ACID TESTS

EARTH matters
Studies For Our Global Future

introduction

When coal, oil, and gas are burned, large amounts of sulfur and nitrogen are released as gases into the air. These substances, known as sulfuric acids and nitric acids, then rise into the atmosphere where they mix with water and oxygen to form **acid rain** (or acid precipitation in other forms such as snow or sleet). Acid rain, with a pH below 5.6, is caused primarily by **fossil fuel** combustion and has negative impacts on many temperate ecosystems, at all levels of the food chain.

In recent years, acid rain has declined, especially in the United States and Europe, due to policy proposals designed to reduce pollution. In the United States, this decrease is largely thanks to Title IV of the **Clean Air Act of 1990**, which implemented a "**cap and trade**" approach in which companies that pollute are provided yearly allowances of pollutants. This system has been largely successful in the United States, targeting the **sulfur dioxide (SO_2)** and **nitrogen dioxide (NO_2)** emissions that are the major contributors to acid rain. Monitoring data from the United States **Environmental Protection Agency (EPA)** shows that by 2019, SO_2 was down 93 percent and nitrogen oxides (NO_x) was down 86 percent from 1990 levels.[1]

Despite these gains, acid precipitation is still a concern, especially as China has experienced rapid industrialization with fewer regulations than the United States and Europe. We must continue to consider the impacts of acid rain on ecosystems as over 38 percent of our world electricity consumption is still powered by burning coal.[2]

Vocabulary: acid rain, cap and trade, Clean Air Act of 1990, Environmental Protection Agency (EPA), fossil fuel, nitrogen dioxide (NO_2), sulfur dioxide (SO_2)

materials

- Distilled water
- Distilled white vinegar
- 100 mL test tubes
- Pipette

concept

Changes in the pH of an ecosystem, caused by acid precipitation, are detrimental to the growth and survival of many species.

objectives

Students will be able to:

- Determine the acidity of a substance by testing with pH paper.
- Measure and graph the results of a lab experiment with radish seeds.
- Compare the effects of different levels of acidity on seed germination and plant growth.

subjects

Environmental Science (General and AP), Biology, Chemistry, Algebra, Health

skills

Lab preparation, collecting and recording data, graphing and analyzing data, measuring, observing, sketching

method

Students test different pH solutions on radish seeds to determine the optimal level for seed germination and use the results to identify effects of acid rain.

For each pair:

- Student Lab Worksheet
- Safety goggles
- Lab aprons
- Plastic gloves
- Petri dish
- Absorbent paper towel
- Scissors
- Radish seeds
- pH test strips
- Small transparent metric ruler
- Graph paper

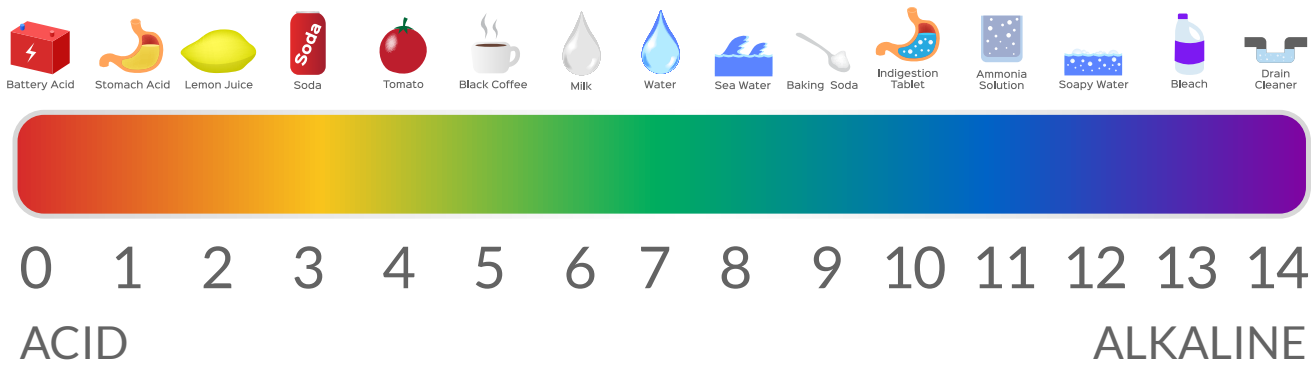
procedure

1. Before class, mix solutions with pH ranging from 3 to 7 using distilled white vinegar and distilled water (avoid tap water, as it is slightly acidic). While results may vary based on the type of water used, the type of vinegar used, and temperature, here is an approximate matrix of water/vinegar ratios to achieve desired pH.

   Note: If you have adequate time, you can provide students with this matrix and the materials to mix their own solutions.

Solution (How much water and vinegar)	pH
Pure distilled water	7
100 mL water + 5-9 drops of vinegar	6
100 mL water + 10-99 drops of vinegar	5
100 mL water + about 100 drops of vinegar	4
Pure distilled white vinegar (5% acetic acid)	3

2. Provide students with a working definition of pH and explain that they will be studying its impact on ecosystems. Display the image below and ask students to identify which things they interact with in everyday life are acidic and which everyday items are basic/alkaline.



3. Ask students to make a hypothesis: What is the ideal pH for most life on Earth to thrive?
   Answers will vary, but students should identify that the pH of pure water, 7, is ideal for most life because organisms need pure water to survive. Some students may notice that a salt lake is slightly alkaline or that fruits are naturally acidic and make an argument for a greater range of pH. At this point, do not confirm or correct students' answers; they will gather data in the lab and draw conclusions.

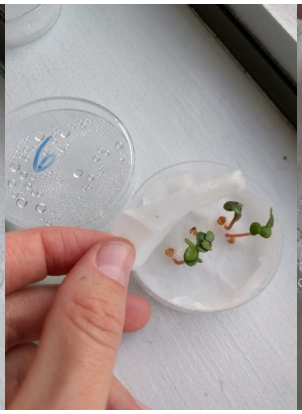
4. Divide the class into lab pairs and distribute the Student Lab Worksheet to each student. Assign each pair one pH solution to work with for the lab from the solutions you mixed (pH 7, 6, 5, 4, and 3), and provide each pair with a set of lab materials: 2 safety goggles, 2 lab aprons, 2 pairs of plastic gloves, petri dish, paper towel, scissors, 4 radish seeds, pH test strips, transparent metric ruler, and paper towel.

5. On Day 1, students will set up the experiment according to directions in Part A of the Student Lab Worksheet. On Days 2-10, students will observe and record findings as indicated in Part B.

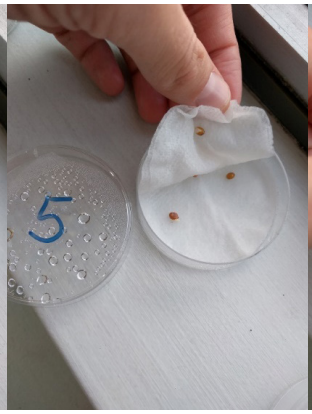
   - Students may need to moisten their paper towels with the correct pH solution once or twice throughout the lab, so we recommend keeping these solutions available and labeled for the full 10 days.
   - In a test of this lab, the radish seeds in the pH of 6 germinated the quickest and grew fastest initially. However, those with a pH of 7 ultimately grew slightly taller (2-3 mm more) over the course of 10 days of testing.
   - The following images can provide some context for what students may observe in the lab. These photos were taken on Day 4. The numbers on the petri dish lids indicate the pH of the solution the seeds were soaked in to induce germination.

6. Distribute a sheet of graph paper to each student so they can create a graph of their final data (average seed length over time). You can create a class graph as well or display all student results side-by-side.

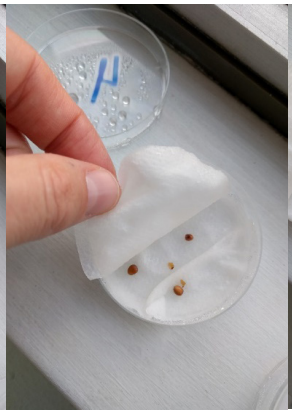

pH:7



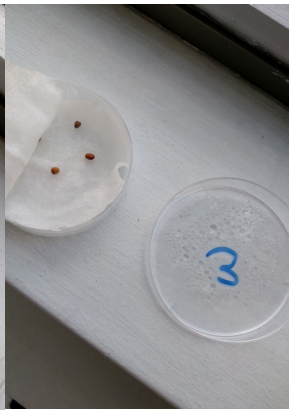
pH:6



pH:5



pH:4



pH:3

discussion questions

1. Observe the data on the completed class graph. What appears to be the optimal pH solution for successful radish germination?

   Answers will depend on class data.

2. What appears to be the least ideal pH solution for successful radish seed germination?

   Answers will depend on class data.

3. What pH do you think rainwater has, based on the data gathered?

   Answers will depend on class data. Even "healthy" rainwater is not neutral on the pH scale because it combines with materials in the atmosphere as it's forming and falling as precipitation. Rain has an average pH of 5.6.

4. Explain to students that acid rain typically has a pH of about 4. Given that data, how did the plants grown in the "acid rain" fare compared to those grown in distilled water?

   Most likely, the plants with pH of 4 did poorly compared to those given pure water.

5. Because we simulated the effects of acid rain in a controlled experiment, what factors might have been left out that are important in the real world?

   Answers will vary. Rainwater and distilled water are different, and water with a pH of 7 is unlikely to fall as rain. Also, we were only considering one type of plant, and it was only a land plant.

6. Based on the data gathered, what would be the impact on agricultural crops and productivity if rainwater has increased acidity?

   In the investigation, the seeds watered with the lower pH solution will most likely have a slower germination and growth rate than the others. From this data, students can assume that rainwater with high acidity will have similar effects on plant growth – slower growth rate and a subsequent drop in food production.

assessment

Collect and assess the completed Student Lab Worksheets for completion and accuracy.

follow-up activities

1. Have students study the effects of germination and/or growth of a marine plant while varying the pH of its environment.

2. Students can germinate and plant seeds in soil and water them regularly with the solutions of varying pH to make the lab more realistic.

Adapted with permission from Biological Sciences Curriculum Study (BSCS). The original activity, "The Effects of Acid Rain on Seed Germination," appears in Biological Science: An Ecological Approach (Kendall Hunt Publishing Company, 1987, 1992, 1998, 2002, 2006).

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[1] United States Environmental Protection Agency. (2020). *Acid Rain Program Results*. Retrieved January 26, 2021 from https://www.epa.gov/acidrain/acid-rain-program-results

[2] International Energy Agency. (2020). *Coal*. Retrieved January 26, 2021 from https://www.iea.org/fuels-and-technologies/coal

ACID TEST | student lab worksheet

Name: _____ **Date:** _____

Problem question: Identify the variables and constants, and write out the question for this lab.

Independent variable: _____

Dependent variable: _____

Constants (what must stay the same): _____

Write the problem question this lab is testing in the correct format below.

_____

_____

_____

Hypothesis

What do you predict will be the ideal pH for the growth of plants? Explain using background information.

_____

_____

_____

Materials

Test tube containing water solution with your assigned pH, pH test strips, paper towel, scissors, 4 radish seeds, 1 petri dish

Procedure for Part A (Day 1)

1. Cut four discs the size of the petri dish from the paper towel.
2. Use pH test strips to test the pH of your assigned water and record it in the title of the data table. This should remain consistent throughout the lab.
3. Dampen all four paper discs with the water solution. Place two of the paper discs on the bottom of the petri dish.
4. Measure the length of each of the four radish seeds in millimeters and record it in the data table for the Day 1 row.
5. Calculate the average length of the radish seeds for Day 1 and record this in the data table in the Average column.

6. Arrange the seeds in the petri dish and cover with the two remaining discs of paper towel. Make sure they are still damp – if not, add more of your water solution.

7. Replace lid on petri dish and label both the lid and the dish with you and your partner's initials.

8. Wash your hands thoroughly before leaving the lab area.

Procedure for Part B (Days 2-10)

1. Remove the lid from the petri dish and remove the two paper discs covering the four seeds. Test the pH of the water remaining in the dish. (If it is different from your initial recorded reading, throw out the paper towels, drain the remaining water, and replace it with paper towels soaked in the correct pH solution.)

2. Measure the length of the seeds in millimeters and record in that day's row, and calculate and record the average for that day.

3. Cover the seeds with the paper discs. Moisten the paper if necessary with the assigned pH solution and replace the lid. (Remember: always test the pH level of the solution before using it.)

4. On graph paper, set up a graph with age in days on the horizontal axis and length of seeds in millimeters on the vertical axis.

5. Plot the average length of your seeds for the two measurements (Day 1 and Day 2) you have made.

6. Repeat procedures 1-6 each day for the length of the investigation. If the seeds begin to germinate during this time, include the length of any growth in your measurement. Each day, record any additional notes in the Qualitative Observations column.

7. Each day, wash your hands thoroughly before leaving the lab.

Data Table: Radish Seed Growth in Water with pH of _____

LENGTH IN MILLIMETERS

	Seed 1	Seed 2	Seed 3	Seed 4	Average	Qualitative Observations
Day 1						
Day 2						
Day 3						
Day 4						
Day 5						
Day 6						
Day 7						
Day 8						
Day 9						
Day 10						