Gasping for Clean Air

The sky's the limit for the billions of tons of pollutants people pump out of factories, homes and cars each year. These pollutants create problems such as urban smog, acid rain and toxic gases. Increased global industrialization and rapid population growth are combining to create more of these pollutants, threatening the very air we breathe. The health of humans and that of our ecosystem are suffering as a result of the largely preventable amounts of pollution with which we poison our air.

In many cities, it is actually hazardous to breathe. In 1996, around 47 million people in the United States and 1.5 billion people worldwide had to breathe air contaminated by dangerous levels of air pollution. Breathing the air in Bombay, India, is equivalent to smoking ten cigarettes a day. And in Mexico City, the world's most polluted and populated city, infectious diseases like salmonella and hepatitis can be contracted simply by inhaling bacteria suspended in the air.

Smog Alert

The most common urban air-quality problem in the United States is ozone. High in the atmosphere, ozone forms a layer that filters out harmful ultraviolet radiation, thus protecting life on Earth. But ozone is also formed at the Earth's surface under certain conditions when sunlight reacts with high concentrations of nitrogen oxides and volatile organic compounds in the air. There are thousands of sources of these gases, the two most common are power plants that burn fossil fuels, and combustion of gasoline in the engines of cars, buses and trucks. Other sources include paint solvents, wood fires like those we have in our fireplaces, and coal-fired boilers; some emissions even come from trees.

Although concentrations of many air pollutants have fallen significantly in the United States in recent years (due to Clean Air Act regulations), elevated ozone levels continue to be a pervasive and damaging problem in many large and smaller cities and some rural areas as well. According to the U.S. Environmental Protection Agency (EPA), in 1996, around 47 million Americans lived in areas that exceeded EPA's ozone standard. In Canada, the annual average ozone concentration increased 20 percent between 1981 and 1990.

Adverse health effects of ozone pollution include shortness of breath, chest pain when inhaling deeply, wheezing and coughing. Long-term exposure may lead to permanent lung tissue damage. A 1996 American Lung Association report estimated that in the 13 metropolitan areas studied, ozone was linked to 10,000 to 15,000 hospital admissions and an estimated 30,000 to 50,000 emergency room visits per year.

Ozone can affect the health of trees, crops and other plants at concentrations even lower than those that harm humans. Ozone has been shown to reduce plant growth by interfering with the plant’s ability to produce and store food, and it can make plants more susceptible to disease, insect attacks and harsh weather. Forest declines in several parts of the country have been attributed to ozone and other pollutants. Ozone causes an estimated 1 to 2 billion dollars worth of loss to crop yields in the United States each year.

The second most common vehicle-related pollutant, behind ozone, is carbon monoxide (CO). Motor vehicle exhaust is responsible for 60 percent of CO emissions nationwide, and in cities, vehicle exhaust can create as much as 95 percent of all CO emissions. CO concentrations in the air dropped 37 percent in the United States over the last ten years, and 45 percent in Canada between 1981 and 1990, largely due to the addition of car pollution control devices called catalytic converters which help remove CO from car exhaust. However, in the United States in 1996, almost 13 million people lived in areas which failed to meet the EPA's health standard for CO emissions.

Carbon monoxide is absorbed into the bloodstream more quickly than oxygen, creating numerous health risks. Exposure to even low levels of CO reduces the body's delivery of oxygen to its organs and tissues, producing impaired perception and thinking, slowed reflexes and drowsiness. Long-term exposure to CO is believed to aggravate arteriosclerosis and cardiovascular disease.
Coal Toll

Other dangerous elements that pollute our air and threaten our well-being include sulfur dioxide (SO₂), particulate matter (suspended particles of soot, ash, dust and chemicals), nitrogen dioxide and lead. Emissions of these elements have been greatly reduced in industrialized countries with the aid of pollution control equipment and improvements in energy efficiency. In much of the world, however, these elements pose dire threats to human and environmental health. In Eastern Europe and the former Soviet Union, hasty industrialization after World War II, powered by high-sulfur, brown coal, has led to widespread environmental degradation and human illness. In India, SO₂ emissions from coal and oil have nearly tripled since the early 1960s.

The World Health Organization (WHO) estimates that around three million people die every year from exposure to particulate matter. The vast majority of deaths occur in developing countries where indoor air pollution results from burning biomass fuel (including firewood and cow dung) and coal for heating and cooking. Particulate matter causes problems in the industrialized world as well. The National Resources Defense Council and the Harvard School of Public Health estimate that about 60,000 deaths occur every year in the United States from particulate pollution caused by fuel combustion and vehicle exhaust. That’s more fatalities than are caused by car accidents and homicides combined.

Acid Attack

Excessive levels of pollutants are just as damaging to the planet’s health as they are to its inhabitants, especially in the form of acid rain. When sulfur and nitrogen oxides combine with oxygen and moisture in the atmosphere, they become sulfuric and nitric acids. These acidic pollutants fall to the ground, often hundreds of miles from their origins, as dry particles or in rain, snow, frost, fog and dew.

Acid rain damages wildlife through direct contact and by leaching or dissolving minerals in the soil. Acid rain leaches away nutrients and, at the same time, releases toxic elements such as aluminum into the soil where they can be harmful to plants and animals. In areas severely affected by acid rain, trees decline in growth and die prematurely, plants and...
microorganisms crucial to the wildlife food chain die, and lakes become too acidic to support fish and birds. Acid precipitation is believed to be responsible for dieback and deterioration of white birch trees in southeastern New Brunswick, Canada, and of red spruce in higher-elevation areas of the United States.12

In Canada, 150,000 lakes are severely affected by acid rain originating from metal smelting in eastern Canada, coal-burning utilities in Canada and the United States and vehicle emissions on both sides of the border.13 In the Netherlands, acid rain has caused the decline of species of songbirds by depleting the soils of calcium, which is essential for the snails that the birds eat.14

Acid rain can also take its toll on the human body. Sulfuric and nitrogen oxide emissions have been linked to increased frequency of asthma, heart disease and lung disease, especially among children and the elderly. Even the water you drink may be tainted. Acid rain can cause a leaching of toxic substances both out of the soil and out of pipes that carry drinking water to millions of people.

Acid rain corrodes our bridges, buildings and monuments, and destroys priceless works of art. It is estimated that ancient monuments in Athens, Greece, have deteriorated more in the past 20 to 25 years from pollution than in the previous 2,400 years. Because the effects of acid rain are not necessarily felt in the same places where contributing chemicals are released, it has been difficult to enforce certain air quality policies. Clearly, individual states and countries cannot solve their problems alone.

Changing Fuel-less Ways

The Clean Air Act of 1970 and the strengthening amendments of 1977 directed the EPA to establish air quality standards for six of the most common and widespread air pollutants. Under the Act, state governments were directed to develop and implement strategies to meet and maintain these air quality standards. Considerable progress was made in cutting urban air pollution, especially with the development of the catalytic converter and the shift to unleaded gas for motor vehicles. The EPA points out that because of the Clean Air Act, air quality in the United States is better today than it was in 1970 despite the fact that the total U.S. population has increased 29 percent, the vehicle miles traveled every year have increased 121 percent, and the size of the economy has doubled.15 While it is frightening to think how bad the air quality could be without federal and state imposed restrictions on pollutants and emission rates, concentrations still remain quite high.

In 1990, Congress amended the Clean Air Act. The new amendments call for enhanced car inspection and maintenance programs, tougher regulations on vehicle exhaust, and development of cleaner-burning fuels. Congress also established an “emissions trading” system which assigned allowances (one allowance = one ton of sulfur dioxide per year) to electric utilities and other industries that produce sulfur dioxide. The system lets each utility or factory decide what is the most cost-effective way to reduce its emissions; then it may sell the allowances it no longer needs after the reductions. In the year 2000, emissions will be
limited to 895 million tons per year. Also that year, the EPA will begin to regulate less-polluting industries, so that a greater number of businesses will have to divide a set number of allowances. This cap on emissions plus more competition for allowances will provide an incentive for further reductions and ensure that the level of sulfur dioxide from industry sources will not increase. In addition, the amendments give the EPA greater power to enforce air quality standards and punish those who fail to comply. In 1997, the EPA re-evaluated and strengthened their national air quality standards for ozone and particulate matter.

Although these measures may allow us to breathe a little easier, the economy continues to grow, and the number of air-polluting cars on the road is expected to increase. Since 1960, the United States has added 87 million people to its population who, in turn, have almost tripled the number of vehicles on the road. Spurred by population growth, vehicle miles traveled in the United States are growing on average by more than 50 billion miles per year. As the population of our country continues to grow, and our urban areas sprawl out farther and farther, the number of cars on the road and the number of miles traveled will continue to grow. This growth is being accompanied by an increase in the demand for electric power from the growing population. These increases will continue to compromise the improvements in air quality made by technological advances which allow cars to burn fuel more efficiently and with less emissions and enable cleaner electric power generation.

Air pollution is undoubtedly a complex problem with no easy, inexpensive short-term solutions. Development of cleaner fuels, better emission-control technology, strengthened federal fuel economy standards for motor vehicles, and a more efficient mix of transportation alternatives, such as mass transit systems, could all play a significant role in achieving clean air in cities. If current population trends continue, however, it will become increasingly more difficult for Americans to clear the air.

**Endnotes**

4. American Lung Association homepage: www.lungusa.org
5. Ibid.
The Acid Tests

Student Activity B

Introduction:
Acid rain is something of a misnomer, because rain is naturally acidic, with a pH of about 5.6. When we speak of acid rain, therefore, we refer to rain with a pH lower than 5.6. Acid rain is produced when sulfur and nitrogen compounds are released into the atmosphere, where they combine with water to form sulfuric acid and nitric acids. Sulfur compounds may come from such natural sources as decomposing organic matter, volcanoes and geysers. The environmental problem known as acid rain, however, does not arise from natural sources. It is caused primarily by fossil fuel combustion. When coal, oil and gas are burned, large amounts of sulfur and nitrogen are released as gases to make the rain more acidic than usual. Acid rain has many effects on an ecosystem. In this investigation, students will examine just one of those effects.

Procedure:
Setup:
You will need to make the water solutions before class, using 10% sulfuric acid (H₂SO₄). If you have not worked with these chemicals before, consult with the chemistry teacher about correct safety procedure. (Note: As you add drops of H₂SO₄, be sure the solution is thoroughly stirred. The number of drops recommended for each solution is approximate, so it is important that you take several pH measurements for each solution.) Use the following recipe:
a) 500 ml of spring water = pH 6
b) 500 ml of spring water + approximately 5 drops of 10% H₂SO₄ = pH 5
c) 500 ml of spring water + approximately 15 drops of 10% H₂SO₄ = pH 4
d) 500 ml of spring water + approximately 25 drops of 10% H₂SO₄ = pH 3
e) 500 ml of spring water + approximately 30 drops of 10% H₂SO₄ = pH 2
f) 500 ml of spring water + approximately 35 drops of 10% H₂SO₄ = pH 1

Facilitating the Activity:
1. Distribute copies of the student worksheets and divide the class into lab pairs. Each pair will receive a set of materials as listed above. Be sure to label each pH solution and assign a different pH (from 1 to 6) to each group.
2. On Day 1, students will set up the experiment according to directions in Part A. On Days 2-10, students will observe and record findings as indicated in Part B.
3. While students are completing their experiment, you should set up a petri dish with bean seeds and rainwater. Record these results with those of the students on the class graph. Have students answer the worksheet discussion questions and supply rainwater samples for students to check their guesses. Discuss the answers with the whole class.

Follow-up Activities:
1. More advanced students could mix their own solutions for testing. They could also experiment with different kinds of acids (sulfuric, nitric, etc.) and levels. Of course, proper safety procedures would have to be strictly observed. Also, each group could have several dishes to observe, to compare and graph the results.
2. Have students test samples of lake or pond water and soil with pH paper in their local areas to determine levels of acidity. They can then compare their findings to those of their classmates who collected samples from different sources.
3. Plants are not the only organisms affected by acid rain. Have students list ecosystems that are negatively affected by acid precipitation. What might be the long-term affects of acid rain for these areas?


Concept:
Acid rain, produced by fossil fuel combustion, is detrimental to the growth of many plant species.

Objectives:
Students will be able to:
• Determine the acidity of a substance by testing it with pH paper.
• Measure and graph the results of lab experiment with radish seeds.
• Compare the effects of different levels of acidity on plant growth.

Subjects:
Biology, chemistry, environmental science

Skills:
Lab preparation, collecting, recording and analyzing data, graphing, measuring, observation, drawing

Method:
Students test different pH solutions on bean seeds to determine optimal level for seed germination. They then test the acidity of pond water in their local areas.

Materials:
Copies of Student Worksheets
2 pairs of safety goggles
2 lab aprons
2 pairs of plastic gloves
Petri dish
4 bean seeds
Glass-marking pencil
Scissors
Transparent metric ruler
Graph paper
Absorbent paper towel
Colored chalk or markers
Rainwater
pH paper
water solution ranging in pH from 1 to 6
The Acid Tests

Student Worksheets

Part A - Day 1
1. Cut 4 paper discs the size of the petri dish from the absorbent paper towel.
2. Dampen the paper discs with the water assigned to you by your teacher. Use pH paper to test the pH of your assigned water and note the pH in your data book.
3. Place 2 of the paper discs on the bottom of the petri dish.
4. Measure the length of your 4 seeds and determine the average length.
5. Record the average length in millimeters at Day 1 in your data book.
6. Arrange the seeds in the petri dish and cover with the 2 remaining discs. Make sure the discs are still moist. If not, add more of your assigned pH solution.
7. Replace lid on petri dish and label both the lid and the dish with your team name.
8. Wash your hands thoroughly before leaving the laboratory.
9. Make a guess as to the ideal pH for bean seed growth. Record your guess in your data book.

Part B - Days 2-10
1. Remove the lid from the petri dish and remove the 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, drain the remaining water and replace with the correct level.)
2. Measure the length of the seeds in millimeters. Average the lengths and record the average in your data book.
3. Sketch the shape of the seeds and note their color.
4. 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.)
5. On the piece of graph paper, set up a graph with age in days on the horizontal axis and length of seeds in millimeters on the vertical axis.
6. Plot the average length of your seeds for the 2 measurements (Day 1 and Day 2) you have made.
7. 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.
8. Students who are working with the same pH should average their results and have one representative for each pH record the data on the class graph. Use the color assigned to your particular pH.
9. Each day, wash your hands thoroughly before leaving the laboratory.

Discussion Questions:
1. Observe the data on the completed class graph. What appears to be the optimal pH solution for successful radish seed germination?
2. What appears to be the least ideal pH solution for successful radish seed germination?
3. What pH do you think the rainwater has, based on the data gathered? Check your guess by determining its pH with pH paper.
4. Based on the data gathered, what would be the impact of rainwater with increased acidity?
5. Do you think there is reason for concern?
**Clearing the Air**

**Student Activity 9**

**Introduction:**
Air pollution is becoming a serious problem in many parts of the world. For example, each year in the United States, 60,000 deaths are caused by particulates found in air pollution. Breathing the air in Bombay, India is equivalent to smoking ten cigarettes a day. Every twenty-fourth disability and every seventeenth death in Hungary is caused by air pollution, according to their National Institute of Public Health. And diplomats stationed in Mexico City are awarded hardship pay for breathing the polluted air. While these examples are extreme, cities worldwide are facing increased problems from industrialization’s unwelcome side effect, air pollution.

**Procedure:**

**Set-Up:**
Before class, copy the air pollution diagram from the Student Worksheet onto the butcher paper or poster board. Make sure to leave enough space under each category so that students will be able to fill in the information from their articles. The middle circle can simply be labeled “Air Pollution,” rather than trying to list all the article titles. Post this master in an easy-to-reach location so that students will be able to add to it during the class.

**Facilitating the Activity:**
1. A few days before the activity, have students collect at least two articles or resources about air pollution. Suggest that they make use of the local library(ies) and their home supply of newspapers and/or magazines. If they have access to the Internet, they can do a search of articles on the topic through a major newspaper’s archives. They may also write a summary of a news show or documentary on television. The following list of topics can serve as a guideline for students in their search:
   - Smog in Los Angeles (or other polluted cities)
   - Effects of Eastern Europe’s rapid industrialization
   - Mexico City’s efforts to control airborne poisons
   - Legislation passed to curb air pollution
   - Health studies about effects of breathing dirty air
   - Damage to outdoor art due to air pollution
   - Traffic and industry’s role in climate change
   - The connection between air pollution and acid rain (& effects of acid rain)
2. After allowing a couple of days for students to collect their articles and summaries, pass out the Student Worksheets and have students diagram the information from their resources. See chart on the following page for an example of how to use the diagram. You might want to chart a sample article on the master chart so that students understand the concept. Emphasize that students should include as much information as possible on their chart, but that not every category will have something listed. Allow about 15-20 minutes to complete their two charts.
3. As students finish their own charts, they may begin adding to the class version. (You might want to check students’ copies for errors before they add to the main chart.) When information is duplicated, students should make tally marks next to the original entry, rather than take up extra space duplicating the information. As some areas become crowded with information, students may need to use arrows to continue the lists. Hang the completed chart in the classroom, and encourage students to add to it if they find further articles or learn more information about air pollution.

**Discussion Questions:**
1. Which of the causes on the chart are increased with population growth? Do any of the causes seem unrelated to a growing number of humans?
2. Make a list of important factors for a realistic plan to reduce air pollution. Using these guidelines, which ideas mentioned in the “solution” section seem most feasible? Which seem least feasible?

**Concept:**
Current industrial and individual practices must be modified to avoid further environmental and health problems caused by air pollution.

**Objectives:**
Students will be able to:
- Find and use publications on current events to understand an issue.
- Identify and categorize useful information from publications.
- Compare and discuss research findings with other students in the class.

**Subjects:**
Environmental science, health, social studies, biology

**Skills:**
Research, collecting and recording data, analyzing and interpreting data, reading comprehension

**Method:**
Students find articles about air pollution issues and as a class use the information to create a chart depicting the causes and effects of air pollution and possible solutions.

**Materials:**
Copies of Student Worksheet
Large sheet of butcher paper or poster board and writing utensils
Optional: Newspapers, news magazines and other resources
Clearing the Air

Student Activity 9

3. What differences exist between the air pollution problems in heavily industrialized countries and those in less developed countries? Are there also differences in the kinds of solutions they seek? What factors contribute to these differences?

4. Are there any direct links between specific causes of air pollution and certain effects? Which of the causes tend to create more health problems? Which tend to contribute more to environmental damage?

5. What health or environmental risks are most closely associated with acid rain?

6. Considering the air pollution problems in many big cities, why do people continue to gravitate to these heavily polluted urban areas?

Follow-up Activities:
1. Students can research one of the topics listed in the guide at the beginning of this activity and write an investigative report on the subject.
2. Have students chart the population growth rate and airborne poisons increase in cities like Mexico City and Los Angeles, if this information is available.

Endnotes
1 American Lung Association homepage: www.lungusa.org
Clearing the Air

**Student Worksheet**

- **Air Pollution**
  - Location of Problem:
    - Industrialized Countries
    - Less Developed Countries
  - Causes of Air Pollution:
    - Industry/Power Plants
    - Automotive Vehicles
    - Individual or Household Actions
    - Other
  - Effects of Air Pollution:
    - Health
    - Environmental
    - Other
  - Solutions to Problem:
    - Use/Develop Alternate Energy
    - Regulate Emissions
    - Change Behavior Patterns
    - Other