Instructor Notes

Sources of Potential Groundwater Contamination

This activity is about the potential risks to groundwater supplies. You may wish to use it following a "parts per million" activity. Participants construct several models that demonstrate potential sources of contamination, including agricultural fields, oil spills, disposal lagoons, sinkholes, landfills, leaky barrels, and faulty septic systems. Each participant will construct one type of system, answer the assigned questions, and share his or her findings with the other members of the group.

The activity is written for workshop participants and may need modification for classroom use.

Suggested Background Reading

- An Introduction to Groundwater Hydrology

National Science Education Standards for Grades 5–12

Science as Inquiry

- Abilities Necessary to Do Scientific Inquiry
  Conduct scientific investigations. Students use sand and gravel models to perform scientific investigations that demonstrate potential sources of groundwater contamination.

  Formulate scientific explanations using logic and evidence. Students use scientific knowledge, logic, and evidence from their investigation to formulate contamination results and explanations.

  Communicate and defend a scientific argument. While discussing their investigational results with the class, students use appropriate language, speak clearly and logically, construct a reasoned argument, and respond appropriately to critical comments.

Science in Personal and Social Perspectives

- Environmental Quality
  Materials from human societies affect both physical and chemical cycles of the earth. Students learn that agricultural contamination, oil spills, disposal lagoons, landfills, leaky barrels, and faulty septic systems can contribute to groundwater contamination.

- Natural and Human-Induced Hazards
  Natural and human-induced hazards present the need for humans to assess potential danger and risk. Students learn that changes humans make to the environment bring benefits and cause risks to society. Students discuss the costs and trade-offs of various

health and environmental hazards and determine that the scale of adverse events and the accuracy with which scientists and engineers predict these events are important considerations.

Materials

For Getting Ready

These materials are needed to make one of each contamination model. Increase the quantities as needed for your workshop.

- 10 g powdered orange-flavored drink mix
- 3-ounce paper cup
- set of 4 food colors
- flexible drinking straw
- 3 jars with lids or zipper-type plastic bags
- small balloon or plastic wrap
- 10–15 cotton balls
- 4, 35-mm film canisters with lids
- 30 mL vegetable oil
- 10 g cocoa
- straight pin
- Phillips-head screwdriver or large nail of the same diameter as the straws used
- candle and matches or other flame source
- balance
- labels
- scissors
- beaker or plastic cup
- graduated pipet
- imitation vanilla flavor
- (optional) other extract flavors
- (optional) hot glue gun and glue or silicone sealant

For the Procedure

Per group of 4 participants

- 4 pop-beakers (prepared from clear plastic 2-L bottles in Getting Ready)
- 4 clear drinking straws
- scissors
- roll of masking tape
- 4, 9-ounce bags of aquarium gravel
- 4 coffee filters
- 4, 9-ounce bags of clean play sand
- Beral pipets

- 2–4 spray bottles containing water (to simulate rainfall)
- 4 small disposable plastic or paper cups or 4 small glass beakers
- 8 sugar cubes
- (optional) box to hold all materials for each group

Getting Ready

Cut off the tops of clear plastic 2-L bottles to make “pop-beakers” as shown in Figure 1.

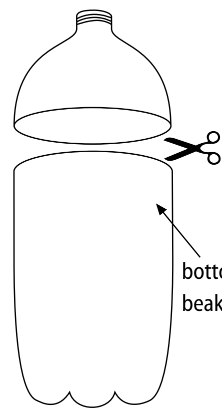

Figure 1: Preparing a pop-beaker

You may find it easiest to put the supplies for each group in a plastic or cardboard container or simply to let the participants obtain the necessary materials from one supply table. Below is a detailed description of the preparation for each model in this lab activity.

Agricultural Contamination

Place 10 g orange-flavored drink mix in a 35-mm film canister labeled “agriculture.”

Oil Spill

Mix 30 mL vegetable oil with 10 g cocoa. Place this mixture in a 35-mm film canister labeled “oil spill.”

Leaky Barrels

Heat a straight pin in a flame and use it to poke 10–15 holes into the bottom and sides of a 35-mm film canister. Label the canister “leaky barrel.” Soak 4–6 cotton balls in food color or some type of extract (cherry, lemon, anise) to add odor, and seal them in a sealable bag or jar. Do not put the cotton balls into the film canister until the groups are ready. Alternatively, you can allow the participants to add the cotton balls themselves (though this can get a bit messy).

Disposal Lagoon

Cut a 3-ounce paper cup to a height of 2 cm. Poke 10–15 holes in the bottom and sides of the cup with a straight pin. Prepare a 50/50 mixture of water and imitation vanilla. Store this mixture in a jar or bottle labeled "lagoon sludge." Have the participants pour the "sludge" into their cups once they have placed them in the sand in their groundwater model. Label each paper cup "lagoon."

Landfill

Soak 4–6 cotton balls in food color or flavored extract and stuff them into a small balloon. (The inexpensive water-balloon type makes a great landfill.) Tie off the balloon. When the groups are ready, use a straight pin to poke 10–12 holes in the balloon. Alternatively, you may use plastic wrap instead of a balloon, as it will "leak" faster.

Septic System

The septic system is the most complex system to construct in this activity. For this reason, if you are short on time, or if you live in an area serviced by city sewers instead of septic tanks, you may want to omit this part of the activity. An assembled septic system model is shown in Figure 2.

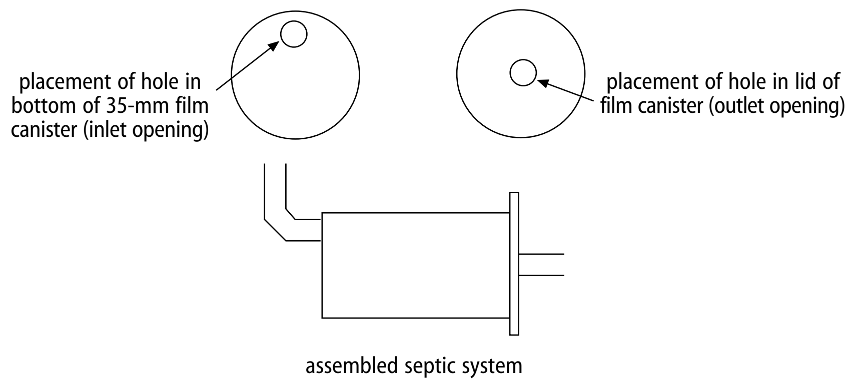

Figure 2: Assembling a septic system model

Use the following steps to construct the septic system.

1. Heat your screwdriver or nail in a flame. Touch the heated point to the bottom of a 35-mm film canister, near the edge of the bottom. The point should melt a clean hole in the bottom of the canister. This is the inlet opening. This is referred to as the "toilet" in the Activity Instructions.
   Use a Phillips-head screwdriver (or a large nail) the same diameter as your straws. When heated in a flame, this screwdriver (or nail) easily melts a hole of the correct diameter in a 35-mm film canister.
2. Reheat your screwdriver or nail in the flame. Touch the heated point to the middle of the film canister lid. This hole is the "outlet" opening.
3. Bend the flexible straw to a 90-degree angle. Using scissors, cut the straw off 1 cm beyond the end of each side of the flexible ridges. Cut a 4-cm section of the nonflexible part of the straw. The bend of the straw serves as the inlet, and the straight section of straw is the outlet.

4. Insert the flexible part of the straw into the bottom of the film canister and the nonflexible part into the lid. Each piece of the straw should just barely extend into the interior of the canister. If the fit is not tight, seal around the straw with a hot glue gun or a silicone sealant. The only openings in this system are the ends of the straw.

Soak 3–4 cotton balls in a very concentrated mixture of 50/50 red and green food color and store them in a sealed container until needed. Label these "septic system." Also, place some of this mixture (or the lagoon sludge) into a beaker or plastic cup. This will represent what is typically flushed down a toilet.

Next, cut off a graduated pipet 1 cm from the 1-mL marking (the bulb). Place this into the bendable straw. Participants will fill the pipet with wastewater (the food color mixture) and "flush" it into the "toilet" through the bent-straw inlet opening. It may take 5–10 flushes to get a significant amount of effluent running through the septic field.

Procedure Notes and Outcomes

Have each participant construct one type of system according to the Procedure, then have them answer the questions assigned for that system and share their findings with the other members of the group.

Answers to question 1 will vary based on participants' opinions and experience. Questions 2–4 will require some outside research to answer for each model. You may wish to assign them as a written assignment or have an additional class discussion on another day.

References

"Leaky Layers." Partners for Terrific Science Program, Miami University, Ohio, 1993, unpublished.

Barker, M. "Modeling Groundwater Contamination" Activity, EPIcenter Program for Teachers: Purdue University, 1996.

Raymond, L.S. *Groundwater Contamination;* New York State Water Resources Institute Bulletin No. 174GWI; Cornell University: Ithaca, NY, July 1988.

Activity Instructions

Sources of Potential Groundwater Contamination

This activity is designed to explore some potential risks to groundwater supplies. Several models will be constructed in this activity that demonstrate potential sources of contamination, including agricultural fields, oil spills, disposal lagoons, sinkholes, landfills, barrels, and faulty septic systems. Each participant within a group will construct a different model, answer the assigned questions, and share his or her model with the other members of their group.

Procedure

Preparing the Groundwater Model

This part of the procedure will be the same for each member of the group. After step 7, continue to the instructions for your chosen contamination model. Each participant within a group should assemble a different contamination model. When finished, demonstrate your model to the instructor and to the other members of the group. Return all materials and supplies and clean up your area.

1. Place a pop-beaker on a smooth, level surface.
2. Cut the straw with scissors to a length equal to the depth of the pop-beaker.
3. Attach this length of straw to the inside of the container with tape. Try to keep the straw as straight up and down as possible. One piece of tape will be sufficient. The straw should almost, but not quite, touch the bottom of the container.
4. Add one bag of aquarium gravel to the container-and-straw assembly.
5. Place a coffee filter on top of the gravel in the container. Try to arrange the filter so that as much of the filter as possible is touching the gravel and the inside of the container. (You may have to slightly fold it.)
6. Pour just enough sand on top of the gravel-filter boundary to keep the filter in place. Keep the rest of your sand; you will need it for later steps.
7. Put one of the pipets into the straw. (This is the well.) If you are unsure about your model, ask your instructor for input.

Agricultural Contamination

1. Pour the rest of the sand evenly into the container.
2. Wet the sand and gravel in the container with the spray bottle until you see a pool of water forming in the gravel and in the straw well.

3. Obtain an “agriculture” container (a film canister) from your instructor.
4. Sprinkle the agriculture mixture onto the surface of the sand.
5. Wet the surface with 8 or 10 pumps of the spray bottle.
6. Withdraw one pipet of water from the well. Notice whether there is any change in the odor or appearance of this first withdrawal. Squeeze the withdrawn water from the pipet into the extra cup.
7. Repeat this process of spraying and withdrawing water at least 10 times. Record any significant changes in appearance or odor of the water.

Oil Spill

1. Pour the rest of the sand evenly into the container.
2. Wet the sand and gravel in the container with the spray bottle until you see a pool of water forming in the gravel and in the straw well.
3. Obtain an “oil spill” container (film canister) from your instructor.
4. Spread the “oil” evenly on the surface of the sand.
5. Wet the surface with 8–10 pumps of the spray bottle.
6. Withdraw one pipet of water from the well. Notice whether there is any change in the odor or appearance of this first withdrawal. Squeeze the withdrawn water from the pipet into the extra cup. You might also want to dip your fingers in this withdrawn water and observe how it feels to the touch.
7. Repeat this process of spraying and withdrawing water at least 10 times. Record any significant changes in appearance, odor, or feel of the water.

Leaky Barrels

1. Obtain a “leaky barrel” from your instructor. Lay it on its side in the middle of your container. Cover the container with the rest of the sand.
2. Wet the sand and gravel in the container with the spray bottle until you see a pool of water forming in the gravel and in the straw well.
3. Withdraw one pipet of water from the well. Notice whether there is any change in the odor or appearance of this first withdrawal. Squeeze the withdrawn water from the pipet into the extra cup.
4. Repeat this process of spraying and withdrawing water at least 10 times. Record any significant changes in appearance or odor of the water.

Disposal Lagoon

1. Pour the rest of the sand evenly into the container.
2. Obtain a paper-cup "lagoon" from your instructor. Press the cup into the sand, moving the sand with your fingers if necessary to set the cup in solidly. Pour lagoon "sludge" into the cup.
3. Wet the sand and gravel in the container with the spray bottle until you see a pool of water forming in the gravel and in the straw well.
4. Withdraw one pipet of water from the well. Notice whether there is any change in the odor or appearance of this first withdrawal. Squeeze the withdrawn water from the pipet into the extra cup.
5. Repeat this process of spraying and withdrawing water at least 10 times. Record any significant changes in appearance or odor of the water.

Landfill

1. Obtain a balloon "landfill" from the instructor. Place the balloon on the sand, knot side up. Pour the rest of the sand around the balloon, covering it entirely, if possible.
2. Wet the sand and gravel in the container with the spray bottle until you see a pool of water forming in the gravel and in the straw well.
3. Withdraw one pipet of water from the well. Notice whether there is any change in the odor or appearance of this first withdrawal. Squeeze the withdrawn water from the pipet into the extra cup.
4. Repeat this process of spraying and withdrawing water at least 10 times. Record any significant changes in appearance or odor of the water.

Sinkhole

1. Obtain 8 sugar cubes from the instructor. Stack them in a cube in the center of your container. You may want to stagger the cubes instead of making a perfect cubic structure. Cover them evenly with the rest of the sand.
2. Wet the sand and gravel down in the container with the spray bottle until you see a water table forming in the gravel and in the straw well.
3. Withdraw one pipet of water from the well. Notice whether there is any change in the appearance of the area occupied by the sugar cubes. Squeeze the withdrawn water from the pipet into the extra cup.
4. Repeat this process of spraying and withdrawing water at least 10 times. Record any significant changes in the appearance of the area occupied by the sugar cubes.

Septic System

1. Obtain the "septic system" setup from your instructor. Place it in the center of the container with the "outlet" (nonflexible straw end) pointed down into the sand. Cover the setup evenly with sand, leaving the "toilet" (the flexible end) exposed above the surface of the sand.
2. Wet the sand and gravel down in the container with the spray bottle until you see a pool of water forming in the gravel and in the straw well.
3. Withdraw one pipet of water from the well. Notice whether there is any change in the odor or appearance of this first withdrawal. Squeeze the withdrawn water from the pipet into the extra cup.
4. Using the wastewater provided, "flush" the toilet several times by inserting the "toilet" pipet full of wastewater into the inlet valve and expelling the water into the septic system. After every third flush, withdraw a pipet of water from the well. Repeat this process 10 times. Record any significant changes in appearance or odor of the water.

Questions

Answer the applicable questions. Compare your answer to question 1 for All Contamination Models with other participants' answers. Some research might be required to answer questions 1–3 for each of the contamination models.

All Contamination Models

1. Were there any significant changes in the appearance, texture, feel, or odor of the withdrawn water? If so, indicate at which withdrawal these changes occurred.

Agricultural Contamination Questions

1. Do all chemical fertilizer, pesticide, and herbicide residues end up in our groundwater supply? Why or why not?
2. What are some ways to reduce the risk of contamination from agricultural residues?
3. Are there any alternative choices to the chemicals mentioned above? Give examples.

Oil Spill Questions

1. What property of oil-based products creates problems in a water supply?
2. How did people clean up the Valdez oil spill, which occurred off the coast of Alaska? How would you have cleaned it up?
3. Which do you suppose is the safest way to transport oil: pipeline, train, truck, or ocean tanker? Give reasons for your answer.

Leaky Barrel Questions

1. What would happen to metal barrels that are buried underground over a long period of time?
2. Do you suppose that everything stored in barrels underground is toxic to humans? Why or why not?
3. Have you ever seen barrels thrown into ditches in your area? If so, did you think that they might contain some dangerous substance?

Disposal Lagoon Questions

1. How could a flood occurring in a lagoon area create more problems than a localized groundwater contamination?
2. What do you suppose could be contained in a lagoon near an industrial site?
3. Would you consider fishing or swimming in a lagoon near an industrial site? Why or why not?

Landfill Questions

1. Where is the closest landfill in your area? Why was this site selected?
2. What special precautions do you suppose landfill operators must take to ensure that their landfill does not leak?
3. Years ago, people just threw their trash in country ditches or even in city streets. Why can't we just continue to do that today?

Sinkhole Questions

1. Many people throw trash and waste in sinkholes. What could result from this action?
2. What type of underlying rock is generally associated with sinkholes? Is that type of rock present in your area?
3. Why do many people living in sinkhole areas have water softeners in their homes?

Septic System Questions

1. What is the basic function of a septic system? Is it storage or biodegradation? Explain.
2. Why do regulations exist concerning the location of septic systems near lakes and rivers?
3. Why do septic tanks need to be pumped out, and where does that material end up?