Groundwater and Surface Water Interactions

Investigation Manual

CAROLINA DISTANCE LEARNING

GROUNDWATER AND SURFACE WATER INTERACTIONS

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Overview

Clean drinking water is vital for all human life. In this lab, students will learn how freshwater sources interact through the natural processes of the **hydrosphere** (all the water on the planet) and what happens to drinking water supplies when our planet becomes altered by human activities. Students will design models of different scenarios that affect the earth's surface water and groundwater. The models will demonstrate overconsumption and drought situations, along with water conditions influenced by point and non-point source pollution, to examine human-induced effects on the earth's water cycle.

Outcomes

- Describe the importance of freshwater availability to the health of human populations.
- Construct multiple groundwater and surface water models and analyze different ways the water can become contaminated.
- Distinguish between point and non-point pollution sources and explain the impact of each.
- Recognize the interconnectedness of groundwater and surface water in the environment.

Time Requirements

Preparation	15 minutes
Activity 1: High Withdrawal and Recharge	45 minutes
Activity 2: Point Source Pollution	15 minutes
Activity 3: Non-Point Source Pollution	45 minutes

Key

Personal protective equipment (PPE)

goggles gloves apron

follow link to video

photograph results and submit

stopwatch required

warning corrosion flammable toxic environment health hazard

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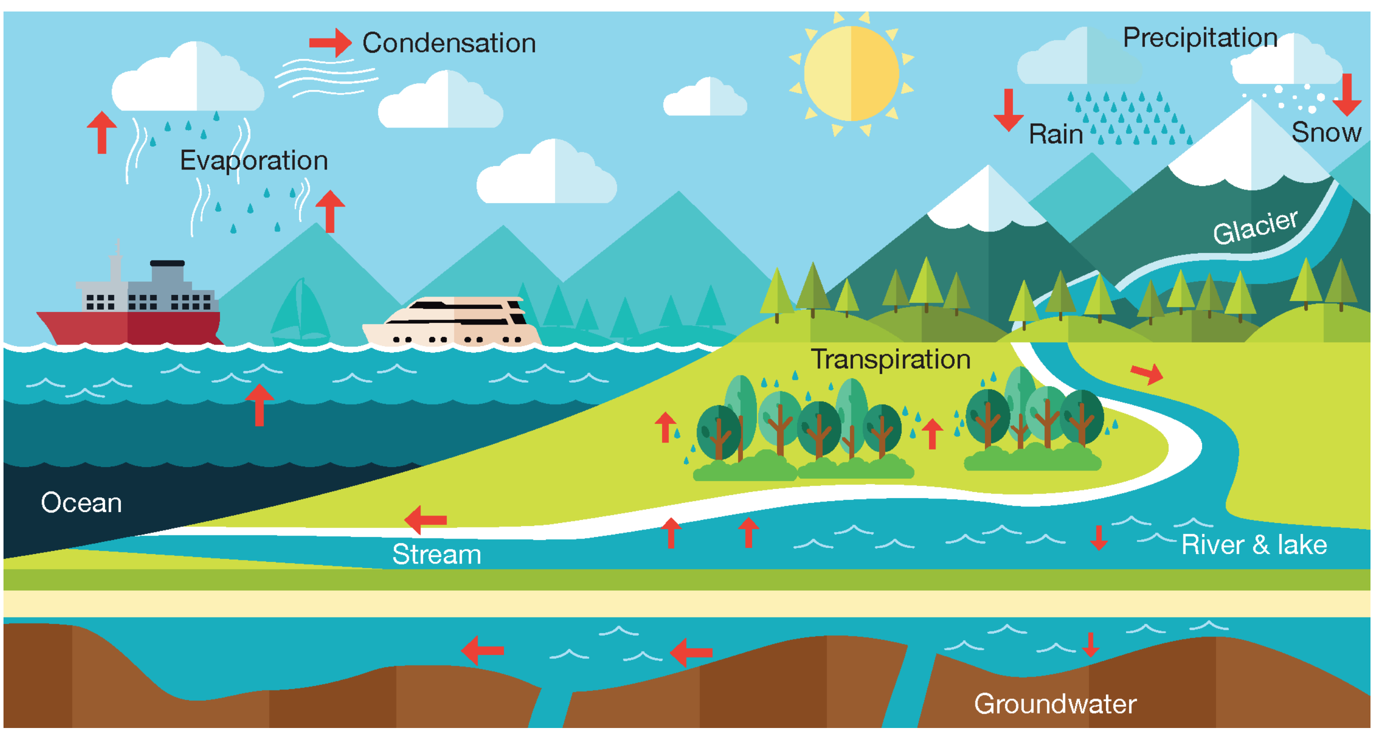
Background

The **hydrosphere** encompasses all the water on the planet. It includes freshwater and saltwater; liquid, solid, and vapor; and water that is both above ground and underground. All of these different sources of water interact and transform into one another through processes within the biogeochemical cycle known as the **hydrological or water cycle** (see Figure 1). Water falls to the earth as precipitation and runs off the land's surface, infiltrates the ground, or evaporates from surface waters such as oceans, lakes, and rivers. The evaporated water vapor condenses in the clouds and falls to the earth over time as precipitation. Then the process begins again. The water that has infiltrated the ground, known as **groundwater**, is located in and below the **water table**, which is the top layer of the soil in which groundwater fills most of the pores. In the water table, water is able to enter the ground through unsaturated surface soil voids, filling the soil below this level due to natural gravitational pull. With this natural movement of water, the hydrosphere continuously cycles all phases of water to all parts of the earth.

While water encompasses approximately 70% of Earth's surface, freshwater, which accounts for only 3% of Earth's water, is the only type of water that is readily accessible for human consumption. However, of that 3%, just under 1% is readily accessible, with the remaining water being held in Earth's icy regions, which include glaciers and polar ice caps. This is known as the **cryosphere**, or the frozen portion of the hydrosphere (see Figure 2).

Figure 1.



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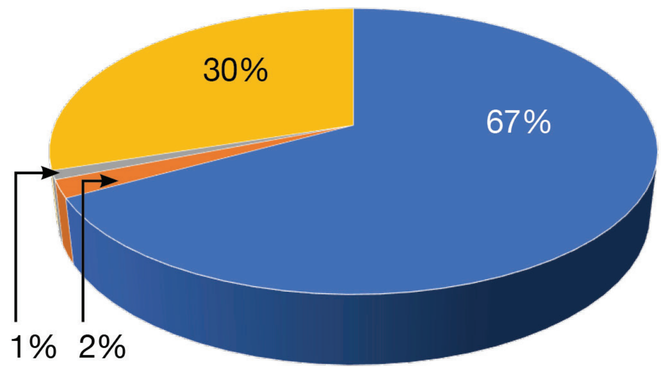
Background continued

Figure 2.



- 67% Saltwater
- 30% Land
- 2% Frozen Water
- 1% Groundwater/Surface Water/ Atmosphere

Groundwater

Freshwater available for human use is made up of surface water and groundwater. When precipitation falls from the atmosphere to the earth, it becomes part of the environment by either washing across the land and into bodies of water or by percolating through the surface of the soil. Here, it can be taken up by plants or filtered deep into the ground. In the latter case, this surface water enters the ground through areas known as **recharge zones**. Water enters these unsaturated zones on the surface of the land by the natural pull of gravity. The **porosity** of a material is a measure of the void spaces in the rocks and soil, and the ability of water to pass through those void spaces is known as **permeability**. This water now enters the groundwater system and saturates the ground beneath. People rely on these zones to recharge aquifers. Through the use of wells, people can supply water to their homes.

Deeper into the ground, multiple layers of unsaturated and saturated soil of many different pore sizes and material types exist. Some of these layers are permeable, whereas others are **impermeable**, which means that water cannot easily pass through them. Many types of ground consist of permeable materials, like rocky sediment, fine sand, or soil. Others are made of less permeable materials that impede the percolation of water, such as claylike dirt, thicker sand, or man-made structures such as paved streets and sidewalks. The types of material that make up the consistency of the ground impacts the ability to access the groundwater.

Groundwater can sometimes be accessed by pumping wells placed in **aquifers**. Aquifers are underground basins from which water can be removed at a reasonable rate, with the most ideal aquifers containing many pore spaces for water storage. However, the size, depth, and amount of water within an aquifer can vary greatly, making the process of extracting groundwater from an aquifer variable as well. While most of Earth's accessible freshwater is held in the ground, much of it is too deep for humans to access.

Surface Water

The small amount of remaining freshwater accessible for human use is made up of all the surface water from lakes, rivers, and ponds as well as the water vapor in the atmosphere (see Figure 2). There are many regions that don't have access to groundwater sources and must rely on reservoirs, such as natural and man-made lakes, as a source of drinking water. With surface water making up a small

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percentage of freshwater worldwide, events such as droughts or excessive withdrawal from reservoirs within these areas can cause rapid depletion of vital water for highly populated, metropolitan areas that rely on these sources of drinking water. Also, many human-induced factors can lead to inaccessible freshwater. Impervious surfaces such as roads, parking lots, and buildings can limit the quality of accessible water by creating a surface for the runoff of pollutants into nearby bodies of water. Additionally, most water that is withdrawn from a waterway or aquifer is returned to the environment, but some is taken up by plants and animals or lost to evaporation, adding another source of inaccessible freshwater for humans.

To understand how surface water and groundwater affect each other, let's investigate some of these same scenarios but from a different perspective. For instance, impervious surfaces not only negatively affect the quality of surface water, but they can also block access to and pollute groundwater sources. Also, when excessive water is withdrawn from a groundwater well that is pumping water stored in the water table, surface water levels can be reduced greatly and can ruin the quality of the water. Similarly, pumping water from a freshwater reservoir can lower groundwater levels and possibly cause contamination.

On the positive side, if there is sufficient rainfall in an environment, the water could overflow the land, feeding into marshes, rivers, or lakes. In contrast, if surface water receives excess rainfall, it could run onto and infiltrate the land to become groundwater. All in all, to truly understand the availability of water in a region, recognizing the interconnectedness of groundwater and surface water is of vital importance.

Human-Induced Actions that Affect the Water Cycle

There are many ways to limit or contaminate the freshwater available to humans. The overload of substances that are harmful to the environment, known as pollution, is a major issue affecting today's freshwater supply. It is easier to determine the origin of certain pollutants than others; in turn, it is easier to prevent certain pollutants from occurring in the future than others. **Point source pollution** is pollution that can be tracked to one specific source. This source of pollution is identifiable and able to be limited if proper action is taken to control the pollutant source. A pipe from a wastewater treatment plant discharging waste into a water source (see Figure 3) and a person dumping gasoline into a water supply (such as a lake)

Figure 3.

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Background continued

are examples of point source pollution. Many restrictions have been put in place to control waste from industries and wastewater treatment plants, but enforcing them is not an easy task.

If the origin of a pollutant is unknown, it may be difficult to determine how it entered the freshwater supply. **Non-point source pollution** usually occurs from the movement of pollutants through a system to a different area, making its origins much harder to discover. When water moves toxic chemicals—such as fertilizers and pesticides, oil, and gasolines—over the ground or through an aquatic system such as a river or stream, the pollutants can travel large distances. Figure 4 shows an example of this movement of polluted water over an impermeable surface (road) into the sewer system. All these types of pollutants can start in one region and end up many miles away, making this type of pollution very difficult to prevent. Non-point source pollution is also the most prevalent type in the environment, making it extremely important to monitor.

Figure 4.

While pollution is a big part of what limits our available freshwater resources, there are also issues with overwithdrawal and overconsumption from aquifers and reservoirs. With very few limits set on water usage in most developed countries, people worldwide use water at a rate that is faster than it is able to be replenished in the environment. Although water is recycled through precipitation, evaporation, and runoff in the water cycle, there is a need for limits on water usage to ensure that sufficient water supplies are accessible. In a model known as the **water budget**, the inputs, outputs, and storage of water in the environment are calculated and balanced to ensure equal recycling.

However, with droughts and excessive withdrawals occurring in many areas around the world, water usage must be monitored and lowered to keep the budget balanced. In the United States, each person uses an average of 150 gallons of water per day; in multiple developing countries, the average person uses fewer than 10 gallons of water per day. Of the large amount of water that is used by the United States, only 13% is used by households. The other 87% is used by industry and for agriculture. Even though there is only a small percentage of freshwater readily available for human consumption around the world, it is still being used at a rate that can lead to dangerously low levels in the near future.

Through the following activities, you will create groundwater and surface water models to demonstrate the impact of several important factors on drinking water.

Materials

Needed from the materials kit:

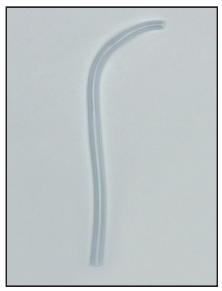
Clay, ¼-pound blue bar

Sand, 4 cups

Gravel, 2 cups

Plastic container, 64 ounces

Kool-Aid® drink mix packet



2 Pieces aquarium tubing

2 Plastic tubes

3 Straws

Syringe, 10 mL

Disposable pipet

Foam cup

Needed from the equipment kit:

Plastic cup

Permanent marker

Needed but not supplied:

- Water
- Tape
- Plastic bowl/container
- Scissors
- Paper towels
- Stopwatch (or a cell phone with a timer)
- Camera (or cell phone capable of taking photographs)

Important: Items will be reused. **Do not throw anything away** between activities. You will rinse items such as sand and gravel over a plastic bowl/container placed in the sink to separate the materials from each other; the bowl will prevent any excess materials from clogging the sink. You will rinse the syringe and aquarium tubing between activities and reuse them. You will also use the clay and Kool-Aid® drink mix for multiple activities, so be sure to save these materials.

Reorder Information: Replacement supplies for the Groundwater and Surface Water Interactions investigation can be ordered from Carolina Biological Supply Company, item number 580817.

Call: 800.334.5551 to order.

Safety

Wear your safety goggles, gloves, and lab apron for the duration of this investigation.

Read all instructions for these laboratory activities before beginning. Follow the instructions closely, and observe established laboratory safety practices, including the use of appropriate personal protective equipment (PPE).

Do not eat, drink, or chew gum while performing these activities. Wash your hands with soap and water before and after performing each activity. Clean the work area with soap and water after completing the investigation. Keep pets and children away from lab materials and equipment.

The clay may stain your clothing and hands, so be sure to use care and wash your hands thoroughly after handling this item, in particular. Make sure to wear your gloves and your lab apron when handling the clay.

Preparation

1. Read through the activities.
2. Obtain all materials.
3. Find a large, open table to serve as the work area. Clean the work area.
4. Have a trash can and an accessible sink nearby.

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ACTIVITY 1

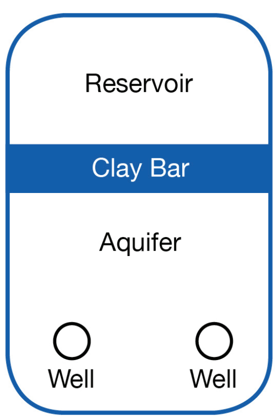
A High Withdrawal and Recharge

In the following activity, you will learn the importance of the water cycle and how withdrawal and recharge are two processes that continuously affect the environment but are not always in a balanced state. You will create a model where a drinking water reservoir and a layer of land with groundwater wells within it will be separated from each other by an impermeable layer. To help better understand the interconnectedness of the two water systems, you will determine different rates of withdrawal and recharge.

How do you think the removal of water from the well will affect the water in the reservoir? Propose a hypothesis stating whether you think the water level in the reservoir will rise, drop, or remain the same, and describe your reasoning. Complete this information in the "Hypotheses" section of the **Lab Worksheet**.

1. Place a block of clay in the plastic container so it is one-third of the total distance away from one side of the container. This piece of clay will act as an impermeable retaining rock, so make sure to mold the clay so that it fits tightly on the sides and on the bottom of the container. If you find the block of clay difficult to mold, heat it in a microwave on high power for 7 seconds, and it will become much more pliable.

Figure 5.



2. The smaller section will represent the reservoir and the larger section will be the aquifer, as seen in Figure 5.
3. Take one of the clear plastic tubes (not to be confused with the aquarium tubing), and cut it in half with a pair of scissors. These two cylinders will model wells drilled into the ground to reach the aquifer.
4. Add just enough sand to cover the bottom of the aquifer section, spreading the sand with your hands to level it out.
5. Place the two cut plastic tube pieces (wells) upright in the sand near the edge of the container in the aquifer farthest from the clay bar at random areas (see Figure 5). Ensure that each well is seated firmly against the bottom of the container.
6. Add another layer of sand, making sure to have the sand slightly higher up on one well than the other.
7. Form the next layer of the aquifer by adding enough gravel to cover the sand while creating a slight incline. Form the top of the incline around the wells. The gravel hill should slope downward toward the retaining wall (clay) and should be even with the top of the clay (see Figure 6a and 6b).

Figure 6a.

Figure 6b.

continued on next page

ACTIVITY 1 continued

8. To represent precipitation, poke approximately 10 holes in the bottom of the foam cup and fill it with water (over the model), allowing the water to sprinkle onto the top of the slope, near the edge of the container behind the wells. Some water may leak into the reservoir.
9. Fill the smaller section (the reservoir) with water until the water level rises a few centimeters over the clay retaining wall.
10. The top of the water table is represented by the height of the water in each of the wells.
11. Insert a straw into one of the wells until it touches the bottom. Hold your forefinger tightly over the open end of the straw to create a seal, and then remove the straw from the well. Use the permanent marker to draw a line to mark the top of the water level in the straw. This line represents the top of the water level in the aquifer.
12. Using a disposable pipet, drain this well by squeezing the round bulb of the pipet before putting it into the water, putting the pipet tip down into the water, and releasing the bulb to suck up the water. This water can be placed in a cup for disposal. Use the pipet to empty all the water in this well. (There may be a mixture of sand and water removed.)
13. As soon as you have removed all the water in the well, place the straw back into the bottom of the well and remove a water sample as you did in Step 11. Mark the top of the water column with a permanent marker as before. This represents the level of water in the well after a period of high withdrawal. Record your observations in the “Observations” section of the **Lab Worksheet**.
14. Wait 2 minutes and observe what happens to the drained well. Measure the water level again using the straw and the permanent marker, and note if the height of the water table has changed in the “Observations” section of the **Lab Worksheet**. Has the height of the water table decreased or increased? Take a photograph, zooming in on the markings on your straw to show how much this water level has changed. Include in your photograph a strip of paper with your name and the date clearly written on it. You will be uploading this photograph to your lab report.
15. If needed, refill the reservoir with water until the water level rises a few centimeters over the retaining wall (as in Step 9).
16. Repeat Steps 11–14 using the other well.

ACTIVITY 2

A Point Source Pollution

For this activity, you will create a model of point source pollution: a large industrial plant is disposing of its waste materials through a discharge pipe into a drinking water reservoir. You will see how these pollutants play a role within the water cycle and if an impermeable layer has an effect in blocking contamination of the groundwater.

Do you think that the polluted water from the reservoir will enter the groundwater supply? Propose a hypothesis stating what you think will

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happen, and describe your reasoning. Complete this information in the “Hypotheses” section of the **Lab Worksheet**.

1. If the water from the reservoir in Activity 1 has a large amount of sand in it, pour it into a bowl and remove any excess sand from the reservoir. Do your best to let only water drain from the aquifer section, ***keeping all other materials (clay, sand, gravel, and tubes) in place***.
2. Take one of the thinner, flexible aquarium tubes and cut it in half. This will act as a discharge pipe from an industrial plant.
3. Tape the aquarium tube half to the inside of the plastic container in the reservoir, making sure the opening is not touching the bottom of the container.
4. Fill the reservoir with clean water until it is just above the top of the clay.
5. Take a cupful of water and pour a small amount of Kool-Aid® drink mix into it (just enough for the water to change color). Mix well. This will represent the waste (pollutant).
6. Use the 10-mL syringe to suck up the waste.
7. Attach the end of the syringe to the aquarium tube, and inject the waste into the aquarium tubing (discharge pipe) you created (see Figure 7).

Figure 7.

8. Observe and record what happens to the water in the reservoir as you pump the waste into the discharge pipe in the “Observations” section of the **Lab Worksheet**.
9. Next, insert a straw into one of the wells until it touches the bottom. Hold your forefinger tightly over the open end of the straw to create a seal, and then remove the straw from the well (as in Activity 1) to see if the polluted water has made its way into the groundwater supply.
10. To verify, wait 1 minute and repeat Step 9; then wait another minute and repeat the step again.
11. Take a photograph of your model with your straw in the picture to show if there is any pollution occurring in the groundwater supply. Include in your photograph a strip of paper with your name and the date clearly written on it. You will be uploading this photograph to your lab report.
12. After you have completed this activity, obtain a medium- to large-size plastic bowl/container. Take a handful of the gravel and sand mixture. Rinse water through it, separating the gravel (in your hand) from the sand and water mixture (now in the bowl). Place the gravel on a paper towel to the side; let the excess water drain into the bowl, either in the sink or outside on the ground, being careful to retain as much sand as possible in the bowl. Reuse the sand and gravel for Activity 3. If weather permits, this step can be done outside for easier cleanup.

ACTIVITY 3

A Non-Point Source Pollution

In this activity, you will see the effects on drinking water in two locations:

- a house on a hill, where drinking water comes from a well confined under an impermeable layer
- a house located downhill by a pond, where drinking water comes from a well in a permeable layer

All the land between the two houses is fertilized each year, and both homeowners want to know the effects that this potential pollutant (fertilizer) has on their water source in the event of runoff from a rain event.

Hypothesize how adding fertilizer to this new model will affect the other components of the model. Describe your reasoning. In your hypothesis, you should consider the following: 1) the groundwater, 2) the pond water, and 3) the drinking water reservoir. Complete this information in the "Hypotheses" section of the **Lab Worksheet**.

1. Take the bar of clay from the previous activity, and flatten it out as much as possible, making an approximate 6 × 6 cm square.
2. Cut the remaining aquarium tube in half, taping one piece to the inside (on a short side) of the plastic container, midway down. Tape the other half of the aquarium tube opposite the previous one and at the same depth in the plastic container. These tubes represent wells (see Figure 8).
3. Choose one side of the container, and fill it with sand to a depth slightly higher than the bottom of the well, as shown in Figure 9.
4. On the other side, make a slope of sand a few centimeters higher as you continue placing sand throughout the container. Supplement this layer with a layer of gravel on top, continuing the sloped approach (see Figure10).

Figure 8.

Figure 9.

Figure 10.

continued on next page

Figure 11.

Figure 12.

5. Place the flattened piece of clay on top of the uphill side, and mold the clay so that it fits tightly around the well (see Figure 11). This will act as an impermeable layer.
6. Top the model with a thin layer of sand, continuing with the sloped approach.
7. In the sand/gravel mixture at the bottom of the hill, dig a small circular hole. Using a plastic cup from the equipment set, pour water into the hole to represent a pond (see Figure 12).
8. Take the opened Kool-Aid® drink mix packet and sprinkle the remaining contents along the surface of the sloped land. This will act as fertilizer on the landscape.
9. Put water (without Kool-Aid® drink mix) in the foam cup, and shake the cup along the land to simulate rain. Observe what happens to the fertilizer and how it affects both the groundwater and pond water (by tracking the now-colored water), and record your observations in the "Observations" section of the **Lab Worksheet**.
10. Wait 30 seconds, and then use the 10-mL syringe to pump water out of the well that is not surrounded by the impermeable clay layer. Observe the color of the water that came out of the well along with the pond water color. (Some sediment may be sucked into the syringe during this step.) Record your observations in the "Observations" section of the **Lab Worksheet**. Take a photograph of your model with the syringe in the picture to show the color of the water. Include in your photograph a strip of paper with your name and the date clearly written on it. You will be uploading this photograph to your lab report.
11. Now use the syringe to draw water from the uphill well that is confined by an impermeable layer. Observe the color of the water that came from this well. (Some sediment may be sucked into the syringe during this step). Record your observations in the "Observations" section of the **Lab Worksheet**.

Submission

Using the **Lab Report Template** provided, submit your completed report to Waypoint for grading. It is not necessary to turn in the Lab Worksheet.

Disposal and Cleanup

1. Rinse and dry the lab equipment from the equipment kit, and return the materials to your equipment kit.
2. Dispose of any materials from the materials kit in the household trash. The plastic container may be recyclable.
3. Sanitize the work space, and wash your hands thoroughly.

ACTIVITY

Lab Worksheet

Hypotheses

Activity 1.

Activity 2.

Activity 3.

Observations

Activity 1.

Activity 2.

Activity 3.

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