DESCRIPTION

Students conduct an experiment to investigate the effects of various factors on the rate of evaporation.

GRADE LEVEL
6 – 12

OBJECTIVES

Students will:

- Make a prediction using prior knowledge and experience
- Model evaporation of water from soil under various environmental conditions
- Synthesize results of an experiment
- Apply understanding of experimental results to make further predictions about Earth's systems

TIME

1 HOUR TOTAL OVER 4 DAYS
DAY 1:20 MINUTES
DAY 2:10 MINUTES
DAY 3:10 MINUTES
DAY 4:20 MINUTES

COMMON CORE STATE STANDARDS

English Language Arts Standards » Science & Technical Subjects » Grade 6-8
CCSS.ELA-LITERACY.RST.6-8.3. Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

CCSS.ELA-LITERACY.RST.6-8.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

English Language Arts Standards » Science & Technical Subjects » Grade 9-10
CCSS.ELA-LITERACY.RST.9-10.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

CCSS.ELA-LITERACY.RST.9-10.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.

English Language Arts Standards » Science & Technical Subjects » Grade 11-12
CCSS.ELA-LITERACY.RST.11-12.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

Grade 6 » Statistics & Probability
CCSS.MATH.CONTENT.6.SP.B.5. Summarize numerical data sets in relation to their context, such as by: CCSS.MATH.CONTENT.6.SP.B.5.C. Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.

NEXT GENERATION SCIENCE STANDARDS

Middle School
MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

High School
HS-PS1-5. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

BACKGROUND

With increasing temperatures and changing weather patterns, climate change will affect evaporation rates in many areas. Evaporation is a major part of the earth's water cycle. It is the process of water molecules gaining enough energy to escape the surface of a water layer. In the water cycle, water from lakes, ponds, rivers, streams, and oceans is heated by the sun and converted into water vapor. This vapor rises into the air and may result in the development of clouds.

Many factors can affect evaporation. Heat makes water evaporate more quickly because water molecules move faster when they are warm. Since the molecules are moving faster, more of them can leave the surface of the water at one time. Humidity, the amount of water vapor in the air, also affects evaporation rates. For evaporation to occur, the humidity of the atmosphere must be less than the evaporation surface. At 100% relative humidity, there is no evaporation. Additionally, wind increases the rate of evaporation by blowing away moist air from the water surface, thus bringing in less humid air with room for more water molecules.

MATERIALS

- *Evaporation Investigation* handout [1 per student]
- Small, sandwich-sized, clear plastic storage containers, approximately 6.5" x 6.5" [10 per class]
- Permanent markers [10]
- Masking tape
- Metric rulers [10]
- Soil, well mixed (from the schoolyard or other location or bagged potting soil)
- Trowels [1-4]
- 100-mL graduated cylinders [5-10]
- Metric scales (Figure 1) [2-10]
- Heat lamps, can be metal clamp lamps or desktop lamps (Figure 2) [2 per class]
- Heating pads (Figure 2) [2 per class]
- Small desktop fans (Figure 2) [2 per class]
- Dried Spanish moss [1-2 bags, approximately 2-L]
- Automatic timers [2-6 per class, depending on location of outlets]
- Power strips [2-6 per class, depending on location of outlets]
- Optional: extension cords (if needed)
- Optional: document camera and projector (if using for the "Class Mean Data Table")

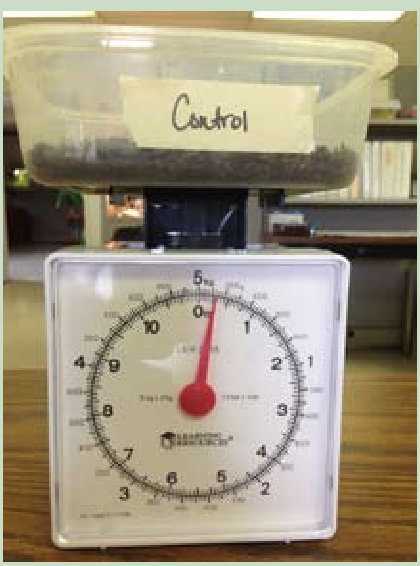

Figure 1. Example metric scale and container

Figure 2. Five experimental containers with treatment materials (left to right): heat lamp, heating pad, desktop fan, Spanish moss, and control

PREPARATION

1. Plan to divide the class into 10 groups. This allows for two replicates of each treatment (control, solar radiation, infrared ground radiation, wind, and ground cover). To save space, you can split each class into only five groups if you have more than one class conducting this experiment. Each class will share their data with other classes, thereby increasing replication.
2. Plan locations for five experimental treatments. Treatment locations can be simple surfaces, such as counters or tables, that are away from direct sunlight. Three locations should be near an outlet.
3. Set up supplies for each treatment. Ideally, the two replicates of each treatment will not be located right next to each other to avoid confounding the results with site-specific factors (e.g., a heating or cooling vent, etc.). However, space constraints may prevent placing the replicate containers far apart.
    a. **Control** (only soil and water): needs a surface away from direct sunlight.
    b. **Solar radiation** (heat lamp): needs a surface away from direct sunlight, near an outlet, and that can accommodate the heat lamp(s). Plug an automatic timer* into a nearby outlet, and program the timer to be on during the day and off during the times when classes are not in session. Plug a power strip and/or extension cord (if needed) into the timer. Set up the heat lamp(s), and plug them into the power strip that is connected to the timer.
    c. **Infrared ground radiation** (heating pad): needs a surface away from direct sunlight, near an outlet, and that can accommodate the heating pad(s). Plug an automatic timer* into a nearby outlet, and program the timer to be on during the day and off during the times when classes are not in session. Plug a power strip and/or extension cord (if needed) into the timer. Set up one or two heating pads; two small containers may fit on one heating pad, depending on the size of the containers and heating pad. Plug the heating pad(s) into the power strip that is connected to the timer.
    d. **Wind** (fan): needs a surface away from direct sunlight, near an outlet, and that can accommodate the fan(s). Plug an automatic timer* into a nearby outlet, and program the timer to be on during the day and off during the times when classes are not in session. Plug a power strip and/or extension cord (if needed) into the timer. Set up the fan(s), and plug into the power strip that is connected to the timer.
    e. **Ground cover** (moss): needs a surface away from direct sunlight. Place the bag of Spanish moss nearby.

    *Note: automatic timers can be shared among treatments, depending on the location of outlets and surface space, by using extension cords and/or power strips.
4. Place scales on level surfaces around the room that will be convenient for student access.
5. Place the container of soil in a central place that will be convenient for student access, and leave 1 – 4 trowels near the container.
6. Attach a small strip of masking or lab tape to the side of each container to be used as a label.
7. On the board or a large piece of paper, draw the "Class Mean Data Table" from page 3 of the handout, or prepare to show it with a document camera.

PROCEDURES

DAY 1

1. Divide the class into 10 groups.
2. Pass out an *Evaporation Investigation* handout to each student.
3. Explain that students will conduct an experiment to investigate evaporation because it is an important process in the water cycle. As the climate changes and temperature increases, evaporation will occur at a greater rate. In this experiment, we will examine some of the factors that affect evaporation and hypothesize about how the results relate to climate change.
4. Inform students that they will be determining which variable results in the most water loss through evaporation. Their experiment will examine the effects of the following variables on water loss from a container of soil: control (nothing is added), solar radiation (under a heat lamp), infrared ground radiation (on top of a heating pad), wind (in front of a fan), and ground cover (with moss on top).
5. Instruct students to complete the prediction at the top of page 1 of the handout.
6. Give each group a plastic container, a permanent marker, and a ruler, and have them measure 2 cm from the bottom of the container and place a mark with the marker.
7. Assign each group to one of the treatments: control, solar radiation, infrared ground radiation, wind, or ground cover. Assign two groups to each treatment. The first group assigned to the control treatment will be group 1 and the second will be group 2. If you are conducting the experiment with more than one class, assign sequential numbers (3, 4, etc.) to groups in subsequent classes.
8. Instruct students to write their treatment name and group number on page 3 of the handout and on the masking tape on their container.
9. Have each group fill the container with dry soil to the 2 cm mark. Tell them not to pat down the soil. They will then take the mass of the container with the dry soil and record the mass on page 3 of the handout.
    a. Soil for the entire class should

be very well mixed in a large container. Groups should not collect their own soil because it may differ considerably in texture.

10. Ask each group to measure 100 mL of water in a graduated cylinder and carefully sprinkle the water on top of the soil in the container. Tell students to make sure that water is sprinkled evenly across the top and not poured into one area of the container.
11. Instruct each group to take the mass of the container immediately after sprinkling the water. Students will record the mass on page 3 of the handout.
    a. The mass of 100 mL of water is 100 g. A quick check of student handouts should show that the mass of the container after sprinkling water is 100 g more than the mass of the container with dry soil.
12. Explain to each group how to set up their container.
    a. **Control**: do not add any other variables.
    b. **Solar radiation** (heat lamp): place the container under the heat lamp, approximately 3-6 inches away. Rotate the container 180° daily. The lamp simulates radiation from the sun.
    c. **Infrared ground radiation** (heating pad): place the container on top of the heating pad. Rotate the container daily. The heating pad simulates ground surface radiation.
    d. **Wind** (fan): set the container in front of the fan, and position the fan so that it blows level with the container. Put the fan on the lowest setting. Make sure that no other containers are in the line of the fan. Rotate the container daily. The fan simulates the wind.
    e. **Ground cover** (moss): place moss on top of the soil in patches. Do not cover the soil completely. Make sure all containers have the same percentage of the surface covered. The moss simulates plants covering the soil surface.

DAYS 2 - 4

1. On a daily basis for the following three days, instruct students to take the mass of the container and record it in "Your Group's Data Table" on page 3 of the handout. If possible, take the mass at the same time each day.
2. Direct students to calculate the amount of water lost by subtracting the current day's mass from the previous day's mass.

DAY 4

1. At the end of the experiment, have students calculate the total mass of water lost in the table on page 3 of the handout by adding the water lost on days two, three, and four.
2. Collect the total mass of water loss for each group in the "Class Mean Data Table" on the board (or displayed on the document camera). Either direct students to write their data on the displayed table themselves, or ask each group for their total verbally, and write it in the table.
3. Instruct students to write the class data in the "Class Mean Data Table" on page 3 of the handout and calculate the mean mass of water loss for each treatment.
4. Have students make a bar graph of the mean mass of water loss for each treatment in the graph on page 4 of the handout.
5. Students draw conclusions from the "Class Mean Data Table" and bar graph and use them to answer the conclusion questions on page 5 of the handout. It may be helpful to lead a discussion of experiment conclusions using the following questions and direct students to use some of the answers to write their own conclusions for conclusion question 2.
    a. Which treatments had the most evaporation?
    b. Which treatments had the least evaporation?
    c. Do the results support your prediction? (This is conclusion question 1.)
    d. What may be the reasons that some treatments had more evaporation than others?
    e. What might be the result of two or more of these variables acting at the same time in an ecosystem?
    f. Why is it important to replicate the experiment (i.e., to have more than one container for each treatment)?
6. After students answer conclusion question 3, discuss how increased evaporation rates affect the water cycle under climate change conditions. Earth is experiencing global warming, and the average global surface temperature is increasing. In this experiment, global warming is equivalent to turning up the heat on the heating pad. As temperatures increase around the world, more areas are experiencing increased evaporation rates, and there is more water in the atmosphere. More water in the atmosphere results in changes to precipitation patterns; some areas receive more precipitation and some receive less. It also results in increased frequency of extreme weather events, such as severe storms. In addition, water vapor is a greenhouse gas and further enhances the greenhouse effect.

EXTENSIONS

1. For older or advanced students, conduct this activity as a student-directed experiment instead of providing students with the procedures. Present the following question to students, "Which factor has the greatest impact on the rate of evaporation?" Explain the available materials, and ask students to develop a hypothesis and design an experiment that will test it. Have students design the needed data tables and determine how to analyze their results if possible.
2. Challenge students to think of at least one more variable that may affect the rate of evaporation and design and conduct an experiment to test its effects.

ADDITIONAL RESOURCES

Website with information about the effects of climate change on the processes of the water cycle:

Environmental Protection Agency (EPA), Climate Change and Water. Water Impacts of Climate Change. Updated 13 Mar. 2014. Web. Accessed 26 May 2015. <http://water.epa.gov/scitech/climatechange/Water-Impacts-of-Climate-Change.cfm>.