Permeability Field Investigation

Using the scientific method to guide this outdoor investigation, students test the permeability of different school-ground areas, record and organize the results with maps and tables, and make recommendations for sustainable stormwater practices. The following are included:

TEACHER INSTRUCTIONS

Use: This activity works well after the Watershed Connections presentation and watershed model activities or doing a different lesson that provides the necessary background for a hypothesis and discussion.

Time: 60-90 minutes, depending on the number of sites tested and extensions. Students also can be involved in drawing a campus map, which requires additional time.

Grades: Grades 5-10

Skills & Standards -- *MD Environmental Literacy Standards 1A, 1B, and 5B; Core Curriculum grades 5 and 6 math:*

- Using the Scientific Method
- Using results to make recommendations for campus Stormwater Sustainable Practices
- Recording and organizing data using a map and tables
- Making measurements, basic math and averaging (with extensions for volume and unit conversion)

Concepts Developed

- Permeability, infiltration, and surface water runoff on different surfaces
- The use of sustainable practices to reduce storm water runoff on the school grounds
- Reliability in scientific research

Supplies for Each Team

- 6-inch PVC pipe 3-in diameter (can be cut with a hacksaw). Draw a line .25 inches (.6 cm) from the bottom on this cylinder with a Sharpie. Option: coffee cans with both ends removed. Make sure the cans are the same size and that sharp ends are covered with duct tape.
- 1000 ml-measuring cup
- Stop watch
- Small map of school grounds
- Clear ruler with metric marks
- Red, green, and yellow markers and pencil
- Directions for Permeability Field Test
- Field Observation Sheet
- Container of water for multiple sites (could be 2-liter soda bottle)

Supplies For Whole Class

- Large map of school yard on large paper
- Large pad of paper, easel, markers, pencil for class data table
- Extra water

BEFORE THE INVESTIGATION

Make School-Ground Maps: Make a large map of the school grounds, depicting the school and areas on the grounds that have different uses and/or land cover -- for example, gardens, woods, parking lots, playgrounds, paths, sidewalks, or athletic fields. (Simple line drawings to designate areas work well, or you can opt for a computer satellite map). This will be used for preliminary discussion and the class data. *Each team also needs a small version of this map.*

Outdoor Discussion with Map: Take your students outside and, using the map(s), ask them which areas on the school grounds might have differing amounts of *permeability*. Explain that they will do a field test to assess the permeability of areas on the school grounds that have different uses or land cover. Discuss factors that could affect the ability of water to *infiltrate* into the soil.

Hypothesis: Ask your students to make group hypotheses about which *area will have the greatest permeability and which will have the least*. The hypotheses should be backed by information from lessons or observations. For instance, gardens could be permeable because the soil has plant roots that create air spaces in the soil. The playground could have less infiltration if it has been compacted by people (fewer air spaces for water to infiltrate). A paved parking lot would not allow water to infiltrate into the ground. Example hypotheses using the formal "If… then" format follow:

- If the garden area has the greatest permeability, then more water will soak into the ground than in the other test areas.
- If the sidewalk is the least permeable surface, then the cylinder water will not infiltrate into the ground.

METHODS

Assign Test Areas: Divide the class into 4 or more teams -- Teams A, B, C, etc. Beforehand, decide how many areas each team will test, keeping in mind that the *data from each area will be averaged*, and the more tests in each area, the more ***reliable*** the results. Show each team the areas they will test, and explain that each team will *use the same methods* to test a *different spot within that area*.

> *Time-saving options:* Each team could test 3-4 different areas, but at least 3 teams should test the same areas. OR choose to focus your investigation on one side of the school. OR have different classes test different areas, and combine the results from both classes.
>
> *Added Challenge:* If age appropriate, introduce the concept of *random sampling within defined areas* by having each team pick a number from a hat. Then one team member twirls around in the center of the area (with eyes closed) and walks that # of steps to the spot to be tested.)

Permeability Field Test (see Directions, page 4): These directions can be copied for the students.

- Demonstrate the test and go over the *Team Field Observation Table* (page 6).
- Provide each team with the materials listed on page 1. Assign "jobs" for the team members , e.g., the person holding the cylinder, water pourer, timer, data recorder, map marker. Have each team practice the procedure.
    - *Ask the students why it is important for all of the teams to use the same procedure.* Answer: Reliability -- if one team were to use a different amount of water, the results would not be consistent with the other teams' data. Repeatedly using the same methods helps ensure *consistency of the* results. This makes it possible to average the results and have a reliable conclusion, or to recognize an anomaly.
    - Ask them why they think you assigned jobs. (This can also improve reliability of the results, because the tests are more likely to be done the same each time.)
    - Ask them how else the procedures will help ensure reliability of the results. (The number of tests being done by multiple teams in each area.)

Recording the Results

Each team records their data and observations on the Team Map and Team Field Observation Table. When the field tests are done, the class gathers to record the results on the group map and a group table.

Group Map: Each team marks their sites on the large map according to the following:

- If all the water seeped into the ground within **3 minutes**, put a **GREEN dot** on the test site. Draw an arrow showing the direction of flow.
- If **less than 2 cm** infiltrated into the ground, mark the test site with a **RED arrow**, showing the direction of water flow.
- If **some water remained in the cylinder, but greater than 2 cm infiltrated** into the ground, put a **YELLOW dot** on the test site. Draw an arrow showing the direction of flow.
- Extrapolate the results: If all the test sites in a designated area have the same color of dots, mark the entire area with that color (or stripes of that color).
- Make a map key. Have the students define what the colors and symbols represent – *permeable, semi-permeable, or impermeable.*

Group Table: Have the group make a table to record their results, or use the one provided on page A. The students will *average* their results.

Conclusions and Recommendations

Sample class discussion questions

- Which areas are the most permeable and impermeable? Was the group hypothesis correct? Why or why not?
- What direction would runoff flow in different areas of the school yard?
- Which areas would have the most stormwater runoff? (What other information might be needed to quantify this question? Answer: size of the area or the roof; slope.)
- Which areas might have puddles?
- Why does the water infiltrate at different speeds in different areas? Possible answers:
  - The area is compacted by people walking or playing on it.
  - Heavy lawn mowers frequently run over it.
  - There is clay underneath the top soil or near the surface.
  - There is mulch and dried leaves on top of the ground.
  - There are plants with roots in the soil.
  - There is more sand or loam or organic material in the soil.
- How does these findings relate to stream water quality in their watershed?

- PRACTICAL APPLICATION: Where could sustainable stormwater practices, such as gardens or rain barrels, be installed to reduce stormwater runoff? *(See the rain garden resource booklets on your CD for more information on this.)*
  - Have students suggest best management practice and discuss the pros and cons of each type.
  - Students can discuss what else they would need to know before deciding what practices would be most effective.

Student Directions for the Permeability Field Test

As you complete each test, mark the *site on your map, and* record your observations on the Team Field Observation Sheet. Label the sites according to your team's letter and the number of the test. (If you are team A, your first site will be labeled A1, your second site, A2, and so on.)

Each team member should do his or her assigned task throughout the investigation (Reader, Recorder(s), Holder, Timer, Pourer). Read and *practice* these instructions before you start.

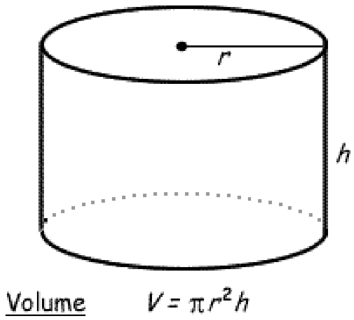
PROCEDURE

1. Fill your cup or bottle with 650 ml of water.
2. Push the cylinder into the ground to the black line on the cylinder. (For areas where the pipe *cannot* be put in the ground, go to Step 3.) Do the following steps:

   - One person applies constant pressure to the top of the container to prevent water from leaking out around the bottom.
   - The Timer starts the stopwatch at the same time the Pourer begins to pour water into the cylinder.
   - *If the water infiltrates before 3 minutes*, the Timer stops the watch at that point. The Data Recorder writes the length of time on the Team Field Observation Sheet.
   - Stop the watch at 3 minutes. If water remains in the cylinder, measure from the cylinder rim to the water level (in centimeters). Record on the Observation Sheet.
   - Lastly, pour 1 liter of water on the ground near your test site and observe whether it flows in one direction or pools. If it flows in one direction, draw an arrow on your map, indicating the direction of the flow. If it pools, write the word pooled on your map.

3. If the cylinder cannot be put into the ground, you will pour the water on the surface and record answers to the following on your table and map.
   - Does it pool? Note this on the Observation Table and Map
   - Does it flow in a certain direction? Make a red arrow on your map that shows which direction the water flows.

Extensions



Finding the volume of a cylinder:

The volume is found by multiplying the *area of one end of the cylinder (base) by its height.*

Since the end (base) of a cylinder is a circle, the area of that circle is given by the formula: area = πr^2

$volume = \pi r^2 h$	where: π is Pi, approximately 3.142 r is the radius of the circular end of the cylinder h height of the cylinder

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Extension 1 Volume: What volume of water is needed to fill the cylinder?

Have the students use the metric system to measure the cylinder's height (from the marked line) and diameter. They will determine the radius by dividing the diameter in half.

Our cylinder: Diameter = 7.7 cm. Height = 14.6

$volume = \pi r^2 h$ = 3.14 x (7.7 cm ÷2)^2 x 14.6 = 679.8 ml

Extension 2 Volume: Students can determine the volume of water that percolated, rather than centimeters of water that percolated.

Extension 3 – Rate of Infiltration and Conversions: Although most sciences use the metric system, interestingly, the science of hydrology often uses English units. The rate of infiltration is measured in either mm/hour or inches/hour. Have them convert their measurements (cm/#minutes) to mm/hour or inches/hour. Naturally, if the test was done for 24 hours, as it is by soil conservation scientists, this rate could differ, another point of discussion about the accuracy of the results.

Extension 4: Discussion of Precision and Reliability: It is likely the students might have slightly different measurements, depending on the preciseness of the cylinder and bottle lines and their measurements. This can be discussed. This is fine for this field test, which does not require fine precision; rather, it requires reliable results – several tests done on the same surface by different teams following the same methods as carefully as possible. Discussion question: What types of research could precise measurements make a huge difference?

Other Extensions

- Have students hypothesize what variable might be included in a roof runoff formula and then research the formula on the internet. The students could then calculate how much runoff would be expected on the school grounds from the school roof. (Many reliable internet sites on rain barrels and rain gardens include formulas. Good sources include county environmental departments. Also see the rain garden booklets provided on the Google drive.)
    - Follow-up to this. Students can determine how large a rain garden would need to be to accommodate the runoff, or how many rain barrels.
- Discuss in detail variables that would affect the rate of infiltration (e.g., types of vegetation, recent rain activity, soil types.) The National Soil Conservation Service website provides lessons and videos.

TEAM FIELD OBSERVATION SHEET

Weather: Did it rain yesterday? ______________

TEST SITE NUMBER (For example, A1, A2, A3…	**TEST SITE DESCRIPTION** (Examples: garden, foot path, playground, parking lot)	**TIME FOR WATER TO INFILTRATE (sec.)** (If the water would not infiltrate, write impermeable.)	**Distance from rim to the water level (cm)** (The amount that infiltrated.)	**OBSERVATIONS** • Note things that could have influenced your results, for instance: Was the ground wet? Did water seep out your cylinder?

A.

EXAMPLE CLASS TABLE

Directions:

Time to infiltrate: Write the time in seconds. If the water did not infiltrate within 180 seconds, write **>180 sec**. If it did not infiltrate at all, write Impermeable.

NOTE: When the water does not infiltrate within 180 seconds, it will take creative thinking to "average" the Time-to-Infiltrate results. Your class can decide the appropriate value to use, or whether to just to consider the average amount of water that infiltrated for that site.

Distance from rim: If the water did not infiltrate into the ground at all, write zero.

	Test Site 1		**Test Site 2**		**Test Site 3**		**Test Site 4**	
	Time to Infiltrate (sec.)	Distance from Rim to Water Level (cm)	Time to Infiltrate (sec.)	Distance from Rim to Water Level (cm)	Time to Infiltrate (sec.)	Distance from Rim to Water Level (cm)	Time to Infiltrate (sec.)	Distance from Rim to Water Level (cm)
Team A								
Team B								
Team C								
Team D								
Team E								
Average								
Is it Permeable or Semi-permeable or Impermeable?								

B.

	Test Site5		Test Site 6		Test Site 7		Test Site 7	
	Time to Infiltrate (sec.)	Distance from Rim to Water Level (cm)*	Time to Infiltrate (sec.)	Distance from Rim to Water Level (cm)	Time to Infiltrate (sec.)	Distance from Rim to Water Level (cm)	Time to Infiltrate (sec.)	Distance from Rim to Water Level (cm)
Team A								
Team B								
Team C								
Team D								
Team E								
Average Time to Infiltrate								
Is it Permeable or Semi-permeable or Impermeable?								

C.