

ESA21

Environmental Science Activities for the 21st Century

The Atmosphere

Introduction

Acid Rain

Acidity is measured on the pH scale ranges from 0 to 14 with 0 being acid, 7 as neutral, and 14 as alkaline. The pH scale measures the concentration of hydrogen ions in solution, which indicates acidity. The pH scale is also logarithmic, so that a change in one unit represents a tenfold change in acidity, thus a solution of pH 4 is 10 times as acidic as one with pH 5 and 100 times as acidic as pH 6.

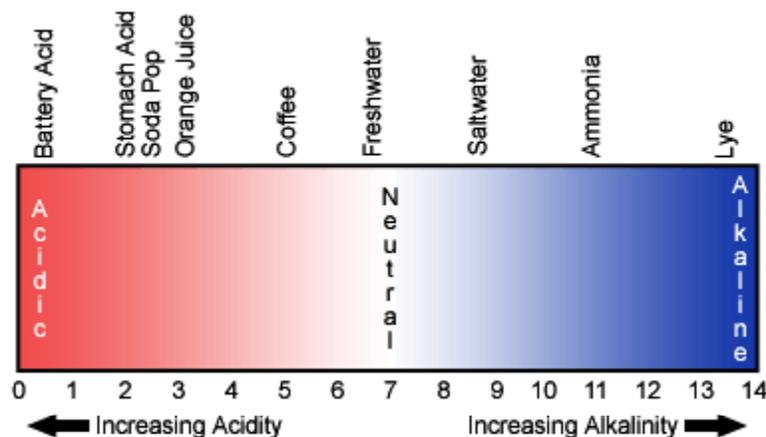


Fig. 1: pH scale (Source: <http://mddnr.chesapeakebay.net/eyesonthebay/whatsitmean.cfm>)

"Natural" or unpolluted rainfall is slightly acidic and has a pH of between 5.6 and 5.8. When fossil fuels, such as coal, are combusted, sulfur dioxide (SO₂) and nitrogen oxide (NO_x) are released into the troposphere. The primary source of acid SO₂ is electrical power plants, whereas NO_x comes from industrial boilers, mineral smelting plants, and automobiles. Once airborne, these acidic gases mix with precipitation such as rain, sleet, and snow and fall back to earth as "acid" rain.

Acid rain can affect both terrestrial and aquatic ecosystems, but the effects can vary depending on local conditions. The American Midwest, for example, has naturally alkaline soils that can buffer acid fallout. Likewise, some lakes lie on limestone, sandstone, or other alkaline formations that help neutralize acidity. On the other hand, some regions where lakes and soils lie on granite or glacial tills have low pH values to begin with and thus are greatly affected by acid rain.

Forests can be greatly affected by acid rain. Extensive stretches of forests in Switzerland and Germany have been damaged or destroyed by acid rain. Extensive vegetation dieback and soil erosion have occurred in the Canadian province of Ontario and acid rain has been implicated in tree damage reaching all the way south along the Appalachian Mountains to Georgia.

Aquatic effects from acid rain result from increasing acidity of rivers, lakes, and streams. Aquatic ecosystems have a preferred and tolerated range for acidity and if levels exceed the tolerated range

plants, insects, and fish can disappear. In Scandinavia, as well as the eastern seaboard, many waterways have been affected. Some have been declared technically "dead" or placed on the critical list.

Materials and structures are also affected by acid rain. The most common problem is corrosion of buildings and statues made of marble and limestone. Steel structures are also susceptible to corrosion resulting from acid rain. In Poland, where there are few or no emissions controls on smokestacks, and where they burn large quantities of high sulfur coal, acid deposition is beginning to erode railroad tracks.

One of the difficulties involved in dealing with acidic deposition is that it often falls in different areas or countries from where it originated. Sulfur dioxide emissions can travel up to 2,000 kilometers in a few days. Most of the acidic deposition in the eastern United States, for example, is the result of coal burning power plants in the Midwest. Acidic deposition has become a significant transboundary issue. Both Sweden and Norway claim that most of the SO_2 they receive comes from other countries, most notably Poland.

A range of specific control technologies exists for both sulfur dioxide and nitrogen oxides. Since sulfur dioxide is produced primarily from the combustion of coal, there are a number of technologies designed to burn coal cleaner. These include more efficient boilers, cleaning technologies, and fluidized combustion beds. Other technologies designed to reduce SO_2 and NO_x emissions include limestone injection burners, reburners, flue gas desulfurizers, in-duct sprayers, and low NO_x burners.

In addition, technologies exist for both wet and dry deposition, monitoring and measurement as well as materials protection. Monitoring and measurement technologies include rain gauges and pH analyzers. Materials protection technologies include waxes, special coatings, and paints.

ESA21: Environmental Science Activities

Activity Sheet
Acid Rain

Student Name:

Professor Name:

Acid Rain – Activity Sheet

Part One - Measuring PH

This exercise will familiarize you with the phenomenon known as acid rain, requires that you take water samples from rainfall. (Note to instructor: To successfully complete the exercise, arrangements will have to be made to allow students to conduct pH tests of water samples. PH testing may be available through an academic department at your college, such as the Chemistry Department. Inexpensive pH test kits are also readily available online. These are a few of a selection of websites online:

<http://www.albuchem.com/strips.htm>, <http://store.yahoo.com/science-city/phactespap.html>,

<http://sargentwelch.com/product.asp?pn=WLS65260%2D10%5FEA>

<http://www.bghydro.com/page/BHOS/PROD/TE/TEPHST><http://www.indigo.com/science-supplies/ph-paper.html>, <http://sciencekit.com/category.asp?c=428998>.

Final Note: The wording of the exercise may need to be altered to match the pH testing arrangements.)

Note to Students - Make arrangements with your instructor to acquire the materials you will need to test the pH of several water samples. Then begin to watch the weather. When the forecast calls for rain, take a clean, meticulously rinsed, air-dried container outside and collect rainfall. Then pour water from the container into a clean, meticulously rinsed drinking glass, cup, or jar. Insert a pH test strip into the cup and record the pH. Take a total of three samples, record the results below, calculate the average pH, and answer questions 1-3 below.

	Date	pH
Sample #1		
Sample #2		
Sample #3		
Average pH		

1. Unpolluted rainfall has a pH of about 5.6. Was your average lower or higher than 5.6?

2. Why do you suppose that you got the readings that you did?

3. What conclusions can you come up with based on your readings?

Part Two - Comparing Results

4. Compare your results with three other students in your class. Was your average lower or higher than those of your classmates?

5. What conclusions can you come up with after comparing your results?

Part Three - Regional Data Comparison

Now that you've taken some samples yourself, let's compare what you discovered with the official data sets for your area. Begin by reading the background information below.

Background Information

Congress established the National Acidic Precipitation Program (NAPAP) in 1980 to conduct a comprehensive 10-year program to research, monitor, and assess the problem of acidic precipitation in the United States. A wealth of scientific research was conducted during the 1980's on the sources, chemistry and effects of acid rain, culminating in a 1990 NAPAP report to Congress. On the basis of that report, Congress voted to revise the Clean Air Act to further reduce emissions of sulfur dioxide and nitrogen oxides.

NAPAP also established the U.S. Geologic Survey (USGS) as the lead federal agency for monitoring acid rain emissions in the United States. To monitor emissions, the USGS established the National Atmospheric Deposition Program (NADP), a network of over 100 federal and federal agencies, universities, tribal nations, and companies. NADP's mission is to provide a long-term, accurate acid emissions monitoring network.

Once you finished reading the background information go to the following website: <http://nadp.sws.uiuc.edu> and, from the main menu, click on "Isopleth Maps" and then on "Annual Isopleth maps". Then click on the "2002 maps". There are a few terms that need to be reviewed before you can compare your results to the official data.

- A. Lab pH (measured at the Central Analytical Laboratory) is the pH of rainfall samples collected, and measured at the Central Analytical Laboratory (CAL) of the Illinois State Water Survey located in Champaign, Illinois.
- B. Lab H Deposition (kg/ha) (measured at the Central Analytical Laboratory) - is the amount of acidic rain deposited per hectare as measured at the CAL. Deposition is calculated by multiplying the average concentration by the total precipitation for the year. This results in the total mass deposited by rainfall per unit area of the Earth's surface for the year, in this case a hectare. A hectare is an area of a square 100 meters on each side. It equates to a little less than 2.5 acres.
- C. Field pH (measured at the field sites) refers to pH measurements taken at NADP field sites. For a map of the field sites, return to the main menu and click on "Data Access". A map of the field sites will come up. Click on your state to see the field sites in your state.
- D. Field H Deposition (kg/ha) (measured at the field sites) - is the amount of acidic rain deposited per hectare as measured at the field sites.
- E. SO₄ are sulfate aerosols formed naturally, as well as from emissions of sulfur dioxide, mainly from power plants. Concentration refers to the atmospheric concentration measured in rainfall. The maps show the precipitation-weighted mean concentrations in precipitation for the year (average mass per unit volume of precipitation).
- F. NO₃ refers to nitrate aerosols, from both natural and human sources, such as automobiles.

G. As we'll be concentrating just on SO₄ and NO₃ for this exercise, there is no review of the other chemicals listed.

Once you've reviewed the terms above, go back to the NADP website, find the field site which is closest to you, and answer the following questions.

6. What is the name and location of the site that is closest to you?

7. About how far is the site from where you live?

8. Click back to the national map and note the location of the field site. Then proceed to the Annual Isopleth maps for 2002 and click on "Field pH (measured at the field sites)" and locate your site. What is the pH value for the site?

9. How does your average pH compare with the value for the site?

10. If your value is different, what are some reasons that might explain the difference?

Review the following material on environmental sampling and answer question 11.

Environmental sampling is, in itself, a science. The goal when taking environmental samples is first to accurately select a sample that represents a larger group of phenomena. In the case of acid rain, a limited number of samples taken on a couple of days might yield skewed results due to an unusual level of activity at or near the test site on the day/days the samples were taken. Accurate sampling requires that a well thought out framework of samples be established in order to assure that the samples taken do, in fact, represent the phenomena being investigated.

Second, in taking a sample, it is important that the procedures for actually taking the sample are consistent. Whether a container is plastic or glass might affect the pH of samples collected. Also, testing kits and equipment are often calibrated differently and can yield different results.

Because environmental sampling can be so complex, the Environmental Protection Agency (EPA) has regulations and procedures regarding the sampling, analysis, procedures and equipment used in testing for possible contaminants. Also, guidelines for sampling are developed and made available by the American Society for Testing and Materials (ASTM).

The National Atmospheric Deposition Program has developed standards, procedures and guidelines for taking precipitation samples and for measuring pH. To get some sense of how complex environmental sampling can be, go to NADP's website and take a quick stroll through NADP's Quality Management Plan (accessible by clicking on the "Quality Assurance Information" link and scrolling down the page).

11. Review your answer for question 10. Might there be other reasons why your sample's pH doesn't match that of the field site? Explain your answer.

Part Four National Trends

Now that you have a better understanding of acid rain and sampling is done, let's take a look and see how the U.S. is doing in resolving the acid rain issue. Go to NADP's website at <http://nadp.sws.uiuc.edu/> and then on "Isopleth Maps" and then on "Isopleth Map Animations". Scroll down the page until the "Animations" table menu is in full view. Click on SO₄ concentrations, either in Flash or Power Point. To start the animation in Flash, click Start. To start the animation in Power Point, click on the year "85".

12. What is the trend or pattern that you observe?

Now, click on NO₃ concentrations, either in Flash or Power Point. To start the animation in Flash, click Start. To start the animation in Power Point, click on the year "85".

13. What is the trend or pattern that you observe?

14. How does the trend or pattern for NO₃ compare with that of SO₄?

15. Given what you know about the sources for SO₂ and the sources for NO_x, what conclusions can you draw?