

Chapter 9. Soil, Dirt, Filters and Water Quality

Lesson 1. How soil acts as a water and sponge.

Overview: In one of the first lessons, we saw that the earth is somewhat like an orange or a grapefruit-the outside skin or peeling acts like a protective layer and unless the protective layer is penetrated, the inside of the fruit will remain clean. Groundwater, the water found in saturated soil and rock layers below the ground, is like the juice inside the orange or grapefruit, protected by the mantle or layer of soil on the land surface. These saturated zones of soil or rock are called aquifers and they serve as a valuable source of relatively clean water. Groundwater, obtained from wells and springs, supplies nearly 50 percent of all the domestic water to Montana residents.

Groundwater, being such a valuable source of water, should be protected from contamination. Unfortunately, often we do not readily know or understand the extent to which groundwater can become contaminated-because we cannot see it all at once. Sometimes, we do not realize the consequences of our actions on the land until a long time after we have stopped our action.

In many respects, the soil on the land surface serves a very effective purpose by protecting groundwater-and by filtering water as it passes from the soil surface to the groundwater aquifer. The soil acts both as a physical filter and as a chemical filter. In addition, the soil acts as a series of pipelines of many sizes, shapes and lengths. These many different pipes store water and regulate the rate at which water flows through the soil. To better understand groundwater, it is important to realize just what role soil plays in water quality and water quality protection.

Purpose: The purpose of this lesson is to help students better understand the process of groundwater recharge and the role that the soil surface (earth, land) plays in regulating and storing water and protecting groundwater by physically and chemically trapping contaminants and filtering water.

Part A: Soil is like both a sponge and a collection of many pipes or tubes of different sizes, shapes and lengths; the storage and flow properties of different soils vary and depend on the type, texture and depth of the soil.

Part B: The soil covering most of the earth's surface serves a very important role in protecting the quality of existing groundwater, storing water, and filtering and cleansing water as it passes from the earth surface to groundwater.

Materials Needed: For each team of 2-3 students you will need the following materials:

- two sponges, each of the same dimensions (length, width, depth) but each with different sizes of pores—one with large holes and one with small holes
- a plastic washtub filled to a depth of about 2" with water
- a simple triple beam balance or platform balance
- a cookie sheet or plastic tray
- food coloring
- Four 12-oz. plastic pop bottles with bottoms cut off (so they are like tall funnels)
- cotton balls - one for each bottle
- used/clean liquid soap dispenser bottle or shampoo bottle full of water
- $\frac{1}{4}$ measuring cup
- 100 ml graduated cylinder
- supply of water
- some type of stand to place bottles on
- Four 8-oz. plastic tumblers
- Four 4-oz. plastic tumblers
- Bulk supply of several different soil materials, including sand, pea gravel, coarse gravel, loam (potting soil), fine silt, clay
- a knife, spoon, pencil, or wooden ruler
- markers (or pencil/pen and tape)
- ware cloth or window screening material in 2" x 2"

Procedure: The first part of this lesson is a demonstration designed to illustrate how the soil is like a sponge or reservoir, filled with rocks and pores, and each soil has its own unique properties. **Note:** with advanced preparation, this demonstration can be set up as a class activity.

Part A. Hold up both of the sponges and ask the class to explain how the sponges are like the soil, i.e., they have physical properties, holes, pores of various sizes, they allow water to pass through, they can store water, and they can filter some contaminants out of water. On the other hand, just like these two sponges, different soils have different physical capacities. The soil on the earth's surface is something like a large, very thin, sheet of blotting paper, stretched over the earth like a skin. The soil layer can absorb water, adsorb contaminants, and both store and filter water applied from the surface.

Before doing anything else, measure the dimensions of each sponge and weigh each sponge. Record this information. Calculate the volume of each sponge.

Wet up a sponge and hold it flat in your hand while it drains. Comment about how the soil has limited ability to store water. After the water has stopped draining, pour 50 ml of clean water directly on top of the sponge. Observe what happens when you add the water. Catch all of the draining water into a bucket or tray or cookie sheet and measure this volume. Compare the amount drained with the 50 ml added. Now let the sponge drain in your hand and weigh it, now that it is saturated. Compare this new "wet" weight to the "dry" weight. What percent of the total weight is water?

Now have a student "wring" as much water as he/she can out of the sponge. Collect this water and compare it to the change in weight from "wet" to "dry," Remind the class that 1 milliliter of water is equal to one gram of water and if you could wring all of the water from the sponge, the amount caught would equal the weight change when the sponge was first wet up. Since less water was wrung out than the difference between "wet" and "dry," the soil/sponge must be holding some water. This is just what the soil does when it is wetted up.

Again wet up the sponge by placing it flat in a tub of water. Lift up the sponge and lightly "wring" out some water, but not all of it. In an 8oz. tumbler, mix 50 ml of water with two teaspoons of soil. Thoroughly mix the soil-water and then slowly pour this mixture over the top (in the center) of the sponge. Catch all of the water that drains out and compare it to the soil water mixture you poured into the sponge. Question the class about their observations. Help them understand that the sponge, again, is like the soil on the earth's surface-it can be very effective as a physical filter. This physical filtering process is what helps make ground water such a "good" source of reliable, clean drinking water.

After the discussion ceases, completely rinse out the sponge and wring the water out of it. Now, place both sponges in a bucket of water and let them absorb water. Pick up sponges, hold each flat in each hand and let them drain freely. Now, weigh each sponge and record the weights. Compare the "wet" and "dry" weights of the two sponges. Calculate the percent water of each sponge by dividing the weight of ["wet" - "dry"] by "wet." Compare these two numbers. Why should/would/did you get two different values for ["wet" - "dry"] and "wet"? Explain to the class that these differences are like soil differences, Le., soils with different sizes and volumes of holes hold/store different amounts of water. These types of differences in physical properties affect the role of soil in water quality.

Note: If you wish, you can have the students calculate the volume of water-filled pores, based on the weight and density of water held and the volume of the sponge.

Part B. When class begins, start by discussing with the class the issue of water quality. Ask them what we mean when we talk about water quality.

To begin this activity, label the pop bottles as A, B, C, \ and D. Label the 8-oz. tumblers the same way (A, B, C, D). Place the four pop bottles upside down in the rack or stand in order from A to D and place a plastic cup / tumbler under the mouth of each of the same lettered pop bottles. Lightly pack/place a wad of cotton or cotton ball in the mouth of each bottle (do not use paper towel). If necessary, cut some small pieces of hardware cloth or window screen material and place a piece over the mouth of each bottle and on the inside. Now pour $\frac{1}{2}$ cup of one of the soils into the bottle labeled A. Pour one cup of the same soil material into the bottle labeled B. Pour $\frac{1}{2}$ cup of another soil material (something different, like gravel or sand) into the bottle labeled C and pour one cup of this material into the bottle labeled D. Using the knife, spoon or ruler, lightly tap around the outside, near the bottom, of each bottle 20 times to get the soil to settle around the inside walls of each bottle.

Fill all four 4 oz. tumblers to the top with water. Simultaneously pour four oz. of water into the bottles labeled A and C. Observe the length of time it takes for water to drain out of each bottle. Also make note of the amount of water that drains from each bottle.

Compare the amounts and times for outflow. If you want, you can compare the percent of water held by each of the different samples. Do this by first learning the number of milliliters in 4 oz. of water. Now measure each outflow in milliliters. Subtract the value for the amount of outflow from the value for the amount of water put in (milliliters in 4 oz.) and then divide this value by the amount of milliliters in 4 oz. If you now multiply by 100%, you will have the percent of water held in the soil.

For example:

1oz. = 28.375 ml (milliliters), so 4 oz. = 113.5 ml put in
 If you measured 60 milliliters flowing out, then $([113.5 \text{ ml in} - 60 \text{ ml out}] / 113.5 \text{ ml in}) \times 100\% = 47.1\%$ held

Complete the following table after collecting the data.

Column	ml added	Time Water Added	Time Outflow Started	Time Outflow Stopped	ml Outflow Collected
A					
B					
C					
D					

Bottle A: time for outflow _____ amount of outflow _____
Bottle C: time for outflow _____ amount of outflow _____

Now repeat this process (4 oz. Of water) for bottles B and D, making the same observations of time and amount of outflow.

Bottle: B: time for outflow _____ amount of outflow _____
Bottle D: time for outflow _____ amount of outflow _____

Now place four 8-oz. tumblers on the bench. Add 50 ml of water to each tumbler. To two tumblers add 2-3 drops of food coloring (red or blue works best) and mix each cup. Add 1-2 teaspoons of fine soil to each of the other two cups and mix the contents of each of these cups up.

Slowly pour one tumbler of colored water into the funnel/soil column marked A, catching all the drainage water. Add one tumbler of colored water to the funnel/soil column marked C, catching all of the water that drains. Compare the volume and color of outflow from A and C. Now, repeat this process with the two remaining funnels/soil columns (B and D) and the tumblers with the soil/water mixtures. Compare the volume and quality of outflows from B and D. Question the students about the differences between A and C, B and D, A-B and C-D.

The students will see the effect of different soils on water storage and transport, and the ability of the soil to filter out physical contaminants. The food coloring should pass directly through the soil, showing that the soil does not necessarily filter out chemicals. Do not let the students think that all chemicals pass readily through the soil; but, they should realize that some chemicals are effectively filtered out by the soil (recall the experience of the mixing and filtering process previously investigated).

Without moving any of the funnel/soil column systems or cups that are catching drainage water, add 50 ml more of water to each funnel and observe the outflow. Again, compare the results from the different cups and have the students explain what has been happening.

Lessons Learned: In Part A we learned that soil is like both a sponge and a collection of many pipes or tubes of different sizes, shapes, and lengths; the storage of flow properties of different soils depend on the type, texture and depth of the soil and just how wet the soil is when more water is added.

In Part B we learned that most soil has both physical and chemical storage capacity; the storage capacity (and trapping ability of soil) depends on the chemical and physical composition of potential contaminants and the physical and chemical properties of the soil.

The lesson above was adapted from "What is Water Quality? A Resource Guide for 4-H Leaders and Teachers," 80 pages of activities and experiments related to water quality. (\$5.00) Order from the Montana 4-H Program at Montana State University-Bozeman. Phone 406-994-3501.