Groundwater Contamination (point source)

Introduction/Information

Water is a vital resource for all living things. It is believed that life originated in water. The bodies of living organisms are mainly composed of water. All living things need water to survive. The many unique properties of water also cause it to have a tremendous impact on our physical environment.

Water has many properties that make it unique. Water can dissolve more substances in greater quantities than any other liquid. However, this natural ability to dissolve and carry materials allows it to be easily contaminated as well.

Groundwater contaminants normally enter the system from the surface, not at points deep within the aquifer as the injection of dye through a piezometer might suggest.

Human activities at or near the land surface can contaminate groundwater by introducing pollutants that move through the unsaturated zone to the water table. Contamination can continue to move within the saturated zone, and discharge wherever groundwater comes to the surface. Human activities which may contaminate groundwater include over-fertilization, misuse of pesticides, oil spills, leaky landfills, leaky septic systems, and leaky underground storage tanks. The three most common contaminants of groundwater are sediment, chemicals, and fecal coliform.

Soil types also play a role in groundwater contamination. Different chemicals react differently with different soil types. Sandy soils tend to let more pollutants pass through than clay soils do. Plants at the land surface, where infiltration occurs, can absorb and/or bind some pollutants, thereby removing contaminants from the water and/or soil. One must know the characteristics of soils and chemicals to manage human activities and reduce the potential for groundwater contamination.
Groundwater pollution can come from many different sources. Some sources are easy to identify, such as a leaky storage tank, or an old landfill. This type of pollution is called **point source pollution**. Other types of pollution are broader and not as easy to identify, such as runoff from fertilized farm areas or contamination from animal wastes. This type of pollution is called **non-point source pollution**.

Remember that pumping water from wells draws water toward the pumped well from all directions. Since wells create a **cone of depression** around them as they draw water, they can also draw contaminants toward them from any direction. Pollutants from areas above, below, and even from areas that would normally be considered “downstream” can be drawn into wells.

**Your Task**

You will examine groundwater contamination concepts including potential sources of contamination and the interrelationship of human activity and groundwater contamination.

**Materials**

- Groundwater Flow Demonstration Model
- Recharge bottles (2)
- Discharge collection bucket
- Food coloring (red, green, yellow, blue)
- Grease pencil

**Safety and Disposal**

Water and diluted food coloring may be flushed down a drain with an excess of water.
Procedure
1. Before you begin, label each of the piezometers with a letter, A-G. Label the two pumping wells 1 & 2.

2. Open the outlet at the lower right side of the model. Make sure the lake outlet is closed. Place a filled recharge bottle on the left side of the model and allow water to flow through the model.

3. Locate the leaky storage tank on the model by looking for the well with the circular form at the bottom. Inject green food coloring, diluted with water, (dye) into the tank until the round tank is filled. Inject red dye into the 1st injection well (located at the far left side of the model) until you see red coloring appearing in the artesian aquifer at the bottom of the model.

Q 1: What does the green dye in the tank represent?
_________________________________________________________________

4. Observe the dye for a few minutes.

Q 2: What happens to the dye in the leaky storage tank?
_________________________________________________________________

5. Pump water from well #2. Try to determine where the water comes from that is being pumped out of the well.

Q 3: What happens to the dye from the leaky storage tank?
_________________________________________________________________

Q 4: What color is the dye that is being pumped from the well?
_________________________________________________________________

Q 5: What conclusions can you draw from this?
_________________________________________________________________
6. **Point source contamination** is contamination that comes from one easily identifiable source, such as the leaky storage tank. When a well is pumped, a cone of depression is created. A cone of depression is a three-dimensional area from which the well draws water; it surrounds the well and draws water from all directions when the well is pumped. If there is a point source nearby, the well will draw the pollutants out along with the water. Drinking water wells can be contaminated by pollutants that are both downstream and deeper than the pumping well. Wells can be contaminated by human activity at or near the land surface.

7. Allow water to continue to flow through the model. Observe that the plumes of green dye you injected into the tank are separating into blue and yellow.

**Q 6:** What does this tell you about the way pollutants travel through the groundwater?

_________________________________________________________________

8. Groundwater can carry pollutants that it has picked up as it flows through the system. However, some chemicals move faster than others in groundwater. The soil particles that make up an aquifer may weakly absorb some chemicals, slowing their flow rate. Others are more soluble and move through more rapidly. These soluble chemicals are good indicator chemicals to test for in drinking water. They can tell us that a pathway exists between a source of contamination and a drinking water well. Other chemicals associated with that source may also move down that pathway, although perhaps not as quickly or in as great a concentration.

9. Observe the water that has been collecting in the lake.

**Q 7:** What color is the water?

_________________________________________________________________

**Q 8:** Where does the water that is filling the lake come from?

_________________________________________________________________

10. Surface water bodies such as lakes and rivers have two major sources of water: surface runoff from rainfall and snowmelt, and groundwater flow, or baseflow. Baseflow is the reason that streams flow even during dry spells. In addition, since the temperature of groundwater is about 50 degrees F year-round, baseflow allows streams to flow in winter even when the ground is frozen. Any contaminants in groundwater can be discharged into surface water through baseflow.
Q 9: What is baseflow?

11. In many ways, surface water is better able to treat contaminants than groundwater. Natural processes such as sunlight, aeration, and turbulence break down some pollutants. Additionally, some pollutants can be tied up in healthy riparian plant growth. However, other pollutants from groundwater can cause algae blooms, weed problems, and turbidity in surface waters.

Q10: Why can surface water treat contaminants better than groundwater?

Q11: List the problems that pollutants from groundwater can cause.

12. Make sure there is sufficient red dye in the lake for it to show in the sediments as it leaves the lake. Inject more dye into the lake if necessary.

13. Pump well #2 steadily until you see dye being drawn toward it from the lake/stream depression.

If the cone of depression created by pumping the well extends all the way to the lake/stream, the lake/stream can actually recharge the groundwater. This occurs in some municipal wells and irrigation wells located in sandy aquifers near river systems. The filtering action of the sand removes most microorganisms, but chemical contamination can still enter the aquifer.

14. Observe that most of the dye you injected has moved downward and to the right. However, some has moved upward. This movement is caused by capillary action. Capillary action, or capillarity, is a phenomenon that explains the upward movement of water above the surface of the water table. Water is attracted to and adheres to surfaces of solid materials. In addition, hydrogen bonds bind water molecules to each other. As water molecules are attracted to soil particles, water is drawn upward into the small pore spaces between the soil particles. This allows water to move upward in small pores above a saturated layer. The pore spaces in the sandy and gravel materials are small enough to act as capillary tubes. The smaller the size of the pores, the higher the water will rise in them. Because soil pores are not straight uniform openings, capillary rise in natural soil is less than it would be in similar sized glass tubes.
Q12: In your own words, define capillary action.

15. Observe that the dye spots, when they first enter the aquifer, occur only in a narrow zone. As the dye plumes move down-gradient, they become wider. Contaminants entering an aquifer often do so only at a point or in a narrow zone. The concentration of the contaminant may be quite high in the small volume of water. Often the contaminant is concentrated near the top of the water table. However, as groundwater continues to move, the zone of contamination widens and spreads out. Here, the contaminated area may be wider, but the concentration of pollutants is not as great. This process is called dilution.

16. Pump water from the well in the deep aquifer. Notice that the water levels drop rapidly in the piezometers which extend into the artesian layer. The water levels in the piezometers in the shallow aquifer are relatively stable, since a confining layer separates the two aquifers. However, also notice that dye begins to move downward in the sand aquifer toward the confining layer.

Q13: What does the movement of the dye seem to indicate?

17. The gravel aquifer is able to yield large volumes of water and recharge itself quite rapidly. However, when water is withdrawn from the artesian aquifer, a zone of lower pressure is created which induces water movement downward through the confining layer. Water moves through the confining layer very slowly, carrying dye with it and showing that the confining layer is not a totally impermeable barrier to water flow-through. In addition, most naturally occurring confining layers vary in thickness, and may be fractured or discontinuous. The presence of a confining layer is not always sufficient to protect a valuable aquifer below from contamination if a large waste source is placed above it.

Q14: How does an artesian aquifer become contaminated by pollutants in the overlying aquifer?
**Discussion and Conclusions**

As you have seen, some sources of contamination occur at an easily identifiable source, called a point source. Some sources of contamination may occur as a single slug, such as a spill. These will eventually move through and be flushed out of the groundwater system. Contamination sources may also input contaminants continuously, such as a wastewater treatment lagoon, septic system, or landfill. As these are flushed out of the groundwater system, additional contaminants from the point source will move in to replace them.

Unlike our model, the environment is not easily able to eliminate pollutants. Contaminants in groundwater may move only a few feet each year, meaning that they will remain in groundwater for many years. Eventually, the contaminants that are not chemically or biologically modified will reach a discharge zone. The contaminated groundwater that discharges into rivers, if not removed by natural treatment processes, eventually makes its way to the ocean. The more contaminants in the water, the less likely it is that natural processes will be able to adequately clean the water.

This activity has been adapted from the Groundwater Flow Demonstration Model Activities for Grades 6 – 12, by Dr. Kitt Farrell-Poe, Extension Environmental Engineer, Utah State University Extension, October 1997, Utah State University Extension.