Environmental Inquiry
Cornell University, Ithaca, NY 14853 EnvInquiry@cornell.edu http://ei.cornell.edu

Acid Rain Experiments

Background

Acid precipitation is defined to have a pH lower than 5.6. In New York, the average pH of rainfall is 4.0-4.5 and individual storms as low as 3.0 are not unusual.

Freshwater lakes commonly are slightly basic. pH's in the range of 6.5 to 8.2 are optimal for most organisms, and below 5.0 is lethal to many fish species. The susceptibility of lakes to changes in pH varies depending on how well buffered they are. Measured as **alkalinity**, the buffering capacity of water is a function primarily of the concentration of carbonate ($CO_3^{=}$) and bicarbonate (HCO_3^{-}) ions.
In areas with limestone ($CaCO_3$) bedrock, surface waters have high concentrations of carbonate and bicarbonate and therefore are able to resist change in pH. The pH of a well-buffered lake does not change dramatically following a storm or snowmelt period because the acidity becomes neutralized by these ions.

In regions where the bedrock is granite, the soils and surface waters are naturally low in alkalinity. One such region is the Adirondack Mountains, where approximately 20% of the lakes are too acidic to support fish life.

One approach to restoring acidic lakes is to add lime to the lake itself, to the influent streams, or to the watershed land. This can be simulated in the laboratory using baking soda ($NaHCO_3$), horticultural lime, or a stomach antacid such as Tums, which is made up of $CaCO_3$.

Experimental Problem #1 (Standard Problem)

What is a buffer? What happens to the pH of a buffered solution when acid or base is added, and how does this compare to an unbuffered solution?

Suggested Steps

Introduction

Discussion of acid rain:

- What is acid rain?
- What are the causes?
- What regions are most affected?
- What can we deduce from maps of geology and soils of New York State?
- Why are some lakes more susceptible to acid rain than are others?

Materials

- distilled water
- Buffered Solution: add 1/2 tsp baking soda to 1 liter distilled water
- Acid Rain Solution: add 4 ml 1M H_2SO_4 to 2 liters distilled water.
- pH meter, test kit, pH paper, or Universal Indicator Solution
- beakers or clear plastic cups (200-ml size, two per student or group
- 25-ml graduated cylinders (one per student or group of students)
- 10-ml pipette (one per student or group of students)
- safety goggles
- gloves
- optional: alkalinity test kit

Procedure

1. Put 25 ml distilled water into one beaker and 25 ml Buffered Solution into another.

2. Add 6 drops Universal Indicator Solution to each beaker. {Note the color differences between the two solutions. The distilled water is slightly acidic because of dissolved carbon dioxide; the baking soda solution is slightly basic.}

3. Using a pipette, carefully add Acid Rain Solution drop by drop to the beaker containing distilled water, swirling after each addition until the color stabilizes. How much do you need to add to make the solution turn pink and stay that color, indicating that it is acidic?

4. Using a 25-ml graduated cylinder, carefully add Acid Rain Solution to the cup containing the buffered solution. Add a few ml at a time, swirling and observing the color changes. How much do you need to add to make the solution turn a stable pink?

5. Optional: Measure the alkalinity of distilled water and of Buffered Solution, then relate the alkalinity measurements to the amounts of acid needed to cause a pH change in the two solutions.

Discussion

- Why were there differences in the amount of acid needed to change the pH of these two solutions?

- What is a buffer?

- How does this relate to lakes in New York State?

Experimental Problem #2 (Original Problem)

Materials: Same as for Experiment Problem #1, plus:
- assorted soil samples
- coffee filters
- rubber bands

Procedure:

Design an experiment or set of experiments that use the materials provided to address one or more of these questions:

1. Does soil change the pH of water that drains through it?
2. Can soil reduce the acidity of water draining into a lake?
3. Do some types of soil buffer drainage water better than do other soil types?
4. Can the buffering capacity of soils be depleted?
5. Does the buffering capacity of a soil relate to the alkalinity of water that has drained through it?
6. What components of soil provide its buffering capacity?

Suggested Outline for Lab Writeup

I. Prediction Statement

II. Lab Log
What you did and when, problems that arose and how you addressed them.

III. Interpretation
A summary of your data, preferably in graphs.

IV. Tips for Future Experimenters
Recommendations for improving upon or extending the research, addressed to students taking this class next year.

Assessment Items

Traditional Items

1. Which of these two lakes is more likely to experience large drops in pH due to acid precipitation? Why?

	Mirror Lake	Loon Lake
pH:	7.5	6.0
temp.:	6^{o}C	4^{o}C
alkalinity	50 ppm	200 ppm
dissolved oxygen	13 ppm	7 ppm

2. If you steadily add acid to a well-buffered solution, you would expect the pH to:
   (a) Increase immediately.
   (b) Initially remain constant, then begin dropping.
   (c) Decrease gradually but steadily.
   (d) Stay constant for a while, then begin rising.

3. Universal Indicator Solution is used to indicate the pH of liquids: it turns red in acidic solutions, green in neutral solutions, and purple in basic solutions. When Universal Indicator Solution is added to a sample of water from Mystery Lake, the water turns green. Adding some weak acid turns the solution red, but after mixing it returns to green. The most likely reason:
   (a) Mixing increases dissolved oxygen and therefore affects the pH.
   (b) Buffers in the water neutralize the acid.
   (c) The acid dissolves organic matter in the water, releasing compounds which cause the color change.
   (d) pH changes over time in all solutions.

4. Acid precipitation causes greater changes in lake acidity in the Adirondacks than in other parts of New York State because of differences in:
   (a) The type of bedrock and soil.
   (b) The acidity of the precipitation.
   (c) The size and shape of the lakes.
   (d) The lower fish populations.

Authentic Assessment Items

Part I.
Suppose you are the lake manager for an exclusive fishing club. You have read news accounts about acid precipitation, and you are worried about its possible affects on your fish populations. Design a study to determine whether acid precipitation is likely to cause problems in your club's lakes. What will you study, and why?

Part II.
Lime is commonly applied to gardens and agricultural fields to neutralize acidity. Experimental programs have been carried out to lime Adirondack lakes and streams. What problems do you think might have been encountered?

Credits

This exercise was written by Nancy Trautmann (Cornell University) under NSF Award #9454428.