

**Lesson Title:** Acid Precipitation

**Lessons Summary:** Students will use a GIS-based lesson to identify geographic areas in the U.S. that are at greatest risk from acid precipitation. These areas will be correlated with sulfur and nitrogen oxide production, population, presence of coal fields, and soil composition.

Before you begin using this module, you will need to know about using the ArcGIS Server Web-based GIS viewer. You can do this by watching the server tutorial video or working through the tutorial. The tutorial video, student activity, and Web-based GIS Tutorial Viewer can be found at <http://gis.lanecc.edu>. Go to the “Modules” tab and click the Tutorial link. You will need a high speed Internet connection and a current version of Adobe Flash Player.

**Prior Skills:** You will need to know how to turn layers on and off, use the ID, zoom in and out of the map, toggle from layers to the legend, use the identify and query tools.

Computer steps are indicated by a ► symbol and questions you need to answer are numbered.

- Open up the web browser go to Lane’s GIS page. <http://gis.lanecc.edu>
- Click Modules link.
- Click Chemistry.
- Click the Link to the web-based GIS map.



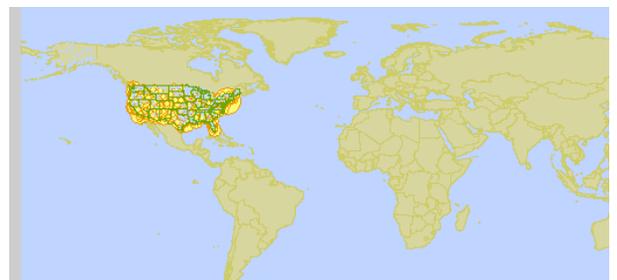
The page will take a minute or two to load. The base map will load first then the other data layers. If it stalls at 55%, just click the **refresh** button on your browser.

- Zoom into the Continental US. 

## Acid Precipitation – An Overview

- Check “pH 96” and uncheck City Population.
- 1) Define “Acid Precipitation” and describe how it is formed.

- Click the Identify tool  and click one of the states with low pH (most acidic). A table will open with state information. Scroll across to get the state name.



- 2) List the 10 states that have the lowest (most acidic) atmospheric pH.
- 3) In what region(s) or area of the U.S. are these states found?
  - ▶ Uncheck the pH 96 layer and check the pH 06 layer. This will show atmospheric pH levels in 2006.
- 4) Again, list the 10 states that have the lowest (most acidic) atmospheric pH.
- 5) Did your list of the states with the most acidic atmospheric pH change from 1996 to 2006? If so describe the pattern you see. For example:
  - Are the states with the most change clustered in a certain area? In a line? Evenly spread out across the U.S.?
  - If clustered, where is the cluster? . . . If in a line, where does the line begin and end? . . . If evenly spread out, is the change associated with features like rivers, lakes, or oceans?

## Acid Precipitation, Population, and Car Exhaust

- ▶ Turn on the “City Population Layer.”
- ▶ Click the triangle to expand the layer legend. Note that the bigger the dot, the larger the population of the city.



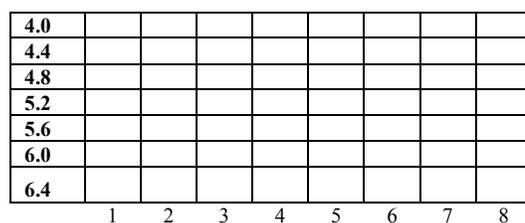
- 6) Describe the relationship you see between large population centers and low atmospheric pH. (Remember, low pH = high acidity.)
  - Where are the large populations within the U.S. (N, S, E, W, etc.)?
  - Where are the regions of low pH?
  - Do these regions seem related?

To describe how U.S. atmospheric pH changes as we move from west to east, we will plot how the pH changes as we move eastward. Graph atmospheric pH values along the line shown below.

- ▶ Turn on the pH line.

Make a solid line on the graph for 1996 pH values and a dashed line for 2006 pH values. See the graph and map below.

Acidic  
  
 Basic



- 7) Describe how pH changed as you moved from west to east across the U.S.
- 8) Describe the difference(s) you observed in atmospheric pH levels from 1996 to 2006.

High population density often means more automobiles. Combustion of nitrogen in car engines can produce atmospheric nitrogen dioxide ( $\text{NO}_2$ ).

- 9) Write a balanced reaction showing nitrogen gas reacting with oxygen gas to form nitrogen dioxide.

Nitrogen dioxide reacts with water vapor in the atmosphere to produce atmospheric nitric acid ( $\text{HNO}_3$ )—a source of the nitrate ion.

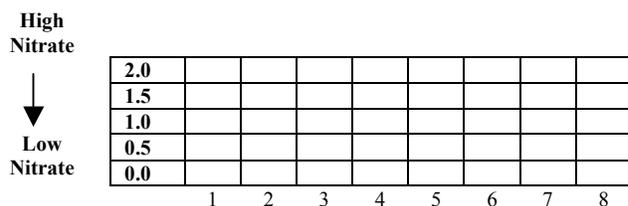
- 10) Write a balanced reaction showing the formation of nitric acid.

► Uncheck “pH 06” or “pH 96.” Check “Nitrate 96” layer. Expand the legend.

To describe how U.S. atmospheric levels of nitrate ( $\text{NO}_3^-$ ) changes as we move from west to east we will plot how the pH changes as we move eastward. Graph atmospheric nitrate ( $\text{NO}_3^-$ ) values along the line shown below.

Make a solid line on the graph for 1996  $\text{NO}_3^-$  values and a dashed line for 2006  $\text{NO}_3^-$  values. See the graph and map below.

- 11) Describe how nitrate levels changed as



you moved from west to east across the U.S.

- 12) Describe the difference(s) you observed in atmospheric nitrate levels from 1996 to 2006.
- 13) If the major source of atmospheric nitrates is automobile exhaust, explain the pattern seen in questions 11?

## Acid Precipitation and High-Sulfur Coal

One source of acid precipitation is sulfur dioxide ( $\text{SO}_2$ ) emitted as coal containing high sulfur content is burned to generate electricity. There are many different types of coal, including lignite, subbituminous, bituminous, and anthracite. Of these types, *bituminous coal* has the highest sulfur content.

- ▶ Uncheck the “City Population” layer. Check the “Coal Deposits” layer.
- ▶ Check “pH 06” layer. Select the “Identify Tool”.

The major coal deposits found in the U.S. should now be indicated on the map.

14) Write a balanced chemical reaction that shows how sulfurous acid ( $\text{H}_2\text{SO}_3$ ) is formed when atmospheric  $\text{SO}_2$  reacts with water vapor in the atmosphere.

- ▶ Use the ID tool to click on a major coal deposit in the U.S where pH is lowest. The type of coal will be listed in the “Type” field in the attribute table.

15) What type(s) of coal is/are present in areas where acid precipitation is a problem (i.e. pH is the lowest)?

- ▶ Click on the major coal fields in the U.S where pH is the highest.

16) What type(s) of coal is/are present in areas acid precipitation is not a problem (i.e. pH is highest)?

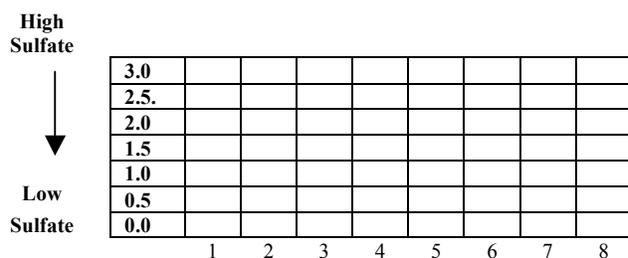
17) Atmospheric sulfurous acid ( $\text{H}_2\text{SO}_3$ ) often reacts with oxygen gas in the atmosphere to form sulfuric acid ( $\text{H}_2\text{SO}_4$ ) - a source of the sulfate ion. Write a balanced reaction that shows this process.

- ▶ Uncheck “pH 06” layer and Check “sulfate 96” layer. Expand the legend.

To describe how U.S. atmospheric sulfate changes as we move from west to east we will plot how the sulfate concentration changes as we move eastward. Graph atmospheric sulfate ( $\text{SO}_4^{2-}$ ) values along the line shown below.

- ▶ Turn on the pH Line – This graph line will work for  $\text{SO}_4^{2-}$

Make a solid line on the graph for 1996 sulfate ( $\text{SO}_4^{2-}$ ) values and a dashed line for 2006 sulfate values. See the graph and map below.



18) Describe how sulfate ( $\text{SO}_4^{2-}$ ) values change as you moved from west to east across the U.S.

- 19) Describe the difference(s) in atmospheric sulfate ( $\text{SO}_4^{2-}$ ) levels from 1996 to 2006.
- 20) From your reading assignment, list ways in which atmospheric sulfate can be reduced.

## Acid Precipitation and Limestone Deposits

Limestone ( $\text{CaCO}_3$ ) is sometimes found in soils, rocks, and minerals. Limestone can offset the effect of acid precipitation by reacting with the acid to neutralize it. Recall from chapter 4 of your text that acids + carbonates  $\rightarrow$  carbon dioxide + water + a salt.

- 21) Write reactions for the neutralization of nitric acid ( $\text{HNO}_3$ ) and sulfuric acid ( $\text{H}_2\text{SO}_4$ ) by limestone. Consult your text if you wish.

► Uncheck “sulfate 96 or 06” and “Coal Deposits”. Check the “Limestone Deposits.”

Recall the areas of the U.S. that have low atmospheric pH. (You can consult the small inset map in the upper left-hand corner of the larger map if you need to refresh your memory.)

Study the regions that have low atmospheric pH and compare it to regions that have limestone deposits. Decide which states have large regions that are protected or are unprotected from acid precipitation because of the presence or absence of limestone deposits. (If you click on a state, its name will appear at the bottom of the map.)

- 22) Which states have large regions that are protected from acid precipitation because of limestone deposits?
- 23) Which states have large regions that are not protected from acid precipitation by to an absence of limestone deposits?

### Career Extension:

- Go to the website <http://esri.com/industries.html>
- Find a career from the list that is of interest to you. For example: In the Natural Resources list, there is a link to forestry. In the forestry link, there are several job descriptions.
- List four ways GIS is used in the career you choose.
- Conduct an internet search to find information about salary ranges and possible job locations.

### Career Extension Option:

The readings and video that accompany this activity make explicit reference to the following:

- Methods utilized by environmental scientists to measure and mitigate the effects of acid precipitation. (Lacing streams with calcium carbonate to protect fish roe and aquatic insects, developing genetically altered plants that are more acid tolerant, etc.)
- Engineering solutions to  $\text{NO}_x$  production through the use of more complete combustion techniques, different fuel formulations, development of hybrid and electric cars.
- Engineering solutions to atmospheric sulfate production by using low-sulfur coal, scrubbers and electric precipitation of particulates in electric power generation smoke stacks.