Chapter 9. Soil, Dirt, Filters and Water Quality

Lesson 3. Most soil has a strong capacity to store, trap and filter contaminates that have a positive electrical charge.

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.

Materials Needed: For each team of students, you will need the following supplies and materials:

- Eight 8-oz. plastic tumblers
- a supply of fine soil, like loam or silt loam
- a supply of coarse soil, like sand
- a 100-ml graduated cylinder
- plastic spoons
- water
- Four funnels
- filter paper (fast and large enough to fit funnels)

- Eight clear flasks or 8-oz. (tall) tumblers
- two solutions of water, one colored yellow and one colored green with food coloring
- a solution of 1/100% (1/100th of 1% by weight) of eosine red/yellow dye (dissolve 1/10 gram in 1 liter of water)
- some type of rack to hold funnels

Note: both eosine red and methyl blue dyes are available from scientific supply businesses. You should be sure to get water-soluble material and you need only a few grams of either dye to supply all your needs for many experiments.

Procedure: Line up the eight 8-oz. plastic tumblers on the bench. Add two spoonsful of fine soil to four tumblers and two spoonsful of coarse soil, sand or gravel to the remaining four tumblers. Now add 40 ml of water to each tumbler. Alternately place one tumbler of fine soil-water beside one tumbler of coarse soil water on the bench in front of you. Add 20 ml of methyl blue to one fine soil-water tumbler and add 20 ml of methyl blue solution to one coarse soil-water tumbler. Do the same with the eosine red, Le., 20 ml to a fine soil-water tumbler and 20 ml to a coarse soil-water tumbler. Now add 10 ml of blue and 10 ml of red solution to a tumbler with fine soil-water and repeat with 10 ml of blue and 10 ml of red solution to another tumbler with coarse soil-water. Finally, add 10 ml of yellow water solution and 10 ml of blue solution to the two remaining tumblers. You should now have eight tumblers: Four with fine soil and water and four with coarse soil and water; one pair (a pair being one tumbler with fine soil and one tumbler with coarse soil) should have methyl blue, one pair should have eosine red, one pair should have purple (red and blue combination), and one pair should have green (yellow and blue combination). Using a spoon, thoroughly mix each of these.

Place an empty cup under each funnel and place a piece of filter paper in each funnel. While mixing, transfer the mixture, one at a time, into each funnel, keeping track of which solution is in each funnel. Catch all the water that drains from the funnels.

Compare the color and volume of each drainage water sample. Remind the students that the fine soil holds more water than the coarse soil. This difference should be consistent through all four pairs. Next, advise the students that the soil has electrical properties, much like a magnet. The predominant charge on soil particles is negative. The finer the soil particles, the more negative the charge. Since methyl blue is a positively charged dye, most of the blue dye is adsorbed onto the soil. However, the class can see some difference in the color/clarity of the drainage water from the fine and coarse soil. The fine soil traps more positively-charged dye than does the coarse soil. Now compare the drainage water from the funnels with the eosine red-you should see some difference between the color from the two soils, but the difference between the input water (red) and outflow water will not be nearly as dramatic as with the blue. Since the predominant charge on the soil is 73 negative and the red dye has a negative charge, little of the red dye is adsorbed: Similarly, the finer-textured soil adsorbs more dye than the coarse-textured soil.

Inform the class that food coloring is noncharged. Now, discuss with the class the outcome of the red and blue combination and the yellow and blue combinations.

Supplemental Activity (Option 2): The degree to which the soil holds water and potential contaminants, whether they are chemical or biological, is heavily dependent on the condition of the soil when water is added. As we saw in the demonstrations with paper towels, contaminants move much more dramatically in wet environments than in dry environments. Similarly, how wet the soil is when contaminants and water are added affects behavior. The following demonstration clearly illustrates this principle.

Materials Needed: For each team you will need:

- four plastic pop bottles that have had the bottoms removed; place a small amount of cotton batting in the mouth of each bottle and fill two of the bottles to an equal volume with sand and fill two of the bottles to an equal volume with potting soil
- supply of water
- red food coloring
- four 8-oz. plastic tumblers
- a rack to hold the soil columns

Procedure: Place the four soil columns in the rack and place a plastic tumbler under each column. Add 300 ml of water, in 100-ml increments, to a sandfilled column. Do the same with a column filled with potting soil. Allow the columns to completely drain-overnight, if possible. After the columns have drained, you should have two dry columns and two wet columns. Without moving or disturbing the columns, place three drops of red food coloring on the top and in, the center of each column. Place an empty 300-ml tumbler under each column. Fill two tumblers with 300 ml of water. Simultaneously and slowly pour 300 ml of water into each of the sand-filled tumblers. Watch what happens with respect to drainage amount and color- the instant you apply the water to the surface of the two columns, and while the 300ml are draining into and through the two sand-filled columns. Catch all the water that drains from the columns. Now, repeat this process with 300 ml additions to both of the columns filled with potting soil. Observe drainage (i.e., amount of food coloring that comes through, when it comes though, the color of the first drainage water, and the total volume of water draining).

After drainage has ceased, compare the color and volume from all of the columns. First compare the color and volume from the two sand-filled columns. Now do the same for the columns filled with potting soil. Compare the volume and color of water drained from the sand and potting soil-filled columns. Discuss the differences with the class. When the soil is already wet, most of the soil pores are filled with water. In order for water to enter from the top, it must push water out the bottom. The water coming out of the wetted columns will be clear, and the food coloring passing through the soil column is diluted by the water. In contrast, the food coloring in the dry columns moves along with the advance of the water. It is not held in the soil. Consequently, the first drop of water out is heavily concentrated with food coloring. Discuss the implications of this behavior, with respect to water quality and ground water contamination, with the class.

Lessons Learned: We have explored the idea of water movement, water storage, and contaminant movement and retention in different soil materials. We have seen the significant role that soil material can play and we have also seen the importance of water content, concerning contaminant retention and movement.

Because of these activities, the students should be aware of the following ideas:

1. Many soil materials exist in nature and because of differences in the properties of soils, the behavior of water and materials that might impair water quality differs from soil to soil.
2. Soil can hold and store water, the degree to which being dependent on the type of soil.
3. Approximately 50% of the total volume of soil is actually space, capable of storing water.
4. Because of the differences in water storage properties and water transport time in soil, the soil acts like a series or collection of many pipes, transmitting and storing water in transit to ground water.
5. Soil material has unique physical and chemical properties, making it possible for soil to absorb and hold on to many different types of contaminants until they can be recovered or degraded by natural processes.
6. Wet soil has much different water and chemical transmission properties than dry 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.