the drainage rate of soil.

3. Predict the drainage rate (fast or slow), if the soil from Activity 1 was in:

a.) Arizona

b.) Wisconsin in August

and

c.) a tropical rain forest

4. If you were to build a house on a type of soil from activities 1 and 2, based on what you know, judge the quality of which soil type would you rather choose? Why?

5. List some limitations in Activity 1 and 2 (*how is this not representative of the real world?*).

Analysis: Activity 3

1. List some limitations in Activity 3 (*how is this not representative of the real world?*).

2. Explain how porosity and permeability are similar and different (besides their definition).
*Similar *Different

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3. What is the relationship between the *porosity* and the grain (particle) size of each soil sample? Give an example.

4. What type of soil retained the most water? Why?

5a. Calculate the permeability of each soil type using the following equation:
Permeability = 1/Initial time for water to reach the bottom of tube. Show **all** work. Must divide.

Sand________

Fine Gravel________

Coarse Gravel__________

5b. Explain results in words for sand vs. coarse gravel's permeability found in 5a.

6. What is the relationship between the *permeability* and grain (particles) size of each soil sample? Give an example.

7. What would the results be if your house was on sand

a.) in Wisconsin in April?

and

b.) On gravel in Wisconsin in April?

8. Distinguish which soil type tested in Activity 3 would cause the most water runoff (define this word)? The least? Why?

	1 - Beginning	2 - Developing	3 - Proficient	4 - Excelling
Standard 6: Constructing Explanations	Does not construct explanations with valid claims, evidence, and reasoning.	Constructs a quantitative or qualitative claim, *(evidence may be inaccurate or irrelevant ; reasoning is inaccurate or inadequate.)*	**and** supports the claim with reliable evidence *(reasoning is inaccurate or inadequate)*	**and** provides reasoning in which scientific principles correctly link evidence to the claim

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Choose one prompt to answer. Include the question in your answer.

1. How could a variable/factor be changed in the procedure? How would results change?

2. What might outsiders or critics argue about the data?

3. Compare or contrast this science concept to another science concept already discussed in class. How do they relate?

4. What kind of extrapolations (extension -inferring unknown values from trends in the known data.) can be made with given results?

5. Inquire further. What information is still needed to continue learning? Question the procedure, or results.

6. Explain how the conclusions of the activity corrected previous knowledge, or enforced what was already known?

7. What conclusions or explanations can be made justified by the evidence?

8. I still have ______________to learn. Or, need help with ___________________.