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Acid Rain and Plants

Student Laboratory Kit

Introduction

What exactly is acid rain and how does it affect our surroundings? In this activity, rain solutions at various pH levels are placed on plants to show the cumulative effects of acid rain.

Concepts

- Acid rain
- pH
- Pollution
- Plant growth

Background

Acid rain is precipitation that has absorbed and reacted with compounds in the atmosphere to form acids. In more precise terms, acid rain is precipitation with a pH less than 5.6. A pH of 5.6 is generally considered to be the pH of "normal" rainwater. The term "acid rain" dates back to mid-19th century England. Following a long period of deforestation, homes and businesses gradually converted to burning coal as a primary source of fuel. It was noted by scientists and others that over this period the pH of rain falling in England and nations to the east was becoming more and more acidic. Eventually the connection between the increasing acidity and the combustion of coal was made.

The pH of pure water is theoretically 7.0, a value considered to be neutral on the pH scale of 0 to 14. Carbon dioxide gas (CO_2), naturally present in the atmosphere, dissolves in and reacts with water by the following equation:

$$H_2O + CO_2 \rightleftarrows \underset{\text{carbonic acid}}{H_2CO_3} \rightleftarrows \underset{\text{hydrogen ion}}{H^+(aq)} + \underset{\text{hydrogen carbonate ion}}{HCO_3^-(aq)}$$

The free hydrogen ions on the right side of the equation above are the cause of the moderate acidification and lower pH of 5.6. With other minor contributors, the pH of normal precipitation may on occasion range as low as 4.0. Although rare cases have been reported where the pH of rain has dropped to a pH of 2.

The chemicals primarily responsible for acid rain fall into two basic classes: sulfur oxides (SO_x) and nitrogen oxides (NO_x). It is important to understand that acid rain is created both naturally and by man-made sources. The primary natural sources for SO_x are volcanoes, fires, wetlands and other systems with significant concentrations of anaerobic bacteria. Man-made sources for SO_x are the burning of coal, oil and gas (fossil fuels), ore smelting and other industrial processes. Natural sources for NO_x include fires (high temperature combustion) and lightning. The most significant man-made source of NO_x is automobile emissions. In industrial regions, human generated sources of both SO_x and NO_x greatly outweigh contributions from natural sources.

Sulfur is present as a contaminant in fossil fuels, most notably in coal and oil, and to a much lesser extent in natural gas. The combustion of these fuels results in the production of sulfur dioxide (SO_2). Compounds naturally present in the atmosphere are capable of further oxidizing the SO_2 to form sulfuric acid (H_2SO_4). These oxidants include hydroxyl radicals, hydrogen peroxides, dissolved oxygen and ozone.

Nitrogen oxides are formed by the combination of nitrogen and oxygen. Since our atmosphere is approximately 78% nitrogen (N_2) and 21% oxygen (O_2) the reactants are certainly abundant. However, the reaction to create acid rain will only take place when these reactants are involved in a high temperature combustion. Truck and automobile engines are ideal environments for this reaction and are by far the greatest sources of NO_x emissions. Oxygen and nitrogen combine to form nitric oxide (NO), which further reacts with oxygen to form nitrogen dioxide (NO_2). Ultimately nitrogen dioxide reacts with hydroxyl radicals and ozone to form nitric acid.

When acid rain comes in contact with plants and the surrounding soil, several things occur. Vital nutrients such as potassium, calcium, and magnesium react with acid rain and are either removed from the soil and transported away or simply become unavailable to plants. Acid rain also dissolves and frees up toxic metals in the soil such as mercury, manganese, lead, zinc and aluminum. The concentrations of these metals may reach levels sufficient to disrupt plant growth. As plants come into direct contact with acid rain, the surface areas of leaves and stems become damaged and make the plants vulnerable to disease. Even if an individual plant survives, it will be very weak and may have difficulty surviving environmental factors such as heavy rainfall, strong winds, and drought. Plant functions such as germination and reproduction are also hampered by the effects of acid rain.

Materials

Radish seeds, 40
Rain solution #1, ~50 mL
Rain solution #2, ~50 mL
Rain solution #3, ~50 mL
Rain solution #4, ~50 mL
Rainbow acid universal indicator
Beral-type pipets, 4
Plant markers, 4
Plant tray
Pots, 4
Plastic wrap
Ruler, metric
Soil

Safety Precautions

The rain solutions may be moderately corrosive. Take care when placing the solutions on the seedlings. Avoid contact with all body tissue. Seeds are routinely treated with mold-inhibiting chemicals to help preserve them. Be sure to wash hands thoroughly upon completion of the laboratory work. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron.

Procedure

1. Fill four growing pots with potting soil to within ½″ from the top of the rim.
2. Label four plant markers as follows:
   a. Rain solution #1
   b. Rain solution #2
   c. Rain solution #3
   d. Rain solution #4

   Also include your group name or initials on each marker.
3. Place one marker in each of the four pots.
4. Thoroughly pre-soak the potting soil in each of the pots with water.
5. Place approximately 10 radish seeds on top of the soil in each of the containers. Press the seeds down gently with a fingertip so the seeds are just below the surface of the soil.
6. Cover each of the pots with plastic wrap to help maintain the humidity and moisture.
7. Water the seeds from the bottom up by placing the pots in a planting tray. Add sufficient water to the planting tray. Watering from the bottom up will allow for minimal disturbance of the seeds.
8. Place the tray and pots under a growing light or in direct sunlight near a window or in a greenhouse.
9. Add water to the tray every few days as needed.
10. When the first seeds have germinated and the seedlings are visible, remove and discard the plastic wrap.
11. One week after the radish seedlings are visible, thin each growing pot so that only three seedlings are present. Record the height of each plant in the Data Table. Measure, in cm, from the top of the plant to the soil level. The first measurement will be recorded as Day 0. Also, record the average height of the seedlings for each growing pot for Day 0.

12. Using a dropping pipet, place the appropriate rain solution on the leaves and stems of the plants in each pot after the initial measurements for Day 0 are taken. Place enough of the rain solution over the seedlings to completely cover the stems and leaves of the seedling. Be sure to isolate each pot when applying the rain solutions. This will help avoid contaminating the other radish seedlings with the incorrect solution.
13. Record the height of each plant and the average height for each pot over the next week. After measurements have been taken daily, use a pipet to place the corresponding rain solution on each plant.
14. After all measurements and calculations have been made, your instructor will use a universal rainbow acid indicator solution to measure the pH of each rain solution. Record the color of the solution and the pH for each rain solution in the Data Table.
15. Answer the Post-Lab Questions from the Acid Rain and Plants Worksheet.

Disposal

Consult your instructor for appropriate treatment procedures.

Name: _____

Acid Rain and Plants Worksheet

Data Table

	Rain Solution #1				Rain Solution #2				Rain Solution #3				Rain Solution #4			
	1	**2**	**3**	**Avg.**	**1**	**2**	**3**	**Avg.**	**1**	**2**	**3**	**Avg.**	**1**	**2**	**3**	**Avg.**
Day 0 Plant Height (in cm)																
Day 1 Plant Height (in cm)																
Day 2 Plant Height (in cm)																
Day 3 Plant Height (in cm)																
Day 4 Plant Height (in cm)																
Indicator Color + pH																

	Observations
Day 0	
Day 1	
Day 2	
Day 3	
Day 4	

Name: _____

Post-Lab Questions

1. Prepare a graph of plant height versus number of days for each rain solution.

2. What group of radish seedlings were most affected by the rain solutions?

3. What group of radish seedlings were least affected by the rain solutions?

4. Which rain solution(s) may be classified as acid rain?

Teacher's Notes

Acid Rain and Plants

Materials Included in Kit

Radish seeds, 1 oz
Rain solution #1, 1 L
Rain solution #2, 1 L
Rain solution #3, 1 L
Rain solution #4, 1 L
Universal indicator, rainbow acid, 100 mL
Disposable pipets, 60
Plant markers, 100
Plant trays, 4
Pots, 60
Soil, 8-lb bag, 2

Additional Materials Needed (for each lab group)

Water
Ruler, metric
Plastic wrap

Safety Precautions

Rain solutions #1, #2, and #3 are of low pH and are corrosive. Instruct students to place all rain solutions directly on the seedlings and to avoid all contact with body tissues. Seeds are routinely treated with mold-inhibiting chemicals to help preserve them. Be sure to wash hands thoroughly upon completion of the laboratory work. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please review current Safety Data Sheets for additional safety, handling, and disposal information.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. The solutions in this activity may be flushed down the drain with excess water according to Flinn Suggested Disposal Method #26b.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement
Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standard C: Life Science, population and ecosystems
Content Standard F: Science in Personal and Social Perspectives; populations, resources, and environments
Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter
Content Standard C: Life Science, matter, energy, and organization in living systems
Content Standard F: Science in Personal and Social Perspectives; environmental quality

Tips and Extensions

- Enough materials are provided in this kit for 30 students working in pairs, or for 15 groups of students. The completion of this laboratory will require at least five class periods over the course of several weeks.
- The acid rain solutions may be placed on the seedlings using dropping pipets or may be sprayed using spray bottles (such as our AP5338).

Teacher's Notes *continued*

- Be sure that all groups of radish seeds are treated in an isolated area to avoid contaminating the other radish plants.
- After the student measurements and calculations have been completed, place 1–2 drops of universal rainbow acid indicator into 10–15 mL of each of the rain solutions. Compare the color to the color chart and have students record the corresponding pH in their worksheets.
- Students may experiment with other test factors such as the effect of the acid rain solutions on different types of seeds, germination rates of seeds soaked in the acid rain solutions, and varied dosage rates and amounts of the acid rain solutions.
- Other solutions of varying pH levels may be made and tested on a "new crop" of plants if desired.

Sample Data

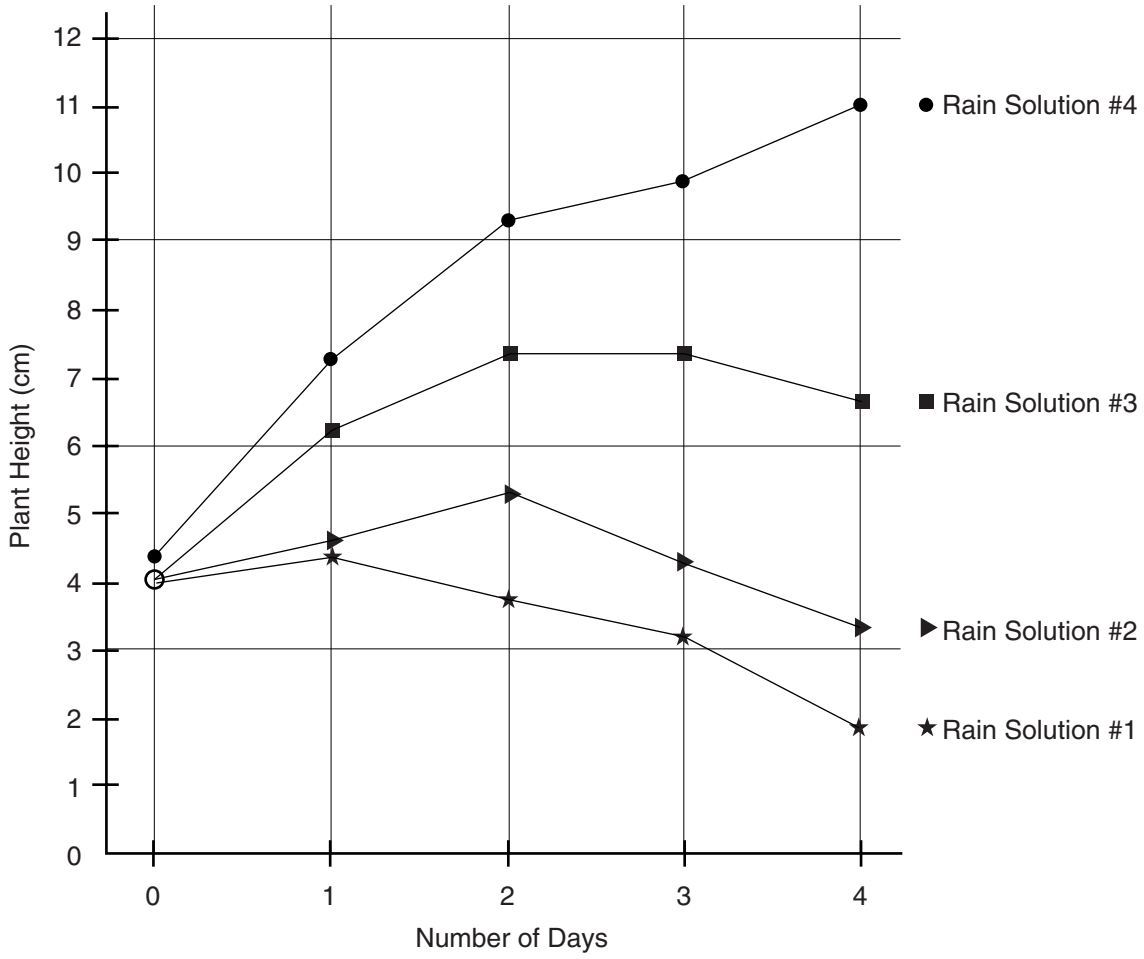
	Rain Solution #1				Rain Solution #2				Rain Solution #3				Rain Solution #4			
	1	**2**	**3**	**Avg.**	**1**	**2**	**3**	**Avg.**	**1**	**2**	**3**	**Avg.**	**1**	**2**	**3**	**Avg.**
Day 0 Plant Height (in cm)	*4.1*	*4.0*	*3.8*	*4.0*	*4.3*	*4.1*	*3.7*	*4.0*	*3.8*	*3.7*	*4.4*	*4.0*	*4.2*	*4.5*	*4.0*	*4.2*
Day 1 Plant Height (in cm)	*4.4*	*4.3*	*4.2*	*4.3*	*4.6*	*4.3*	*4.3*	*4.4*	*6.4*	*5.8*	*6.0*	*6.1*	*7.4*	*6.9*	*7.2*	*7.2*
Day 2 Plant Height (in cm)	*3.5*	*3.6*	*3.3*	*3.5*	*5.2*	*5.0*	*4.8*	*5.0*	*7.2*	*7.4*	*6.9*	*7.2*	*9.2*	*9.4*	*8.6*	*9.1*
Day 3 Plant Height (in cm)	*3.4*	*3.3*	*3.1*	*3.1*	*4.1*	*4.3*	*3.9*	*4.1*	*7.0*	*7.2*	*7.1*	*7.0*	*9.3*	*9.6*	*9.5*	*9.5*
Day 4 Plant Height (in cm)	*1.8*	*1.3*	*1.3*	*1.5*	*3.6*	*2.9*	*3.2*	*3.2*	*6.5*	*6.4*	*6.7*	*6.5*	*10.3*	*9.9*	*10.1*	*10.1*
Indicator Color + pH	*Orange* pH = 2–3				*Yellow-green* pH = 4				*Green* pH = 5				*Blue* pH = 7			

	Observations
Day 0	*All plants look normal and healthy.*
Day 1	*The plants treated with rain solutions #1 and #2 are somewhat shriveled and have brown spots on the leaves.*
Day 2	*Plants treated with rain solution #4 are thriving. Plants treated with #1 and #2 are showing stunted growth.*
Day 3	*A pattern is appearing: Growth of plants is best in the following order #4, #3, #2, #1.*
Day 4	*Growth has stopped for #1; #2 and #3 have stunted growth. #4 has normal growth.*

Teacher's Notes *continued*

Post-Lab Questions

1. Prepare a graph of plant height versus number of days for each rain solution.



2. What group of radish seedlings were most affected by the rain solutions?

   The radish seedlings treated with rain solution #1 were most affected.

3. What group of radish seedlings were least affected by the rain solutions?

   The radish seedlings treated with rain solution #4 were least affected.

4. Which rain solution(s) may be classified as acid rain?

   Rain solutions #1, #2 and #3 were all below a pH of 5.6, which is the critical value for acid rain.

The *Acid Rain and Plants—Student Laboratory Kit* is available from Flinn Scientific, Inc.

Catalog No.	Description
AP6300	Acid Rain and Plants—Student Laboratory Kit
AP5338	Spray Bottles
AB1439	Radish Seeds, 1 oz

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.