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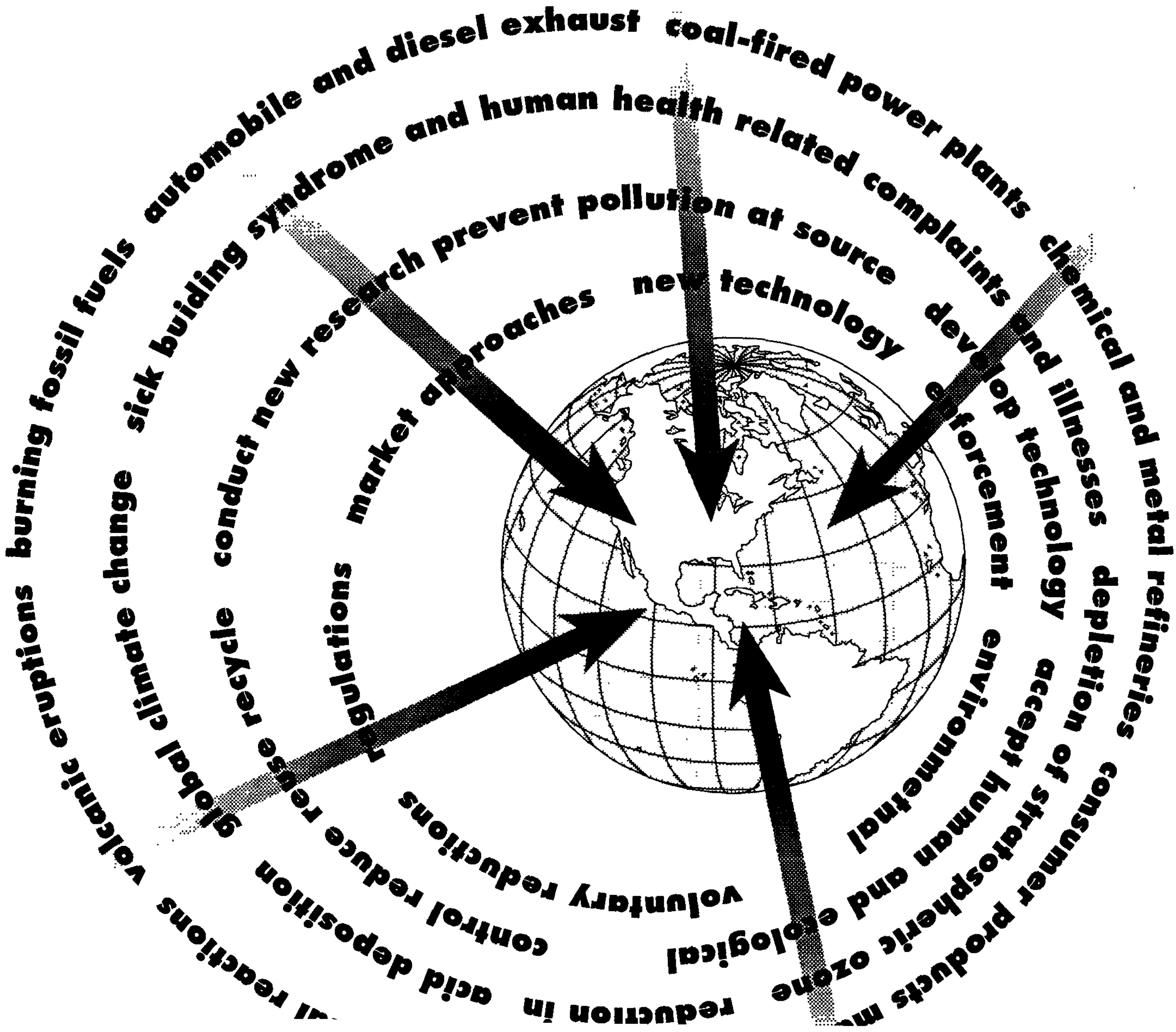
EPA

# Project A.I.R.E
# Air Information Resources for Education (K-12)

701D94101

## A Guide for Instructors



## NOTICE

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April 1994

PRE-PUBLICATION COPY

## FOREWORD

Dear Educator:

We take for granted the ability to breathe. Our bodies breathe automatically thousands of times a day, awake or asleep. Without adequate air, we would loose consciousness in about three or four minutes and suffocate within seven to ten minutes. We take for granted our breathing, and we take for granted an inexhaustible supply of clean air. It is important, then, that we know and care about the quality of our air. In a greater context, we know that public policy decisions to safeguard our environment or restore or mitigate polluted resources do not lend themselves to easy choices. Many of us would admit that the choices are difficult, but how many of us look the other way or simply defer to our elected or appointed representatives the burden of choice? How many of us assume that environmental problems are intractable or that we as individuals cannot make a difference? (See Warm-up C and Activities 1, 5, and 17.)

The biggest burden to society is an ill-informed citizenship. Many of the issues surrounding clean air are complicated by scientific uncertainty. Our decisions will be made with the best available information we have at the time. Problems related to air pollution such as global climate change, depletion of stratospheric ozone, acidic deposition, visibility, health effects from hazardous air pollutants, airborne particulates, and radon—the list goes on—involve many options for action and as much contradictory evidence. No place in this Nation, and few places on Earth, are free from potentially unhealthy air quality conditions. Air pollution is not easily contained by physical or political barriers, or even continental-scale distances. No resource more typifies the "global society" than clean air. Unfortunately, clean air does not come without cost, and those costs are determined by the decisions we make. (See warm-up exercises A, H, and D and activities 3, 9, 10, and 12.)

The U.S. Environmental Protection Agency (EPA) is charged by law to monitor and protect our air, and EPA plays a major role in the design and conduct of scientific research that underlies our clean air regulations and standards. As a matter of national policy and common sense, EPA believes that an informed citizenship is crucial to wise management of our environment. In this spirit, EPA has an active program of environmental education designed to transfer to the public the scientific, policy, and economic knowledge necessary to make informed judgments and balance risks. EPA believes that environmental education requires more than a dissemination of facts or scientific certitudes; it demands that we are informed about the process of environmental decision-making as well. Scientific measurements produce the data, but human judgment produces the policy. (See Warm-ups G and H and Activities 4, 8, 11, 13, 15, and 21.)

These instructional materials reflect EPA's belief that environmental education and an informed population can begin early. Young people who learn the environmental issues and challenges portrayed here may also influence their elders, their own career paths, and may encourage early participation in their community environmental programs. Much of the technology, information, or understanding we now rely upon for our National environmental policies did not exist prior to the 1980s. The generation now in primary and secondary school is the first to have an opportunity to learn of these issues while in school. By the time this generation begins to make our National decisions, much will have changed and much will have been learned. The risks associated with the decisions we make today will be borne by this new generation. But what is really meant when we talk about risks expressed as an increase of "one in a million" excess mortality or disease? Often relating to such data is difficult and can only be done in terms of what is acceptable or unacceptable. Having the appropriate experiences to judge such data within the framework of our daily lives can be obtained in school. (See Warm-ups E and F and Activities 6, 7, 14, and 17.)

EPA sincerely hopes that 1994's Clean Air Month™ Project A.I.R.E. materials will help you nurture in our students the message that our environment is shaped and influenced by an inextricable bond between science, technology, and public policy. (See Activities 15, 19, 20, and 21.)

We hope that the materials offered here will help you deliver this message.

Ron Slotkin, Education Coordinator
Office of Research and Development
U.S. Environmental Protection Agency

# CONTENTS

# INTRODUCTION

The following learning units have been developed to focus the attention of elementary, junior high, and high school students on air pollution issues as part of EPA's observance of the Clean Air Month™, sponsored by the American Lung Association, in May 1994. In keeping with ongoing efforts to reform science-related education to provide students with the tools necessary to be more competitive in the world economy, the units in this package have been designed to help students think more critically and creatively about air pollution problems and the alternatives for resolving them. Additionally, they are designed to encourage more EPA employees to volunteer their time to assist teachers in introducing environmental science into their classrooms.

## INSTRUCTIONAL GOALS

The units have been designed with four primary instructional goals in mind. They are structured to be "hands-on/minds-on" and give students practice in:

- collecting, analyzing, and interpreting environmental data;
- clarifying value systems—their own and those of others—that impact how we perceive and treat the environment;
- analyzing how economics, law, politics, technology, and other factors contribute to air pollution or their resolution; and
- synthesizing alternatives for resolving air pollution problems.

To participate effectively as citizens in our society, students must develop an understanding not only of the scientific and technical concepts related to the environment, but also that these concepts are useful and applicable in the world. To show the relevance and utility of the concepts and skills underlying these units beyond the classroom, we have made an effort to link each of the units with actual occupations in EPA and in other workplaces. In addition, many of the units challenge students to extrapolate real world applications from the information presented.

## WHAT THIS PACKAGE CONTAINS

The package includes eight Warm-up Exercises and 21 Activities. These units focus on the most important air-related issues in a simple, straightforward style. Most of them can be completed in one class period, but some require two class periods or portions of several classes over a specified period of time. Most begin with explanations or presentations by teachers or guest presenters, but a few involve presentations from students and facilitated discussions led by teachers or guest presenters.

The Warm-ups and Activities are designed for a range of grade levels from kindergarten through high school. A table showing the grade range for all units is provided at the end of this section for quick reference.

The package also includes a set of Reading Materials about the topics around which Warm-ups and Activities are built; a Glossary that contains definitions for terms and concepts students encounter in the exercises and activities; a Bibliography containing all the books, videos, and articles cited as supplementary reading in the individual Warm-ups and Activities, as well as other helpful resources; and a list of Project A.I.R.E. contacts in EPA Headquarters and the Agency's Regional Offices throughout the country who can provide additional information about air pollution topics and assist teachers identify and arrange for EPA guest presenters.

## WARM-UP EXERCISES

The Warm-ups are general in nature and focus on the development of basic skills—such as observation; formulation and testing of hypotheses; collection, display, and interpretation of data, and decision-making. These exercises are designed for use by classroom teachers, alone or to precede related Activities. Warm-ups may be conducted by teachers or by invited EPA employees and other technical/subject experts.

## ACTIVITIES

The Activities build on the foundation established with the Warm-ups. They call for students to examine air pollution-related issues by conducting experiments, analyzing alternatives, synthesizing solutions, and developing action plans. The Activities are designed for presentation by appropriate EPA employees or others with expertise in the relevant issues, in concert with classroom teachers. Since some of the Activities take more than one class period, teachers may consider sharing the delivery with an invited guest presenter.

Wherever possible, Warm-up exercises are linked with Activities to reinforce underlying concepts and skills. For the same reason, we have intentionally created overlap among some of the Activities.

## HOW EXERCISES AND ACTIVITIES ARE STRUCTURED

Each Warm-up and Activity is introduced with a paragraph describing its subject and its relationship, if any, to others in the package. The text of each unit is structured to provide information in several areas as illustrated in the diagram on the next page.

## HOW TO USE THIS PACKAGE

It is envisioned that, for EPA's observance of Clean Air Month™, this package would be distributed through EPA Headquarters and Regional Office personnel to teachers with a suggestion that they schedule EPA employees as guest presenters for one or more of the Activities during the month. Teachers can choose to conduct one or more of the Warm-up exercises to set the stage for the EPA employees' presentations.

There are a variety of other options available, however, and teachers are encouraged to use the material well beyond Clean Air Month™. While units are labeled as Warm-ups or Activities and the intended links between them are indicated, they can and should be used alone or in various other combinations to accommodate the needs of individual classes and grade levels. Some teachers, for example, may choose to conduct several of the Activities, as well as the Warm-ups, on their own. Others may choose to invite more than one guest to take part in the presentation of one or more of the units. Students also may wish to present their findings and questions from units to an EPA employee.

We encourage teachers and EPA employees to work together to determine how to take best advantage of the material to achieve the overall instructional goals and the specific objectives of each unit.

### Dealing with Grade-Level and Geographic-Location Adjustments

In order to get the most out of the various Warm-ups and Activities, teachers should work with guest presenters to select the material from individual lessons for presentation. The units, as they are presented in this package, are intended as resources. Teachers and guest presenters should feel free to make adjustments in the material to fit in with topics and concepts the class

**Guest Presenters** links the concepts and skills included with actual occupations by suggesting professionals who might be appropriate guest instructors

**Skills** lists the science or mathematics skills used in the lesson

**Related** Warm-ups or Activities

**Critical Objectives** are stated in terms of what the student will know or be able to do following this activity

**Reading Materials** that provide additional information (located in the Reading Materials

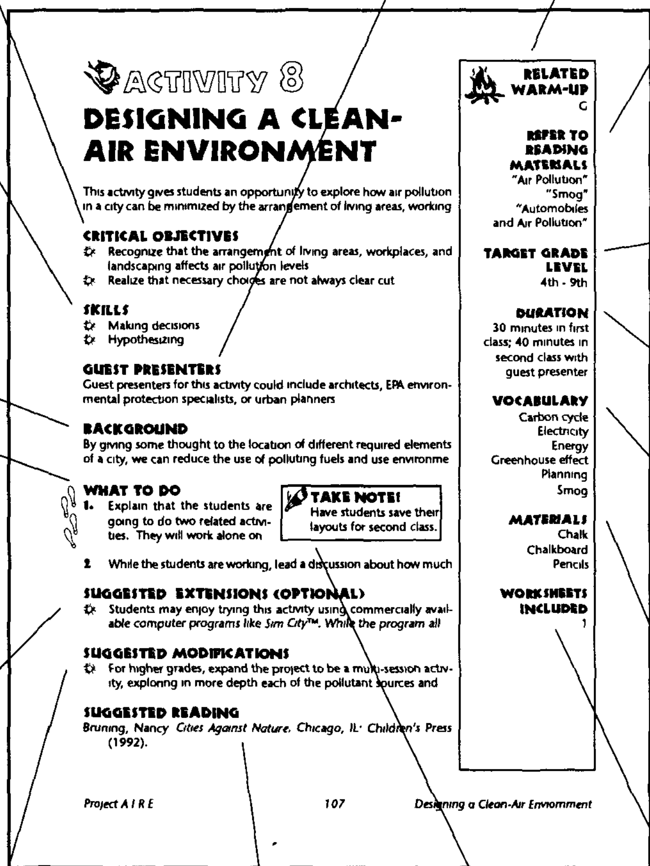
**Background** contains basic facts and context information for use by the teacher or presenter. This section also references additional information available in the Reading Materials section of the package

**Target grade levels** for this unit

**What To Do** provides step-by-step instructions for executing the lesson. Wherever appropriate, this section includes questions the presenter should ask or anticipate from the students

Planned **duration** of the lesson

**Vocabulary** students will encounter in the unit (defined in the Glossary section of the package



ACTIVITY 8

DESIGNING A CLEAN-AIR ENVIRONMENT

This activity gives students an opportunity to explore how air pollution in a city can be minimized by the arrangement of living areas, working

CRITICAL OBJECTIVES
- Recognize that the arrangement of living areas, workplaces, and landscaping affects air pollution levels
- Realize that necessary choices are not always clear cut

SKILLS
- Making decisions
- Hypothesizing

GUEST PRESENTERS
Guest presenters for this activity could include architects, EPA environmental protection specialists, or urban planners

BACKGROUND
By giving some thought to the location of different required elements of a city, we can reduce the use of polluting fuels and use environme

WHAT TO DO
1. Explain that the students are going to do two related activities. They will work alone on

TAKE NOTE! Have students save their layouts for second class.

2. While the students are working, lead a discussion about how much

SUGGESTED EXTENSIONS (OPTIONAL)
- Students may enjoy trying this activity using commercially available computer programs like *Sim City*™. While the program all

SUGGESTED MODIFICATIONS
- For higher grades, expand the project to be a multi-session activity, exploring in more depth each of the pollutant sources and

SUGGESTED READING
Bruning, Nancy *Cities Against Nature*. Chicago, IL: Children's Press (1992).

RELATED WARM-UP
C

REFER TO READING MATERIALS
"Air Pollution"
"Smog"
"Automobiles and Air Pollution"

TARGET GRADE LEVEL
4th - 9th

DURATION
30 minutes in first class; 40 minutes in second class with guest presenter

VOCABULARY
Carbon cycle
Electricity
Energy
Greenhouse effect
Planning
Smog

MATERIALS
Chalk
Chalkboard
Pencils

WORKSHEETS INCLUDED
1

Project A I R E    107    Designing a Clean-Air Environment

**Materials** necessary to do the exercise or activity

**Suggested Extensions (optional)** offers ideas for carrying the lesson farther—by suggesting follow-up activities or ways to expand participation beyond the classroom. Extensions are not suggested for all units

**Student worksheets** included as part of the Warm-up or Activity

**Suggested Reading** lists relevant books, videos, and articles that may be appropriate for students in the target grade levels

**Suggested Modifications** offers suggestions for making the unit applicable for higher or lower grade levels. Modifications are not suggested for all units

**Notes** are included, as needed, to deal with safety issues and to highlight special instructions may already be studying or to address topics of particular importance to students in a given geographic area. Also, we encourage teachers and guest presenters to use of their knowledge of the geography and make-up of the community to add texture to the lessons and reinforce students' in-classroom work.

**Delivery Style**

How teachers and guest presenters deliver these lessons is all-important. Underlying all of the units is an effort to help students think critically about the world around them and their role in preserving the environment. While many of the lessons provide subject questions to stimulate student discussion, few have a single, "right" answer. Instead, these questions are intended to draw on the students' ability to identify various options, strategies, and reasons in arriving at their answers. We suggest that teachers and guest presenters continue to use this "constructivist" approach in delivering these lessons. This can be done, for example, by asking students to describe how they arrived at a particular answer and encouraging them to compare their answers and approaches with those used by other students to answer the same question. In a case where there may be several answers to the same question, challenge students to explore why answers are different and how to determine which, if any, are correct. This type of delivery approach helps students develop critical thinking skills in a stimulating, non-competitive environment.

# TABLE 1. TARGET GRADE LEVELS FOR PROJECT A.I.R.E. UNITS

| Subject | Grade Level | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| **Warm-Ups** | | | | | | | | | | | | | |
| A Prediction | | | | | | ✓ | ✓ | ✓ | ✓ | | | | |
| B Read My Data | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| C Seeing the Big Picture | | | | | | ✓ | ✓ | | | | | | |
| D Learning from Stories | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | |
| E Tracking Air Quality | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| F Where's That Odor? | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| G Making Decisions | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| H Scales, Rules, Policy, Standards, and Science | | | | | | | | ✓ | ✓ | ✓ | | | |
| **Activities** | | | | | | | | | | | | | |
| 1 Lifestyles and the Environment | | | | | | | | | | ✓ | ✓ | ✓ | ✓ |
| 2 The Rain Forest is Alive | ✓ | ✓ | ✓ | | | | | | | | | | |
| 3 How Green Are We? | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 4 Action=$CO_2$ Savings and $ | | | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 5 Breathing Room | | | | | | | | | | ✓ | ✓ | ✓ | ✓ |
| 6 The Radon Game | | | | | | | | ✓ | ✓ | | | | |
| 7 Inventing a Monitor | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 8 Designing a Clean-Air Environment | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| 9 Finding Sources of Air Pollution | | | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 10 Is Your Air Clean? | | | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 11 Acid Rain and Plants | | | | | ✓ | ✓ | ✓ | | | | | | |
| 12 The Greenhouse Effect | | | | | | ✓ | ✓ | ✓ | | | | | |
| 13 Climate and the Greenhouse Effect | | | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 14 Smog | | | | | ✓ | ✓ | | | | | | | |
| 15 Deciding To Clean the Air | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 16 Choosing a Better Future | | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 17 The Business of Clean Air | | | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ |
| 18 Air Pollution Allowance Trading | | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 19 The Cost of Polluting | | | | | | | | ✓ | ✓ | | | | |
| 20 Writing Environmental Laws | | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 21 Translating Science into Public Policy | | | | | | | | | ✓ | ✓ | ✓ | ✓ | |

# WARM-UP EXERCISES

# WARM-UP A
# PREDICTION

This exercise lets students practice making predictions, experimenting to test their hypotheses, and refining their predictions based on the results. It can be used with the activities called "Finding Sources of Air Pollution" and "Climate and the Greenhouse Effect," which include use of prediction skills.

## CRITICAL OBJECTIVES

- Recognize role of predictions in science
- Refine predictions based on observation and experimentation
- Test hypotheses

## SKILLS

- Forming and refining predictions
- Observing
- Comparing
- Interpreting and using results

## GUEST PRESENTERS

Guest presenters for this exercise could include atmospheric scientists, environmental scientists, EPA environmental protection specialists, or meteorologists.

## BACKGROUND

Making predictions and developing theories are central to the scientific method. History is replete with examples of scentists using their imagiNations and sound logic to hypothesize explaNations for things they observed and predict what should, or could, come next. While scientific predictions generally speculate about future observations or events, they also can focus on the past. For example, scientists may use observations from the present to predict where evidence related to the origins of humans might be found.

Environmental scientists and others use data collected in a variety of different experiments to examine trends and changes in the atmosphere and air quality. Using their observations and data from these experiments, they can predict, for example, whether the Earth's temperature is warming or cooling, what conditions will influence these changes, and how long it will take for each increase or decrease in temperature to occur.

There is always some uncertainty involved in making such predictions, because we still do not know everything about how individual

**RELATED ACTIVITIES**
9,13

**REFER TO READING MATERIAL**
"Weather and Air Quality"

**TARGET GRADE LEVEL**
5th - 8th

**DURATION**
45 minutes

**VOCABULARY**
Hypothesis
Precursor
Prediction
Variable

**MATERIALS**
Current day's newspaper
Three 12-oz. glasses
An 8-oz. plastic or styrofoam container (small enough to fit inside one of the glasses)
Tray of ice cubes
Chalkboard
Graph paper
Pencils

environmental processes work, much less how they interact. But the process of making predictions is important because it helps us gain more knowledge about unobserved phenomena and potential problems. (For example, predictions enable local government officials to warn health authorities and the public of the potential for conditions, like air inversions and smog, that could be harmful to people with respiratory difficulties and advise them how to protect themselves.)

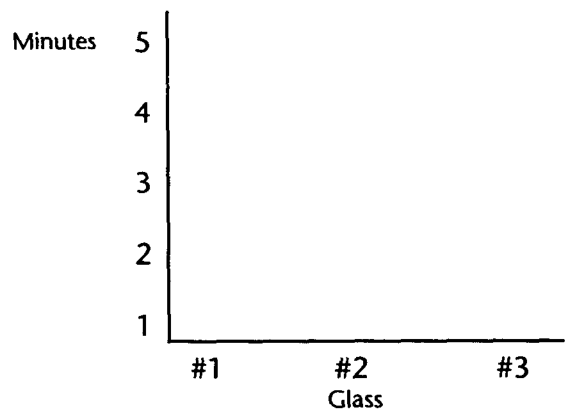
The ability to make predictions like these has been honed over time by continuously testing predictions and hypotheses and revising them based on observed results. It is through this process, for example, that scientists have been able to identify specific variables in the weather (called "precursors") that signal the formation of smog. (See reading material on "Weather and Air Quality.")

## WHAT TO DO

1. Ask the class why we would want to know what will happen tomorrow? Let students give their answers. Try to have them analyze and group their answers by category. For example, which answers have to do with "feeling secure"? How many relate to "being in control" or "being able to plan"? (This serves to illustrate the significance of the process of prediction.)

2. Hold up today's newspaper. Read the local weather forecast, including the information on air quality. Ask students how they think forecasters decide what to predict? What do they base their predictions on?

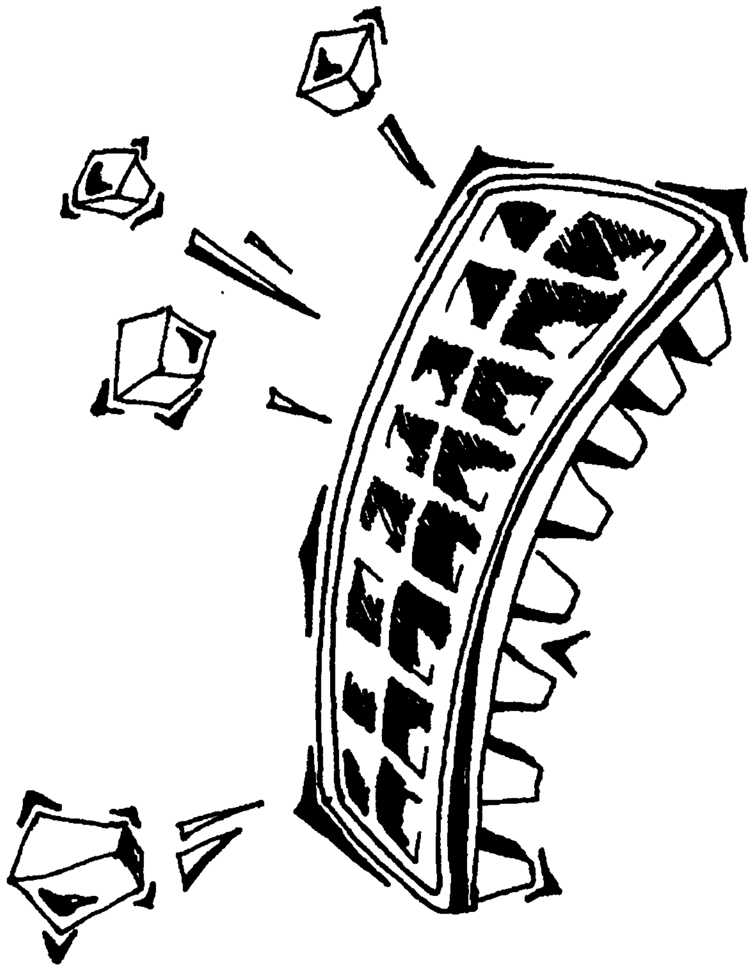
3. Explain that the class is going to do an experiment to see how well the students make predictions. (Make sure all students have a sheet of graph paper.) Instruct students to draw a graph on graph paper like the one shown below. Put a similar graph on the chalkboard.




4. Place the three glasses on a desktop or shelf in plain view of the class. Explain that you are going to put the same amount of ice in each glass. (*Do not do it yet.*) Explain that the ice will be surrounded by water in glass #1, by another container in glass #2, and by air in glass #3.

5. (Group students in teams if you prefer.) Ask the students to predict how long it will take the ice in each glass to melt (completely). Ask them to mark their predictions on the graph. (Glass #1 will have the water, glass #2 the plastic cup, and glass #3 the ice cubes alone.) In addition, have them write a hypothesis (basis for their reasoning) for each prediction (next to the graph or on another sheet of paper).

6. Explain that you will be checking their predictions and hypotheses in 5 minutes. Explain that they will have an opportunity to revise their predictions and hypotheses, if necessary, at that time. Call on a number of students to share their initial predictions with the class. Record them on the graph on the chalkboard.



7. Now put three ice cubes in glasses #1 and #3. Put the same amount of ice in the plastic cup and put it into glass #2. Pour water into glass #1 to fill it half full.

8. In the 5-minute interval, have students discuss the predictions shown on the chalkboard. Do they cluster? Do they differ widely? Why? Ask students to share their hypotheses—how they arrived at their predictions. Then ask if predictions or forecasts, like the examples on the chalkboard, are always right. If not, what is the value in making predictions? How do the students think forecasters—weather forecasters, for example—learn to make accurate predictions? (The discussion should point out that accurate weather forecasts result from forecasters' understanding of the scientific principles involved in weather and learning from their mistakes—analyzing the results of one prediction, making adjustments, and making another, more informed prediction.)

9. After five minutes, have students examine the three glasses. Did the ice melt in any of the glasses? If not, in which glass has the ice melted the most? Have the students participate in checking the predictions recorded on the chalkboard against the results at this point. Did anyone make an accurate prediction? How many students are on the

right track in terms of choosing the glass in which the ice will melt the fastest?

10. Ask students to revise their predictions and hypotheses. Have them record their new predictions and hypotheses on the same graph. (Make sure they mark which is the second prediction.)

11. Ask students to share their revised predictions (record these on the graph on the chalkboard) and what they considered in revising the predictions.

12. Have students examine the new set of predictions recorded on the graph on the chalkboard. Is the pattern generally the same or different than before? Ask students what conclusions they can draw about the process for making predictions from this exercise?

## SUGGESTED EXTENSIONS (OPTIONAL)

☼ Repeat the experiment on another day, but divide the class in half and add a variable (the addition of heat). Duplicate the original setup of glasses for each half of the class and have each group select a student to participate in the experiment. Explain that one group will use a hair dyer to blow warm air at the side of the glasses. The other group will use a hair dryer to blow warm air down from above the glasses. Have each group discuss and arrive at predictions about the ice in the other group's glasses. Remind everyone to consider what happened in the first set of trials. During the 5-minute interval, encourage students to share their predictions (record them on the chalkboard) and discuss how the heat variable affected their hypotheses. When the time has passed, examine the results and discuss what students observed, what conclusions they can draw, and how they would use that information in revising their predictions.

## SUGGESTED READING

Cosgrove, Brian. *Eyewitness Books: Weather.* New York: Alfred A. Knopf (1991).

Gibbons, Gail. *Weather Forecasting.* New York: Chelsea House Publishers (1992).

Root-Bernstein, Robert. "Future Imperfect (Incomplete Models of Nature Guarantees All Predictions Are Unreliable)." *Discover,* 14 (November 1993) p. 42.

WARM-UP B

# READ MY DATA

Most environmental decisions and regulations are based upon large quantities of numerical data and trends. This exercise introduces students to the fundamentals of reading and analyzing data and extracting comparisons and averages. It can be delivered by the teacher or a guest presenter, or by both together. It is related to the "Breathing Room," "The Greenhouse Effect," and "Smog" activities.

## CRITICAL OBJECTIVES

- Understand how data is collected and analyzed
- Recognize air pollutants the government requires to be monitored

## SKILLS

- Computing
- Analyzing data

## GUEST PRESENTERS

Guest presenters could include air quality engineers, environmental scientists, EPA risk assessment specialists, EPA environmental protection specialists, meteorologists, or statisticians.

## BACKGROUND

No matter where you live, but especially in urban areas, each breath you take contains gases or particles that may be unhealthy. We know this from the analysis of air quality data from around the country. We also know that much of the air pollution is invisible and cannot be detected by human senses. Realistically, in our industrial society, it is not practical to expect that air pollutants can be eliminated totally anywhere, so it becomes important to determine what "acceptable" concentrations will be allowed, and equally important to monitor ambient air quality so that these "acceptable" limits are not exceeded. Most air quality monitoring is done automatically by specialized equipment located strategically throughout the country. These monitoring stations collect vast quantities of data and create a record of the concentrations and durations of specific pollutants. The Clean Air Act establishes certain "standards," or acceptable levels, for various "criteria" pollutants. Most laws and regulations have separate standards for averaged concentrations over certain short- and long-terms (such as maximum 8-hour average concentrations). The Clean Air Act establishes National Ambient Air Quality Standards for six criteria pollutants: carbon monoxide, sulphur dioxide, nitrogen oxides, ozone, particulate matter, and lead. The short-term National Ambient Air Quality Standards (NAAQS) for several pollutants are shown on the accompanying table.

**RELATED ACTIVITIES**
5, 12, 14

**REFER TO READING MATERIALS**
"The Clean Air Act"
"Air Pollution"

**TARGET GRADE LEVEL**
5th-12th

**DURATION**
40 minutes (or additional session with guest presenter)

**VOCABULARY**
Air quality monitoring
Ambient air
Data
Pollutant
Standards
Trend

**MATERIALS**
Paper
Pencils

**WORKSHEETS INCLUDED**
2

This exercise will look at concentrations for the first four pollutants in several cities around the country. Just how clean is your air? You could guess—but check the accompanying data and find out. (See reading materials on "The Clean Air Act," and "Air Pollution.")

## WHAT TO DO

1. Write "1 ppm" on the chalkboard, and next to it write the fraction:

$$\frac{1}{1{,}000{,}000}$$

   Explain that "ppm" means "parts per million" and is similar to "percent" in that "percent" means "parts per hundred." Explain that, like "percent," ppm has no units or dimensions (such as grams or cubic meters). Challenge the class to state which quantity is smaller, 1 ppm or 1 percent. For older students, ask them to compute how much smaller 1 ppm is than 1 percent. Point out that since there are 10,000 "hundreds" in a million, 1 ppm must be 10,000 times smaller than 1 percent.

2. Using Student Worksheet 1, explain to the class what the numbers represent and ask the students to answer the questions. (For more advanced students, request the answers in quantitative terms.)

3. Using Student Worksheet 2, direct the students to calculate the percentage change in pollutant concentrations from 1975 to 1991 for the listed pollutants. Call students' attention to the fact that two of the six pollutants have units of $\mu g/m^3$, which means micrograms per cubic meter, while the other four pollutants have units of ppm, or parts per million. Explain to them that both represent concentrations of pollutants in the air. The four ppm pollutants are all gases, and most fluids (gases and liquids) normally have concentrations expressed as milliliters per liters (part per thousand) or microliters per liter (parts per million). Lead and particulates are solids, and their density cannot be arbitrarily established in relation to air. Therefore, their concentrations are normally expressed as a unit of weight (mass) per volume of air. The difference in the units of measure does not affect the calculation of percentage change.

4. Ask the students to identify significant changes. Have them speculate as to why the changes might have occurred. Discuss their answers with the guest speaker.

5. Point out to the students that the standards are very different from each other. Ozone's permissible level, for instance, is 75 times lower than that of carbon monoxide. Ask the class to speculate why the standards may be different for different substances. Explain that the human health tolerances are different for each pollutant and each pollutant may cause different health effects. The regulations account for these differences.

## SUGGESTED MODIFICATIONS

- Call your Regional EPA contact (see the Project A.I.R.E. Contacts listed at the back of this package) for information about where to obtain similar data for your geographic location. Conduct a similar analysis.

## SUGGESTED READING

Baines, John. *Conserving Our World, Conserving the Atmosphere.* Austin, TX: Steck-Vaughn Company (1990).

Gay, Kathlyn. *Acid Rain.* New York: Franklin Watts (1983).

*Pollution (Science Kit).* Delta Education (1990).

## STUDENT WORKSHEET 1

# READ MY DATA

### MAJOR AIR POLLUTANTS FOR SELECTED CITIES IN THE UNITED STATES – 1991

| City | Carbon monoxide* | Ozone** | Sulphur Dioxide*** | Nitrogen Oxides*** |
|---|---|---|---|---|
| (National Standards) | 9 ppm | 0.12 ppm | 0.030 ppm | 0.053 ppm |
| Atlanta | 7 | 0.13 | 0.008 | 0.025 |
| Boston | 4 | 0.13 | 0.012 | 0.035 |
| Chicago | 6 | 0.13 | 0.019 | 0.032 |
| Detroit | 8 | 0.13 | 0.012 | 0.022 |
| Houston | 7 | 0.20 | 0.007 | 0.028 |
| Indianapolis | 6 | 0.11 | 0.012 | 0.018 |
| Los Angeles | 16 | 0.31 | 0.005 | 0.055 |
| New Orleans | 4 | 0.11 | 0.005 | 0.019 |
| New York City | 10 | 0.18 | 0.018 | 0.047 |
| Pittsburgh | 6 | 0.12 | 0.024 | 0.031 |
| San Francisco | 8 | 0.07 | 0.002 | 0.031 |
| St. Louis | 7 | 0.12 | 0.016 | 0.026 |

* Second highest 8-hour average
** Second highest 1-hour average
*** Yearly average

1. **Which cities have carbon monoxide levels above the National Standards? Express the answers in percentages over or under the limit.**

   For example, New York's 10 ppm is

   (10 - 9) ÷ 9 = 1/9 = 0.111 = 11% over the National Standard.
   (data - permissible limit) ÷ (permissible limit) = ? x 100 = % over limit

2. **Speculate why any of the cities would exceed the permissible limits.**

3. **Do the same for the other three air pollutants.**

## STUDENT WORKSHEET 2

# READ MY DATA

### CHANGES IN AVERAGE CONCENTRATION POLLUTANTS IN THE UNITED STATES — 1975-1991

| Pollutant | 1975 | 1991 | % Change | |
|---|---|---|---|---|
| Carbon Monoxide | 10 ppm | 6 ppm | ______ | Show increase with plus (+) sign and decrease with a minus (-) sign in front of percentage. |
| Lead | 0.68 μg/m³ | 0.048 μg/m³ | ______ | |
| Nitrogen Oxides | 0.021 ppm | 0.021 ppm | ______ | |
| Ozone | 0.147 ppm | 0.115 ppm | ______ | |
| Particulates | 63 μg/m³ | 47 μg/m³ | ______ | |
| Sulphur Dioxide | 0.0132 ppm | 0.0075 ppm | ______ | |

Source: United States Environmental Protection Agency, *National Air Quality and Emissions Trends Reports*. 1981 and 1991

Calculate the percentage change for each pollutant. To do this, subtract the 1991 value from the 1975 value (to get the actual difference), then divide that answer by the 1975 value, to get the percentage change since 1975.

1. **What was the percentage change (either increase or decrease) in each pollutant for each city from 1975 to 1991?**

   For example, sulphur dioxide went down by 43%:

   (0.0132 - 0.0075) ÷ 0.0132 = 0.4318 x 100 = 43.18%
   (rounded to 43%)
   (1975 value - 1991 value) ÷ (1975 value) = ? x 100 = % change

   Round your answers to whole percentages.

2. **Did any pollutant concentrations go up?**

3. **Which pollutant changed the most?**

WARM-UP C

# SEEING THE BIG PICTURE

This exercise lets students examine our tendency for short-term versus long-term thinking and how it affects the environment. The exercise highlights how short-term thinking has resulted in actions that have contributed to air pollution. It stresses that individuals, by focusing more on the future, can help reduce air pollution. Related activities include "How Green Are We?," "Action = Savings in $CO_2$ + $," "Is Your Air Clean?," "Acid Rain," "Smog," and "Deciding to Clean the Air."

## CRITICAL OBJECTIVES

- Recognize the tendency for people to focus on the short-term
- Appreciate the impact that short-term thinking has had on the problem of air pollution
- Understand that every individual can have an impact on air pollution
- Identify ways to reduce air pollution

## SKILLS

- Organizing data
- Considering alternatives
- Drawing conclusions

## GUEST PRESENTERS

Guest presenters could include conservationists, environmental scientists, or EPA environmental protection specialists.

## BACKGROUND

The expression "can't see the forest for the trees" means that most people focus on the short-term. They get so overwhelmed by the little things of daily life—all the "trees" around them—that the bigger, more long-term picture, like the "forest," gets lost. For example, as population grew and our standard of living rose, consumption of natural resources increased. We needed to burn coal, oil, wood, and other fuels to run factories, cars, and the power plants that generate energy to heat and light our homes. The focus was on supporting immediate needs rather than the long-term environmental impact of these actions. But burning more fuels and increasing industrial activity helped to pollute the air.

Every individual has the ability to help protect the environment. If we all would set our thermostats to a lower temperature in winter and a higher temperature in summer, walk or bike instead of always using our cars, and turn off lights when we leave a room, we would cut

**RELATED ACTIVITIES**
3, 4, 10, 11, 14, 15

**REFER TO READING MATERIALS**
"Air Pollution"
"Automobiles and Air Pollution"
"Clean Fuels"

**TARGET GRADE LEVEL**
5th - 6th

**DURATION**
45 minutes (with possible extensions)

**VOCABULARY**
Consumption
Pollution
Standard of living

**MATERIALS**
Sheets of letter-size paper
Pencils
Chalk
Chalkboard

down the amount of energy used and the amount of pollution released into the atmosphere.

The cumulative effect of many individual actions can preserve the environment for future generations. Often, however, we do not understand or appreciate the value of their individual actions. While it can be hard to always keep the big picture in mind, it is important. And with practice, everyone can contribute to cleaner air. (See reading materials on "Air Pollution," "Automobiles and Air Pollution," and "Clean Fuels.")

## WHAT TO DO

**1.** Before telling students anything about the activity, have them write down ten things they need to do or want to do. They can be anything at all. Beside each, have them write down when they think they should do it. Don't give any other instructions or information.

**2.** Once everyone has made a list, draw a big rectangle on the chalkboard. Make five rows and five columns in the rectangle. Each of the columns has to do with time. Label the columns "tomorrow," "next week," "sometime this year," "sometime in my life," and "sometime in my children's lives." Each of the rows has to do with people. Label the rows "family," "friends/neighbors," "city/region," "country/ethnic group," and "world." (See sample.)

| | Tomorrow | Next week | Sometime this year | Sometime in my life | Sometime in my children's lives |
|---|---|---|---|---|---|
| Family | | | | | |
| Friends and Neighbors | | | | | |
| City or Region | | | | | |
| Country or ethnic group | | | | | |
| World | | | | | |

**3.** Have each student, in turn, put dots in the boxes where the items on his or her list belong. For example, if someone listed going to the shopping mall with friends tomorrow, a dot belongs in the box where the "friends/neighbors" row meets the "tomorrow" column. If someone listed joining the park clean-up campaign next week, a dot belongs in the box where the "friends/neighbors" row meets the "next week" column.

**4.** When everyone has filled in their dots, step back and look at the big picture. Have the students discuss why most of the dots cluster in the rows representing people they know and columns representing the short-term (if they do). Have students speculate about how the results of this exercise would apply to reducing air pollution.

## SUGGESTED EXTENSIONS (OPTIONAL)

- Ask students to keep a diary of all the things they do to reduce air pollution. Periodically, discuss these efforts and their impact on future pollution.

- Have an EPA representative visit the class to discuss efforts EPA is taking to address air pollution.

## SUGGESTED READING

Baines, John. *Exploring: Humans and the Environment.* Austin, TX: Steck-Vaughn Company (1993).

Elkington, John, et al. *Going Green: A Kid's Handbook to Saving the Planet.* New York: Puffin Books (1990).

Greene, Carol. *Caring for Our Air.* Hillside, NJ: Enslow Publishers (1991).

Gutnik, Martin J. *The Challenge of Clean Air.* Hillside, NJ: Enslow Company (1990).

Langone, John. *Our Endangered Earth: The Fragile Environment and What We Can Do To Save It.* Boston: Little, Brown (1992).

Leggett, Jeremy K. *Air Scare.* New York, NY: Marshall Cavendish Corp. (1991).

Stille, Darlene. *Air Pollution.* Chicago, IL: Children's Press (1990).

WARM-UP D

# LEARNING FROM STORIES

This exercise uses fiction designed for young children as a basis for lessons about ecology and environmental responsibility. It can be used independently or in conjunction other classroom activities. It is related to the "The Rain Forest Is Alive" activity.

## CRITICAL OBJECTIVES

- Recognize the relationship of plants, animals, and humans in the world
- Explore and observe their environment
- Recognize humans' influence on the environment, as individuals and as a group

## SKILLS

- Listening
- Observing
- Questioning
- Comparing ideas

## BACKGROUND

Storytelling is a time-honored teaching tool used in many cultures. The storybooks listed below all have environmental themes. They can serve as a starting point for conversations that call on children to synthesize information and experiences and think creatively about themselves and the world around them.

## WHAT TO DO

1. Choose a book from the following reading list:
   - *Keepers of the Earth* by Michael J. Caduto and Joseph Bruchac
   - *Chadwick Forever* by Pricilla Cummings
   - *The Violators* by Gunnard Landers
   - *The Great Kapok Tree* by Lynne Cherry
   - *The Talking Earth* by Jean Craighea George
   - *Mushroom Center Disaster* by N.M. Bodecker
   - *Alvin Fernald, Superweasel* by Clifford B. Hicks
   - *Canyon Winter* by Walt Morey
   - *Poison Factory* by John Branfield
   - *Baney's Lake* by Nan Hayden Agle
   - *Beaver Valley* by Walter Dumau Edmonds
   - *Who Really Killed Cock Robin?* by Jean Craighea George
   - *The Lorax* (picture book) by Dr. Seuss

**RELATED ACTIVITY**
2

**TARGET GRADE LEVEL**
K - 5th (with modification for grades 6 and higher)

**DURATION**
one or more class periods, depending on the choice of books

**MATERIALS**
One of the books from the reading list shown

*If I Built A Village* (picture book) by Kazue Mizumura
*All Upon A Stone* (picture book) by Jean Craighea George
*The Salamander Room* (picture book) by Anne Mazer
*Once There Was A Tree* (picture book) by N. Natali Romanov
*Tree House Town* (picture book) by Miska Miles

Depending on your students' reading level, you may choose to read the story aloud to the class or have children take turns reading.

2. Follow up the story by leading children in a conversation about it. Ask questions that challenge their thinking. For example, explore why things happened or people acted in given ways, what changed during the story, how something in the story is alike (or different) from something the child knows or believes. Challenge students to find ways they can use the lesson in the story. For example, what can they do to help save the rain forests, or take care of animals, or help their parents conserve energy?

3. Whenever possible, create activities to follow up on the lessons taught by the stories to enhance the experience. Use your imagination. If the story is about industrial pollution, take students for a walk and have them point out smokestacks and other things that might be visible examples.

## SUGGESTED MODIFICATIONS

- For students in grades 6 and above, you may wish to assign book reports based on fiction involving environmental themes. Have students present book reports to the class and discuss the environmental messages gleaned from the stories. Following is a list of books you may want to consider for this purpose:

> **TAKE NOTE!** These books should be reviewed to verify their appropriateness for your class. Your school or local librarian can help you choose other environment-related titles suited to your class.

*Emerald River of Compassion* by Rowena Pattee Kryder
*A Most Unusual Lunch* by Robert Bender
*Dear Children of the Earth* by Schim Schimmel
*Necessary Risks: A Novel* by Janet Keller
*Winter in the Heart* by David Poyer
*California Blue* by David Klass
*In Cahoots: A Novel of Southern California* by Malcolm Cook
*McCampbell's War* by Robert Herring
*Oh, What a Paradise It Seems* by John Cheever
*Heyduke Lives: A Novel* by Edward Abbey

*The Monkey Wrench Gang* by Edward Abbey
*The Profeteers: A Novel* by Max Apple
*The Forest Prime Evil* by Alan Russell
*The Killing Winds: A Novel* by Clare Francis
*A View from the Air: Charles Lindbergh's Earth and Sky* by Reeve Lindbergh
*Covered Bridge* by Brian Doyle
*Bushmaster Fall* by Carl A. Posey

WARM-UP E

# TRACKING AIR QUALITY

This exercise lets students graph changes in the weather that have implications for air quality in the community. It is related to the activities called "The Greenhouse Effect," and "Climate and the Greenhouse Effect." This exercise is best conducted over a long period of time (especially in the Fall) in order for students to observe significant variations in the Air Quality Index and correlate them with weather parameters.

## CRITICAL OBJECTIVES

- Observe the impact of weather on air quality
- Demonstrate data gathering, analysis, graphing, and presentation skills
- Apply techniques of comparison and critical thinking

## SKILLS

- Researching
- Observing
- Collecting and analyzing
- Graphing
- Interpreting

## GUEST PRESENTERS

Guest presenters could include air quality engineers, environmental scientists, or meteorologists.

## BACKGROUND

Graphing—the ability to depict information, relationships, and trends—is a basic skill for communicating ideas and sharing information. It is a skill that supports endeavors in science and mathematics. It is with graphical analysis that scientists and engineers at EPA look for relationships and processes that are not immediately apparent with single, one-time measurements.

Conceivably, this activity could be conducted througsulphurhe year or periodically to build a data set large enough to establish seasonal trends and determine indicators of change. When the same collecting techniques are applied to air pollutants, the accuracy, frequency, location, and testing protocol become critical for obtaining useful data with which to explain the movement of pollution in the environment and the extent to which we are exposed to air pollutants.

Pollutants in the air come from many sources. Natural air pollution caused by volcanoes, forest fires, and other natural sources has always existed,

**RELATED ACTIVITIES**
12, 13

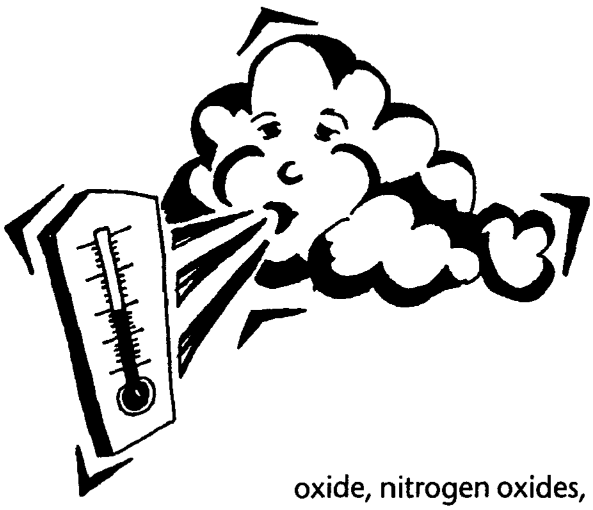
**REFER TO READING MATERIAL**
"Weather and Air Quality"

**TARGET GRADE LEVEL**
6th - 10th

**DURATION**
Class #1: 15 minutes; Classes #2-5 (over 2-to-6-week period): 5 minutes each; Class #6: 40 minutes

**VOCABULARY**
Air Quality Index
Carbon monoxide
Criteria pollutant
Lead
Nitrogen oxides
Ozone
Particulate matter
Precipitation
Relative humidity
Sulphur dioxide
Temperature
Thermal inversion

**MATERIALS**
Five sheets of white (or light colored) poster board or heavy construction paper each measuring 2 feet by 2 feet
Felt-tip markers in black, green, blue, red, purple, orange (1 in each color)



and naturally produced pollutants are present in greater amounts than those made by humans. They do not present as serious a problem as man-made pollutants, however, because they are dispersed over large areas and many are less harmful. Air pollutants from man-made sources are the result of our increasing use of large quantities of fuel to produce electricity and to run everything from factories to automobiles and other vehicles. Not only are some of these pollutants very harmful, but also they tend to be concentrated in urban areas where most people live and work. Six of the major man-made pollutants—sulphur dioxide, nitrogen oxides, carbon monoxide, ozone, lead, and particulate matter—have been designated "criteria" pollutants and are regulated by the federal government.

Daily weather conditions directly affect whether and how much we are exposed to pollutants in the air. Shifting air masses (weather systems) and wind can move pollutants from one place to another. On the other hand, stationary air systems, like thermal inversions, can trap harmful pollutants over an area for days at a time. Rain, snow, and other forms of precipitation help wash pollutants from the air and onto the ground. While precipitation cleanses the air we breathe, it also may increase pollution of the land and surface water.

Meteorologists use the Air Quality Index to classify and measure contaminants in the air and report conditions to the public. The index is used to convert data from air monitoring stations at various locations around a community to a scale that indicates the potential effects of measured levels of various contaminants, including the "criteria" pollutants (listed above), on human health, property, and vegetation. This information enables local government officials to take appropriate protective steps in thchalkboardarmful conditions like thermal inversions and smog. (See reading material on "Weather and Air Quality.")

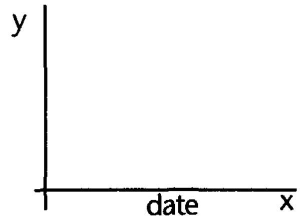
## WHAT TO DO

### Class #1

1. Divide the class into five teams and assign each team one of the following five weather parameters: Temperature, Wind Direction, Precipitation, Air Quality Index, and Relative Humidity.

2. Explain that each team will record daily changes in these aspects of the weather on posted graphs over a period of time (specify the period). At the end of the selected period, each team will prepare their findings and make a short presentation defining the aspect of the weather they have been tracking. Where appropriate, students should record the range of values (for example, the high and low temperatures for the day) and a mean value.

3. Give each team a sheet of poster board. Instruct them to draw a graph on their posters that will allow them to track published information about the weather aspect they have been assigned. (Teams should share the black markers for this task.) The "x" axis for all the graphs should be "date."




4. Encourage students to call the local weather bureau or the weather reporter at the local television station for help in determining the appropriate "y" axis range for the parameter they have been assigned. Suggest that the students obtain data to fill in their graphs from the local weather bureau, weather reporter, or newspaper.

5. Hang or otherwise display the posters in the classroom where students can see them and record data on them each day. The teams should be given the flexibility to organize themselves to ensure that the recording of data is accomplished every day.

### Classes #2-5

1. Take five minutes during each class to call attention to the status of the graphs and give students a few questions to consider in preparation for the discussion at the end of the exercise. For example: Would you expect some aspects of the weather to have more (or less) influence on the quality of the air we breathe? If so, which ones and why? The Air Quality Index is usually expressed for particular contaminants—such as ozone, sulphur dioxide, and ragweed pollen. From your observation, does it appear that changes in weather have more (or less) effect on air quality for some contaminants? If you have found no correlation, does that mean there is no effect? Is there another, better approach for determining a correlation?

2. During one of the classes near the end of the data collection period, give students a few additional questions to address in the presentations to be made in the final class. For example: How would you describe the weather in our area? What causes the weather to be like it is? Is the weather different elsewhere? If so, what causes it to be different in different places? Suggest that students brainstorm with their teammates and present the group's perspective in their presentations.

### Class #6

1. Before teams prepare their data for presentation, repeat the questions you posed during the periodic status checks—Would you expect some aspects of the weather to have more (or less) influence on the quality of the air we breathe? If so, which ones and why? The Air Quality

Index is usually expressed for particular contaminants—such as ozone, sulphur dioxide, and ragweed pollen. From your observations, does it appear that changes in weather have more (or less) effect on air quality for some contaminants? Encourage discussion.

2. Have each team make 5-minute presentations defining the weather parameter they have been assigned, reporting on the data collected, and addressing the general questions you posed in an earlier class. (See item 2 in the previous section.)

3. Ask the teams to compare the graphs. Now that they have seen all the data, ask if they would change their answers to any of the questions discussed at the beginning of class. Ask them to explain why (or why not).

4. Give each team one of the colored felt-tip markers. Encourage students to use the markers to point out similarities (or wide variances) between data on different graphs to illustrate and support their answers.

5. Encourage students to discuss what the results of this exercise might mean (for example, if the data collection period is "typical" for this time of year, how the weather might stress people with asthma or other respiratory problems, and how it might affect plants and trees in the area, or even their pets.) Have them discuss possible options for making the air quality better in these kinds of weather conditions.

6. Ask the students how they would determine whether their assumptions and conclusions are correct. End the class by recording on the chalkboard a list of their ideas. (The list should include going to the library to do research and talking to the local weather bureau, meteorologists, physicians, or local Health Department personnel.)

## SUGGESTED EXTENSIONS (OPTIONAL)

- Assign each team to act on one of the ideas offered for verifying the validity of conclusions and write a report to present in class.

- Look up historical weather data (go through local newspapers or other sources recommended by the weather bureau) for the same period in previous years. See if a pattern or relationship can be found between the conditions in previous years and the data collection period for this exercise by graphing the historical data in the same manner as the current data and comparing it with the current graphs.

## SUGGESTED READING

Albers, Daniel. "What Makes a Rainy Day?" *Sierra*, 74 (November 1989) p. 104.

Baines, John. *Conserving Our World, Conserving the Atmosphere.* Austin, TX: Steck-Vaughn Company (1990).

Catherall, Ed. *Exploring Weather.* Austin, TX: Steck-Vaughn Company (1990).

Clark, John Owen Edward. *The Atmosphere.* New York: Gloucester Press (1992).

"Climate: Worldwide Weather Threatens Millions." *USA Today Magazine,* 117 (April 1989) p. 1.

Cosgrove, Brian. *Eyewitness Books: Weather.* New York: Alfred A. Knopf (1991).

Freiman, Chana, and Nancy Karkowsky. "Weathering the Summer of 1993." *Science World,* 50 (22 October 1993) p. 10.

Gibbons, Gail. *Weather Forecasting.* New York: Chelsea House Publishers (1992).

Trefil, James. "Modeling Earth's Future Climate Requires Both Science and Guesswork." *Smithsonian,* 21 (December 1990) p. 28.

WARM-UP F

# WHERE'S THAT ODOR?

This exercise lets students use their noses as monitoring devices to determine the source of odors introduced into the classroom atmosphere and to demonstrate the importance of monitoring air pollution sources. It is related to the "Breathing Room," "Inventing a Monitor," and "Finding Sources of Air Pollution" activities.

## CRITICAL OBJECTIVES

- Recognize the importance of environmental monitoring
- Recognize that this experiment serves as a model for how monitoring is accomplished
- Explain the purpose and placement of monitoring devices
- Recognize conflicting information
- Recognize the role citizens can play in environmental cleanup

## SKILLS

- Observing
- Collecting and analyzing data
- Graphing

## GUEST PRESENTERS

Guest presenters could include air quality engineers, environmental scientists, EPA air quality monitoring specialists, or state or local air quality managers.

## BACKGROUND

The Earth's atmosphere is almost completely made up of invisible gaseous substances. Most of the major air pollutants also are invisible, gaseous substances that can adversely affect human health, as well as damage the environment. Among the major ambient air pollutants that may reasonably be anticipated to endanger public health are carbon monoxide, lead, nitrogen oxides, sulfur dioxide, ozone, and particulate matter. (A table describing these pollutants, their sources, and effects is included as a student handout.) To protect public health and welfare, the EPA has set national emissions standards for these pollutants. However, in order to prevent these and other potentially dangerous air pollutants from reaching harmful levels, it is important to be able to detect their presence and to identify their emission sources.

This exercise allows students to use their ability to detect and recognize odors as a model of an air monitoring device. Odor is the subjective perception of the sense of smell (olfaction). Odor intensity refers

**RELATED ACTIVITIES**
5, 7, 9

**REFER TO READING MATERIALS**
"Air Pollution"
"Indoor Air Quality"
"Health Effects"

**TARGET GRADE LEVEL**
4th - 12th

**DURATION**
40 minutes

**VOCABULARY**
Concentration
Intensity
Monitoring
Odor detection threshold
Odor recognition threshold

**MATERIALS**
6 shallow plastic containers with lids
Vanilla extract
Nail polish remover (use type with strong odor)
Food coloring (blue, red, and yellow)
Chalkboard
Chalk (white and one other color)

**WORKSHEETS INCLUDED**
1

to the perceived strength of the odor stimulus. The minimum concentration (threshold) of an odor that can be detected (smelled) and identified is dependent primarily on the sensitivity of the olfactory cells, which vary considerably, and the method of presenting the odor stimulus (such as flow rate and purity). The odor detection threshold relates to the minimum concentration required to perceive the existence of the stimulus. An odor recognition threshold relates to the minimum concentration required to identify the odor. Detection occurs at a lower concentration than recognition. For example, the detection threshold for ammonia is about 17 parts-per-million (ppm) volume/volume, and the recognition threshold is 37 ppm (v/v). Odor thresholds are statistical values determined by sampling individuals in a given population. (See reading materials on "Air Pollution," "Indoor Air Quality," and "Health Effects.")

## WHAT TO DO

### Before class begins

1. Mix the blue, red, and yellow food coloring to make a color that is similar to the color of vanilla extract. (You may use any substance or combination of substances to approximate the color of the vanilla, but they should create as little odor as possible. The idea is to use this mixture as blanks or decoys for the real vanilla extract.)

2. Put a small amount (just enough to cover the lid surface) of vanilla extract into one of the container lids. (Sandwich-size containers with lids that have a lip work best for this exercise.)

3. Put an equal amount of nail polish remover in another container lid.

4. Put equal amounts of a look-alike liquid in the remaining containers lid.

5. Place the lids around the room and cover them by inverting the containers over them.

6. On the chalk board, draw two maps (with white chalk) of the classroom, one for charting time and the other for charting intensity. (Students will have one worksheet for tracking both measures.)

### When class begins

1. Explain how determining what and where air pollutants come from (monitoring) is an important part of protecting people and the environment. Detection (what is there) of pollutants can be accomplished by different kinds of monitoring devices (tools). A simple example of visual detection is the dirt on the classroom window where pollutants have stuck to (or deposited on) the glass. When you breathe, the hairs in your nose act like a monitoring tool by filtering dust, and special cells (olfactory) in the back of the nose allow you to identify some chemicals in the air. Explain that because monitoring tools are expensive and take longer to use than you have in class, the students are going to

use their noses to detect and identify air chemicals. Instruct them to use their noses like scientists would use a monitoring device to detect and estimate the strength (volume or intensity) of an odor and to determine the source of that odor.

2. Explain that they will need to map the classroom to chart the results of the experiment. Hand out the worksheets. You fill in the maps on the chalkboard as each student fills in his or her own. Fill in the maps to show the location of each student. (Use white chalk.) Make sure the students understand where they are on the map.

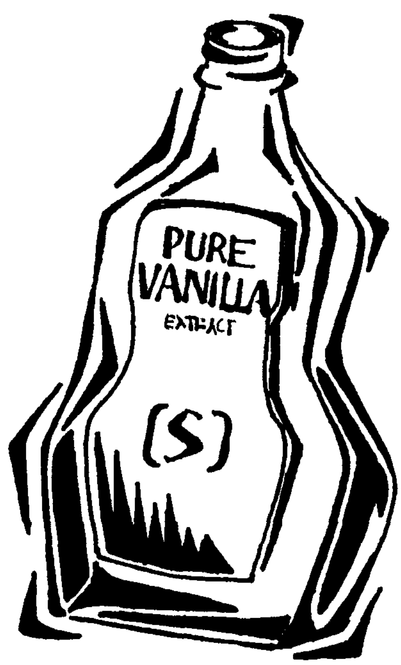
3. When the maps are complete, briefly describe the experiment. Tell them the idea is to record when they first smell an odor and to measure how strong it is at various times. Go over the time and intensity (strength) measurements and make sure everyone understands how to fill out his or her worksheet. (Plan on taking extra time for the lower grades.)

4. Remove the covers from the sources throughout the room containing the liquids. Leave the lids uncovered for 2 minutes. Announce the time every 30 seconds (for example, "A" on the worksheet would be T+30 seconds; "B" would be T+60 seconds, and so on). Remind students to find their place on their worksheet map and fill in the letter (time) and number (intensity) the FIRST TIME they smell an odor. If they detect more than one odor, they should fill in the letter (time) and number (intensity) the first time they smell EACH odor.

5. At the end of two minutes, cover all the sources again.

6. Call on a number of students in different parts of the room. (If time permits, let all students participate.) Have each, in turn, come forward and mark their location (in colored chalk) on each of the maps on the board with the time and intensity information they have recorded on their worksheet.

7. Lead a student discussion of the results of the experiment. Ask why some students recorded stronger odors sooner than others. Did the odor move in one direction more than another? If so, what does that suggest about the way pollutants move in the air? Did anyone detect more than one odor? Where did the odor(s) come from? The students' answers should point you to the real sources. (If not, be prepared to point out the real sources and explain how real scientists might use additional trials or put out more monitors to be sure the results are accurate.)



8. Describe why it is necessary to determine where contaminants, particularly invisible ones, are coming from (health effects, environmental and ecological effects). Give some examples. Explain that if the contaminants in the experiment had been harmful, finding out where they were coming from would make it possible for their local officials and EPA to take steps to remove them.

## SUGGESTED EXTENSIONS (OPTIONAL)

- Expand the discussion following the experiment by suggesting variables (such as what if a door or window were opened? What if there were more people in the room?) that could influence the path and speed with which the odor moves. Encourage the students to discuss the potential impact of these variables and, by extension, how variables complicate the process of monitoring air pollution.

- Ask the students how they might design a monitoring system that could locate the worst source (that which releases the highest volume) of a pollutant among multiple emission sources of the same pollutant? Suggest that they use the classroom model to help structure their thinking.

## SUGGESTED READING


Bailey, Donna. *What Can We Do About Noise and Fumes.* New York: Franklin Watts (1991).

Baines, John. *Conserving Our World, Conserving the Atmosphere.* Austin, TX: Steck-Vaughn Company (1990).

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STUDENT HANDOUT

# FINDING SOURCES OF AIR POLLUTION

## MAJOR MAN-MADE AIR POLLUTANTS

| POLLUTANT | DESCRIPTION | SOURCES | SIGNS/ EFFECTS |
|---|---|---|---|
| Carbon monoxide (CO) | • colorless, odorless gas | • vehicles burning gasoline<br>• indoor sources, including kerosene, wood-burning, natural gas, coal, or wood-burning stoves and heaters | • headaches, reduced mental alertness, death<br>• heart damage |
| Lead (Pb) | • metallic element | • vehicles burning leaded gasoline<br>• metal refineries | • brain and kidney damage<br>• contaminated crops and livestock |
| Nitrogen oxides ($NO_x$) | • gaseous compounds made up of nitrogen and oxygen | • vehicles<br>• power plants burning fossil fuels<br>• coal-burning stoves | • lung damage<br>• react in atmosphere to form acid rain<br>• deteriorate buildings and statues<br>• damage forests<br>• form ozone & other pollutants (smog) |
| Ozone ($O_3$) | • gaseous pollutant | • vehicle exhaust and certain other fumes<br>• formed from other air pollutants in the presence of sunlight | • lung damage<br>• eye irritation<br>• respiratory tract problems<br>• damages vegetation<br>• smog |
| Particulate matter | • very small particles of soot, dust, or other matter, including tiny droplets of liquids | • diesel engines<br>• power plants<br>• industries<br>• windblown dust<br>• wood stoves | • lung damage<br>• eye irritation<br>• damages crops<br>• reduces visibility<br>• discolors buildings and statues |
| Sulphur dioxide ($SO_2$) | • gaseous compound made up of sulphur and oxygen | • coal-burning power plants and industries<br>• coal-burning stoves<br>• refineries | • eye irritation<br>• lung damage<br>• kills aquatic life<br>• reacts in atmosphere to form acid rain<br>• damages forests<br>• deteriorates buildings and statues |

# STUDENT WORKSHEET 1

# WHERE'S THAT ODOR?

## CLASSROOM MAP

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | Front of | classroom | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | Back of | classroom | | | |

TIME

A = ________
B = ________
C = ________
D = ________
E = ________

INTENSITY

1 — No odor detected at all
2 — Begin to smell the odor
3 — Odor is strong
4 — Odor is very strong

# WARM-UP G

# MAKING DECISIONS

This exercise lets students explore how decisions are made and practice solving problems that require choices. It is related to the activities entitled "Lifestyles and the Environment," "The Radon Game," "Designing a Clean-Air Environment," "Is Your Air Clean?," "Deciding the Clean the Air," "Choosing a Better Future," "The Business of Clean Air," "Air Pollution Allowance Trading," and "The Cost of Polluting."

## CRITICAL OBJECTIVES

- Understand that solving problems requires a strategy or plan
- Recognize that "common sense" is really practiced decision-making
- Recognize that decisions involve trade-offs
- Understand that making decisions is part of everyone's life

## SKILLS

- Listening
- Asking questions
- Comparing ideas
- Drawing conclusions

## GUEST PRESENTERS

Guest presenters could include air quality engineers, economists, EPA environmental protection specialists, EPA policy analysts, or meteorologists.

## BACKGROUND

Making decisions is an important part of life for everyone—students, executives, homemakers, shopkeepers, or scientists. Solving a problem requires comparing alternatives and thinking about the probable results of one's choices. Every choice, or decision, leads to certain direct results and more indirect results. Many choices will end up influencing or limiting future decisions. For example, choosing a hamburger for lunch might mean that one is less inclined to choose meatloaf for dinner. Or deciding to spend money for a new bike now may mean forfeiting the money for a new computer game. The worst kind of decisions are those made on a whim, without thinking through the consequences. The best kind of decisions are those made after thinking about the possible alternatives, and the advantages and disadvantages of each.

One way to begin a thoughtful decision-making process is to ask yourself questions and find honest answers for them. Typically, a number of limitations affect the quality or cost of the decisions we make. Cost does not necessarily mean money. It could also be any valuable thing

**RELATED ACTIVITIES**
1, 6, 8, 10, 15, 16, 17, 18, 19

**TARGET GRADE LEVEL**
3rd-9th

**DURATION**
40 minutes

**VOCABULARY**
Benefit
Cost
Risk

**MATERIALS**
Chalk
Chalkboard
(or flip chart and marking pens)

that is given up in order to implement the choice, such as time or lost opportunities. Clearly, there is a trade-off between getting all the best information and spending too much time fussing over the choice. Sometimes, one can spend so much effort collecting or weighing alternatives that you run out of time or money or both and loose much of the benefits of careful decision-making. Sometimes, what we all call "common sense" is the best decision, but if you think about it, simple common sense usually has a good reason behind it.

Many important decisions are made after a careful and formal analysis, sometimes called a "benefit-cost" analysis. It usually is structured by writing down all the advantages or "pros" on one side of a page, and all the disadvantages or "cons," on the other side. Then by comparing the pros and cons one can systematically arrive at a "best" decision. One mark of a good decision based on careful thought is that none of the results or consequences of the decision—good or bad—should come as a surprise. If one makes a decision with too little information about its consequences, then there is a greater "risk" involved that the decision may not solve the problem or that the decision may cause some other problem not thought of.

Making good decisions is a skill that comes about with practice and experience. Nobody is "born" with it. Also, the confidence that comes with practice often results in better and quicker decisions.

There are seven steps in good public decision-making:

(1) What is the problem or issue? Ignore all the complicating issues, or "red herrings," and articulate a clear, simple problem. Identify who and what may be affected by the problem, and who and what may benefit from the decision.
(2) What are the options for solving the problem? Leave out all the really unlikely solutions, and just list the ones that are most realistic. Keep them as straightforward as possible.
(3) Do I know enough about each alternative? Compare each alternative solution to the problem, and write down what is known and what we need to find out about each alternative.
(4) What are the advantages and disadvantages of each alternative? Sometimes, advantages or disadvantages include the effort required to get all the necessary information. If it seems that the effort, or "cost," of getting the necessary information outweighs the benefits, the decision-maker may need to consider his or her willingness to accept the consequent risks.
(5) Which advantages and disadvantages are critical? Cross out those that don't really matter; these are just confusing extras.
(6) Which of the options seem to best solve the problem, considering the advantages and disadvantages of each?
(7) Finally, share and discuss results publicly and with those affected by the decision even if you have already involved some of them in the process.

## WHAT TO DO

1. Introduce the topic of decision-making to the class, write the seven decision-making steps on the chalkboard or flip chart and explain them.

2. Have the students suggest several real or invented air-pollution problems that require decisions to solve, such as, "Should I convert all my electric lights to energy-savers at home?" or "Why should we work to save the rain forest?" or "What is the best way I can contribute to the reduction of greenhouse gases?" or "How can we control the quality of the air in the classroom or school?" Assign one student to record on the chalkboard or flip chart suggestions by the students during the problem-solving process. You can use current events articles that raise issues yet unresolved as a means of jogging students' thoughts on selecting problems. Have students formulate a problem statement for each question suggested.

3. Select a few problems to focus on and have students volunteer answers to each of the first six problem-solving steps. For each answer, get the student to specify which problem it addresses and which step it fits under. Note that the class can be considering all the problems at once. Allow students to question or comment on each others' suggestions.

4. Once each problem has answers under each of the first six steps, begin narrowing the selections by encouraging the class to evaluate each of the steps. Have the scribe annotate the chalkboard or easel as decisions are made. Encourage dissenters or skeptics, but get the class to consider all angles.

## SUGGESTED MODIFICATIONS

- For lower grades, decision-making can be fun but also frustrating. Use a decision-making exercise that addresses group activities such as the best way to spend time. Let the students decide how the day or an hour should be spent, and why. Modify the seven decision-making steps, as appropriate, and use them to facilitate such a discussion. For lower grades, the decision-making steps may have to be stated more simply to help students participate in the process.

- For upper grades, have students develop a subset of questions (between the lines) to explore each of the seven decision-making steps in more depth. Use the expanded list to facilitate the discussion.

- You may want to ask a guest presenter to add to the list some real-world problems or issues with which he or she is currently working.

- Have students select a news clipping that raises a problem or issue that others are working to resolve. Assign a special project in which students will use the steps presented here to research and develop a potential resolution. When completed have the student present his or her findings and the rationale for the selected option.

## SUGGESTED READING

Berry, Joy. *Every Kid's Guide to Decision Making and Problem Solving.* Children's Press (1987).

*Citizenship with Bambi and Friends (Filmstrip).* Walt Disney (1988).

*The Environment (Apple II computer program).* Tom Snyder (1990).
A role playing simulation in which students address crucial environmental questions.

*I Don't Know What To Do: Decision-Making Skills (Videotape).* Guidance (1988).

*A Kid's Guide to Decisions (Filmstrip).* Learning Tree (1988).

*The Oil Game (Apple II computer program).* AV System (1988).

Smith, Sandra Lee. *Coping with Decision-Making.* New York, NY: Rosen Publications Group (1989).

Ulrich-Hagner, Linda. *Decisions in Action.* South-Western Publishers (1988).

*Understanding Decisions (Filmstrip).* Learning Tree Publishing (1990).

*Yes? No? Maybe? Decision Making Skills (VHS videotape).* Sunburst (1990).

WARM-UP H

# SCALES, RULES, POLICY, STANDARDS AND SCIENCE

This exercise examines the role of opinions, values, attitudes, beliefs, and science on the development of standards. Students will answer a series of abstract questions designed to demonstrate how a standard is developed. Students also will answer questions related to ecological standards. From the results of the survey, classroom-wide standards will be developed to reflect the "consensus" of the class. This exercise is related to the "Writing Environmental Laws" and "Translating Science into Public Policy" activities.

## CRITICAL OBJECTIVES

- Identify methods to obtain information for developing standards
- Recognize conflicts that may exist between what people want and what can be achieved
- Translate objective and subjective data into standards

## SKILLS

- Collecting, tabulating, and analyzing data
- Drawing conclusions

## GUEST PRESENTERS

Guest presenters could include environmental scientists, EPA environmental protection specialists, or EPA risk assessment specialists.

## BACKGROUND

Governments rely on the development of standards as the basis of most regulations. For example, most environmental regulations are based on public or environmental health standards that help gauge the dangers posed by a certain level of pollution or contamination. However, people should understand that such standards are not purely scientific: "hard" scientific data is always subject to the political process before it is written into regulations. What's more, there is often much disagreement within the scientific community over the data itself. Standards, then, are the result of these processes.

This exercise poses the question "How do we decide what a standard should be?" and focuses on the interplay of personal belief, opinion, and scientific facts and evidence in the development of standards and rules. Air quality policy and regulations are a result of the synthesis of scientific information and public attitudes and values. What costs

**RELATED ACTIVITIES**
20, 21

**REFER TO READING MATERIALS**
"The Clean Air Act"
"Air Pollution"

**TARGET GRADE LEVEL**
7th - 12th

**DURATION**
30 minutes

**VOCABULARY**
Scale
Standards

**WORKSHEETS INCLUDED**
1

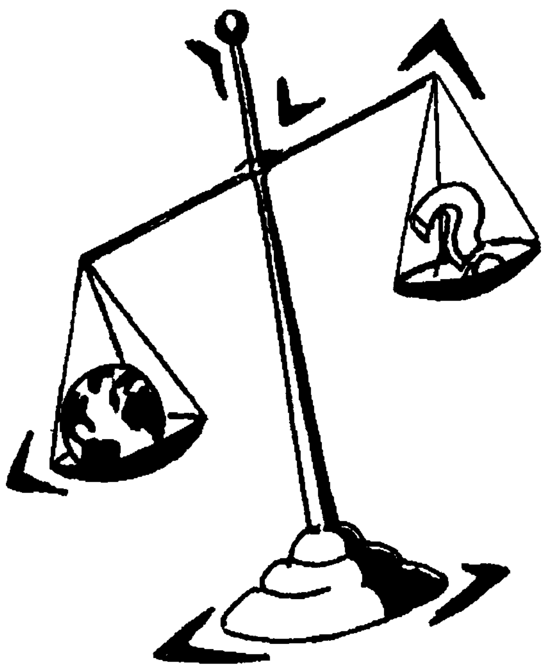
people are willing to tolerate to maintain air quality is as critical to the development of air quality standards as the scientific health risks posed by air pollution.

In one sense, an air pollution standard reflects how much air quality the public is willing to buy. Often, there is a conflict between what people are willing to tolerate and what may be good for them. For example, smog is a major health concern in southern California, but people in Los Angeles have consistently resisted the imposition of restrictions on automobile driving even though auto exhaust is a major factor in smog production. Between the two extremes on this issue lies a position which, presumably, most people would be willing to adopt. This exercise demonstrates how such conclusions are reached. (See reading materials on "The Clean Air Act" and "Air Pollution.")

## WHAT TO DO

**1.** Discuss scales and methods by which things are measured: size, weight, volume, time, temperature. For example, time passes whether or not it is broken up into days. Discuss how it is reduced to discrete units (days, hours, weeks, years) in ways that all agree upon so that it may be used. In what ways are scales and measures useful? (Answer: so that one thing may be compared with another thing.)

**2.** Discuss standards and where they come from. For example, how would your class decide what the temperature of the room should be? Each person could be asked, and the result would be a range of temperature values. From there, the statistical mean temperature would represent a "fair" determination of the classroom-wide consensus. Mention Goldilocks and the Three Bears and the "just right" standard. How do we know what is "just right?" What effect does custom and convention have on an individual's belief?



**3.** Discuss the concept of rules and how standards are fashioned into rules. Ask students for examples of rules that govern their lives. What is the rationale for these rules? Distinguish the roles of objective facts and subjective beliefs. For example, young children may have a certain bedtime. Is this the result of extensive studies on the effects of sleep deprivation or because parents think it is a good idea? Discuss how sound rule-making requires information collection and the application of shared values.

**4.** Distribute the student worksheet. Ask each of the survey questions and have students mark their answers. Collect and tabulate the results. Discuss how to determine the classroom-wide standards based on the results? Discuss the tradeoffs that are inherent in developing standards based on opinions and beliefs rather than strictly scientific conditions. (For example, how did they decide how much is "too much" pollution?)

5. Discuss the roles of scientific evidence and personal belief in answering these questions. Ask individual students what led them to answer a question in a certain way. Select students who answered the same question in opposite ways to "make their case."

## SUGGESTED MODIFICATIONS

☼ For grades 10 through 12, have students follow up this exercise by researching how generally accepted standards get translated into government policies, regulations, or laws. Have them make short presentations of their findings.

## SUGGESTED READING

"Green, Greener, Greenest." *Economist*, 311 (6 May 1989) p. 67.

# STUDENT WORKSHEET 1

# SCALES, RULES, POLICY, STANDARDS, AND SCIENCE

## SURVEY

This questionnaire will be used to determine a classwide standard for a healthy environment. It also will ask questions about what individuals would be willing to do to achieve a healthy environment. Since it is Clean Air Month™, the questions focus on air pollution reduction and prevention.

### AIR POLLUTION: HOW MUCH IS TOO MUCH?

1) Air pollution is not a major problem in the United States.
   1 - strongly agree  2 - agree  3 - neutral  4 - disagree  5 - strongly disagree

2) Air pollution is not a major problem in our town.
   1 - strongly agree  2 - agree  3 - neutral  4 - disagree  5 - strongly disagree

3) Air pollution should be reduced to levels that do no harm to the environment or to people.
   1 - strongly agree  2 - agree  3 - neutral  4 - disagree  5 - strongly disagree

4) Air pollution should be reduced to levels that do no harm to people and the environment regardless of cost.
   1 - strongly agree  2 - agree  3 - neutral  4 - disagree  5 - strongly disagree

5) There is a safe level of air pollution (that is, some level of air pollution should be tolerated).
   1 - strongly agree  2 - agree  3 - neutral  4 - disagree  5 - strongly disagree

6) A safe level of air pollution should be achieved regardless of cost.
   1 - strongly agree  2 - agree  3 - neutral  4 - disagree  5 - strongly disagree

7) The cost of air pollution reduction and prevention should determine the amount of pollution permitted.
   1 - strongly agree  2 - agree  3 - neutral  4 - disagree  5 - strongly disagree

8) Activities that pollute the air should be prohibited.
   1 - strongly agree  2 - agree  3 - neutral  4 - disagree  5 - strongly disagree

### AIR POLLUTION: WHERE DOES IT COME FROM?

1) Human activity is the source of most air pollution.
   1 - strongly agree  2 - agree  3 - neutral  4 - disagree  5 - strongly disagree

2 Visible air pollution is the most significant problem.
   1 - strongly agree  2 - agree  3 - neutral  4 - disagree  5 - strongly disagree

3) Most air pollution is the kind that can be seen coming from smokestacks.
   1 - strongly agree  2 - agree  3 - neutral  4 - disagree  5 - strongly disagree

4) Most air pollution is emitted from automobiles.
1 - strongly agree   2 - agree   3 - neutral   4 - disagree   5 - strongly disagree

5) If it can not be smelled or seen, it does not matter.
1 - strongly agree   2 - agree   3 - neutral   4 - disagree   5 - strongly disagree

## AIR POLLUTION: WHAT IS THE SOLUTION?

1) I am willing to change some of my everyday habits and ways of doing things that may cause air pollution (for example, conserve energy, use mass transit rather than drive, purchase environmentally friendly products).
1 - strongly agree   2 - agree   3 - neutral   4 - disagree   5 - strongly disagree

2) I am willing to pay reasonably higher prices when necessary if it will help reduce air pollution.
1 - strongly agree   2 - agree   3 - neutral   4 - disagree   5 - strongly disagree

3) Future changes in technology will probably eliminate most causes of pollution by the time I am an adult.
1 - strongly agree   2 - agree   3 - neutral   4 - disagree   5 - strongly disagree

4) I am willing to have the government tell me how to reduce pollution.
1 - strongly agree   2 - agree   3 - neutral   4 - disagree   5 - strongly disagree

# ACTIVITIES

# ACTIVITY 1

# LIFESTYLES AND THE ENVIRONMENT

This activity demonstrates that our lifestyles are supported by complex industrial activities that consume vast quantities of natural resources and result in large quantities of air pollution. As the population grows and the standard of living increases, the consumption of resources and emission of pollutants also increase. These trends have significant implications for the lifestyles of students and their families. This activity is related to the warm-up exercise called "Making Decisions." Related activities include "Deciding To Clean the Air" and "Choosing a Better Future."

## CRITICAL OBJECTIVES

- Distinguish between renewable, non-renewable, and recyclable resources
- Recognize the impact that lifestyle changes have had on the level of industrial activities that cause air pollution
- Recognize the relationship between population and consumption
- Understand the effect of supply and demand on the price of resources
- Identify ways to use less resources and to reduce air pollution

## SKILLS

- Graphing
- Comparing data
- Defining problems
- Drawing conclusions

## GUEST PRESENTERS

Guest presenters could include conservationists, economists, environmental scientists, or EPA environmental protection specialists.

## BACKGROUND

The manufacture and consumption of many goods and services results in the production of pollution as a side effect. Much pollution, if not controlled, can cause diseases in humans and other species, as well as property damage. In addition, these air pollutants can cause changes in the Earth's climate that may make it more difficult and, therefore, more costly to produce food and the resulting melting of polar icecaps may cause the sea level to rise to dangerous levels.

**RELATED WARM-UP**
G

**REFER TO READING MATERIALS**
"Air Pollution"
"The Greenhouse Effect"
"Automobiles and Air Pollution"

**TARGET GRADE LEVEL**
9th - 12th

**DURATION**
40 minutes in class #1, with a take-home assignment;
40 minutes in class #2

**VOCABULARY**
Free good
Non-renewable resource
Raw material
Recyclable resource
Renewable resource
Scarce good
Supply and demand

**MATERIALS**
Chalk
Chalkboard
Two student worksheets

**WORKSHEETS INCLUDED**
2

There have always been pollutants in the atmosphere, both from natural and human sources. The most important human source is combustion of fuels (wood, coal, natural gas, petroleum) for transportation, heating and cooling, electricity generation, and manufacturing. In the past, human sources represented just one of many sources of pollutants. However, the importance of human sources has increased in recent years because of several developments:

- The products we use in our everyday lives (automobiles, electric equipment) have been growing more and more sophisticated, thereby requiring more industrial processes that emit large quantities of pollutants. Some chemicals are toxic even in small amounts.
- The per person consumption of goods and services has increased substantially.
- The U.S. and world populations have increased substantially over the past 100 years.

Because the Earth's atmosphere is a finite size, it will not sustain the continued growth of the current patterns of consumption. The following are among options available to us:

- Continue our current practices: this strategy ultimately might result in a crisis sometime in the future.
- Change our consumption patterns and, as necessary, our lifestyles to use fewer resources and use resources that pollute less.
- Improve our technology so we can produce the materials and offer the services we want with fewer resources. For example, a solid state radio may consume less steel, plastic, and glass, and use less electricity, than an old vacuum-tube-based radio, and more efficient electronic data communications may lead to a reduction of travel, because many people can work at home several days a week.

## WHAT TO DO

### Class #1

1. Distribute the student handout called "Major Man-Made Air Pollutants." Review the sources and the basic health and environmental effects of air pollution with the class.

2. Present and discuss the concepts of a "free good," "scarce good," "supply and demand," "renewable," "non-renewable," and "recyclable" resources. After defining each concept, ask the class for examples.

3. Put the following table on the chalkboard and assign a student to fill it in as the class discussion progresses. Have the class list things they currently have (such as a car, TV, Walkman, Nintendo) and their typical activities (such as traveling to school, playing softball, going to the movies). Then list the associated raw materials and direct and indirect pollutants. (The first entry is provided as an example.)

| Current Goods and Activities | Raw Materials Required | Pollutants Directly Resulting | Pollutants/Activities Indirectly Resulting |
|---|---|---|---|
| Driving to school | Fuel, oil, lubricants | $CO_2$, NOx, lead, hydrocarbons | Steel, rubber, glass, electricity to manufacture car |

4. Put a second table (shown below) on the chalkboard and assign a student to fill it in as before. Have the class list things they would like to have and activities they would like to undertake in the future. Then, list the associated raw materials and pollutants. (A call to local manufacturing companies prior to the class may be useful in helping students with the quality and quantity of the information.)

| Future Goods and Activities | Raw Materials Required | Pollutants Directly Resulting | Pollutants/Activities Indirectly Resulting |
|---|---|---|---|
| | | | |

5. Compare the two tables. Ask the class what conclusions they can draw from the comparison and speculate about the implications for our store of raw materials and pollution.

6. Distribute the student worksheet called "Growth in the Use of Critical Resources," which provides examples of historical trends in consumption of raw materials, as well as trends of population and energy consumption. Have students enumerate products and activities in our daily lives that use these materials and speculate what the future consumption of these materials might be. In discussing the data in the table, you may note the following as needed:

- Per capita use of lumber has been declining. This decline was caused by several factors: Diminishing supply and relative to the growing population, substitution of other materials such as plastics and metals for wood, and increased price of wood over time.

- Although the United States accounts for 26 percent of world petroleum consumption, it is only 5 percent of the world population. If per capita consumption does not change, the U.S. would consume 26.8 million barrels of oil per day, which is about 26 percent of current annual production. It is not known whether there is enough petroleum in the ground to increase world production substantially higher than current production.

- The per person consumption of steel and aluminum decreased from

1960 to 1990. This is not necessarily indicative of the long-term trend. During this period, imports of products such as automobiles and electrical and electronic equipment that contain these metal have also increased.

7. Assign different students or teams of students to take a different raw material and prepare a graph illustrating the data on the handout and their projections for the future.

### Class #2

1. Review the graphs prepared in the previous class.

2. Have the class discuss potential problems if we continue our current consumption and production patterns. Focus the discussion on the following questions:
   What does this imply for the prices and availability of the goods you want?
   If you earned a fixed amount each month, would you be able to afford all the things you want?
   If everyone could afford all the things they wanted in the future, what would happen to air quality?

3. Ask for ideas on how we could reduce these problems and obtain the things we want. If necessary, prompt students with the following:
   Change our desires?
   Change how products are designed to use fewer resources and pollute less (smaller cars, simpler packaging of consumer products)?
   Use more recyclables and renewable materials?
   Reduce consumption of fuels for transportation, heating, and cooling?

## SUGGESTED EXTENSIONS (OPTIONAL)

- Give students a library assignment to compare the energy use of different models of cars. Include small, medium, large, sports, "muscle" and utility vehicles, and vans. They can estimate the average miles driven per year by their families, compare these to National averages, and look up EPA fuel consumption estimates for specific car models. (*Consumer Reports,* which is available at most libraries, publishes this information in the April edition each year.) Have them do the calculations in both gallons of fuel and dollars per year. Then have them discuss the following questions:
  If the cost of gasoline doubles by the year 2004, will you buy a different car?
  What characteristics of the car (size, comfort, acceleration, safety) would you be willing to trade for better fuel consumption?

- Ask the students to take an inventory of their families' energy use for a typical week (or year) using the student worksheet called "Family Resource Use." Have them take the worksheet home, fill it in with their family's help, and bring it back to class. After the worksheets have been completed, have students discuss the reasons for differences and how their families could improve their resource use. (To facilitate this discussion, you may want to divide students into groups according to the type of fuel used, then record the fuel usage on the chalkboard for heating, cooling, and water heating. Within each group, have students discuss differences by referring to the other factors on the worksheet such as insulation, storm windows and doors, and the use of set-back thermostats.)

- Ask students to look up in the library, or in articles you may supply, the energy required (in kilowatt-hours) and the air pollution emitted (in pounds or tons) in the manufacture a ton of aluminum, steel, and paper.

## SUGGESTED READING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## STUDENT WORKSHEET 1

# LIFESTYLES AND THE ENVIRONMENT

### GROWTH IN USE OF CRITICAL RESOURCES

| Natural Resource | Per Capita Consumption | Population | Total Consumed | World Consumption | Percent |
|---|---|---|---|---|---|
| Petroleum | (Barrels/day) | | (Thous. barrels per day) | | |
| 1800 | NA | 5,308,000 | NA | | |
| 1900 | 0.002 | 75,994,000 | 217 | | |
| 1930 | 0.02 | 122,773,000 | 2,494 | | |
| 1960 | 0.04 | 179,373,000 | 8,853 | | |
| 1990 | 0.07 | 248,710,000 | 16,710 | 65,700 | 26% |
| 2090 *(estimate)* | *(0.07)* | *382,674,000* | *(26,787)* | | |
| Paper Products | (Pounds) | | (Thous. of Tons) | | |
| 1800 | 1.1 | 5,308,000 | < 3 | | |
| 1900 | 108.0 | 75,994,000 | 4,103 | | |
| 1930 | 201.0 | 122,773,000 | 12,340 | | |
| 1960 | 438.5 | 179,373,000 | 39,324 | | |
| 1990 | 702.0 | 248,710,000 | 87,300 | 238,238 | 37% |
| 2090 *(estimate)* | *(702.0)* | *382,674,000* | *(134,319)* | | |
| Steel | (Tons) | | (Thousands of Tons) | | |
| 1800 | NA | 5,308,000 | NA | | |
| 1900 | 0.15 | 75,994,000 | 11,227 | | |
| 1930 | .36 | 122,773,000 | 44,591 | | |
| 1960 | .50 | 179,373,000 | 90,282 | | |
| 1990 | 0.40 | 248,710,000 | 98,900 | 848.8 | 12% |
| 2090 *(estimate)* | *(.40)* | *382,674,000* | *(153,070)* | | |
| Aluminum | (Pounds) | | (Thousands of tons) | | |
| 1800 | NA | 5,308,000 | NA | | |
| 1900 | NA | 75,994,000 | < 1 | | |
| 1930 | 1.1 | 122,773,000 | 65 | | |
| 1960 | 17.2 | 179,373,000 | 1,541 | | |
| 1990 | 16.6 | 248,710,000 | 4,135 | 17,977 | 26% |
| 2090 *(estimate)* | *(16.6)* | *382,674,000* | *(6,353)* | | |
| Lumber | (Board Feet) | | (Mil. Board Feet) | | |
| 1800 | 75.4 | 5,308,000 | 400 | | |
| 1900 | 459.2 | 75,994,000 | 34,900 | | |
| 1930 | 229.7 | 122,773,000 | 28,200 | | |
| 1960 | 201.3 | 179,373,000 | 36,100 | | |
| 1990 | 142.4 | 248,710,000 | 54,500 | 254,862 | 21% |
| 2090 *(estimate)* | *(219.1)* | *382,674,000* | *(83,844)* | | |

NA = Not available or negligible
One ton = 2,000 pounds

## STUDENT WORKSHEET 2

# LIFESTYLES AND THE ENVIRONMENT

### FAMILY RESOURCE USE

Use the following questions and table to record your family's energy use for a typical year or week. This information is most likely available in your home. Discuss it with your family.

**Home Heating:**
Indicate the followin:
Type of fuel (for example, oil, natural gas, coal) ____________________
Volume used last year (in gallons, cubic feet, therms, or other measure) ____
Cost last year $____
Do you use a set-back thermostat? ___,
Days of the week are they used? ____, hours used? ____
Size of your house in square feet, not including garage, basement, or unfinished attic ____

**Water Heating:**
Indicate the following:
Type of fuel (for example, natural gas, electricity) ____________________
Do you use a set-back thermostat? ___,
Days of the week are they used? ____, hours used? ____
Size of water heater in gallons ____

**Home Cooling:**
Indicate the following:
Type of fuel (for example, natural gas, electricity) ____________________
Volume used last year (in cubic feet, therms, or kilowatt hours) ____
Cost last year $____
Do you use a set-back thermostat?
Days of the week are they used? ____ hours used? ____
Size of your house in square feet, not including garage or basement ______

**Home Insulation:**
Indicate the following:
Roof insulation Material (for example fiberglass, rockwool, cellulose, none)_________________
Roof insulation thickness (for example, 3.5 inches, 6 inches, 7.5 inches) ____
Wall insulation material (for example fiberglass, rockwool, cellulose, none) _________________
Wall insulation Thickness (for example, 3.5 inches, 6 inches, 7.5 inches) ____
Type of wall (for example, masonry, wood frame) ____________________
Do most of the windows have storm windows? ____
Do most of the windows have double glazing (two pains of glass separated by an air space)?
____

**Recycling:**
What products do you recycle in your home (plastic, aluminum foil, aluminum cans, steel cans, plastic jars and bottles, newspaper, other paper)?

______________________________

**Travel:**
How do you get to school (school bus, public transportation, auto, car pool)?

____________

Distance from house to school? ________ How long would it take to walk? _____, Bike? ____, Skate? ____

How do your other family members travel to school or work? ____

What other methods might they use?_______________ Why are these not used?

______________________________

# ACTIVITY 2

# THE RAIN FOREST IS ALIVE

This activity uses role-playing and empathy to encourage students to learn about the life and purpose of the rain forest. Students create stick puppets to represent animal inhabitants of a South American rain forest and use the puppets to act out the story in "The Great Kapok Tree." The activity serves as a useful illustration of how to adapt environmental reading material for classroom learning. It is related to the warm-up exercise called "Learning from Stories."

## CRITICAL OBJECTIVES

- Appreciate that animals, plants, and humans need each other to maintain the balance in nature
- Work with others on environmental projects
- Understand that the destruction of the rain forests may cause some animals to become extinct
- Recognize that plants and trees in rain forests absorb carbon dioxide
- Recognize that carbon dioxide absorption is important in regulating climate

## SKILLS

- Asking questions
- Cooperating with others
- Coloring, cutting, pasting
- Acting out

## GUEST PRESENTERS

Guest presenters for this activity could include EPA environmental protection specialists, conservationists, or environmental scientists.

## BACKGROUND

Rain forests are very large and very dense. They are usually in tropical areas—areas near the equator where the temperature is very warm and where rain is very heavy throughout the year. The largest tropical rain forest covers a large part of South America, including the Amazon River and parts of the country of Brazil. Rain forests are made up mainly of evergreens (trees and shrubs that have leaves or needles all year round), but they also are the home for many rare flowering plants, ferns, and herbs. In addition, rain forests provide a habitat for a rich variety of animals and have been the home for many people throughout history.

**RELATED WARM-UP**
D

**REFER TO READING MATERIAL**
"Greenhouse Effect"

**TARGET GRADE LEVEL**
K-2nd

**DURATION**
1 class period (40 minutes) to create puppets;
1 class period (40 minutes) for role-play exercise

**VOCABULARY**
Carbon dioxide
Climate
Rain forest

**MATERIALS**
Brown paper (3 ft. by 6 ft.)
Green construction paper (optional)
Popsicle sticks (1 per student)
Crayons or marking pens in various colors
Scissors
Clear tape
Glue or stapler and staples
"The Great Kapok Tree" by Lynne Cherry

**WORKSHEETS INCLUDED**
20

All rain forests have five main layers, and each layer is populated with plant and animal life specifically suited to it. The Emergent layer is made up of the tallest trees, some as high as 165 feet. In this layer, Harpy eagles and other birds of prey watch for animals to feed on, and it is here that the "great kapok tree" in the story grows. The Canopy is 100 to 130 feet above ground and about 30 feet thick. The majority of plants, vines, and animal life is found in this layer. The Understory, made up of the tops of small trees, gets less light than the Canopy. Palm trees are typical of growth in this layer. The Shrub layer contains shrubs and small trees. Sunlight can reach this layer and help the plants to grow wherever there is a gap in the Canopy. The Herb layer, closest to the ground, is made up of ferns and herbs. It is the habitat for ground dwelling animals, such as the tapir, and many varieties of insects.

Tropical rain forests play an important role in regulating the world's climate by rapidly recycling dead plants and by absorbing carbon dioxide that is produced when humans breathe, coal and other materials are burned, and exhaust is emitted by car engines. Without the rain forests our climate could change, causing droughts, damaging food crops, and causing some types of animal life to die out. In addition, rare animals could become extinct without the rain forest, and rare plant life, useful in making many medicines for treating human diseases, could disappear. (See the reading material called "Greenhouse Effect.")

Many rain forests are being destroyed because people are cutting them down, using the plants and trees to produce products like rubber, oils, medicines, and dyes, and clearing the land for timber and farming. This not only affects the environmental balance but also has caused people, like Brazil's Indian population, to be driven from their homes.

A number of organizations have programs to help save the rain forests. Some give deeds as tokens for monetary contributions that they use to buy up rain forest land to protect it from destruction. Information about these organizations should be available in the local library. Organizations that provide information about how to help save rain forests and the animals, insects, and people who live in them are listed below.

- Friends of the Earth (FOE), Earth Action (the youth section), 530 7th St., NE, Washington, DC 20003
- Rainforest Action Network, 466 Green St., San Francisco, CA 94133
- Defenders of Wildlife, 1244 19th St., NW, Washington, DC 20036
- World-Wide Fund for Nature (WWF), 1250 24th St., NW, Washington, DC 20037
- Survival InterNational, 2121 Decatur Place, NW, Washington, DC 20008
- Intermediate Technology, 777 United Nations Plaza, New York, NY 10017

## WHAT TO DO

### Before class begins

Make enough copies of the worksheets so that the class will have the following:

1 Boa Constrictor
1 Tree Frog
1 Leaf Cutter Ant
1 Iguana
1 Scarlet Macaw
4 Tree Porcupines
1 Butterfly

1 Cock of the Rock
4 Night Monkeys (Troupe)
1 Jaguar
1 Amazonian Umbrella Bird
1 Three-Toed Sloth
1 Black-handed Monkey
1 Blue Morpho Butterfly

1 Bumble Bee
1 Hummingbird
1 Tarantula
2 Anteaters
1 Macaw
1 Ocelot

Other characters will include two men and one child. These characters will be acted out by the students.

### When class begins

1. Show the class the map of South America inside "The Great Kapok Tree." Explain the make-up of rain forests.

2. Read the story of "The Great Kapok Tree" to the class.

3. Have students draw and color a kapok tree on the brown paper. (If you have green construction paper, have students draw leaves, cut them out, and glue or staple them on the tree.) The picture will be used as background for the role-playing activity.

4. Have each student choose a picture of one of the rain forest animals or insects from the selection included at the back of this activity. (You may prefer to copy or paste the pictures onto more rigid material before using them in class.) Have students color their pictures using the illustrations in the book as examples. When the pictures have been colored, have students cut out and glue or staple their pictures to a Popsicle stick to make a puppet.

5. While the students are making their puppets, tape the picture of the kapok tree to a wall in the classroom that has enough room in front of it for all the students to sit.

6. Gather the students with their puppets in front of the tree and read the story again. Have students use their puppets to act out the story as you read it. At the end of the story, discuss the importance of the rain forests to humans and to the Earth's environment. Use some of the following questions to stimulate discussion:

    How tall do you think the great kapok tree is?
    How can all these animals and insects live in just one tree?
    How are rain forests important to you?
    What can you do to help save our rain forests?

## SUGGESTED MODIFICATIONS

- In making puppets, a number of options exist. The puppet idea and pictures included can be modified depending on the type of class, skills of students, and willingness of the teacher. Modifications include making face masks using colored construction paper and crayons or using pâpier maché and tempera paints; creating the animals' and insects' shapes using glued-together pieces of construction paper; or creating a coloring book. Pictures of animals and insects cut from magazines also may be used in addition to or in place of the included pictures.

- If the students become proficient with the puppet show, consider presenting the show for other classes and for parents on a Parents' Night.

- Take students on a field trip to see rain forest exhibits at local zoos, museums, or botanical gardens.

- Use this activity as a model for adapting other environmental stories, such as those listed in the Warm-up exercise called "Learning from Stories."

- For students proficient at reading, encourage them to read all or parts of the story.

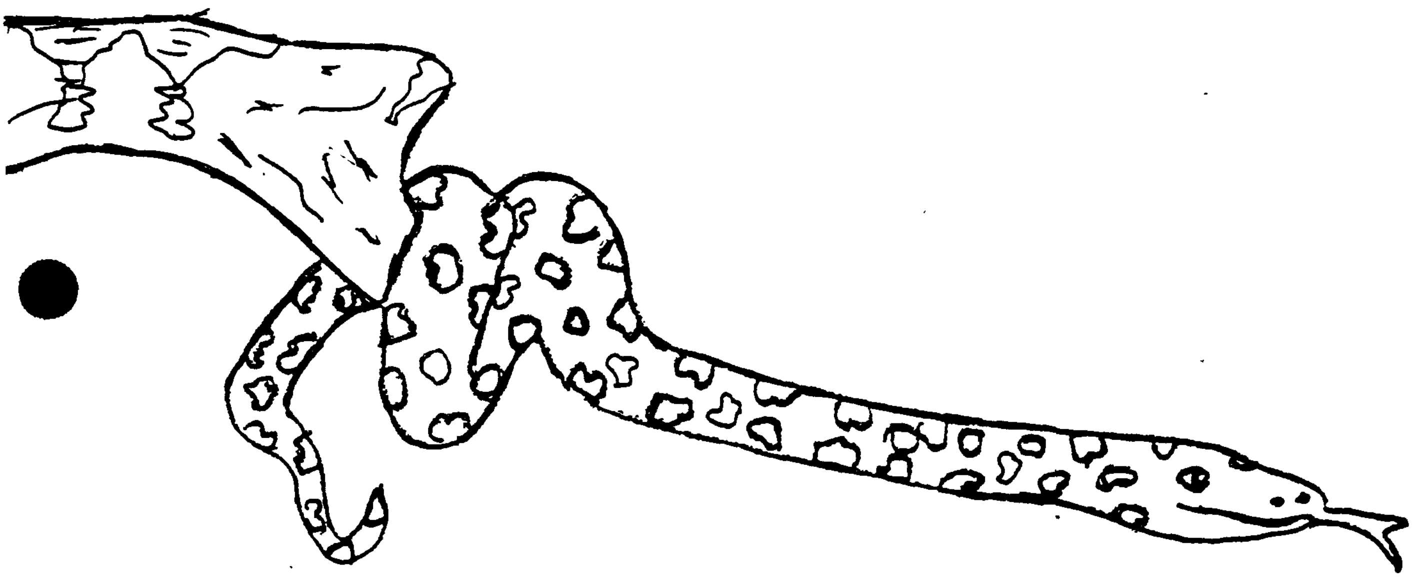
- For higher grades, students need not make paper puppets. They can use face paints to paint their own faces with a schoolmate or alone. They can paint one hand and arm to resemble the species, and using their painted arm as the puppet.

- Encourage students to empathize with their species and learn more about them.

## STUDENT WORKSHEET 1

# THE RAIN FOREST IS ALIVE

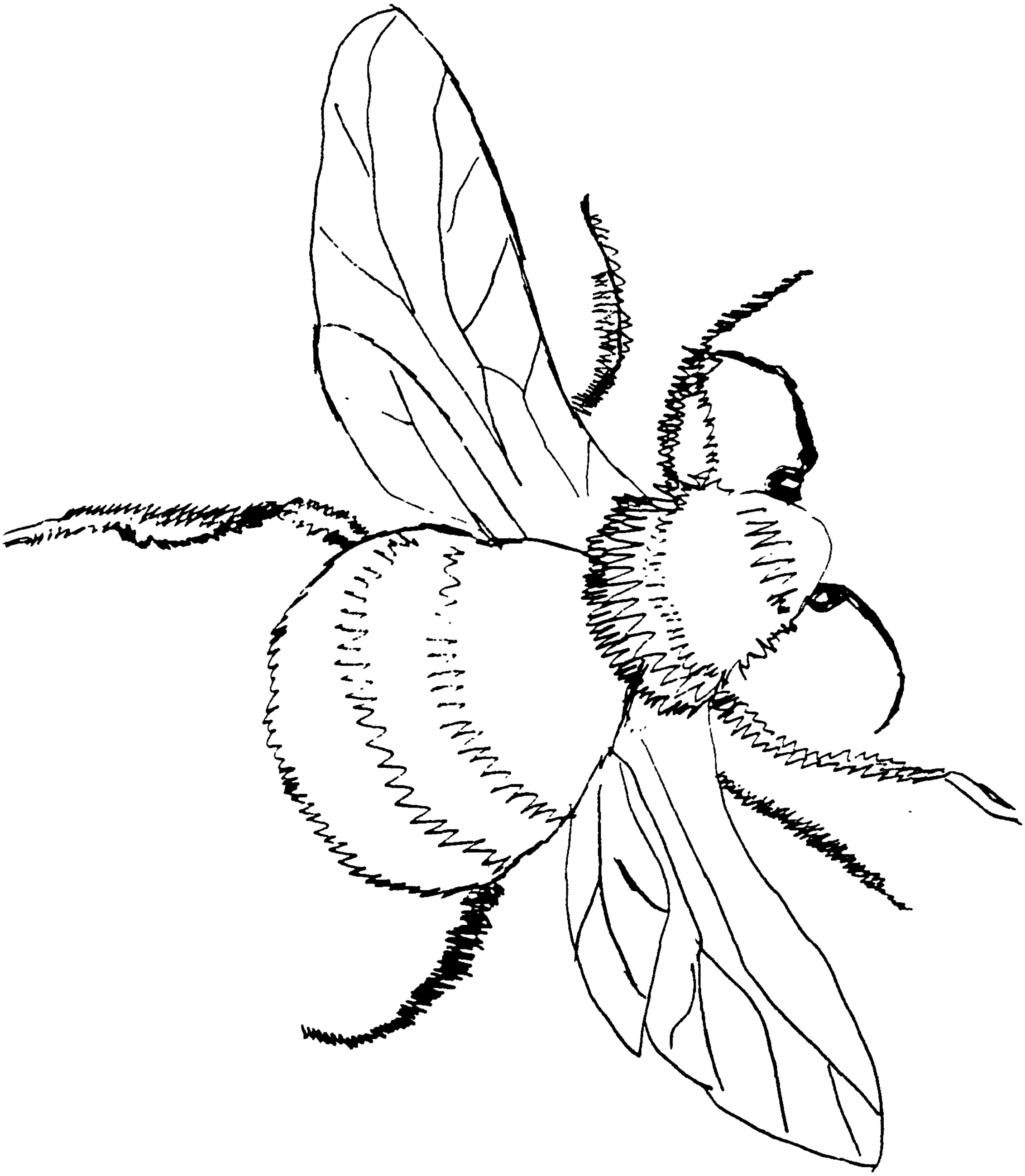
### BOA CONSTRICTOR



## STUDENT WORKSHEET 2

# THE RAIN FOREST IS ALIVE

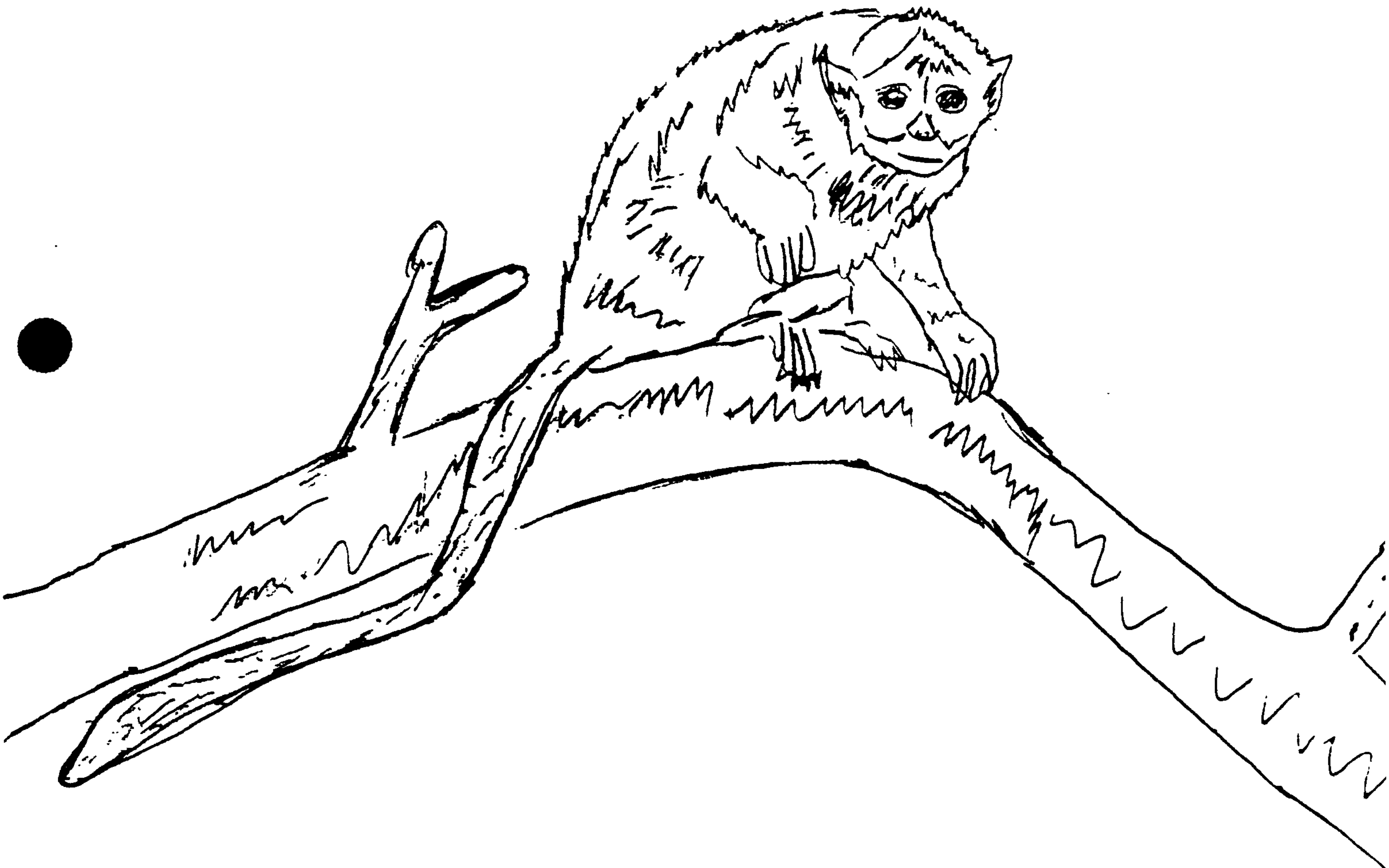
### BUMBLE BEE



STUDENT WORKSHEET 3

# THE RAIN FOREST IS ALIVE

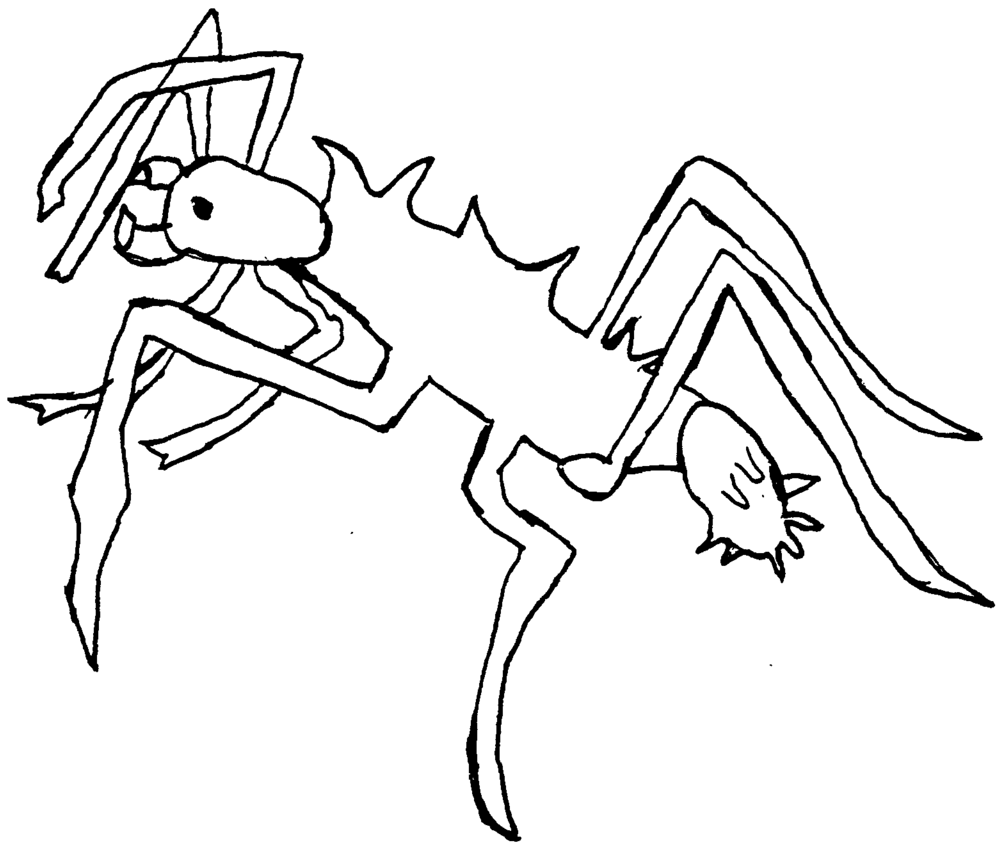
## NIGHT MONKEY (MAKE 4)



## STUDENT WORKSHEET 4

# THE RAIN FOREST IS ALIVE

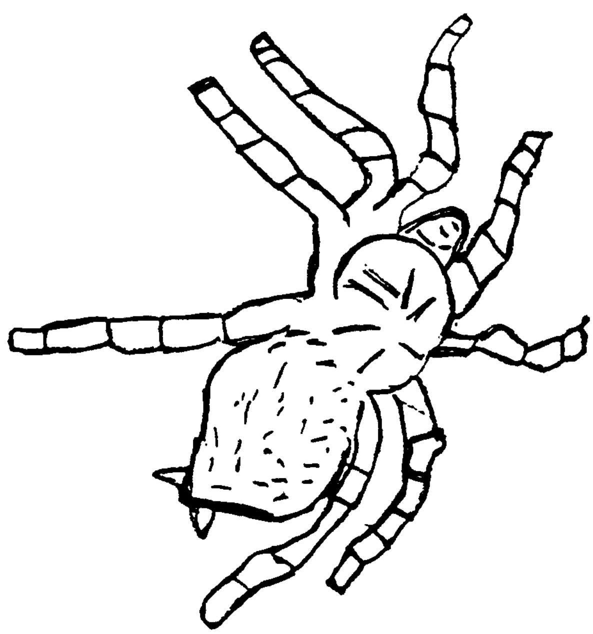
### LEAF CUTTER ANT



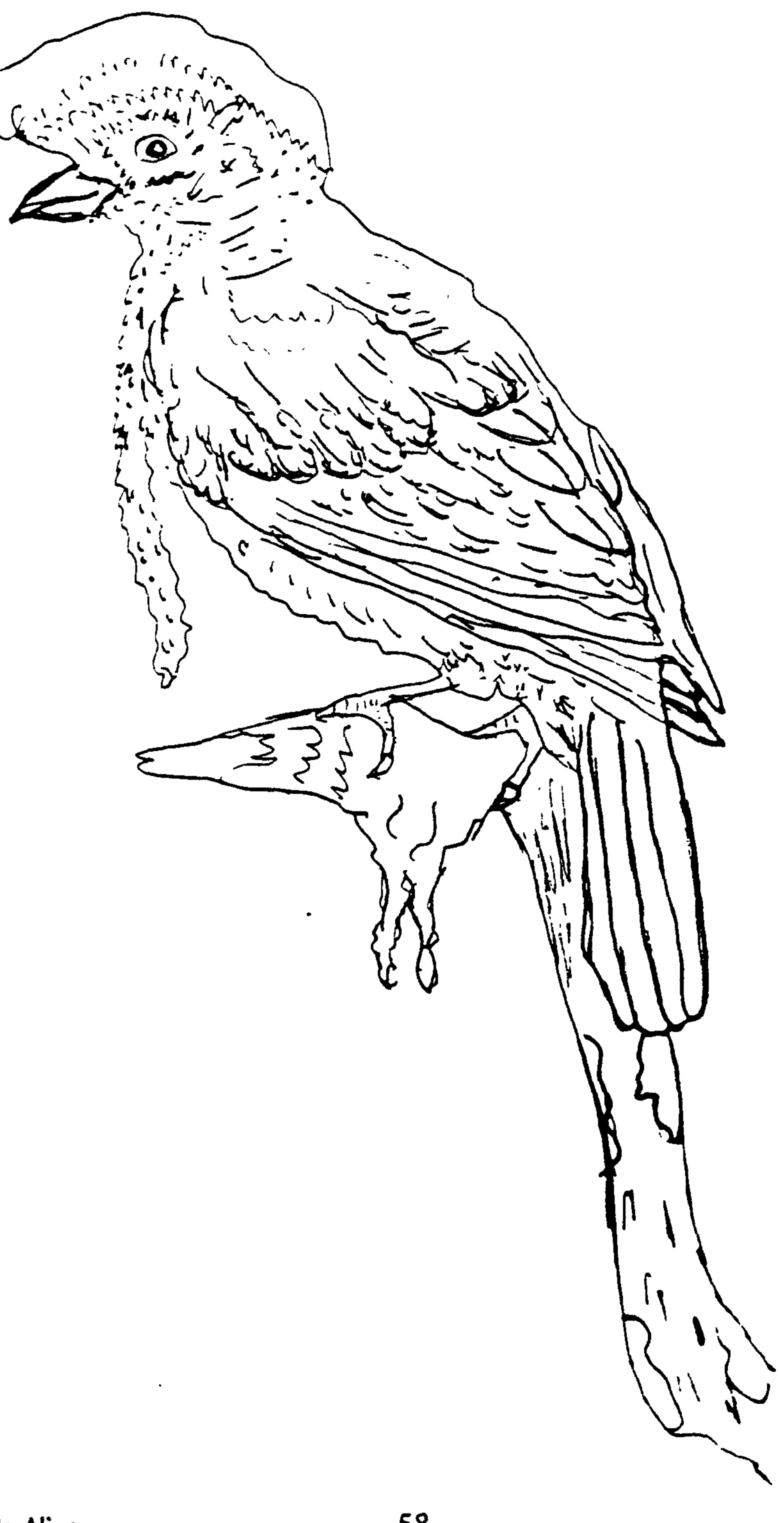
STUDENT WORKSHEET 5

# THE RAIN FOREST IS ALIVE

## TARANTULA



# STUDENT WORKSHEET 6
# THE RAIN FOREST IS ALIVE
## AMAZONIAN UMBRELLA BIRD



## STUDENT WORKSHEET 7

# THE RAIN FOREST IS ALIVE

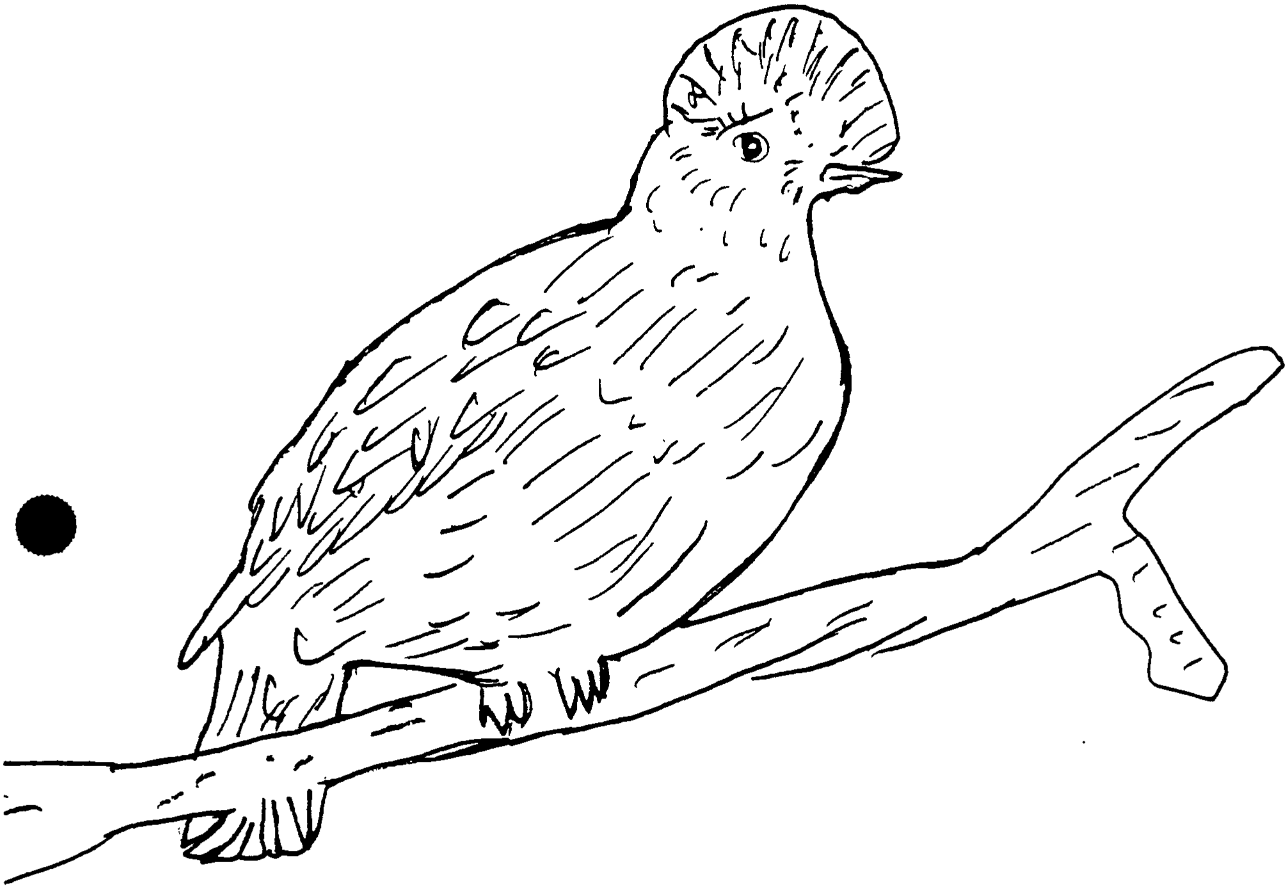
### SCARLET MACAW

# STUDENT WORKSHEET 8
# THE RAIN FOREST IS ALIVE
## MACAW

## STUDENT WORKSHEET 9

# THE RAIN FOREST IS ALIVE

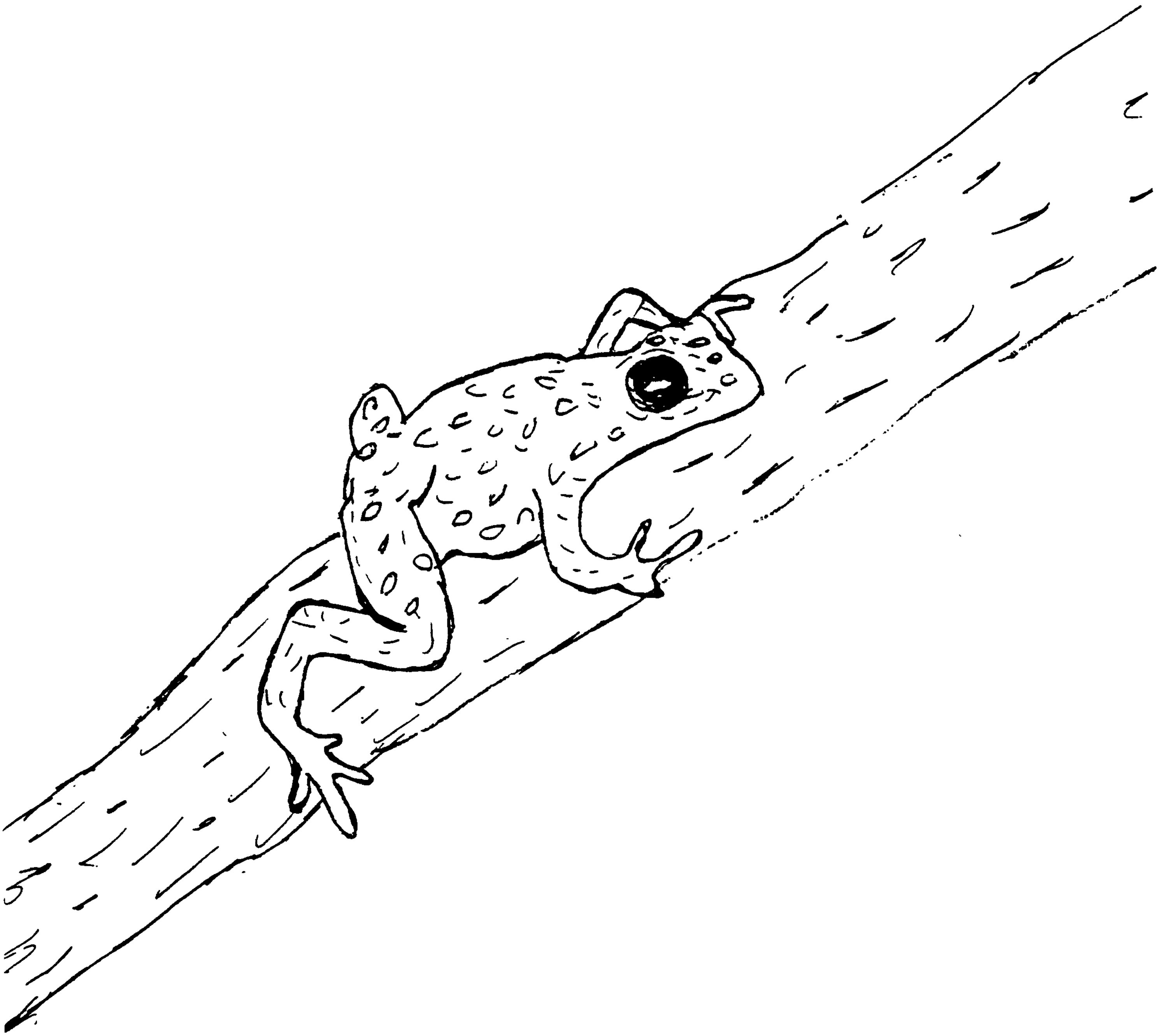
### COCK OF THE ROCK



STUDENT WORKSHEET 10

# THE RAIN FOREST IS ALIVE

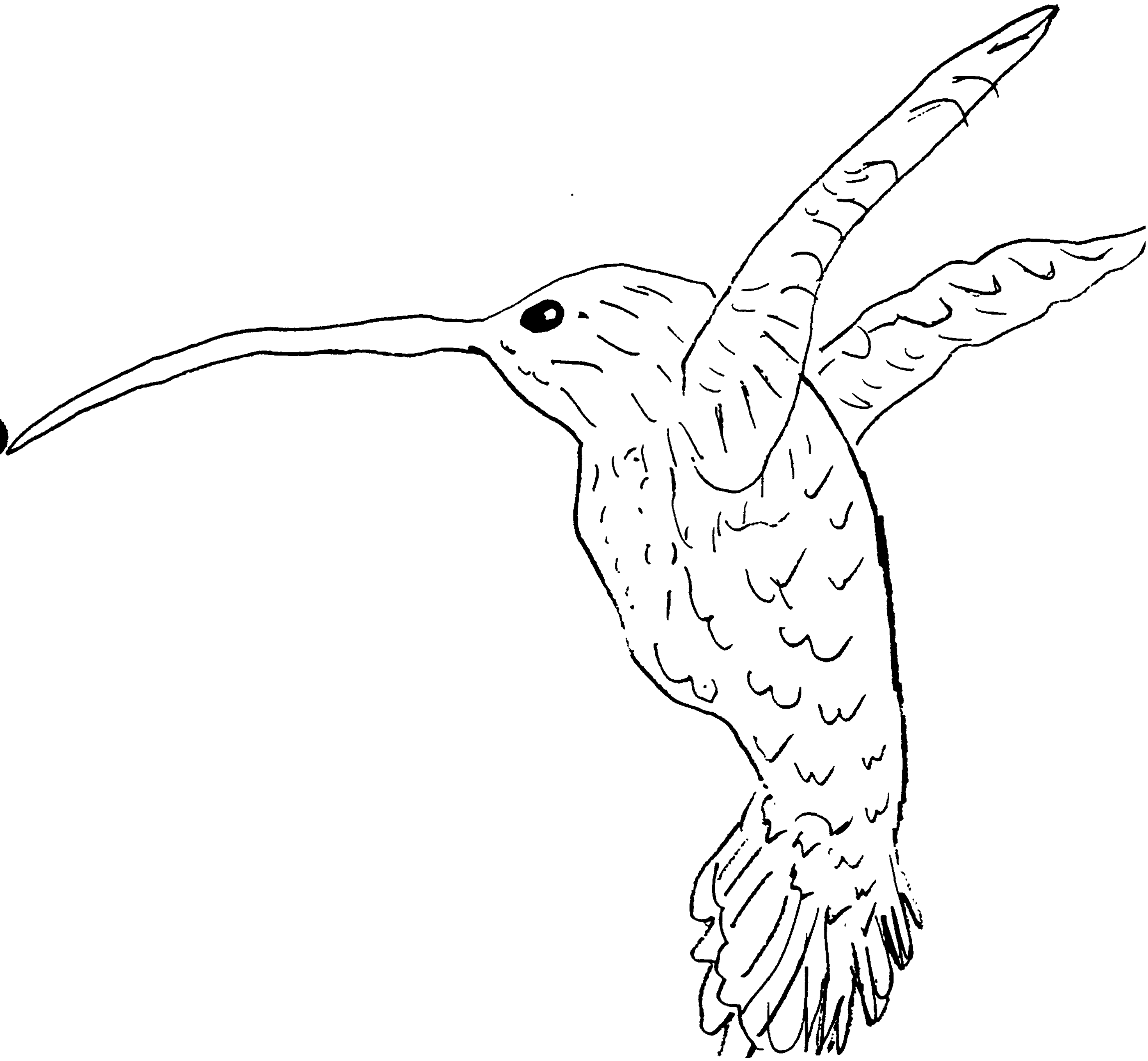
## TREE FROG



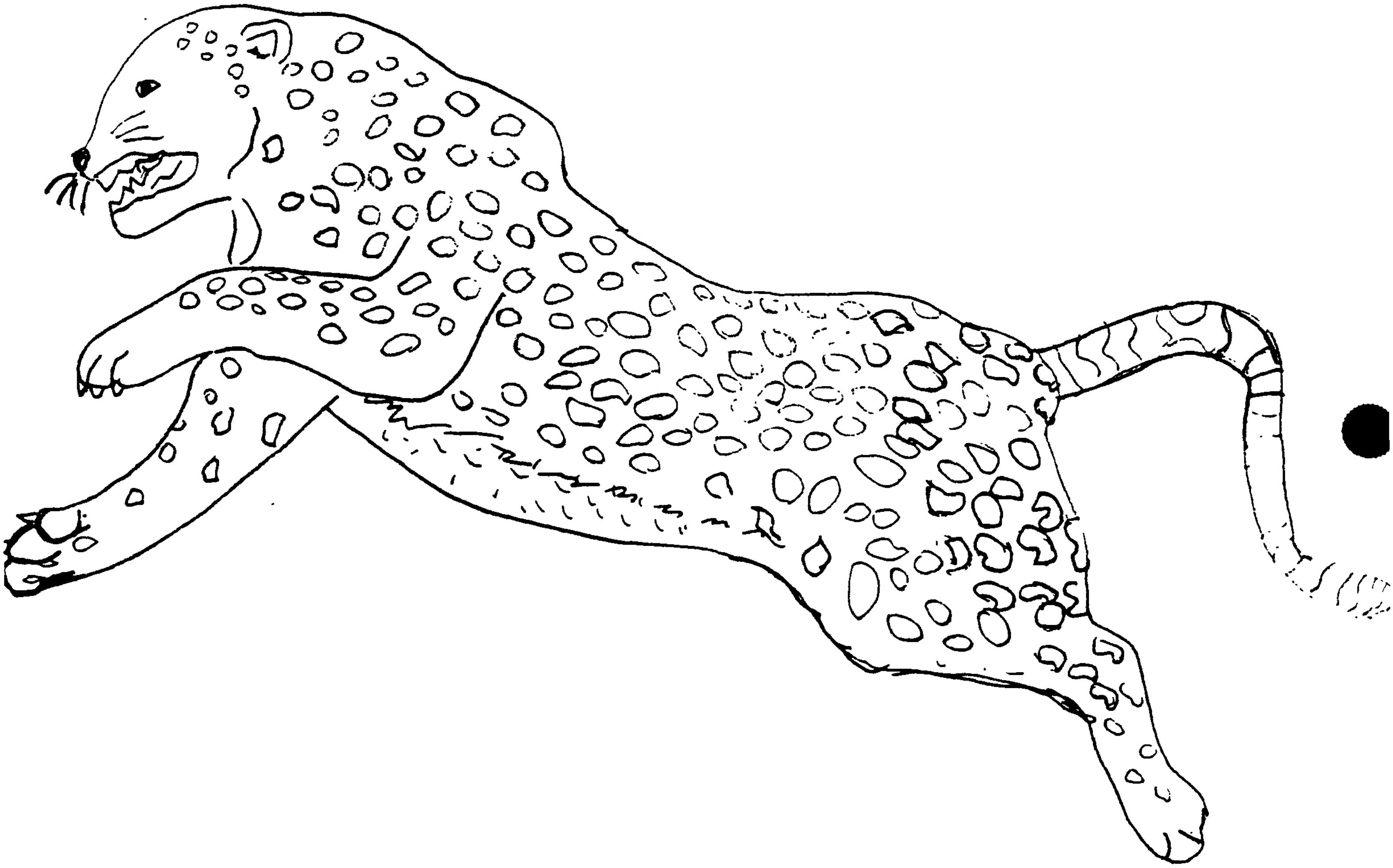
STUDENT WORKSHEET 11

# THE RAIN FOREST IS ALIVE

## HUMMINGBIRD



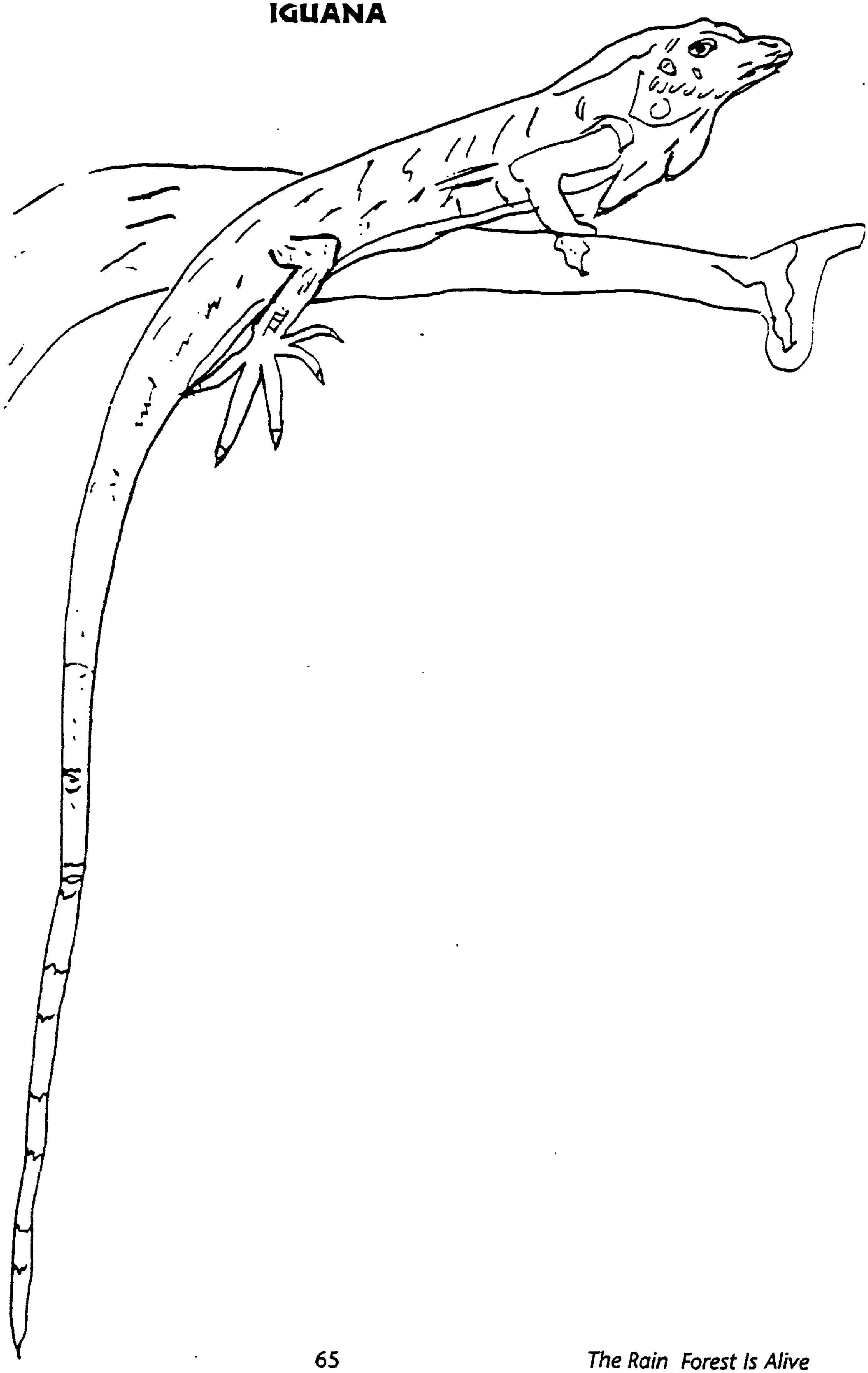
# STUDENT WORKSHEET 12
# THE RAIN FOREST IS ALIVE
## JAGUAR



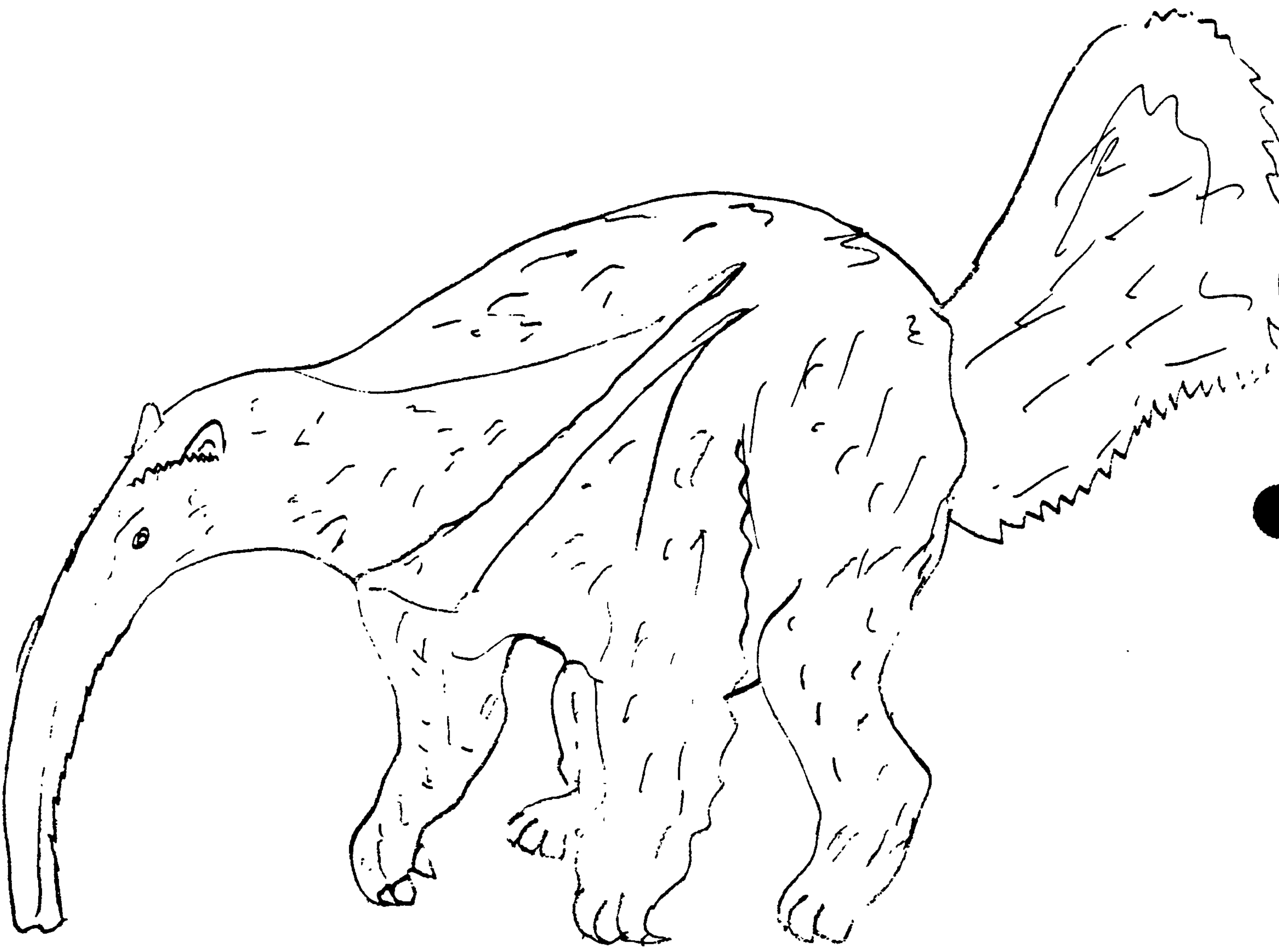
## STUDENT WORKSHEET 13

# THE RAIN FOREST IS ALIVE

### IGUANA



# STUDENT WORKSHEET 14
# THE RAIN FOREST IS ALIVE
## ANTEATER (MAKE 2)

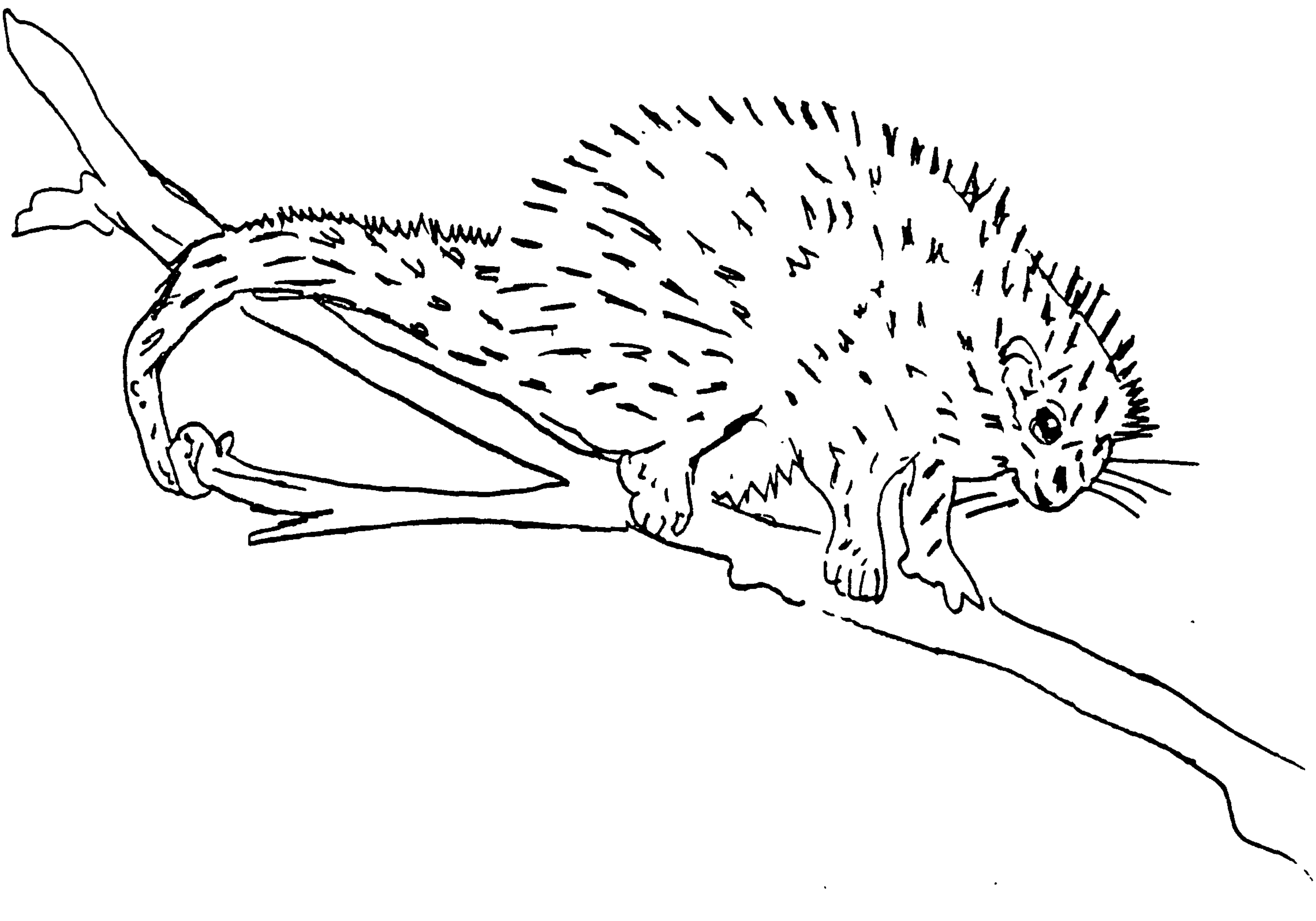


# STUDENT WORKSHEET 15
# THE RAIN FOREST IS ALIVE
## THREE-TOED SLOTH

## STUDENT WORKSHEET 16

# THE RAIN FOREST IS ALIVE

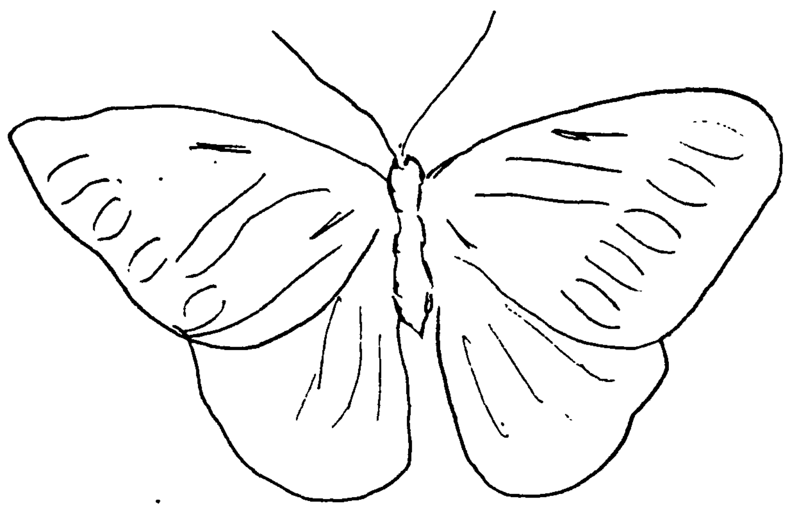
### TREE PORCUPINE (MAKE 4)



STUDENT WORKSHEET 17

# THE RAIN FOREST IS ALIVE

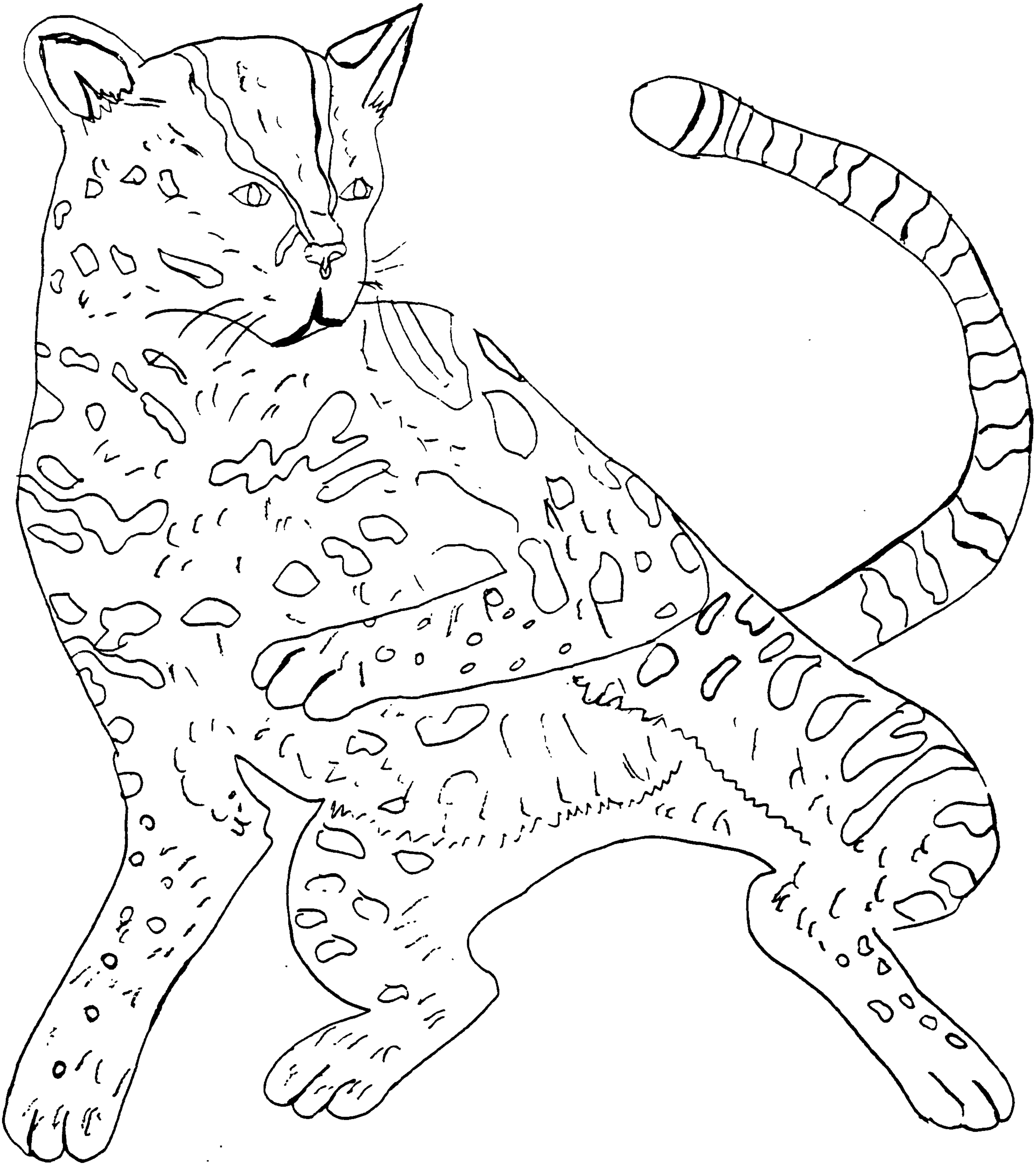
## BUTTERFLY



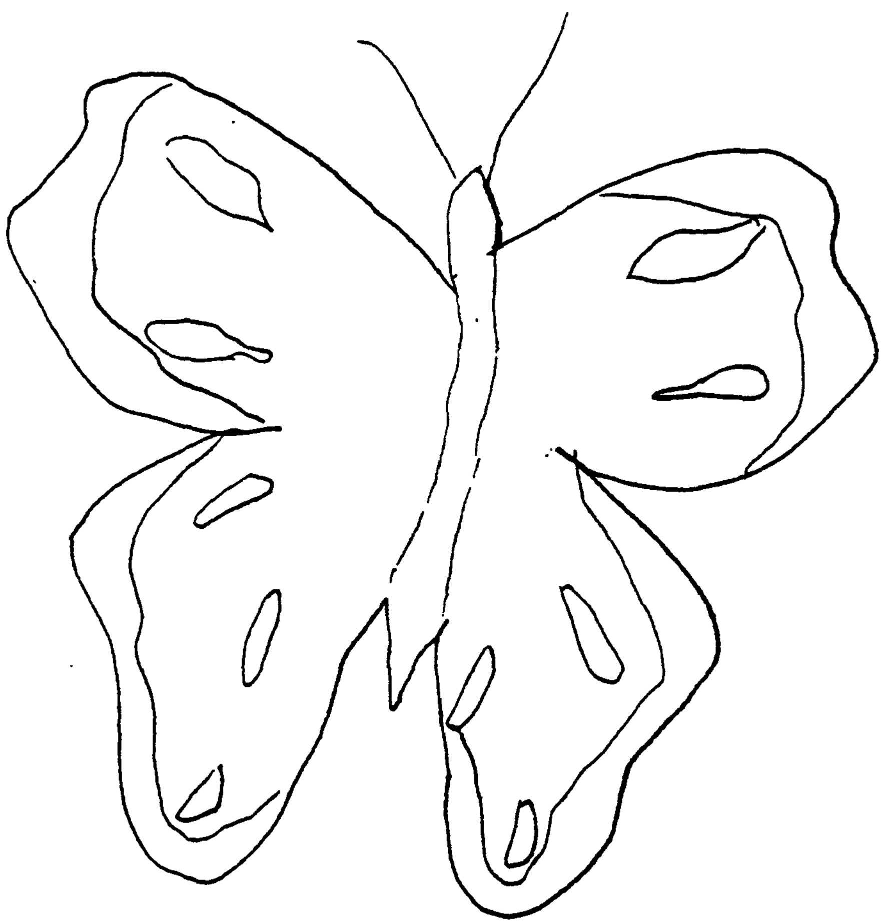
STUDENT WORKSHEET 18

# THE RAIN FOREST IS ALIVE

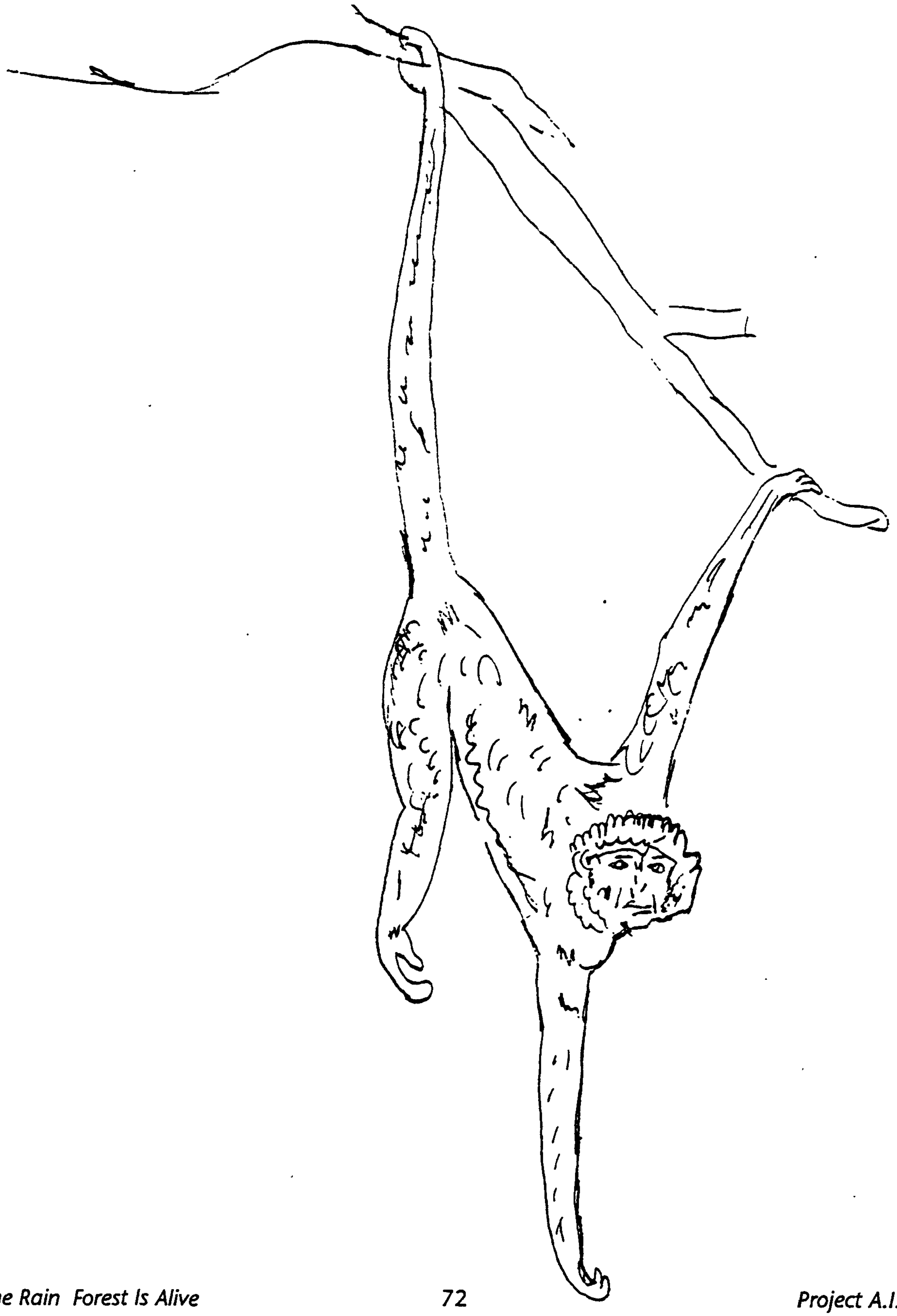
## OCELOT



# STUDENT WORKSHEET 19
# THE RAIN FOREST IS ALIVE
## BLUE MORPHO BUTTERFLY



# STUDENT WORKSHEET 20
# THE RAIN FOREST IS ALIVE
## BLACK-HANDED MONKEY



# ACTIVITY 3

# HOW GREEN ARE WE?

This activity enables students to audit their homes, their school, and their community to evaluate steps being taken to prevent or reduce air pollution. It is related to the "Seeing the Big Picture" warm-up. Related activities include "Lifestyles and the Environment," "Designing a Clean-Air Environment," "Deciding to Clean the Air," and "Action = Savings in $CO_2$ and $."

## CRITICAL OBJECTIVES

- Understand the importance of energy efficiency in connection with air pollution
- Communicate with families and peers about ways to more effectively contribute to cutting down on air pollution

## SKILLS

- Collecting data
- Observing
- Drawing conclusions
- Making oral presentations

## GUEST PRESENTERS

Guest presenters could includes an air quality engineer, economist, ecologist, or conservationist.

## BACKGROUND

Air pollution has become a major problem in many areas of the United States. Even though some of this pollution comes from natural sources, such as volcanoes, forest fires, and other natural occurrences, much of it can be traced to man-made sources. Air pollution from human sources is the result of our increasing use of large quantities of fuel to produce electricity and to power automobiles, trucks, and other vehicles. Many of these air pollutants come from burning coal, oil, wood, and other fuels used to run factories, cars, and the power plants that generate heat and light for our homes.

Many air pollutants are not only harmful, but also tend to be concentrated in urban areas where industrial activity is greatest and energy use by the community is highest. Even though these areas are affected the most by pollutants, there are things that individuals and families, schools, and communities can do to reduce this effect.

Individuals and families can play a role in cutting down on air pollution by cutting electrical and fuel costs. Electrical costs can be reduced by

**RELATED WARM-UP**
C

**REFER TO READING MATERIALS**
"Air Pollution"
"Smog"
"Automobiles and Air Pollution"
"Clean Fuels"

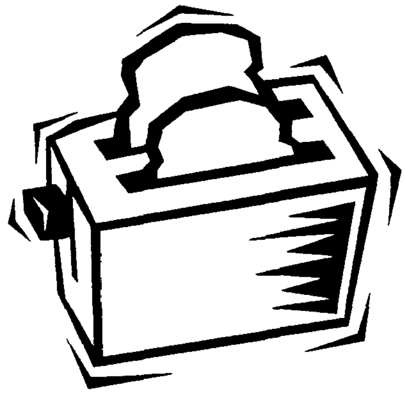
**TARGET GRADE LEVEL**
3rd - 6th with modifications for 7th - 12th

**DURATION**
Two class sessions and one week to conduct the audit

**VOCABULARY**
Compact fluorescent
Energy-efficiency
Incandescent

**MATERIALS**
Paper
Pencil
Chalk
Chalkboard

**WORKSHEETS INCLUDED**
5



using fluorescent or compact fluorescent bulbs in the home, adjusting the setting of the thermostat during the summer and winter, turning off appliances when they are not in use, and using alternative sources for accomplishing tasks that traditionally use electricity, such as drying clothes outdoors instead of always using the clothes dryer. Other measures can be taken, such as using sunlight instead of electricity for warmth and light, buying appliances with low wattages and favorable efficiency ratings, and keeping filters clean on furnaces, air conditioners, and refrigerators. Fuel costs can be reduced by walking or driving instead of using the car orby consolidating errands so that only one trip needs to be made to accomplish everything.

Schools also can cut down on electrical and fuel costs by taking similar measures that individuals can take in the home. Turning off lights at night, using solar energy instead of electricity to heat the homes, and keeping the temperatures at 68°F (20°C) in the winter and 77°F (25°C) in the summer are just a few measures they can take to conserve energy. In addition, they can alter bus routes to accommodate more students so that fewer buses are on the road and encourage their employees to use public transportation, walk, bike, or carpool to get to work.

Communities can help cut down on air pollution by participating in the "Green Lights" program, which is a "clean-air" effort sponsored by EPA. The program works with business and industry to help them cut down on electricity while at the same time save money. The program focuses on upgrading lighting systems and encourages the use of fluorescent and compact fluorescent light bulbs, which last ten times as long as traditional incandescent bulbs and emit more light per watt. The direct result is improved lighting and cost savings for participating businesses, as well as a reduction in air pollution. Communities also can reduce air pollution by promoting use of public transportation, designating High-Occupancy Vehicle lanes on major roads during rush-hour, improving bus routes to reach more citizens, and designating bike routes to encourage use of bikes instead of cars. This could reduce harmful emissions from cars, as well as heavy congestion on major roads.

The focus of this exercise is to learn about energy conservation practices in the home and to find out how energy efficient your students' families are. To do this, the students will compile an audit. This audit will be conducted by filling out the student worksheet on conservation practices in the home. (See reading materials on "Air Pollution," "Smog," "Automobiles and Air Pollution," and "Clean Fuels.")

## WHAT TO DO

### Class #1

1. Explain to students the causes of air pollution and how air pollution can be reduced through the use of energy efficient appliances and light bulbs and fuel efficient cars.

2. Introduce the exercise by telling the students that they will be conducting an audit. Explain to them that the audit will be a formal examiNatiŏn of each student's home and family practices related to energy use. Data will be collected and observations will be recorded on the student worksheets.

3. Hand out "Student Worksheet 1" with specific instructions to answer all of the questions. Explain to the class that data collected from the audit will be used as part of a future in-class discussion to assess the energy efficiency of their homes and to discuss the importance of energy conservation.

4. Give the students one week to complete the audit of their home. Be sure to tell them that they should feel free to make additional observations and to collect data related to energy use that is not necessarily on the student worksheets.

### Class #2

1. Meet with the class to discuss the data collected from their audits.

2. Discuss the importance of energy conservation and how it relates to reduced air pollution. Tell students that there are many measures their families can take to conserve energy, such as purchasing new appliances that have energy efficiency ratings or setting the thermostat to 68°F (20°C ) in the winter and 77°F (25°C) in the summer.

3. Explain how energy conservation measures not only reduce air pollution, but save money as well.

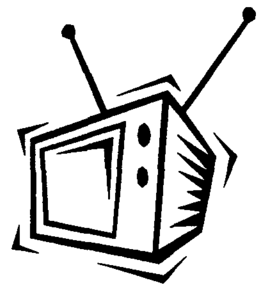
4. Discuss the importance of fuel conservation and how it relates to air pollution.

5. Discuss how car emissions contribute to the air pollution problem, but that this can be combatted by more people using public transportation, carpools, and biking or walking.

## SUGGESTED EXTENSIONS (OPTIONAL)

- In addition to the extended audits, have students fill out "Student Worksheets 4 and 5," an exercise that enables students to calculate the costs of running common appliances in the home and the school. This exercise could be used as part of a discussion of how reduced electrical costs not only save a family or a school money, but also can reduce air pollution.

## SUGGESTED MODIFICATIONS



- For grades 7-9, have students conduct an audit of the school in addition to auditing their homes. Using "Student Worksheet 2," they can answer questions related to energy conservation by the school and its students and personnel.

- For grades 10-12, expand the activity to include an audit of the community. Have students use "Student Worksheet 3." This additional activity will require time to do research outside of class and includes an evaluation of energy use by industry and businesses in the community and the efforts that the community takes to encourage energy efficient practices by its citizens.

## SUGGESTED READING

[illegible] and Maureen Sangiorgio. "Pollution-Fighting Plants." *Prevention*, 44 (September 1992) p. 10.

Javna, John, et al. *50 Simple Things Kids Can Do To Save the Earth.* Andrews and McMeel (1990).

*What You Can Do To Reduce Air Pollution.* Washington, DC: U.S. Environmental Protection Agency EPA/450/K-92/002 (1992).

Willis, Terri, and Wallace B. Black. *Cars: An Environmental Challenge.* Children's Press (1992).

STUDENT WORKSHEET 1

# HOW GREEN ARE WE?

## HOME AUDIT

1. How many light bulbs do you have in your home? ____________________

2. How many are fluorescent or compact fluorescent bulbs? ____________________

3. What is the total wattage of all bulbs in your home? ____________________

4. What temperature does your family set your thermostat set at in the winter? __________ Summer? ____________________

5. Is your home properly insulated to help keep the house warm in the winter and cool in the summer? ____________________

6. What locations in the house should be insulated the most? ____________________

   ____________________

   ____________________

7. Does your family wait until there is a full load of laundry to wash clothes? __________

8. Do you dry washed clothes outside or use a clothes dryer? ____________________

9. How many miles per gallon does your family's car get? ____________________

10. How many gallons of gas does your car use in a week? ____________________

11. What kind of gas does your family use in their car? ____________________

12. How often do you walk, ride your bike, or use public transportation instead of riding in a car per month? ____________________

# STUDENT WORKSHEET 2

# HOW GREEN ARE WE?

## SCHOOL AUDIT

1. How long do the lights stay on in the school after the students have left for the day? _____
2. Who is responsible for turning off the lights? ______________________________
3. Do you ever see the lights turned on in the evening hours? ______________________
4. What kinds of light bulbs are used in the lighting fixtures at the school? ____________
5. Are the windows in the school properly insulated? (Find this out by holding a piece of tissue paper or a ribbon next to the windows. If it moves, there is probably a draft, which means that cold air is getting in and the school's furnace has to use more electricity to keep the school warm.) ______________________________
6. What are ways to fix the windows? ______________________________

   ______________________________
7. Who is responsible for getting this done? ______________________________
8. How do you and your friends get to school each day? ______________________
9. Does the bus system reach enough students so that no one has to rely on other transportation? ______________________________
10. If a parent drives you, do other students ride with you? ______________________
11. What alternate modes of energy-efficient transportation could students use to get to school?

    ______________________________
12. Can you make arrangements to pick up a friend or several friends to ride to and from school with you and your parents? ______________________________
13. How do most teachers and other school personnel (such as the principal, teachers, or your guidance counselor) get to school each day? ______________________
14. What other forms of transportation would you suggest them to use for getting to and from school each day? ______________________________
15. Do you see parents picking up children from school? ______________________
16. If so, do they leave their car running while they wait? ______________________
17. What measures could the school take to discourage drivers from doing this? __________

    ______________________________

## STUDENT WORKSHEET 3

# HOW GREEN ARE WE?

### COMMUNITY AUDIT

1. What industries in your community are major polluters? ______________________

   ____________________________________________

2. What federal regulations that relate to air pollution affect their business? __________

   ____________________________________________

   Do they abide by these regulations? ______________________

   If not, why? ______________________

3. What local regulations affect their business? ______________________

4. What other businesses in your community indirectly contribute to air pollution? ______

   ____________________________________________

5. What measures do these companies take to cut down on air pollution? __________

   ____________________________________________

6. Are there enough buses and subways to help people get around town easily without having to get into their car? ______________________

   Could the routes be changed to accommodate more people? ______________

7. Do major streets have bicycle lanes to make it easier for people to ride bikes as an alternative to driving their car? ______________________

8. Does the community sponsor a car pool program? ______________________

   How many people are participating? ______________________

9. Do the major roads in your community encourage carpooling by designating High-Occupancy Vehicle (HOV) lanes during rush hour? ______________________

10. Are traffic signals timed to reduce the amount of time that cars sit at lights? __________

11. Are gas stations required to install special devices on pumps to capture gas fumes that can be released into the atmosphere, causing air pollution? ______________

12. Does your community require emissions inspections for all registered vehicles? ______

    How often are these inspections required? ______________________

# STUDENT WORKSHEET 4

# HOW MUCH ENERGY DO YOU USE IN YOUR HOME?

## HOW GREEN ARE WE?

| APPLIANCES | VOLTS* × | AMPS* = | WATTS × | USAGE (IN HOURS PER WEEK) = | WATT HOUR ÷ | 1,000 = | KILOWATT HOUR (KWH) × | 8.25¢/ KWH = | COST TO RUN / WEEK |
|---|---|---|---|---|---|---|---|---|---|
| TELEVISION | | | | | | | | | |
| RADIO | | | | | | | | | |
| WASHER | | | | | | | | | |
| DRYER | | | | | | | | | |
| HAIR DRYER | | | | | | | | | |
| DISHWASHER | | | | | | | | | |
| OVEN | | | | | | | | | |
| MICROWAVE | | | | | | | | | |
| LIGHT BULBS (BASED ON TOTAL # IN HOUSE) | | | | | | | | | |

| CARS | MILES DRIVEN PER WEEK ÷ | MILES TO THE GALLON = | GALLONS OF GAS USED PER WEEK × | PRICE OF A GALLON OF GASOLINE = | COST TO DRIVE CAR PER WEEK |
|---|---|---|---|---|---|
| CAR #1 | | | | | |
| CAR #2 | | | | | |

* If wattage is known, there is no need to fill in this block

# STUDENT WORKSHEET 5

## HOW GREEN ARE WE?

### HOW MUCH ENERGY DO YOU USE IN YOUR SCHOOL?

| APPLIANCES (BASED ON TOTAL # IN SCHOOL) | VOLTS* X | AMPS* = | WATTS X | USAGE (IN HOURS PER WEEK) = | WATT HOUR ÷ | 1,000 = | KILOWATT HOUR (KWH) X | 8.25¢/ KWH = | COST TO RUN / WEEK |
|---|---|---|---|---|---|---|---|---|---|
| CLOCKS | | | | | | | | | |
| COMPUTERS | | | | | | | | | |
| WATER FOUNTAINS | | | | | | | | | |
| PUBLIC ADDRESS SYSTEM | | | | | | | | | |
| DISHWASHERS | | | | | | | | | |
| OVENS | | | | | | | | | |
| COFFEE POT | | | | | | | | | |
| LIGHT BULBS (BASED ON TOTAL # IN SCHOOL) | | | | | | | | | |

| TRANSPORATION | MILES DRIVEN PER WEEK ÷ | MILES TO THE GALLON = | GALLONS OF GAS USED PER WEEK X | PRICE OF A GALLON OF GASOLINE = | COST TO DRIVE CAR PER WEEK |
|---|---|---|---|---|---|
| SCHOOL BUSES | | | | | |

* If wattage is known, there is no need to fill in this block

# ACTIVITY 4

# ACTION = SAVINGS IN $CO_2$ + $

This activity uses a take-home survey to inventory current use and calculate the savings a household could achieve in dollars and carbon dioxide ($CO_2$) emissions by undertaking certain conservation measures. It is related to the "Seeing the Big Picture" warm-up and the "How Green Are We?," "The Greenhouse Effect," and "Climate and the Greenhouse Effect" activities.

## CRITICAL OBJECTIVES

- Identify sources of $CO_2$ emissions
- Measure savings in $CO_2$ emissions resulting from undertaking energy conservation measures
- Recognize additional dollar savings resulting from lower energy consumption

## SKILLS

- Collecting data
- Organizing data
- Analyzing and interpreting data
- Computing

## GUEST PRESENTERS

Guest presenters could include EPA environmental protection specialists or economists.

## BACKGROUND

This exercise requires an understanding and appreciation of the carbon cycle and the importance of maintaining global equilibrium between oxygen and carbon dioxide. Carbon dioxide ($CO_2$) is a byproduct of most living things and many commercial processes. Organisms "burn" food (fuel) to release the energy required for life activities. Humans also burn fossil fuels such as coal and oil for energy. $CO_2$ is a waste product of these processes. Plants use carbon dioxide for photosynthesis, but concern is growing that the amount of $CO_2$ is accumulating in the atmosphere because fossil fuel consumption worldwide is outpacing plants' ability to use it.

Carbon dioxide in the atmosphere absorbs and traps heat emitted by the Earth, much as heat is trapped in a greenhouse. The concern of scientists is that if the amount of $CO_2$ and similar gases in the atmosphere continues to rise, the average temperature of the Earth could

**RELATED WARM-UP**
C

**REFER TO READING MATERIALS**
"The Greenhouse Effect"
"Air Pollution"
"Smog"
"Automobiles and Air Pollution"

**TARGET GRADE LEVEL**
8th-12th

**DURATION**
40 minutes in first class, plus take-home survey; 40 minutes in second class

**VOCABULARY**
Carbon cycle
Carbon dioxide
Emissions
Fossil fuel
Greenhouse effect
Photosynthesis

**MATERIALS**
Chalk
Chalkboard

**WORKSHEETS INCLUDED**
2

rise 8 to 10°F (4 to 6°C). This is called the "greenhouse effect." While such an increase may sound small, climatologists foresee dramatic impacts on future climates. For example, it could cause polar ice cap melting and a subsequent rise in sea levels, possibly inundating coastal cities and populations. In addition, it could cause species that cannot adapt to these relatively sudden climate changes to die out. (See reading materials on "The Greenhouse Effect," "Air Pollution," "Smog," and "Automobiles and Air Pollution.")

There are many simple energy conservation steps an individual can take to help reduce fossil fuel consumption and cut $CO_2$ emissions. In addition to the benefits conservation provides for the environment, conservation is a money-saver as well and can provide dollar savings through lower fuel bills. This activity stresses the both of these types of benefits of energy conservation.

## WHAT TO DO

### First class

1. Review with the students the greenhouse effect concept, including the process by which global $CO_2$ levels rise and the ramifications for the global climate.

2. Distribute both student worksheets. Explain that the worksheet called "Inventory of Current Use" will help them collect information about the way they and their families use the family car, lighting, and home heating and cooling systems, and their recycling practices. This, in turn, will let them calculate how much $CO_2$ they may be releasing to the atmosphere. The worksheet called "$CO_2$ and \$ Savings" will let them calculate the $CO_2$ their families could save by taking some simple conservation steps. In addition, the worksheet can be used to calculate how much money the family can save by conserving.

3. Instruct the students to take the worksheets home and fill them out with their parents. Set a date for them to bring the completed worksheets back, so the class can discuss the results. (If you want to calculate the class-wide $CO_2$ use and savings potential prior to the class discussion, have students turn in the completed worksheets several days in advance of the discussion.)

### Second class

1. Put the potential conservation measures from the "$CO_2$ and \$ Savings" worksheet on the chalkboard. Beside the list draw two columns. Label one

"Current" and the other "Future." With a show of hands, count the number of students whose families currently conserve in each of the ways listed and record it on the chalkboard beside each item. Encourage students to share the reasons for taking (or not taking) specific conservation actions.

2. With a show of hands, count the number of students whose families are willing to conserve in the future in each of the ways listed and record it on the chalkboard in the "Future" column. Explore whether financial savings are expected to result from these actions. If so, ask how much the students' families considered that in the decision to conserve. Would they have done it anyway? Or were the prospect of financial savings a major motivation?

3. Calculate (you may have done this already) current class-wide $CO_2$ conservation. Congratulate them on a job well done. Calculate (you may have done this already) potential class-wide savings in $CO_2$ and in dollars.

5. Suggest that the class consider a year long (or school-year long) analysis to see if there is a limit to what they can save as individuals and as a group. If students express interest, divide up and coordinate assignments.

## SUGGESTED MODIFICATIONS (OPTIONAL)

- For upper grades, encourage students to make predictions on $CO_2$ savings that may be achieved by their school, town or city, region, or the entire United States if conservation steps are undertaken. These measures could include, for example, increased use of mass transit, more efficient insulation and lighting of public buildings, developing High-Occupancy Vehicle (HOV) programs for local highways to encourage car pooling, and restricting traffic in specific areas of the city. Results could be presented to the local school board or the city (town) council to introduce students to the political aspects of conservation.

## SUGGESTED READING

Baker, Susan. *First Look at Using Energy.* Milwaukee, WI: Gareth Stevens (1991).

Javna, John, et al. *50 Simple Things Kids Can Do To Save the Earth.* Andrews and McMeel (1990).

Klaber, K. A., K. N. Weiss, and J. W. Gallagher. "Charting a Course through the Clean Air Act Amendments." *National Environmental Journal,* (November 1993)

U.S. EPA. *Office of Radiation and Indoor Air: Program Description.* Washington, DC: U.S. EPA, Office of Air and Radiation EPA/402/K-93/002 (June 1993).

Yanda, Bill. *Rads, Ergs, and Cheeseburgers: The Kid's Guide to Energy and the Environment.* Norton (1991).

## STUDENT WORKSHEET 1

# ACTION = SAVINGS IN $CO_2$ + $

## INVENTORY OF CURRENT USE

### 1) AUTOMOBILES

**Rule of thumb: Every gallon of gasoline used by an automobile costs approximately $1.10 and releases about 20 lbs. of $CO_2$.**

For each automobile in your household, calculate the daily and annual fuel cost and $CO_2$ emissions:

**TABLE 1**

| | Auto 1 | Auto 2 | Auto 3 |
|---|---|---|---|
| Miles per Gallon (MPG) | | | |
| Cost per Mile (CPM) = $1.10÷MPG | | | |
| $CO_2$ Emissions per Mile (EPM) = 20 lbs.÷MPG | | | |
| Daily Miles (DM) | | | |
| Daily Cost = CPM x DM | | | |
| Daily Emissions of $CO_2$ = EPM x DM | | | |
| Annual Miles (AM) = DM x 365 or actual mileage if known | | | |
| Annual Cost = CPM x AM | | | |
| Annual Emissions of $CO_2$ = EPM x AM | | | |

Daily commuting: A bus gets about 8 miles per gallon of gasoline (CPM = $0.14) and releases about 22 lbs. of $CO_2$ per gallon (EPM = 2.75 lbs.). Using the above daily cost and emission figures for Auto 1, calculate the savings if 20 people rode the bus rather drove the same distance in the same type of car.

20 Cars

Daily Cost (from above) x 20 = ________________

Daily Emissions (from above) x 20 = ________________

1 Bus

Daily Cost = DM (from above) x $0.14 = ________________

Daily Emissions = DM (from above) x 2.75 lbs. = ________________

If you or anyone in your family uses an alternative to driving for daily commuting (for example, to work or school), calculate the total annual savings in money and $CO_2$:

________________

## 2) ELECTRIC LIGHTING

**Rule of thumb: Every kilowatt-hour of electricity consumed costs $0.085 releases 0.5 lbs. of $CO_2$.**

Calculate the $CO_2$ and money you save at home now.

For each 27-watt compact fluorescent light bulb:
160 lbs. of $CO_2$ and $58/year ____________

For each 18-watt compact fluorescent light bulb:
120 lbs. of $CO_2$ and $43/year ____________

## 3) HOME HEATING AND COOLING

Type of heating fuel (for example, electric, oil*, natural gas*):
* Dollar figures associated with oil and natural gas savings are not available.

If you turn the heat down in your home overnight or when no one is home:

| | | | |
|---|---|---|---|
| By 10 degrees, save: | electric: | 2,070 lbs. $CO_2$ and $745/year | ____________ |
| | oil: | 1,260 lbs./year | ____________ |
| | gas: | 900 lbs./year | ____________ |
| By 5 degrees, save: | electric: | 1,000 lbs. $CO_2$ and $360/year | ____________ |
| | oil: | 610 lbs./year | ____________ |
| | gas: | 440 lbs./year | ____________ |

If your furnace has received tune-up within last year:

| | | | |
|---|---|---|---|
| | electric: | 1,030 lbs. $CO_2$ and $371/year | ____________ |
| | oil: | 640 lbs./year | ____________ |
| | gas: | 450 lbs./year | ____________ |

If your air conditioner has received tune-up within last year:
220 lbs. $CO_2$ and $80/year ____________

If doors and windows are insulated (weather-stripping):

| | | | |
|---|---|---|---|
| | electric: | 1,600 lbs. $CO_2$ and $576/year | ____________ |
| | oil: | 1,000 lbs./year | ____________ |
| | gas: | 700 lbs./year | ____________ |

If your home water heater has an insulation jacket:

| | | | |
|---|---|---|---|
| | electric: | 600 lbs. $CO_2$ and $216/year | ____________ |
| | oil: | 360 lbs./year | ____________ |
| | gas: | 260 lbs./year | ____________ |

## 4) RECYCLING

What products do you recycle in your home (aluminum cans, steel cans, plastic jars and bottles, newspaper)?

Estimate the number of aluminum and steel cans and the number of glass bottles that you recycle annually. If you are not sure, keep track of the number of items recycled in one week and multiply by 52.

Every 10 aluminum or steel cans recycled saves 4 lbs. of $CO_2$. Every 10 glass bottles recycled saves 3 lbs. of $CO_2$. Calculate the amount of $CO_2$ you currently save annually by recycling aluminum, steel, and glass: ________________

If you recycle newspapers: 50 lbs./year ________________

## 5) TOTAL

Add up the amount of $CO_2$ and the money you and your family save every year as a result of the steps listed above:

$CO_2$ = ________________
\$ = ________________

# STUDENT WORKSHEET 2
# ACTION = SAVINGS IN $CO_2$ + $
## $CO_2$ AND $ SAVINGS

### 1) AUTOMOBILES

CPM (from Table 1 of the Inventory of Current Use): ____________________

EPM (from Table 1 of the Inventory of Current Use): ____________________

Automobile miles and gasoline consumption may be reduced in a number of ways:
- a person walks, bikes, or takes public transportation instead of driving
- car errands are combined
- car pooling

In addition, if your family switches to a more fuel efficient car, it will save money and reduce $CO_2$ emissions. If your family' car(s) gets less than 30 miles per gallon (MPG), compare to a car that gets 30 MPG. Use the data from Table 1 of the Inventory of Current Use to complete Table 2 for up to two cars.

**TABLE 2**

| | Auto 1 | Auto 2 | Compare |
|---|---|---|---|
| Miles per Gallon (MPG) | | | 30 |
| Cost per Mile (CPM) = $1.10÷MPG | | | $0.037 |
| $CO_2$ Emissions per Mile (EPM) = 20 lbs.÷MPG | | | 0.67 |
| Daily Miles (DM) | | | |
| Daily Cost = CPM x DM | | | |
| Daily Emissions of $CO_2$ = EPM x DM | | | |
| Annual Miles (AM) = DM x 365 or actual mileage if known | | | |
| Annual Cost = CPM x AM | | | |
| Annual Emissions of $CO_2$ = EPM x AM | | | |

How much would you and your family save if you switched to more fuel efficient cars?
$ = ____________________
$CO_2$ = ____________________

For every annual mile saved from current automobile usage, add one CPM and EPM unit. Total your savings in fuel costs and $CO_2$ if you reduce driving and switch to fuel efficient automobiles:
$ = ____________________
$CO_2$ = ____________________

## 2) ELECTRICITY

**Rule of thumb: Every kilowatt-hour of electricity consumed costs $0.085 releases 0.5 lbs. of $CO_2$.**

If you replace conventional incandescent light bulbs with compact fluorescent light bulbs, you will save money on electricity and reduce $CO_2$ emissions. (27-watt compact fluorescent bulbs replace 75-watt incandescent bulbs; 18-watt fluorescent bulbs replace 60-watt incandescent bulbs.)

For each 27-watt compact fluorescent light bulb:
160 lbs. of $CO_2$ and $58/year ______________
For each 18-watt compact fluorescent light bulb:
120 lbs. of $CO_2$ and $43/year ______________

## 3) HOME HEATING AND COOLING

Type of heating fuel (for example, electric, oil*, natural gas*): ______________
* Dollar figures associated with oil and natural gas savings are not available.

If you begin to turn the heat down in your home overnight or when no one is home:
By 10 degrees, save:

| | | |
|---|---|---|
| electric: | 2,070 lbs. $CO_2$ and $745/year | ______________ |
| oil: | 1,260 lbs./year | ______________ |
| gas: | 900 lbs./year | ______________ |

By 5 degrees, save:

| | | |
|---|---|---|
| electric: | 1,000 lbs. $CO_2$ and $360/year | ______________ |
| oil: | 610 lbs./year | ______________ |
| gas: | 440 lbs./year | ______________ |

If your furnace receives a tune-up within the next year:

| | | |
|---|---|---|
| electric: | 1,030 lbs. $CO_2$ and $371/year | ______________ |
| oil: | 640 lbs./year | ______________ |
| gas: | 450 lbs./year | ______________ |

If your air conditioner receives a tune-up within the next year:
220 lbs. $CO_2$ and $80/year ______________
If you insulate doors and windows with weather-stripping:

| | | |
|---|---|---|
| electric: | 1,600 lbs. $CO_2$ and $576/year | ______________ |
| oil: | 1,000 lbs./year | ______________ |
| gas: | 700 lbs./year | ______________ |

If you put an insulation jacket on your home water heater:

| | | |
|---|---|---|
| electric: | 600 lbs. $CO_2$ and $216/year | ______________ |
| oil: | 360 lbs./year | ______________ |
| gas: | 260 lbs./year | ______________ |

### 4) RECYCLING

Every 10 aluminum or steel cans recycled saves 4 lbs. of $CO_2$. Every 10 glass bottles recycled saves 3 lbs. of $CO_2$. What products can you begin to recycle in your home (aluminum cans, steel cans, plastic jars and bottles, newspaper)?

Estimate the number of aluminum and steel cans, and the number of glass bottles that you will recycle annually. If you are not sure, keep track of the number of items recycled in one week and multiply by 52.

Calculate the amount of $CO_2$ you can save annually by recycling aluminum, steel, and glass: ____________________

If you begin to recycle newspapers:
50 lbs./year ____________________

### 5) TOTAL

Add up the amount of $CO_2$ and the money you and your family could save every year as a result of the steps listed above:

$CO_2$ = ____________________
$ = ____________________

# ACTIVITY 5

# BREATHING ROOM

This activity lets students calculate the volume of air in the classroom and illustrates the importance of preserving the quality of indoor air. It also introduces concepts of human exposure, and draws a parallel between indoor air and ambient air. This activity is related to the warm-ups called "Read My Data" and "Where's That Odor" and the activity called "The Radon Game."

## CRITICAL OBJECTIVES

- Define some visible or invisible and odorous and non-odorous indoor air pollutants
- Describe the link between illness and breathing polluted air
- Explain how the amount of air in a given space is related to the size of the space
- Calculate the amount of air in the classroom and how much air people breathe per minute and in one hour

## SKILLS

- Observing
- Collecting data
- Organizing data
- Computing
- Drawing conclusions

## GUEST PRESENTERS

Guest presenters could include air quality engineers, architects, EPA environmental protection specialists, or heating and ventilation technicians.

## BACKGROUND

Most people are aware that outdoor air pollution can damage their health but may not know that the quality of the air indoors can be very poor, too. Studies of human exposure to air pollutants indicate that indoor levels of many pollutants may be two to five times, and occasionally more than 100 times, higher than outdoor levels. Comparative risk studies performed by EPA have consistently ranked indoor air pollution among the top five environmental risks to public health. Carpeting, manufactured wood products, and combustion appliances (gas and oil cooking stoves and furnaces, for example) are the three most important sources of hundreds of indoor air pollutants. Typical examples are methyl methacrylate, aliphatic hydrocarbons, ketones, formaldehyde, xylene, lead, bacteria, mold, dust mites, and known carcinogens like benzene, trichloroethylene, vinyl

**RELATED WARM-UPS**
B, F

**REFER TO READING MATERIALS**
"Indoor Air Quality"
"Health Effects"

**TARGET GRADE LEVEL**
9th - 12th

**DURATION**
40 minutes

**VOCABULARY**
Odor detection threshold
Odor recognition threshold
Tidal volume
Total minute volume
Ventilation rate

**MATERIALS**
Metric conversions
Ventilation volumes in human lungs
Tape measure for teacher/presenter
Large wall clock with second hand
Adhesive tape
Paper
Marker

**WORKSHEETS INCLUDED**
1

chloride, and tobacco smoke. Some three hundred volatile organic compounds are known, and many of them are common in houses. Some houses are filled with synthetic materials that can release a wide range of hazardous chemicals into the air over time. In addition, many common household products, used without proper ventilation, and gases like radon, pose a serious health threat to people—most of whom spend over 90 percent of their time indoors. To make matters worse, while insulating our homes is important for energy conservation, it can decrease air exchange and increases pollutant concentrations indoors. The air in tightly sealed homes and buildings can constitute a health hazard. Air pollutants enter the body primarily through the lungs, which have a total surface area about 25 times greater than that of the body's skin surface. This large surface area makes the lungs an excellent filter. (See the reading materials on "Indoor Air Quality" and "Health Effects.")

## WHAT TO DO

1. Ask students where they spend most of their time. Have students estimate the percentage of time they spend at home, at school, in the car, and so on. Have them draw a pie chart on a sheet of paper, illustrating this information. This process should reveal that most of their time is spent indoors. Ask students to estimate how much of a 24-hour day they spend indoors in winter and summer.

2. Discuss the importance of ensuring that the places they spend most of their time are free of pollutants that could make them sick. Ask students if they know of any pollutants in their homes that could make them sick. If necessary, prompt students by suggesting, for example, tobacco smoke, dust, particulates, paint thinners, grease cleaners, pesticides, radon gas seeping into the house through cracks in the basement walls or floor, dry-cleaned clothing and drapes, chemically formulated personal care products, faulty heating units, cooking appliances, wood burning fireplaces and stoves, some synthetic building materials, wall coverings, carpet, and furniture.

3. Ask students how they would know whether there are pollutants in the air at home or school? Can such pollutants be seen or smelled? Discuss the fact that only some indoor air pollutants like tobacco smoke and insecticides are visible or smelly enough to detect easily at certain concentrations.

4. Explain that many pollutants, such as radon, have no odor and are invisible.

5. Burn a candle or incense to produce visible and invisible (carbon dioxide) pollutants. Ask the students if all pollutants smell bad. Discuss odor detection threshold (minimum odorant concentration required to perceive the existence of the pollutant) and odor recognition threshold (minimum odorant concentration required to identify the pollutant). For example, ammonia has a detection threshold of 17 parts per million (ppm) and a recognition threshold of 37 ppm. Ask the students if they think that if they can't smell a pollutant it is safe to breathe.

6. Explain that concentrations in the air are measured as parts per million (ppm), not as percentages (as in the pie chart they drew).

7. Explain that pollutants in the air can make people sick depending in large part on how much air is in the space people occupy, how much pollutant is in that space, how much air people breathe, and the sensitivity of the individual.

8. Explain that it is often necessary to rely on specialized scientific equipment to measure the presence and amounts of such substances in the air.

9. Introduce the activity. Hand out the student worksheet. Go over with students the formulas on the worksheet for calculating cubic feet and to convert cubic feet to liters for easy comparison to human lung volumes. Tape measurements to the walls to show the height of the room. Tape measurements to the floor showing the length and width. (If you prefer, do this before class begins). Point out the location of the measurements, and notify the students that they have three minutes to gather and record the measurements on their worksheets. (You also could challenge the students to make these measurements without your assistance.)

10. Ask the students to do the calculations on their worksheets using the room measurements they have gathered.

11. Go over with students the formula on the worksheet for calculating human ventilation volumes. Ask the students to measure their own ventilation rates per minute and to compare their own rates with the average adult rate (14 breaths/minute) at rest. Using the formula and assumptions (0.5 L tidal volume) provided on the worksheet, ask the students to calculate total minute volume and the ventilation volumes over one hour.

12. Compare the calculated ventilation volumes in liters with the amount of air in the room and discuss the implications to health if air pollutants are present. Have students consider the following questions:

    How much air do you and your classmates need to breathe comfortably?
    Is there enough air in the room for you and all your classmates too?
    Where is the fresh air you need in the classroom coming from? Is it really fresh?
    If the room were sealed (no outside air coming into the room), how long would you and your classmates survive at your current breathing rates?

## SUGGESTED EXTENSIONS (OPTIONAL)

- Compare ventilation volumes over eight hours with the volume of air in the room. Facilitate a student discussion of how increased physical activity would affect their exposure to air pollution.

## SUGGESTED READING

Becker, Brenda L. "Is Your Home Hazardous to Your Health." *Woman's Day,* 56 (21 September 1993) p. 36.

"Can a Building Really Make You Sick?" *University of California, Berkeley Wellness Letter,* 7 (July 1991) p. 1.

Delaney, Lisa. "The Air Doctors' Report: How to Protect Yourself from Dangers Blowing Through Your House." *Prevention,* 43 (August 1991) p. 44.

Greenfield, Ellen J. *House Dangerous: Indoor Pollution in Your Home and Office—And What You Can Do About It.* New York, NY: Random/Vintage (1987).

"How to Improve Indoor Air." *University of California, Berkeley Wellness Letter,* 8 (February 1992) p. 6.

"Indoor Air Pollution." *Mayo Clinic Health Letter,* 11 (November 1993) p. 4.

Lecard, Marc. "Better Homes in Gardens." *Sierra,* 78 (January 1993) p. 20.

Rifkin, Janey M. "When Breathing is Hazardous to Your Health." *Let's Live,* 59 (August 1991) p. 62.

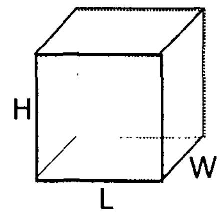
Safran, Claire. "Schools That Make Kids Sick." *Good Housekeeping,* 214 (March 1992) p. 176.

Turiel, Isaac. *Indoor Air Quality and Human Health.* Stanford, CA: Stanford University Press (1985).

## STUDENT WORKSHEET 1
# INDOOR AIR MEASUREMENT

### Measure Indoor Air Volumes

1. Follow your instructor's directions for collecting the measurements of the room.




2. Put the room measurements in their appropriate places on the lines below and calculate the volume of air in the room in cubic feet:

   **Length______ (ft) x Width______ (ft) x Height______ (ft) = ______ ft$^3$**

3. To convert cubic feet to liters (L), multiply by 28.317.

### Calculate Human Ventilation Volumes

1. Use the following formula to calculate the ventilation volume per minute (total minute volume). Assume the tidal volume is 0.5 L of air for each breath. Follow your instructor's directions for measuring the number of breaths you take per minute (ventilation rate). Put your measurement and the 0.5 L tidal volume in their appropriate places on the lines below and calculate total minute volume:

   **Tidal volume __.5__ (L) x Ventilation rate_____ (breaths/min) = _____ L/min**

2. Multiply the total minute volume by 60 minutes to obtain the volume of air breathed during one hour.

### Compare Volumes

1. Compare the volume of air you breathe in one hour with the total volume of air in the room.

2. Calculate how much air is breathed by all those in the room. Multiply the total hourly volume by the number of people in the room, and compare this value to the total volume of air in the room

> **TAKE NOTE!**
> This exercise does not consider the exchange of fresh air in an enclosure depending on the ventilation capacity. Be sure to discuss this with your students so that they do not get the impression that their classroom is hazardous to their health.

# ACTIVITY 6

# RADON GAME

This activity lets students test what they may have heard or know about radon and challenges them to think about why radon is different in many ways from other indoor air pollutants. It is related to the "Making Decisions" warm-up. Related activities include "How Green Are We?" and "Breathing Room."

## CRITICAL OBJECTIVES

- Identify the special aspects of radon pollution that distinguish it from other indoor air pollutants
- Identify correct from incorrect information about radon
- Devise methods for minimizing indoor radon levels

## SKILLS

- Comparing
- Organizing
- Explaining
- Developing solutions

## GUEST PRESENTERS

Guest presenters could include EPA environmental protection specialists, heating and ventilation technicians or engineers, or radon detection experts.

## BACKGROUND

Radon is a naturally occurring radioactive gas, produced from the radioactive decay of uranium in rocks such as granite. Uranium and radon gas are widely distributed throughout the Earth's crust in virtually all types of rock and soil. Radon continually escapes from soils and rock into the atmosphere. Most of the radon in homes enters through cracks and holes in the foundation. Other sources include drinking water (especially well water) and bricks and concrete. As radon decays, it emits radioactive particles that could damage lung tissue and lead to lung cancer. An estimated 7,000 to 30,000 radon-related deaths occur each year in the United States (about 10 percent of the lung cancer deaths attributed to cigarette smoking). Radon detection is easy and inexpensive. The most common home detectors are the charcoal canister, alpha track monitor, and electret ion chamber. Common mitigation strategies include natural ventilation (such as open windows) on the lower levels, forced ventilation with or without heat recovery into (never out of) the lower levels, sealing entry points (such as foundation cracks and floor drains), and soil ventilation.

**RELATED WARM-UP**
G

**REFER TO READING MATERIAL**
"Radon"

**TARGET GRADE LEVEL**
7th - 8th

**DURATION**
20 minutes (additional time may be needed for the presenter to illustrate some of the answers, and display equipment if possible)

**VOCABULARY**
Radioactivity
Radon detector
Vacuum

**MATERIALS**
Student worksheet (or large chalkboard on which the information can be listed)

**WORKSHEETS INCLUDED**
1

Because the radon problem involves large numbers of private homes and varies greatly in concentration in these homes, the EPA and the states work together to address the problem. EPA developed a non-regulatory, technical assistance and public information program in 1985 to help citizens make informed decisions about radon. This program involves the states and over a dozen National organizations, such as the American Lung Association. In 1989, EPA published guidance for radon testing in schools and began a survey of schools Nationwide. Legislation requires federal agencies to test for radon in its own buildings. EPA developed the New Construction Demonstration Program and standards for use by states to develop building codes and issued guidance on techniques to reduce radon in schools. EPA also is involved in a voluntary program to test the proficiency of companies that measure indoor radon levels. (See reading material on "Radon.")

## WHAT TO DO

1. Hand out a student worksheet or write the following points on the chalkboard (mix the true and false information if you use a blackboard):

2. Split the class into groups of two to five students, and give each student a worksheet. Give each group one extra worksheet and appoint someone in each group to record the group's answers on the extra worksheet. Ask each group to put a check mark by all of the information points on the worksheet that are true for radon. Discourage them

**True for Radon**

- Not synthetic (occurs naturally)
- Can't see, smell, or taste at any concentration
- Radioactive gas
- Comes from rocks and soil
- Enters the house through cracks and holes in the foundation/basement
- Is in the water supply, especially well water
- Building materials like concrete and brick can be a source of the pollutant
- Accumulates in basements and lower floors
- Levels of the pollutant in one house can vary a lot from the house next door
- Levels of the pollutant tend to be higher indoors when its cold outside
- Emits particles (radioactive decay products) that damage lungs
- Causes lung damage that leads to lung cancer
- Only cigarette smoking causes more lung cancer deaths than this pollutant
- Testing indoor air for the pollutant is easy and inexpensive
- Using exhaust fans (stove top/bathroom) tends to increase the pollutant levels in the house
- Using a fireplace tends to increase the pollutant levels in the house

**NOT True for Radon**

- Synthetic (human-made) air pollutant
- Made by manufacturing or refining it from other chemicals
- Smells vaguely like ammonia
- Smells slightly metallic
- Can be produced in the house by a faulty heating unit like a furnace
- Comes from petroleum
- Can enter indoor air from improperly sealed canisters stored in the house
- Found in some household cleaners
- Levels of the pollutant tend to be higher indoors when the temperature outside is 70-80° F (21-27°C)
- Health problems occur when the pollutant is used without proper ventilation
- Causes liver damage that leads to liver cancer
- Causes vomiting, diarrhea, sweating, cramps, coughing, and nerve disorders
- Damages kidneys
- Irritates eyes
- Radon can only be detected or tested by using special equipment operated by professionals
- Using exhaust fans that vent to the outdoors (stove top/bathroom) tends to decrease the pollutant levels in the house
- Using a fireplace tends to decrease pollutant levels in the house

from guessing without a good explaNation. (If you have to use a chalkboard to list the information points, ask students to write their answers on paper.)

3. After each group has completed its list, ask one of the groups to read its first entry and explain the reason for the answer. Continue querying each group until all information points have been discussed. Ask the students why venting air out of a house, such as through a bathroom exhaust fan or fireplace, may increase indoor radon levels. Discuss the difference between natural ventilation, such as opening windows, and forcing air out of the house. You may keep score and determine a winner among the groups.

4. Ask the students to devise some methods for minimizing radon levels in a house or other building.

## SUGGESTED EXTENSIONS (OPTIONAL)

- Hand out copies of the attached map of the United States that indicates where the greatest levels of radon are found. Have the students discuss what the map means. For example, should homes in areas with low levels of radon be tested?

- Invite a radon detection expert to demonstrate radon detection equipment and devices used to lower indoor radon levels.

- Build a model (using smoke, glass, or a plastic cylinder and a balloon) to illustrate the effect of a vacuum on the amount of radon seeping into a house.

## SUGGESTED READING

*Indoor Radon and Its Hazards.* Seattle, WA: University of Washington Press (1987).

Lafavore, Michael. *Radon: The Invisible Threat (What It Is, How To Keep Your House Safe).* Emmaus, PA: Rodale Press (1987).

"Radon Detectors: How to Find out if Your House Has a Radon Problem." *Consumer Reports,* 52 (July 1987) p. 440.

"Radon: Risk or Rubbish?" *Medical Update,* 14 (March 1991) p. 2.

Silberner, Joanne. "What To Do about Radon." *U.S. News and World Report,* 105 (26 September 1988) p. 62.

Stone, Richard. "New Radon Survey: No Smoking Gun." *Science* (28 January 1994)

U.S. EPA. *A Citizen's Guide to Radon.* Washington, DC: U.S. EPA, Office of Air and Radiation EPA/402/K-92/001 (1992).

# STUDENT WORKSHEET 1

# RADON

## POLLUTANT DESCRIPTIONS

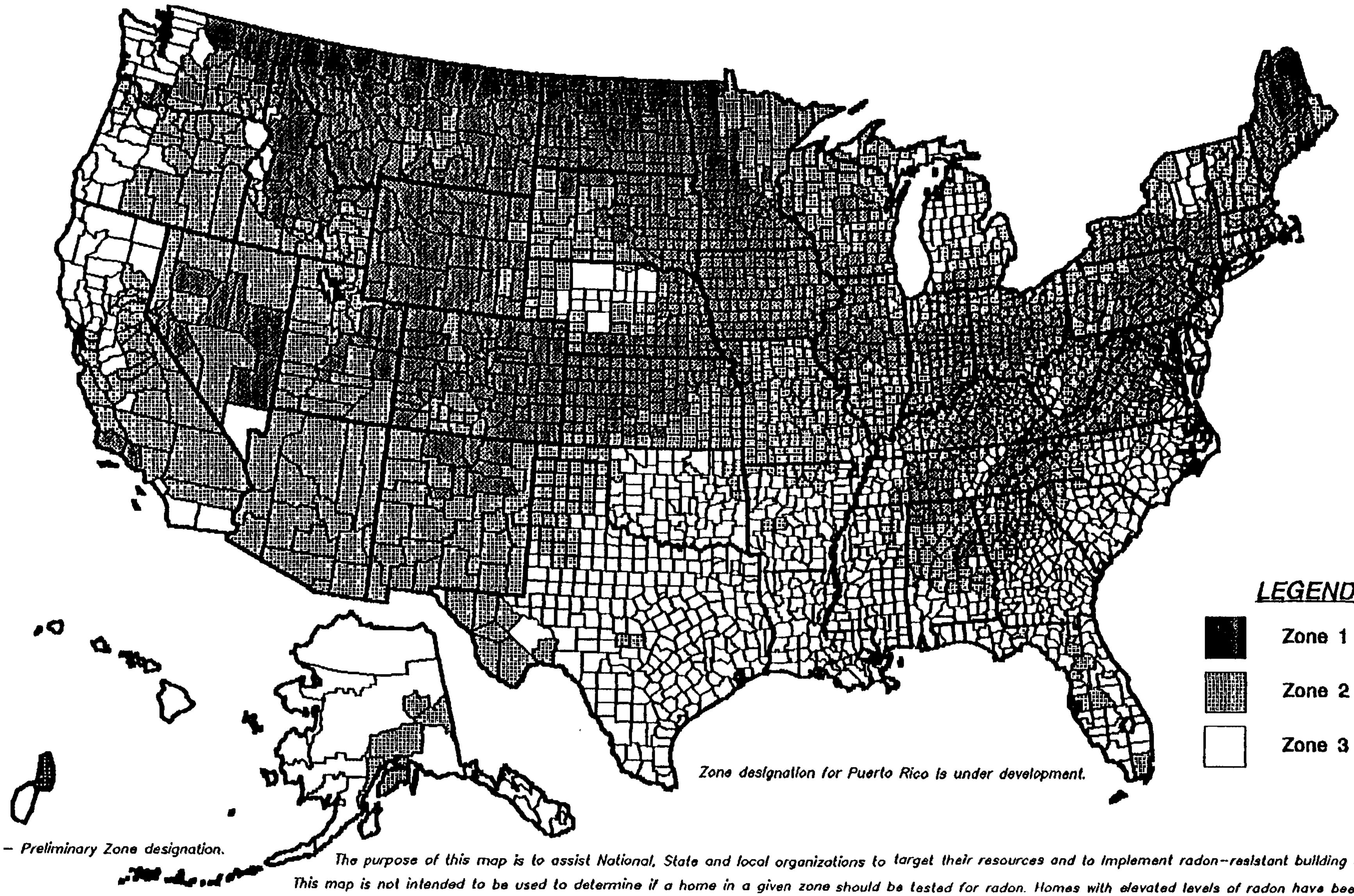
Place a check mark by the following points that apply to radon. If you guess, you should have a good reason for your answer.

___ 1. Synthetic (human-made) gas
___ 2. Comes from automobile exhaust
___ 3. Radioactive gas
___ 4. Made by manufacturing or refining it from other chemicals
___ 5. Smells vaguely like ammonia
___ 6. Smells slightly metallic
___ 7. Can't see, smell, or taste at any concentration
___ 8. Comes from rocks and soil
___ 9. Comes from petroleum
___10. Can be produced in the house by a faulty heating unit like a furnace
___11. Enters the house through cracks and holes in the foundation/basement
___12. Can enter the house from improperly sealed canisters stored in the house
___13. Found in some household cleaners
___14. Is in the water supply, especially well water
___15. Building materials like concrete and brick can be a source of the pollutant
___16. Accumulates in basements and lower floors
___17. Levels of the pollutant in one house can vary a lot from the house next door
___18. Levels of the pollutant tend to be higher indoors when it's cold outside
___19. Levels of the pollutant tend to be higher indoors when the outside temperature is 70-80° F (21-27° C)
___20. Health problems occur when the pollutant is used without proper ventilation
___21. Only cigarette smoking causes more lung cancer deaths than this pollutant
___22. Causes liver damage that leads to liver cancer
___23. Only carbon tetrachloride causes more deaths from liver disease than this pollutant
___24. Causes vomiting, diarrhea, sweating, cramps, coughing, and nerve disorders
___25. Emits particles (radioactive decay products) that damage lungs
___26. Damages kidneys
___27. Causes lung damage that could lead to lung cancer
___28. Irritates eyes
___29. Testing indoor air for the pollutant is easy and inexpensive
___30. Radon can only be detected/tested by using special equipment operated by porfessionals
___31. Using exhaust fans (stove top/bathroom) tends to decrease the pollutant levels in the house
___32. Using exhaust fans (stove top/bathroom) tends to increase the pollutant levels in the house
___33. Using a fireplace tends to increase the pollutant levels in the house
___34. Using a fireplace tends to decrease the pollutant levels in the house

# STUDENT HANDOUT

# RADON

## AREAS WITH POTENTIALLY HIGH RADON LEVELS




*The purpose of this map is to assist National, State and local organizations to target their resources and to implement radon-resistant building codes.*

*This map is not intended to be used to determine if a home in a given zone should be tested for radon. Homes with elevated levels of radon have been found in all three zones. All homes should be tested, regardless of geographic location.*

*__IMPORTANT:__ Consult the EPA Map of Radon Zones document (EPA-402-R-93-071) before using this map. This document contains information on radon potential variations within counties. EPA also recommends that this map be supplemented with any available local data in order to further understand and predict the radon potential of a specific area.*

TEACHER FACT SHEET

# THE RADON GAME

## FACTS ABOUT THE MAP OF AREAS WITH POTENTIALLY HIGH RADON LEVELS

### PURPOSE:

- EPA is required to identify and list areas of U.S. with the potential for elevated indoor radon levels.

- EPA's Map of Radon Zones assigns each of the 3,141 counties in the United States to one of three zones based on radon potential:

  - Zone 1 counties have a predicted average indoor screening level greater than 4 pCi/L (dark grey)
  - Zone 2 counties have a predicted average screening level between 2 and 4 pCi/L (light grey)
  - Zone 3 counties have a predicted average screening level less than 2 pCi/L (white)

### AUDIENCES:

- National, state, and local governments and organizations – to assist in targeting their radon program activities and resources.

- Building code officials – to help determine areas that are the highest priority for adopting radon-resistant building practices.

### MAP DEVELOPMENT:

- Five factors were used to determine radon potential:
  - indoor radon measurements, geology, aerial radioactivity, soil permeability and foundation type

- Radon potential assessment is based on geologic provinces:
  - Radon Index Matrix is the quantitative assessment of radon potential
  - Confidence Index Matrix shows the quantity and quality of the data used to assess radon potential

- Geologic provinces were adapted to county boundaries for the Map of Radon Zones.

### MAP DOCUMENTATION:

- Detailed booklets are available for each state that discuss the matrices and data used.

- State booklets are an essential tool in employing the map's information.

### IMPORTANT POINTS:

- All homes should test for radon, regardless of geographic location or zone desigNation.

- There are many thousands of individual homes with elevated radon levels in Zones 2 and 3. Elevated levels can be found in Zone 2 and Zone 3 counties.

- All users of the map should carefully review the map documentation for information on within-county variations in radon potential and supplement the map with locally available information before making any decisions.

- The map is not to be used instead of testing during real estate transactions.

ACTIVITY 7

# INVENTING A MONITOR

This activity lets students brainstorm and problem-solve to find methods for collecting particulates as a first step in finding what pollutants may be in their classroom or outdoors. It is related to the "Where's That Odor?" warm-up. Related activities include "Breathing Room," "Finding Sources of Air Pollution," and "Is Your Air Clean?"

## CRITICAL OBJECTIVES

- Explain the importance of monitoring air pollution
- Describe various methods that could be used to monitor air pollution
- Participate in problem-solving to determine the most effective method for particulate matter (as an example)

## SKILLS

- Defining problems
- Comparing ideas
- Drawing conclusions

## GUEST PRESENTERS

Guest presenters could include air quality engineers, environmental scientists, EPA air quality monitoring specialists, state or local air quality managers, or toxicologists. (Give preference to presenters who can display and describe some monitoring equipment for particulates).

## BACKGROUND

Air pollution is caused by many types of contaminants, including chemicals, microorganisms, and particulate matter. Particulate matter includes visible and invisible particles of liquids and solids, including dust, smoke, and other matter carried in the air. Particulate matter containing acids (dry deposition) can deteriorate buildings and other structures. Particulate matter larger than about ten micrometers (microns) in diameter is filtered out in the nose or caught by mucus in the respiratory tract and propelled up to the throat by tiny hairs (cilia). Although the cilia can be damaged by air pollutants, the particulate matter below ten microns (PM-10) in diameter is of greatest concern to human health, because it is not filtered and thus reaches the critical areas of the lungs where oxygen exchange takes place and where there are no cilia or mucus to remove it. (See reading material on "Air Pollution.")

**RELATED WARM-UP**
F

**REFER TO READING MATERIAL**
"Air Pollution"

**TARGET GRADE LEVEL**
6th - 12th

**DURATION**
45 minutes

**VOCABULARY**
Carbon monoxide
Cilia
Lead
Micrometer (micron)
Monitoring
Mucus
Nitrogen oxides
Ozone
Particulate matter
Sulphur dioxide
Toxic Release Inventory

**MATERIALS**
Chalkboard
Chalk
Monitoring equipment (if available)
Paper
Pencils

The most common source of PM-10 and other suspended particles in air is smoke from commercial and industrial combustion sources, forest fires, burning leaves, fireplaces, wood stoves, diesel engines, and poorly maintained motor vehicles. Dust is another important source of particulate matter. Wind storms carry dust and fine sand. Farmland, when plowed or left exposed to wind, construction sites of all kinds (including highway sites), and logging and mining operations are major sources of dust.

## WHAT TO DO

1. Explain the importance of monitoring to determine if air pollutants are being released. The air around us is more polluted than ever before, and with the increasing number of pollution sources, especially in urban and industrialized areas, reducing the risks to human health and the environment presents a major challenge to society. In order to design and evaluate pollution reduction programs, it is necessary to determine which air pollutants are reaching harmful levels. An extensive monitoring and emissions tracking program is in place for ambient carbon monoxide, lead, nitrous oxides, sulphur dioxide, ozone, and PM-10, but there is no similar program for the emissions of 189 hazardous air pollutants considered toxic to people. The EPA's Toxic Release Inventory (TRI) is currently the only database available for assessing trends in emissions of these air toxics. The TRI requires certain facilities emitting above specified quantities of air toxics to submit annual reports to EPA on their releases. Some non-manufacturing facilities such as mining, electric utilities, and mobile sources are not required to report. Monitoring equipment generally is expensive and difficult to maintain. Consequently, cost-effective air monitoring devices are needed.

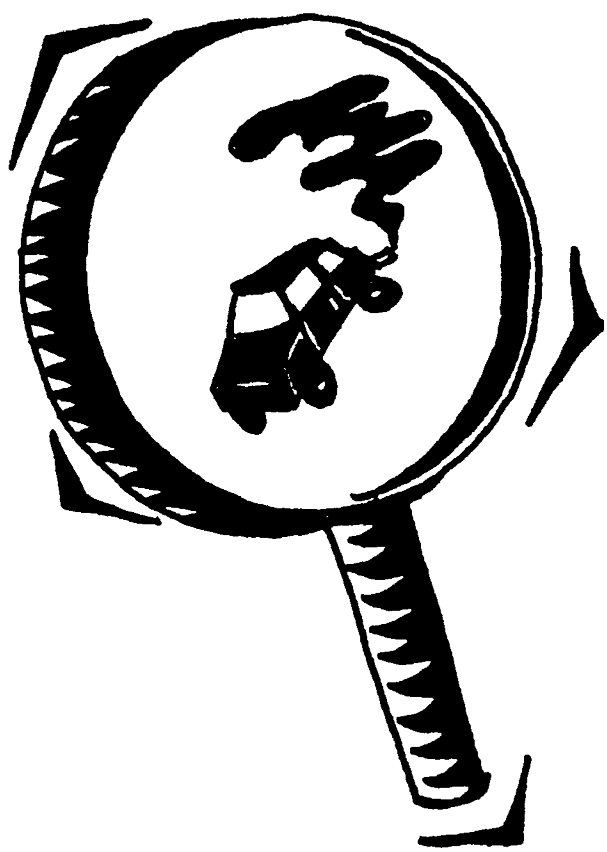
2. Explain that for the purposes of this activity students are to assume they have to design a monitoring device to collect particulate matter (PM) in the air in this classroom. Ask what would be their first step? Remember, many pollutants cannot be easily seen or smelled. If necessary, prompt the discussion with some of the following questions:
   What kind of particulate matter is likely to be in the classroom—smoke, dust?
   How is it likely to enter the classroom air—via the ventilation system, windows, peoples' clothing?
   Is there likely to be more than one type of particulate matter in the classroom air?
   Would it be necessary to monitor them all, or would monitoring one be adequate to draw conclusions about the others?
   Could molds, bacteria, and other pollutants affect monitoring results?
   Could the humidity (high or low) of the air in the room affect the accuracy of the results?
   Would it be necessary to control the movement of air through the room? If so, how would you do it?

3. Help students brainstorm different ideas for collecting particulates (for example, filters, collection dishes, electrostatic materials). Record their ideas on the chalkboard. Encourage students to explain how and why their suggestions would work. (Their suggested designs should show consideration of the size of the particulate matter they are trying to monitor, how to eliminate bogus materials, and how the particulate matter collected in the monitor could be measured—for example, with a microscope, by washing and counting electronically, or through chemical analysis.)

4. Poll the rest of the class to see if they agree or disagree with each suggestion. Ask them to explain why. When you have elicited two or three good, supportable alternatives, ask the class to choose the best one and ask several to explain their choices.

5. When some consensus has been reached on the best method for collecting particulates, ask if one of the chosen monitoring devices will be sufficient to get accurate results. What would be the advantage, if any, in locating monitors in several locations around the classroom? Record students' answers on the chalkboard.

6. Have students draw the outline of the classroom on a sheet of paper. Instruct them to mark the locations of the classroom's doors and windows. Assuming they would use the monitor chosen by the class, have students mark on this "map" where they think the device, or devices, should be placed to ensure the best results. When the activity is completed, encourage students to share their suggestions and explain why. (You may want to draw a classroom "map" on the chalkboard for students to use in presenting their ideas.)



7. Have students discuss the alternatives presented and choose the best one. Suggest that accurate monitoring only yields part of the answer to what is in the air.

8. Help the students examine what they can do to reduce particulate air pollution in their classroom. If necessary, prompt the discussion by asking the following questions: What factors influence the quality of the air in the classroom? For example, what kinds of pollutants do humans generate? Which of those do we bring into the indoor environment? Can all of these pollutants be measured? Can you or the school change any of those factors?

9. Record answers on the chalkboard. (Make sure the following suggestions are brought out in the discussion: Change the filters in the ventilation system; clean the ventilation system regularly; close the windows on high smog days (not relevant for many schools with sealed windows); increase the air humidity.

## SUGGESTED EXTENSIONS (OPTIONAL)

- If a light microscope is available and the classroom has an electronic device like a computer or television that is used often, place a glass slide on the electronic device (for example, on top of the computer monitor) for at least three days before the lesson. (Electronic devices tend to attract particulates.) During the lesson, examine the slide under the microscope, and discuss the magnification limits of the microscope.

## SUGGESTED READING

Gutnik, Martin J. *The Challenge of Clean Air.* Hillside, NJ: Enslow Company (1990).

ACTIVITY 8

# DESIGNING A CLEAN-AIR ENVIRONMENT

This activity gives students an opportunity to explore how air pollution in a city can be minimized by the arrangement of living areas, working areas, and landscaping. It is related to the warm-up called "Making Decisions" and the activities "How Green Are We?," "Deciding to Clean the Air," and "Lifestyles and the Environment."

## CRITICAL OBJECTIVES

- Recognize that the arrangement of living areas, workplaces, and landscaping affects air pollution levels
- Realize that necessary choices are not always clear cut
- Understand that automobile exhaust and the power production required to run air conditioning units contribute to air pollution

## SKILLS

- Making decisions
- Hypothesizing

## GUEST PRESENTERS

Guest presenters for this activity could include architects, EPA environmental protection specialists, or urban planners

## BACKGROUND

By giving some thought to the location of different required elements of a city, we can reduce the use of polluting fuels and use environmental processes to aid us in our goals. If the places we go to often are near one another, we drive less and pollute the air less.

The nitrogen oxides (NOx) and carbon dioxide ($CO_2$) in automobile exhaust contribute to the greenhouse effect. The global temperature rise that is a predicted result of the greenhouse effect could cause major shifts in global weather patterns and a rise in sea-levels. These same components of automobile exhaust are also the ingredients that react with sunlight to form "smog."

By planting trees near highways, $CO_2$ in automobile exhaust will be absorbed by the leaves and turned into oxygen through photosynthesis. By planting trees and shrubs to shade the roofs, windows, and air conditioning units of our homes in the summer, we don't need to run the air conditioner as much. This, in turn, reduces air pollution because it reduces electricity generation at power plants. Power plants

**RELATED WARM-UP**
G

**REFER TO READING MATERIALS**
"Air Pollution"
"Smog"
"Automobiles and Air Pollution"

**TARGET GRADE LEVEL**
4th - 9th

**DURATION**
30 minutes in first class; 40 minutes in second class with guest presenter

**VOCABULARY**
Carbon cycle
Electricity
Energy
Greenhouse effect
Planning
Smog

**MATERIALS**
Chalk
Chalkboard
Pencils

**WORKSHEETS INCLUDED**
1

that run on fossil fuels typically emit many pollutants, including sulphur dioxide, carbon monoxide, nitrogen oxides, and suspended particulates. Perhaps more importantly, burning fossil fuels or wood produces large amounts of carbon dioxide, which contributes to the greenhouse effect.

While designing a city with these considerations in mind, students will see that their choices have important consequences and that not all problems have satisfactory solutions. This is related to real tradeoffs such as short-term gain versus long-term benefit and convenience versus conservation.

## WHAT TO DO

1. Explain that the students are going to do two related activities. They will work alone on the first project. Hand out a copy of the attached worksheet to each student and ask them to cut out and arrange the elements from the worksheet on another piece of paper to layout a "city" that looks like the one they live in. For this exercise, define the boundaries of the city: the neighborhood near the school, each student's home neighborhood, or the whole city. You may want to get them started by identifying the relative location of a few important landmarks or highways. You can decide which of the elements on the worksheet the students are to use.

2. While the students are working, lead a discussion about how much time families must spend driving around in their cars because of the distances between places. Does the layout of the city contribute to air pollution by separating, for example, working and living areas? Students can analyze their city layouts as the discussion progresses. Have them save their layouts for the second part of the exercise on another day.

3. For the second exercise, you or the guest presenter will need to review with students the concepts of the carbon cycle, the greenhouse effect, smog, and how the production and use of energy (heating, electricity, cooling) causes air pollution. This second exercise will be done in small groups. Form the groups and hand out a clean worksheet to each group. Explain that the students are going to pretend to be urban planners. Urban planners are professionals who determine the arrangement of roads, buildings, and parks in a city. Students are to design a city from the ground up. **When deciding on the placement of the necessary elements and choosing energy sources, their primary goal will be to minimize air pollution.**

3. After the students have designed their "perfect" cities, lead a discussion with the goal of coming to consensus on the best location for each element. Layout the elements on the students' worksheets. Erase and reposition the elements as students debate the best arrangement of elements.

4. Compare the drawings of the actual cities from the first class to the "perfect" cites designed in the second. Have the class discuss the following questions:

- How are the two cities different?

- What are some reasons you would want the workplaces—factory, office building—near homes? Far from homes? (They are more convenient if they are nearby. The farther away, the more pollution caused by cars.)

- Does the city have a public transportation system? Why or why not? Do people use them? Why or why not?

- What are the advantages of urban areas and their high population density? Disadvantages? (Fewer trees per person need to be cut down in order to build apartments as compared to suburban single family homes. Smog is more apparent in downtown areas.)

- What are advantages of suburban areas and their lower population density? Disadvantages? (Residents have to use cars more often for everyday activities, but residents get to have yards, trees, landscaping, gardens.)

- Is there a limit to the size a city can be for it to be efficient?

- How can the placement of trees help lower the use of utilities? (For example, by shading buildings to lower the use of air conditioning and as windbreaks to lower use of heating.)

## SUGGESTED EXTENSIONS (OPTIONAL)

- Students may enjoy trying this activity using commercially available computer programs like *Sim City*™. While the program allows the user to design a city, numerous built-in modules reflect the effects of the user's decisions. For example, if the user builds a freeway, air pollution levels rise and are displayed in a pop-up graph. If the user builds ten new office buildings, smoke starts belching from the stacks at the power plant.

## SUGGESTED MODIFICATIONS

- For higher grades, expand the project to be a multi-session activity, exploring in more depth each of the pollutant sources and reduction measures discussed in the activity. A different guest presenter could be invited to discuss each topic.

- For grades 8 and 9, have students collect data to support the decisions they made during the discussions in the second exercise. For example, they may locate actual figures on energy savings from not running the air conditioner, data on air pollution from cars, and case studies that show how the use of public transportation reduces pollution or ways factories can cut emissions. Have them make presentations on their findings.

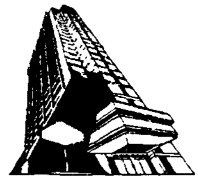
## SUGGESTED READING

Bruning, Nancy. *Cities Against Nature*. Chicago, IL: Children's Press (1992).

Shaffer, Carolyn. *City Safaris: A Sierra Club Explorer's Guide to Urban Adventures for Grownups and Kids*. San Francisco, CA: Sierra Club Books (1987).

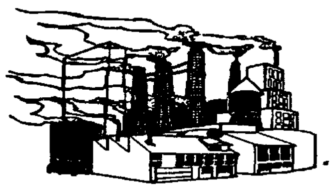
## STUDENT WORKSHEET 1
# DESIGNING A CLEAN AIR ENVIRONMENT

single-family homes

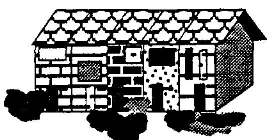


office buildings

walking & jogging trails



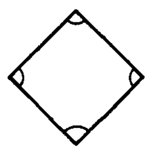
industries



apartments & townhouses

trees, parks, forests

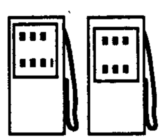
bike trails



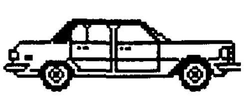
playgrounds & ballfields


restaurants

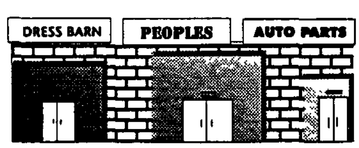
schools



gas stations



highways




stores & shopping malls

bus & subway routes

ACTIVITY 9

# FINDING SOURCES OF AIR POLLUTION

This activity calls for students to locate on a map the potential areas of air pollution in their community. It is related to the "Prediction" and "Where's That Odor?" warm-ups. Related activities include "Is Your Air Clean?" and "Deciding to Clean the Air."

## CRITICAL OBJECTIVES

- Identify the possible sources and types of air pollution in the community based on observations
- Predict and locate on a map potential areas of pollution in the community

## SKILLS

- Researching
- Observing
- Organizing information
- Predicting

## GUEST PRESENTERS

Guest presenters could include EPA enforcement specialists, EPA environmental protection specialists, EPA policy analysts, lawyers, or state air pollution permit writers.

## BACKGROUND

The atmosphere is necessary for plants, animals, and people to live. Air pollution is any visible or invisible particle or gas found in the air that is not part of the normal composition of air. Natural air pollution caused by volcanoes, forest fires, and other natural occurrences has always existed. Naturally produced pollutants are present in greater amounts than those of human origin. They do not present as serious a problem as man-made pollutants, however, because they are dispersed over large areas, and many are less harmful than man-made ones. Air pollution from man-made sources is the result of our increasing use of large quantities of fuel to produce electricity and to power automobiles, trucks, and other vehicles and industrial activity. Not only are some of these pollutants very harmful, but also they tend to be concentrated in urban areas where many people live and work. Many of these air pollutants come from burning the coal, oil, wood, and other fuels we use to run factories, cars, and the power plants that generate heat and light for our homes. Six have been designated "criteria" pollutants: particulate matter, sulphur dioxide, nitrogen oxides, car-

**RELATED WARM-UP**
A

**REFER TO READING MATERIALS**
"Air Pollution"
"Health Effects"
"Smog"
"Acid Deposition"
"Automobiles and Air Pollution"
"The Clean Air Act"

**TARGET GRADE LEVEL**
8th - 12th

**DURATION**
40 minutes

**VOCABULARY**
Ambient air quality standards
Carbon monoxide
Clean Air Act
Criteria pollutants
Lead
Nitrogen oxides
Ozone
Particulate matter
Sulphur dioxide
Toxic Release Inventory

**MATERIALS**
A large street map of the community
Push pins in several colors
Chalkboard
Chalk

**WORKSHEETS INCLUDED**
1

bon monoxide, ozone, and lead. (A table describing these pollutants, their sources, and their effects is included as a student handout.) The EPA has set National ambient air quality standards to protect health and welfare in connection with these pollutants. When these standards are exceeded, the EPA can take steps to control pollutant emissions. (See reading materials on "Air Pollution," "Health Effects," "Smog," "Acid Deposition," "Automobiles and Air Pollution," and "The Clean Air Act.")

## WHAT TO DO

**1.** Explain that in a few days (use specific date if you have it) someone who works for the EPA is coming to visit the class. To prepare for the visit, the class is going to talk about pollution, air pollution in particular.

**2.** Pass out the worksheets. Ask the students if they think there is air pollution in your community. If they say yes, ask if air pollution is always visible. If they say no, ask how they can tell it's there. What are some of the signs of pollution that they might see? Record the signs of air pollution suggested by students on the chalkboard and instruct students to list them on their worksheets under the "Signs of Pollution" heading. If necessary, prompt the brainstorming by listing "smoke" as a sign of pollution. The completed list should include smoke, odors, smog, stunted or discolored plants and trees, and damaged or discolored buildings and statues.

**3.** Ask the students if air pollution affects people. If they say yes, ask how. Record students' answers on the chalkboard and instruct them to list them on their worksheets under the "Health Effects of Pollution" heading. (If necessary, prompt students by asking if they know anyone who has asthma or other breathing problems. The criteria air pollutants can cause or contribute to problems like these, plus headaches; irritated eyes; and brain, heart, kidney, and lung damage.)

**4.** Ask students where they think the pollution in your community comes from. What are the sources of the pollution? Record the sources suggested by students on the chalkboard and instruct students to list them on their worksheets under the "Sources of Pollution" heading. (If necessary, prompt students by listing "cars and trucks" as the first example. The completed list should include cars and trucks, local industries, and local electric power plants, at a minimum. Other possibilities could include dry cleaners, gas stations, and windblown dust.)

5. Place the map on an easel or hang it on a wall where it can be seen by the students. Point out significant landmarks such as the school, the city/town hall, major factories, and shopping malls. Ask students to help you mark on the map some of the possible sources of air pollution in the community. Explain that the map will be used as a starting point for discussion when the EPA official comes to visit.

6. Divide the class into teams. Assign each team the responsibility for gathering information outside of class to help refine the map by adding other pollution sources and finding out what pollutants various sources release. Suggest that the local health department, planning department, or environmental board (office) can provide information on sources of pollution in the community. In addition, access to EPA's Toxic Release Inventory (TRI) may be available in your area. The TRI is a database containing information about the amount of toxic chemicals released into the air by manufacturing and other facilities. Information on the libraries and other facilities in your area with access to the database can be obtained by calling the Emergency Planning and Community Right-To-Know Hotline, 1-800-535-0202.

7. Select (or let the class nominate) students to make short presentations on the information the students have developed about signs, effects, and sources of air pollution at the beginning of the EPA official's visit.

## SUGGESTED EXTENSIONS (OPTIONAL)

- Assign each team the responsibility of designing an attractive way (possibly a poster) to present the lists developed in today's class. For example, one team could prepare a poster on signs of pollution; one team could work on health effects of pollution; the third team on sources.

## SUGGESTED READING

*Air and Water: Concerns for Planet Earth (VHS videotape).* United Learning (1991).

Bailey, Donna. *What Can We Do About Noise and Fumes.* New York: Franklin Watts (1991).

Baines, John. *Conserving Our World, Conserving the Atmosphere.* Austin, TX: Steck-Vaughn Company (1990).

Becklake, John. *Thinking for the Future: Pollution.* New York: Gloucester Press (1990).

Gutnik, Martin J. *The Challenge of Clean Air.* Hillside, NJ: Enslow Company (1990).

Hare, Tony. *Save Our Earth: Acid Rain.* New York: Gloucester Press (1990).

Leinwand, Gerald. *The Environment: American Issues*. New York: Facts on File (1990).

Moos, Shawna. "Pollution-Prevention Power to the People (EPA's Toxics Release Inventory Database)." *Technology Review*, 95 (October 1992) p. 15.

O'Neill, Catherine. "Cleaner Air! Cough! Wheeze! Gasp!" *Washington Post (Washington Health)*, 115 (6 October 1992) p. WH18.

Penny, Malcolm. *Our World: Pollution and Conservation*. Englewood Cliffs, NJ: Silver Burdette Press (1988).

Stille, Darlene. *The Ozone Hole*. Chicago: Children's Press (1991).

## STUDENT WORKSHEET 1

# FINDING SOURCES OF AIR POLLUTION

| SIGNS OF POLLUTION | |
|---|---|
| | |
| | |
| | |
| | |
| | |
| **HEALTH EFFECTS OF POLLUTION** | |
| | |
| | |
| | |
| | |
| **SOURCES OF POLLUTION** | |
| | |
| | |
| | |
| | |

STUDENT HANDOUT

# FINDING SOURCES OF AIR POLLUTION

## MAJOR MAN-MADE AIR POLLUTANTS

| POLLUTANT | DESCRIPTION | SOURCES | SIGNS/ EFFECTS |
|---|---|---|---|
| Carbon monoxide (CO) | • colorless, odorless gas | • vehicles burning gasoline<br>• indoor sources, including kerosene, wood-burning, natural gas, coal, or wood-burning stoves and heaters | • headaches, reduced mental alertness, death<br>• heart damage |
| Lead (Pb) | • metallic element | • vehicles burning leaded gasoline<br>• metal refineries | • brain and kidney damage<br>• contaminated crops and livestock |
| Nitrogen oxides ($NO_x$) | • gaseous compounds made up of nitrogen and oxygen | • vehicles<br>• power plants burning fossil fuels<br>• coal-burning stoves | • lung disorder<br>• react in atmosphere to form acid rain<br>• combines to deteriorate build-ings and statues<br>• adds to forest damage<br>• form ozone & other pollutants (smog) |
| Ozone ($O_3$) | • gaseous pollutant | • vehicle exhaust and certain other fumes<br>• formed from other air pollutants in the presence of sunlight | • lung disorder<br>• eye irritation<br>• respiratory tract problems<br>• damages vegeta-tion<br>• smog |
| Particulate matter | • very small particles of soot, dust, or other matter, including tiny droplets of liquids | • diesel engines<br>• power plants<br>• industries<br>• windblown dust<br>• wood stoves | • lung disorder<br>• eye irritation<br>• damages crops<br>• reduces visibility<br>• discolors buildings and statues |
| Sulphur dioxide ($SO_2$) | • gaseous compound made up of sulphur and oxygen | • coal-burning power plants and industries<br>• coal-burning stoves<br>• refineries | • eye irritation<br>• lung damage<br>• kills aquatic life<br>• reacts in atmo-sphere to form acid rain<br>• damages forests<br>• deteriorates buildings and statues |

ACTIVITY 10

# IS YOUR AIR CLEAN?

This activity is a follow-up to the activity called "Finding Sources of Air Pollution" in which students located potential areas of air pollution on a map of the community. It calls on students to develop an action plan for investigating air pollution in the community more thoroughly and communicating their findings to different audiences. The activity begins with student presentations of the map and information developed in the earlier activity. It also is related to the warm-ups called "Seeing the Big Picture" and "Making Decisions."

## CRITICAL OBJECTIVES

- Identify local, state, and federal resources for obtaining accurate information on air pollution
- Identify local laws governing air pollution control
- Identify individuals and organizations responsible for enforcing air pollution control in the community
- Plan how to determine what the local government is doing to enforce air pollution control laws and what local industry and other organizations are doing to control air pollution

## SKILLS

- Researching
- Observing
- Investigating
- Developing and carrying out plans
- Making oral presentations

## GUEST PRESENTERS

Guest presenters could include EPA environmental protection specialists, EPA policy analysts, or EPA risk assessment specialists.

## BACKGROUND

Every citizen has the ability to participate in building and protecting his or her community. But, in order to do so, citizens must be aware of the problems that exist. Citizens also must have some sense of confidence that they can have an impact. Knowing how to recognize pollution and identify its sources is the first step in protecting the environment in a community. This awareness, however, serves little purpose if students do not also learn to use research and investigation skills to verify their assumptions. Determining who controls sources of pollution and finding out what they are doing to limit adverse impacts are important next steps in becoming a responsible citizen. (See reading materials on "Air Pollution," "Health Effects," "Smog," "Acid

**RELATED WARM-UPS**
C, G

**REFER TO READING MATERIALS**
"Air Pollution"
"Health Effects"
"Smog"
"Acid Deposition"
"Automobiles and Air Pollution"
"The Clean Air Act"

**TARGET GRADE LEVEL**
8th-12th

**DURATION**
45 minutes (with possible extensions)

**VOCABULARY**
Pollution
Toxic Release Inventory

**MATERIALS**
The map prepared by students in the warm-up exercise
An easel or some other method of displaying the poster
Chalk
Chalkboard

Deposition," "Automobiles and Air Pollution," and "The Clean Air Act.")

## WHAT TO DO

### Before class begins

1. Display the map prepared by the students in the "Finding Sources of Air Pollution" activity.

2. Call on the three previously selected students for 5-minute presentations. These presentations are to describe the signs, health effects, and possible sources of pollution in the community and the reasoning that led students to these conclusions.

3. Following the presentations, begin the discussion by commenting on (encouraging, offering constructive criticism) their observation and mapping effort.

4. Now that they have developed a theory about the pollution sources in the community, ask how they would investigate and verify their information. How would they find out what is being done to control the pollution? Through this discussion students will identify some specific ways to carry out a more detailed investigation of the air pollution in the community. Most of the work involved may have to be done outside of class.

5. Ask for a student volunteer to record ideas contributed during the discussion on the chalkboard, and ask for a second volunteer to record them on paper, so they can be copied and distributed to the class later.

6. To begin, ask who in the community students would expect to know about air pollution. (If necessary, prompt students by asking if the local health department would know.) The completed list might include the local health department, the local library, doctors, someone who works for the EPA, the local Heart or Lung Association, and others.

7. Ask students which of these knowledgeable people they would want to talk to. Do they think any one of these people would be able to answer all their questions? If not, how many others would they talk with? Ask what they would do if they got different, conflicting information from their sources. How would they decide what is correct? (The point here is to reinforce that it may be necessary to examine information from several sources to sort out the most definitive information.) You may want to take this opportunity to describe the Toxic Release Inventory (see Glossary for definition) and discuss how it might be used in this investigation. A sample record from the TRI is shown on Student Handout 1.

8. Besides verifying that the information on the map is correct, ask what other kinds of information they would want to get? For example, would

it help to know if the government has made any laws requiring the control of air pollution? How would they find out what laws exist? What would they need to know about them? (The list should include items such as what the requirements are, who is responsible for enforcing them, how they are being enforced, the penalties for breaking the laws, if there are plans for making the laws stricter or more lenient, and why these changes are being considered.)

9. Ask how they would go about finding out what currently is being done to control air pollution. (If necessary, prompt students by suggesting they might interview some of the polluters they have identified.) Encourage them to suggest others who might be doing things to control pollution? (The point here is to help students recognize that the local government and other organizations may be taking other actions to control pollution in the community and, therefore, they should be interviewed also.)

10. Ask how they would use all the information once they have gathered it. Who would they want to tell about it? What would be the best, most effective way to present the information? (The point here is to elicit some ideas for presentation formats. The list might include writing a report, writing an article for the school newspaper, designing a display and putting it in the school lobby or taking it to local malls, making a presentation at a school assembly or at a PTA meeting.)

11. Explain that through this discussion the students have begun to develop an "action plan." At this point, suggest that copies of the plan be made and distributed to all students in the class and that they discuss (in class on another day) which, if any, of the actions they want to pursue.

## SUGGESTED EXTENSIONS (OPTIONAL)

- Assign a student or a team of students to write an article for the school newspaper about the visit from the EPA representative and the action plan the class developed.

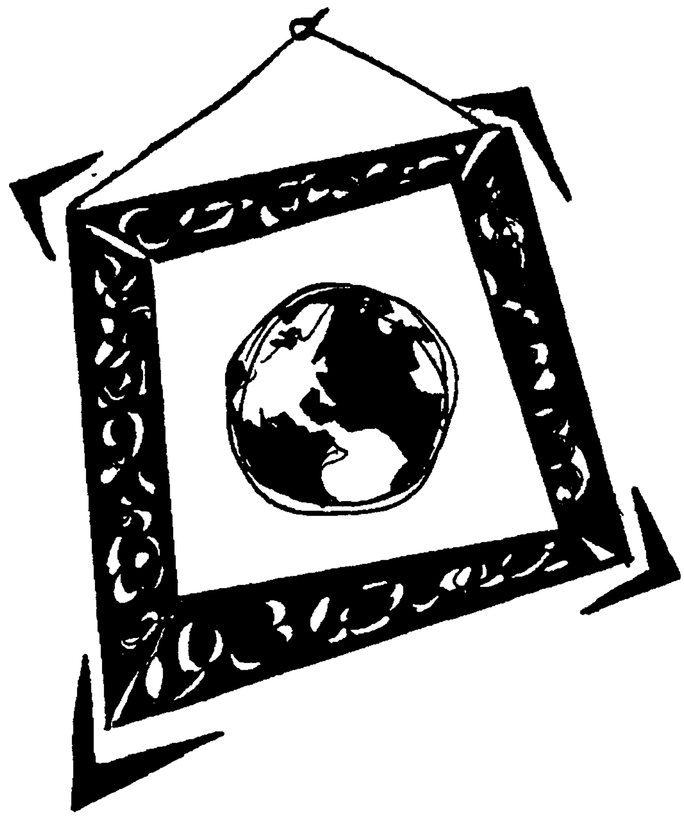
- Divide the class into teams and assign each team a part of the "action plan" to pursue. (For example, one team would be responsible for interviewing potentially polluting industries and others about what kinds and how much pollutants they release and about what they are doing to control releases. Another team would research existing pollution control laws. Another would interview appropriate sources about what the local government is doing to control pollution. When their work is completed, the same EPA employee could be invited back to hear each team report on their activities. Teams also could be tasked to present the information in one of the formats suggested during the class discussion (see step 10).

## SUGGESTED READING

Edelson, Edward. *Clean Air.* New York: Chelsea House Publishers (1992).

Moos, Shawna. "Pollution-Prevention Power to the People (EPA's Toxics Release Inventory Database)." *Technology Review,* 95 (October 1992) p. 15.

O'Neill, Catherine. "Cleaner Air! Cough! Wheeze! Gasp!" *Washington Post (Washington Health),* 115 (6 October 1992) p. WH18.



# STUDENT HANDOUT 1

# IS YOUR AIR CLEAN?

## SAMPLE RECORD FROM THE TOXIC RELEASE INVENTORY

FACN - 20851SMITH2355L
FNM - XXX PAINT WORKS CO.
FAD - 0000 SMITH AVE.
FCTY - ROCKVILLE
FST - MD (MARYLAND)
FZIP - 20851-1234
PUBC - JOHN SMITH
TEL - (301) 555-5555
SIC - (2851) Paints and allied products
SIC - NA
FDBN - 00-324-1234
NAME - ETHYLENE GLYCOL
RN - 107-21-1
MUSE - NO DATA
PUSE - (2b) As a formulation component
OUSE - NO DATA
MAX - (03) 1,000-9,999 lbs. (5,000M)
o AIRNR- NON-POINT AIR RELEASE : 11-499 lbs. (250m)/rep yr - 1991
o AIRNB- BASIS OF ESTIMATE : (O) Other Approaches
o AIRPR- POINT AIR RELEASE : 1-10 lbs. (5m)/rep yr - 1991
o AIRPB- BASIS OF ESTIMATE : (O) Other Approaches
AIRT - 255 lbs./rep yr - 1991
o RSTR - RECEIVING STREAM : NA
o WR - WATER RELEASE : 0/0 lbs./rep yr - 1991
o WB - BASIS OF ESTIMATE : NA
o SPER - PERCENT FROM STORMWATER : 0.00%
o RSTR - RECEIVING STREAM : NA
o WR - WATER RELEASE : 0/0 lbs./rep yr - 1991
o WB - BASIS OF ESTIMATE : NA
o SPER - PERCENT FROM STORMWATER : 0.00%
o RSTR - RECEIVING STREAM : NA
o WR - WATER RELEASE : 0/0 lbs./rep yr - 1991
o WB - BASIS OF ESTIMATE : NA
o SPER - PERCENT FROM STORMWATER : 0.00%
WT - 0 lbs./rep yr - 1991
o LANDM- DISPOSAL METHOD : (D02) On-site Landfill
o LANDR- LAND RELEASE : 0/0 lbs./rep yr - 1991
o LANDB- BASIS OF ESTIMATE : NA
o LANDM- DISPOSAL METHOD : (D03) Land Treatment/Application/Farming
o LANDR- LAND RELEASE : 0/0 lbs./rep yr - 1991
o LANDB- BASIS OF ESTIMATE : NA
o LANDM- DISPOSAL METHOD : (D05) Surface Impoundment
o LANDR- LAND RELEASE : 0/0 lbs./rep yr - 1991
o LANDB- BASIS OF ESTIMATE : NA
o LANDM- DISPOSAL METHOD : (D99) Other Disposal
o LANDR- LAND RELEASE : 0/0 lbs./rep yr - 1991
o LANDB- BASIS OF ESTIMATE : NA
LANDT- 0 lbs./rep yr - 1991
o UINJR- UNDERGROUND INJECTION RELEASE : 0/0 lbs./rep yr - 1991
o UINJB- BASIS OF ESTIMATE : NA
UINJT- 0 lbs./rep yr - 1991

ERELT- 255 lbs./rep yr - 1991
o TWNM - NAME : NA
o TWNM - NAME : NA
POTWT- 0/0 lbs./rep yr - 1991
o OTR - OFF-SITE LOCATION TRANSFER: 0 lbs./rep yr - 1991
OLOCT- 0 lbs./rep yr - 1991

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o QREL - QUANTITY RELEASED
o ONRV - ON-SITE ENERGY RECOVERY
o OFRV - OFF-SITE ENERGY RECOVERY
o ONCC - ON-SITE RECYCLING
o OFCC - OFF-SITE RECYCLING
o ONTRT- ON-SITE TREATMENT
o OFTRT- OFF-SITE TREATMENT

| | PRIOR(90) | CURRENT(91) | % CHANGE |
|---|---|---|---|
| QREL | 156 | 123 | -21.15% |
| ONRV | 0 | 0 | 0.00% |
| OFRV | 0 | 0 | 0.00% |
| ONCC | 0 | 0 | 0.00% |
| OFCC | 0 | 0 | 0.00% |
| ONTRT | 0 | 0 | 0.00% |
| OFTRT | 0 | 0 | 0.00% |
| TOTAL | 156 | 123 | -21.15% |

o SRRTP- SOURCE REDUCTION & RECYCLING TOTAL PRIOR YEAR : 156 lbs./rep yr - 1991
o SRRTC- SOURCE REDUCTION & RECYCLING TOTAL CURRENT YEAR : 123 lbs./rep yr - 1991
o SRRTN- SOURCE REDUCTION & RECYCLING TOTAL NEXT YEAR : 100 lbs./rep yr - 1991
o SRRTF- SOURCE REDUCTION & RECYCLING TOTAL FUTURE YEAR : 80 lbs./rep yr - 1991
ARELT- 0 lbs./rep yr - 1991
FCO - MONTGOMERY

# ACTIVITY 11

# ACID RAIN AND PLANTS

This activity lets students observe the effects of acid rain on plants in a simulated experiment using vinegar or lemon water. The results from the experiment could be used as an introductory presentation to an EPA representative who is an expert on acid rain. The representative could then follow up with a presentation to the class about EPA's efforts to reduce acid rain in the United States and internationally. This activity is related to the "Seeing the Big Picture" warm-up and the "Finding Sources of Air Pollution" and "Is Your Air Clean?" activities.

## CRITICAL OBJECTIVES

- Observe the impact of acids on plants
- Recognize how acid rain can affect the environment

## SKILLS

- Observing
- Comparing

## GUEST PRESENTERS

Guest presenters could include EPA acid rain specialists, botanists, chemists, ecologists, EPA environmental protection specialists, or environmental scientists.

## BACKGROUND

Acid rain is precipitation that is more acidic than normal. The terms "acidic" and "basic" (or "alkaline") are used to describe two chemical extremes, much like hot and cold describe two temperature extremes. Mixing acids and bases can cancel out their extreme effects, much like mixing hot and cold water moderate the temperature. A substance that is neither acidic or basic is called "neutral." The pH scale measures how acidic or basic a substance is. The pH scale ranges from 0 to 14. A pH of 7 is neutral. A pH lower than 7 is acidic; higher than 7 is basic. Pure water is neutral. But when chemicals are mixed with water, the mixture can become either acidic or basic. For example, lemon juice is acidic; the pH of lemonade is between 2 and 3. Ammonia, on the other hand, is alkaline; its pH is just over 11. Each unit of pH is ten times greater or smaller than the next unit. For example, a pH of 5 is 100 times more acidic than a pH of 7. This is called a "logarithmic" scale.

Air pollution is a major cause of acid rain. When precipitation becomes more acidic than normal, it can damage soil, water, building materials, plants, animals, and humans. The effects of acid rain may not be immediately apparent in all places. For example, at a glance, a lake might

**RELATED WARM-UP**
C

**REFER TO READING MATERIALS**
"Air Pollution"
"Acid Deposition"

**TARGET GRADE LEVEL**
4th - 6th

**DURATION**
45 minutes (with possible extensions)

**VOCABULARY**
Acid rain
Acidic
Alkaline
Base
Logarithm
Neutral
pH
Precipitation

**MATERIALS**
Three small and healthy potted plants, all the same type
Three large jars with lids
Vinegar
Water
Measuring cup
Masking tape
Paper
Pen

look clear and beautiful. But when you look closely, you might begin to see some problems. Where are the fish? Why are there few or no plants? Many lakes in the Adirondack Mountains of New York, the upper midwest, and many streams in the Appalachian Mountains, in particular, have experienced losses of aquatic life. Nature can cope with some changes in acidity. Areas with limestone (which reacts with acid) are able to neutralize acidic rainfall so the damage is reduced. However, large parts of the world do not have this acid rain coping ability and, in any case, no area can handle very large amounts of acid rain.

Acid rain can affect plants in many ways. It takes nutrients away from the soil so that plants can't grow. It weakens trees so that they become diseased more easily. Branches at the top of trees lose their leaves. Tree leaves might be an unusual color. Trees may not have as many leaves or may lose their leaves earlier each year. Eventually, trees die. In this experiment, with potted plants, the more acid rain in the plant water, the sooner a plant dies. The plants are watered with solutions that have a lower pH than most rainfall. (See reading materials on "Air Pollution" and "Acid Deposition.")

## WHAT TO DO

1. Divide the class into 3 teams. Give each group a 1-gallon container (a milk container would work). Have one team fill their container with 1 gallon (3.8 liters) of tap water. They can use a piece of masking tape to label the container "tap water."

2. Have another team fill their container with 1 pint (0.5 liters) of vinegar and 7 pints (3.3 liters) of tap water. Have them use a piece of masking tape to label the container "slightly acidic."

3. Have the third team fill their container with 2 pints (0.9 liters) of vinegar and 6 pints (2.8 liters) of tap water. Have them use a piece of masking tape to label the container "very acidic."

4. Give each team one of the plants and have them label it the same as their container. Make each team responsible for watering their plant from the container with the matching label.

5. Place all three plants in the same spot so that they get the same amount of light. Students should water the plants when they need it (every two to four days). Make sure the plants get the same amount of water in each watering cycle. Have team members examine their plants every day and write down what they look like—what color they are, if their leaves are dropping, whether they look healthy.

6. Continue this activity for two to three weeks. Then have students examine the plants and discuss the results of the experiment. What happened to the plants watered with acid solutions? How long did it take to see the effects of the acid? Do the plants differ in color? If so, why? Which plant showed the most effects?

## SUGGESTED EXTENSIONS (OPTIONAL)

- If you live in an area affected by acid rain, take students on a field trip and have students write down what they observe about the area. Can they see dying or dead plants or trees, stained or eroded building surfaces or statues? If there is a lake or stream nearby, can they see any wildlife? Discuss ways that the area may be saved. Discuss the sources of the pollution that may have contributed to the acid rain that falls in the area.

- In a follow-up class with an EPA representative working on acid rain, have the students present their results from the experiment. The EPA representative could discuss the results and provide some additional information on acid rain.

## SUGGESTED READING

*Acid Rain Kids Handbook.* Washington, DC: National Geographic Society (1988).

*Acid Rain: The Invisible Threat (VHS videotape).* Scott Resources (1992).

Baines, John. *Conserving Our World, Conserving the Atmosphere.* Austin, TX: Steck-Vaughn Company (1990).

Berreby, David. "The Parasol Effect." *Discover,* 14 (July 1993) p. 44.

Boyle, Robert H., and Alexander R. Boyle. *Acid Rain.* New York: Schocken Books (1983).

Gay, Kathlyn. *Acid Rain.* New York: Franklin Watts (1983).

Gould, Roy. *Going Sour: Science and Politics of Acid Rain.* Cambridge, MA: Birkhauser Boston, Inc. (1985).

Gutnik, Martin J. *The Challenge of Clean Air.* Hillside, NJ: Enslow Company (1990).

Hare, Tony. *Save Our Earth: Acid Rain.* New York: Gloucester Press (1990).

Lucas, Eileen. *Acid Rain.* Chicago: Children's Press (1991).

McCormick, John. *Acid Rain*. Gloucester Press (1986).

Miller, Christina G., and Louise A. Berry. *Acid Rain: A Sourcebook for Young People*. New York: Julian Messner (1986).

O'Neill, Catherine. "Saving Statues from Acid Rain." *Washington Post (Washington Health)*, 116 (6 April 1993) p. WH18.

Pringle, Laurence P. *Rain of Trouble: The Science and Politics of Acid Rain*. New York, NY: Macmillan (1988).

*Problems of Conservation: Acid Rain (VHS videotape)*. EBE (1990).

Stubbs, Harriet, Mary Lou Klinkhammer, and Marsha Knittig. *Acid Rain Reader*. Raleigh, NC: Acid Rain Foundation (1989).

# ACTIVITY 12

# THE GREENHOUSE EFFECT

This activity introduces the concepts of climate change and the "greenhouse effect." While global warming may sound great, thinking through the possible effects upon plants, sea levels, and the world's food supply may cause the students to better appreciate how complex a role the atmosphere has in our lives. It is related to the "Read My Data" and "Tracking Air Quality" warm-ups and the "Climate and the Greenhouse Effect" activity.

## CRITICAL OBJECTIVES

- Understand that the atmosphere traps heat and makes the surface of the Earth warm enough for life
- Recognize that air pollution can cause a rise in temperature and ecological decline
- Recognize that human activities can cause air pollution

## SKILLS

- Observing
- Comparing
- Interpreting test results
- Drawing conclusions

## GUEST PRESENTER

Guest presenters could include air quality engineers, chemists, ecologists, meteorologists, or physicists.

## BACKGROUND

The greenhouse effect is a term scientists use to describe the trapping of heat on the surface of the Earth by the atmosphere, a normal atmospheric occurrence. As a result of this, the Earth's surface is about 53°F (12°C) warmer than it would be without this trapping. This effect is magnified by certain greenhouse gases in the atmosphere, most notably carbon dioxide, methane, nitrogen oxides, and chlorofluorocarbons (CFCs). Methane is a product of natural decay from living (or once-living) things; nitrogen oxides are generally a result of man-made burning and automobile and similar internal-combustion engines; and CFCs are a class of chemicals used often in air conditioners, refrigerators, and as the pressurizing gas in aerosol spray cans. While all of these pollutants contribute to air pollution, and contribute to the greenhouse effect, carbon dioxide is the most important greenhouse gas.

Scientists believe that concentrations of greenhouse gases in the atmosphere will double over the next hundred years, producing average

**RELATED WARM-UPS**
B, E

**REFER TO READING MATERIALS**
"Air Pollution"
"The Greenhouse Effect"

**TARGET GRADE LEVEL**
5th - 7th

**DURATION**
20 minutes (suggested optional extensions can further time).

**VOCABULARY**
Albedo
Carbon dioxide
Chlorofluorocarbons
Greenhouse effect
Greenhouse gas
Methane
Nitrogen oxides

**MATERIALS**
Two clean, dry, wide-mouth glass jars with lids (such as mayonnaise jars)
Heavy aluminum foil
Piece of dark cloth or construction paper
Stop watch or watch with a second hand
Two identical thermometers that fit into the jars ("Instant-read" meat thermometers work well)
Paper
Pencils

temperature rises of about 8 to 10°F (4 to 6°C). While most scientists believe that the greenhouse effect will gradually warm up the Earth's climate, there are some who believe that increased cloud cover will eventually reflect more sunlight away from the Earth and lower the average temperature. This increased reflectivity is called the Earth's albedo. (See reading material on "Air Pollution" and "The Greenhouse Effect.")

## WHAT TO DO

1. Divide the class into two work groups. Give each group one of the jars. Have each group put a piece of dark cloth or paper into their jar. Have them put a thermometer in each jar so that the scale can be read through the side. Have one group screw the cover onto their jar. Have the other group leave their jar open.


2. Have the groups place the jars, on their sides, in the sunshine so that their bottoms face the sun.

3. Instruct each group to watch the thermometers and have one person from the group record the temperature shown in their jar every minute. Instruct the group with the closed jar to announce when the thermometer in their jar levels off or reaches 140°F (60°C). Stop the experiment at that point.

4. Have students discuss the following questions:
   In which jar does the temperature rise fastest?
   How much faster did it rise? Why?
   How is this like a greenhouse?
   How is this like the real world's atmosphere?
   What was the role of the dark cloth in the jars?

## SUGGESTED EXTENSIONS (OPTIONAL)

- Have students wrap one of the jars with aluminum foil, leaving a clear area away from the sun to read the thermometer. Repeat the experiment, and compare the times to reach 140°F (60°C). Discuss why it took longer.

- Have students try the experiment on a cloudy day. Discuss the difference in results. Have them try the experiment without the dark cloths and discuss the difference in results.

## SUGGESTED READING


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# ACTIVITY 13

# CLIMATE AND THE GREENHOUSE EFFECT

This module is intended to help educators guide an experiment to demonstrate the greenhouse effect and to stimulate discussion among students on the effects of global climate changes upon the environment. While global warming may sound great ("endless summer"), thinking through the possible effects upon plants, sea levels, and the world's food supply may cause the students to better appreciate how complex a role the atmosphere plays in the way we live. This activity is related to the warm-ups called "Prediction" and "Tracking Air Quality." Related activities include "The Greenhouse Effect."

## CRITICAL OBJECTIVES

- Recognize that relatively small changes to our environment can stimulate significant climate changes
- Understand that the "scientific method" is a process of testing hypotheses
- Appreciate that global climate changes will affect us far beyond simply warming the outdoor air temperatures

## SKILLS

- Observing
- Forming hypotheses
- Predicting
- Graphing

## GUEST PRESENTERS

Guest presenters could include chemists, ecologists, environmental scientists, EPA environmental protection specialists, meteorologists, or physicists.

## BACKGROUND

Most of the electromagnetic energy (light) radiated from the sun that reaches the Earth passes through our atmosphere and is absorbed at the surface. Some of the incoming, or "incident," light waves are reflected away by clouds in the atmosphere or light-colored surface features such as large snow or ice fields. The energy that is absorbed is converted in part to heat energy that is re-radiated back into the atmosphere. Heat energy waves are not visible, and are generally in the infrared (long-wavelength) portion of the spectrum compared to visible light. Physical laws show that atmospheric constituents—notably water vapor and carbon dioxide gas—that are transparent to vis-

**RELATED WARM-UP**
A, E

**REFER TO READING MATERIAL**
"Greenhouse Effect"
"Air Pollution"

**TARGET GRADE LEVEL**
8th - 12th

**DURATION**
35 minutes (or two class periods with extensions)

**VOCABULARY**
Baseline
Carbon dioxide
Convection
Energy
Greenhouse effect
Hypothesis
Prediction
Scientific method
Temperature

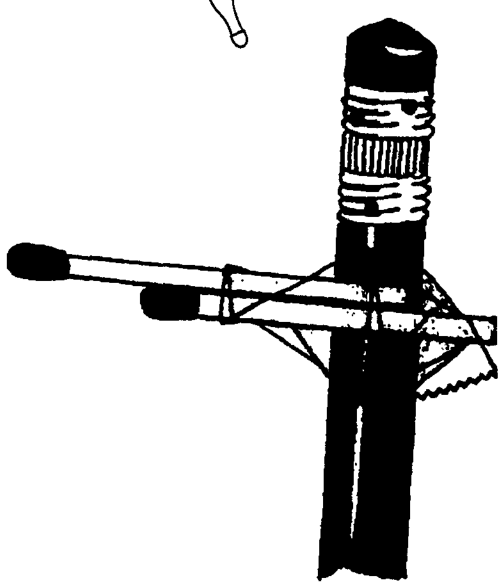
**MATERIALS**
A clean, dry, wide-mouth glass jar with a tight cap (such as a mayonnaise jar)
Thermometer capable of fitting into the jar (meat thermometer works well)
Heavy aluminum foil
Stop watch (or clock with a second hand)
Wooden kitchen matches
Graph paper
Colored pencils

ible light are not transparent to heat waves. Hence, re-radiated energy in the infrared portion of the spectrum is trapped within the atmosphere, keeping the surface temperature warm. This phenomenon is called the "greenhouse effect" because it is exactly the same principle that heats a greenhouse (or in a glass jar as in this experiment) where the glass performs the same function as the atmosphere. On the moon, for example, where there is no atmosphere, re-radiated energy is entirely lost to space. Thus, objects on the surface of the moon would feel hot if they were in direct sunlight while the side turned away from the direct rays of the sun would be as cold as space. Obviously, the Earth's atmosphere serves a function beyond providing air to breathe: the atmosphere mediates the extremes of energy received from the sun, and serves as an energy storehouse. (See reading materials on "The Greenhouse Effect" and "Air Pollution.")

## WHAT TO DO

### Before class begins

1. Make a number of match holders (see illustration) that will keep the burning match away from the thermometer.



### When class begins

1. Students should be challenged throughout the activity to volunteer predictions of what will happen in each step of the experiment. Where appropriate, ask them to write down actual numbers that they expect to see during the experiments. They should then be encouraged to suggest reasons why their hypotheses were (or were not) substantiated by experiment. Finally, they should be encouraged to explain the real-world implications of the experiments in the glass jar.

2. Have the students create a graph with temperature along the vertical axis (50° to 200°F, in 5° increments) and time along the horizontal axis (0 minutes to 20 minutes). Tell the students to label each axis. Have them use a different colored pencil to enter data for each version of the experiment so they can compare data.

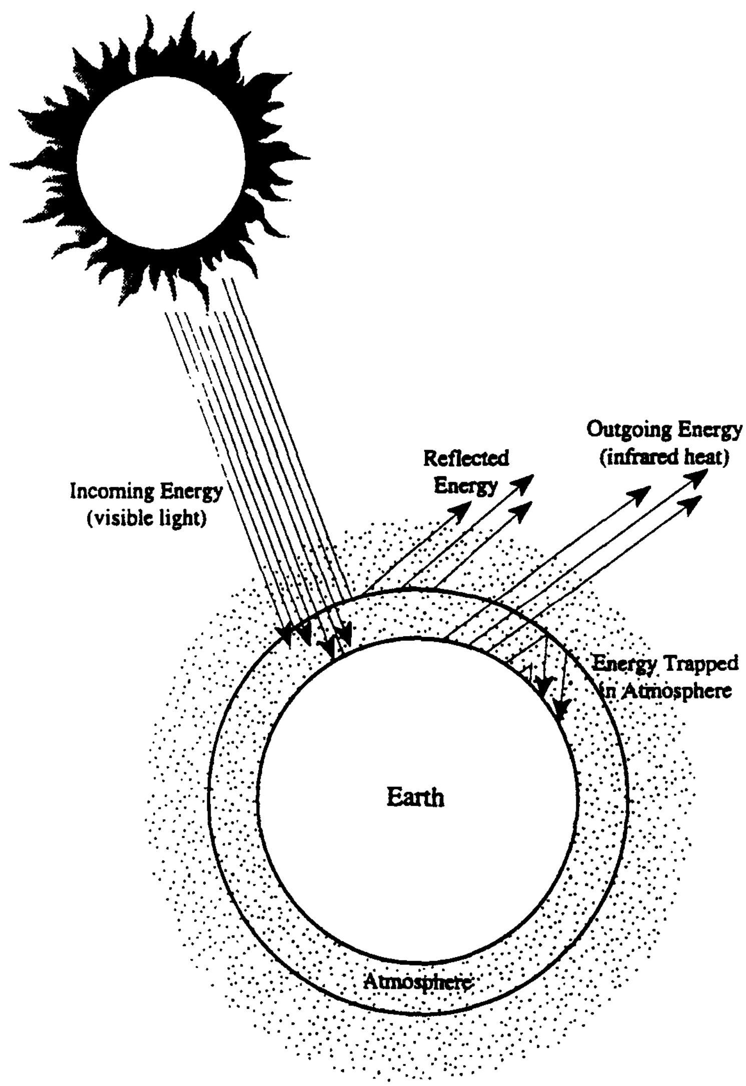
3. Select a student or group of students to perform the experiment. Have them wrap one half the jar's circumference with heavy aluminum foil, shiny side out, making sure that the foil extends the entire height of the jar. They can tape it in place if necessary.

4. Have them put the thermometer in the jar so that it can be read through the side of the jar that is not covered with foil. Leave the lid off for now.

5. Let them measure the air temperature in the room, making sure that the thermometer is not in direct sunlight or close to an electric light bulb. Have all students read and write down the temperature.

6. Have the experimenter(s) place the jar in a sunny window, or next to the spotlight. Caution that the thermometer should be completely shadowed by the aluminum foil (rotate the jar so that the foil faces the sun). Have each student write down the temperature. Have the students predict whether the temperature will be different from the first temperature, and by how many degrees, and make them give a hypothesis. If they think that the temperature will go up, ask them to explain the mechanism by which the heat is added to the jar. (The temperatures should not be appreciably different, because you are reading the room air temperature both times.) Ask the students to consider what temperature is really being measured. (It is really the temperature of the air within the jar.)

7. Have the experimenter(s) rotate the jar so that sunlight hits the clear side of the jar and the thermometer directly. Ask the students to predict what the temperature will now do. Get them to suggest reasons. The temperature should be much warmer, because the energy in the sunlight is directly warming the mercury in the thermometer as it converts from visible light energy to invisible heat energy. If anyone guesses the answer, challenge them to think of a way to test that theory. The next experiment will test the theory.




8. Rotate the jar again so that the thermometer is shadowed. Start the stopwatch. Call students' attention to how long it takes for the temperature to fall back to normal room temperature. It should fall fairly quickly because the increase was due only to the sunlight. The air within the jar was not warmed much because it is open to the room and any heated air escaped and was replaced by cold air through convection.

**9.** Cover the jar with the lid snugly, and repeat steps 6, 7, and 8. Have the students use a different colored pencil to record the temperature curve on their graph paper. Ask the students to predict whether the results will be the same, and why or why not. Even with the cover on, the repeat of 6 should not increase the temperature significantly because the sunlight is being reflected away from the jar. When the sunlight hits the clear part of the jar in the repeat of experiment 7, the temperature will go up just as quickly as before. However, when you turn the jar away in the repeat of 8, the temperature will fall much more slowly because of the greenhouse effect. Ask why the temperature fell more slowly than before? If heat was stored in the jar, what part of the system was probably the heat "bank"? The gases in the system, including water vapor.

**10.** Open the jar and drop in a lighted kitchen match attached to the match holder and quickly close the lid again.

When the oxygen is gone, the match will die out by itself in about ten seconds. Challenge the students to guess what the burning matches are doing in the closed system. The fire is combining the oxygen in the enclosed air with the carbon from the burning wood to produce carbon dioxide. Ask them what in the real world might create a similar situation in the atmosphere. Ask them why the match went out even though not all of the wooden match stick was burned up. Set the jar aside away from sunlight for a couple of minutes to let the heat created by the fire equilibrate. The match didn't give off much heat, but the temperature will likely go up about 5°F (3°C). Have the students read the thermometer (to get a temperature baseline). Repeat steps 7 and 8, asking the students to again predict what will happen and why. This time, emphasize that they should consider and speculate on whether the carbon dioxide in the jar will accelerate or retard the temperature rise and later fall. This time, the temperature will warm up much more quickly and will stay warm longer because of the greenhouse effect of the carbon dioxide.

> **TAKE NOTE!** Be careful that the flame does not touch the thermometer or any plastic or cardboard casing around it.

**11.** Challenge the students to extrapolate the results of the experiments to the real world. The conclusion of these experiments should demonstrate that the greenhouse effect is real, that a colorless atmospheric gas (carbon dioxide) is a significant contributor to atmospheric warming.

## SUGGESTED EXTENSIONS (OPTIONAL)

- Divide the class into three groups and have Group One conduct and record the experiments with the jar open to the air; Group Two should conduct the experiments with the jar sealed, and Group Three with the jar sealed after the matches are burned in it. (Don't forget to prepare the match holders before class). If results from measurements of more than one thermometer are to be compared, be sure to calibrate the thermometers with each other first to cancel out analytical errors.

- Divide the class into three groups and have each group conduct the identical experiments. Compare their results. Discuss why the values were different? Discuss calibration of the thermometers, "experimental errors," and different conditions.

- Have the students plant a tree. Explain that they can make a small dent in the carbon dioxide surplus by planting trees. Have the students contact a local nursery to see if the owners will donate some tree seedlings to help combat climate change.

## SUGGESTED MODIFICATIONS

- For grades 10 through 12, divide the class into two groups. Have one group represent the position of the United States and our citizens. The other group should represent a poor country that relies upon subsistence agriculture, fishing, and the sale of its forests for lumber to the United States. The groups should work separately. Each group should make a list of the benefits it (the represented country) would receive if global warming was halted. Each group should list the things it can do within its own borders to help stop global warming. Each group then should list the "costs" it would be required to bear to help stop global warming. Have students discuss whether the benefits to both groups are the same. Can both countries contribute equally to slow down or stop global warming? Are the costs to both groups the same?

- Have students in higher grades research and present oral reports to the class to answer the following questions:

  How can greenhouse gases be controlled, and is the greenhouse effect reversible?

  If temperatures are warming, what are the consequences to humans from melting polar icecaps?

  If the greenhouse effect is raising global temperatures to an appre ciable degree, what will happen to the world's food supply in the next century?

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# ACTIVITY 14

# SMOG

This activity lets students create artificial "smog" in a jar. Teachers can use this module as an introduction to a planned visit from an air-quality scientist, or as the basis for extended discussions on the health problems associated with smog. This activity is related to the warm-up exercises called "Read My Data" and "Seeing the Big Picture." Related activities include "Lifestyles and the Environment," "Is Your Air Clean?," "Deciding To Clean the Air," and "Choosing a Better Future."

## CRITICAL OBJECTIVES

- Recognize that invisible air pollutants and weather conditions are involved in creating smog
- Understand that not all air pollution is visible
- Appreciate that human activities can cause air pollution

## SKILLS

- Observing
- Drawing conclusions

## GUEST PRESENTERS

Guest presenters could include EPA air quality monitoring specialists, state or local air quality managers, chemists, laboratory technicians, or meteorologists.

## BACKGROUND

The expression "smog" was first used in "Turn-of-the-Century" London to describe a combiNation of "smoke" and "fog." Smog occurred when water vapor in the air condensed on small particles of soot in the air, forming small smog droplets. Thousands of Londoners died of pneumonia-like diseases due to the poisonous air. Today, smog is usually produced photochemically, when chemical pollutants in the air (notably nitrous oxide and hydrocarbons from automobile exhausts) are baked by the sun and react chemically. Ground-level ozone is produced by a combiNation of pollutants from many sources such as automobile exhausts, smokestacks, and fumes from chemical solvents like paint thinner or pesticides. When these smog-forming pollutants (called "precursors") are released into the air, they undergo chemical transformations and produce smog. Weather conditions, such as the lack of wind or a "thermal inversion," also cause smog to be trapped over a particular area.

Smog causes health problems such as difficulty in breathing, asthma, reduced resistance to lung infections, colds, and eye irritation. The

**RELATED WARM-UPS**
B, C

**REFER TO READING MATERIALS**
"Smog"
"Air Pollution"
"Ozone"
"Automobiles and Air Pollution"

**TARGET GRADE LEVEL**
3rd - 5th

**DURATION**
20 minutes

**VOCABULARY**
Hydrocarbons
Ozone
Photochemical
Precursor
Smog
Thermal inversion

**MATERIALS**
Clean, dry, wide-mouth glass jar (such as a mayonnaise jar)
Heavy aluminum foil
Two or three ice cubes
Ruler
Scissors
Stop watch or watch with a second hand
Matches

ozone in smog also can damage plants and trees, and the haze reduces visibility. This is particularly noticeable from mountains and other beautiful vistas such as National Parks.

Severe smog and ground-level ozone problems exist in many major cities, including much of California from San Francisco to San Diego, the mid-Atlantic seaboard from Washington, DC to southern Maine, and over major cities of the Midwest. (See reading materials on "Smog," "Air Pollution," "Ozone," and "Automobiles and Air Pollution.")

## WHAT TO DO

1. Explain that the class will perform an experiment in which they will create artificial "smog" in a jar. Make sure that students understand that the jar is only a model, and models by nature are limited. For example, the purpose of this model is to illustrate the appearance and behavior of smog, not the composition or effects. It is important to understand that smog is not just a "smoky fog," but a specific phenomenon.

2. Select students to perform the experiment. Have them cut a strip of paper about 6 inches by 2 inches. Fold the strip in half and twist it into a rope.

3. Have them make a snug lid for the jar out of a piece of aluminum foil. Shape a small depression in the foil lid to keep the ice cubes from sliding off. Carefully remove the foil and set it aside.

4. Have the students put some water in the jar and swish it around to wet all the inside of the jar. Pour out the extra water.

5. Have them light the paper "rope" with a match and drop it and the match into the damp jar. Put the foil lid back on the jar and seal it tightly. Put ice cubes on the lid to make it cold. (The ice cubes will make the water vapor in the jar condense.) You must do this step very quickly, perhaps with some assistance.

> **TAKE NOTE!** Be careful to supervise students using matches. DO NOT let anyone breathe the "smog" produced in the experiment, and when the experiment is completed, be sure to release the "smog" outside.

6. Ask students to describe what they see in the jar. How is this like real smog? What conditions in the jar produced "smog"? (Moisture plus soot particles from the burning matches plus carbon dioxide and other solvent vapors.)

7. Ask the students if they have ever seen smog (not fog). Have they ever breathed air outside that smelled funny?

## SUGGESTED EXTENSIONS (OPTIONAL)

- Have students put a glass thermometer (not plastic) into the jar before they do the experiment. Have them record the temperature before proceeding to step 4. Have them record the temperature during step 5. Ask them to describe what the temperature did and why. Let them try it again without adding water.

## SUGGESTED MODIFICATIONS

- For grades 7-12, assign students to small groups to answer the following questions and report back to class in two weeks. One group will consider the physical and chemical sciences and the other group will consider the health and ecological sciences. Each group should consider referring to several sources of information to answer the questions. Students could possibly interview the weather reporter or meteorologist at the local television or radio station or airport, or interviewing a health scientist from the city or county health department or air quality agency.

  (a) What conditions are necessary to produce smog in the air? Under what circumstances will these conditions exist in the city? How often are they likely? Can they be predicted in advance?

  (b) What are the health effects of smog on people? On plants and trees? Why doesn't everyone in the city get sick or have similar symptoms from smog? What types of people are most sensitive to smog?

## SUGGESTED READING

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# ACTIVITY 15

# DECIDING TO CLEAN THE AIR

This activity lets students practice making choices and experience the sometimes difficult process of making decisions related to air pollution. It is related to the warm-ups called "The Big Picture," and "Making Decisions." Related activities include "Lifestyles and the Environment," "How Green Are We?," "Designing a Clean-Air Environment," "Choosing a Better Future," and "Writing Environmental Laws."

## CRITICAL OBJECTIVES

- Understand the impact of choices on the nature and quality of life
- Understand the process for making decisions
- Recognize that different people have different perspectives on the same air pollution issue

## SKILLS

- Researching
- Comparing ideas
- Considering alternatives
- Making and justifying decisions

## GUEST PRESENTERS

Guest presenters could include EPA environmental protection, risk assessment, or enforcement specialists, environmental scientists, or lawyers.

## BACKGROUND

Whether we are children or adults, our lives are influenced by a constant series of choices. Some choices we make for ourselves. Some are made by parents for their children, and many are made by people we don't even know. The combinations of all of these choices determine the quality of each of our lives. Making these choices is not easy because sometimes what a person perceives as the right choice for him or her as an individual may be perceived as the wrong choice for the neighborhood, the community, or the Nation. For example, a person may not want to join a car pool to get to school or work in the morning because it means coordinating his or her schedule with someone else's and, maybe, getting up earlier in the morning to be ready on time.

The combination of choices made by individuals, business and industry owners, and government over the years has had a huge impact on

**RELATED WARM-UPS**
C, G

**REFER TO READING MATERIALS**
"Automobiles and Air Pollution"
"The Clean Air Act"

**TARGET GRADE LEVEL**
6th - 12th

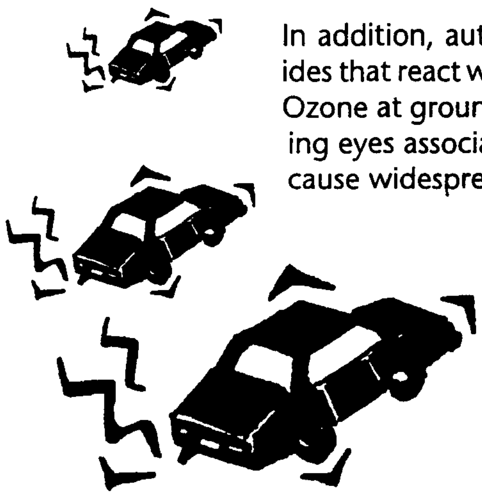
**DURATION**
2 class periods (80-90 minutes)

**VOCABULARY**
Acetaldehyde
Auto emissions
Benzene
Carcinogens
Clean fuel
Criteria pollutants
Formaldehyde
Hydrocarbons
Nitrogen oxides
Non-attainment area
Ozone
Particulate matter
Smoke
Soot
Standards

**WORKSHEETS INCLUDED**
1

the quality of the air we breathe and the air pollution problems the world faces today. For example, as a country, we have chosen to pay the higher prices of cars with emission control systems in order to reduce pollution from motor vehicles.

Auto exhaust is a major contributor to air pollution. Automobiles emit several pollutants that EPA classifies as probable or definite carcinogens, including benzene, formaldehyde, acetaldehyde, and particulates (soot or smoke, especially from diesel vehicles). EPA estimates that toxic emissions from cars, trucks, and buses could be responsible for as many as 1,500 cases of cancer each year. (See reading material on "Automobiles and Air Pollution.")



In addition, automobile exhaust contains hydrocarbons and nitrogen oxides that react with sunlight to create ozone, the major component of smog. Ozone at ground level is responsible for the choking, coughing, and stinging eyes associated with smog. Ozone also inhibits plant growth and can cause widespread damage to crops and forests. In typical urban areas, at least half of the hydrocarbons and nitrogen oxides come from motor vehicles. Nitrogen oxides also are produced by power plants, factories, and even lawnmowers. Hydrocarbons are found in many consumer products, including paints, hair spray, charcoal starter fluid, solvents, and plastic "popcorn" or "bubble" packaging. EPA sets national standards for ozone (one of the six widespread "criteria pollutants"), and the states must take action to ensure that standards are met. Areas that fail to meet the standards for at least one criteria air pollutant are called "non-attainment areas." (See reading material on "The Clean Air Act.")

Many of the smog clean-up requirements involve motor vehicles (cars, trucks, buses) because virtually everyone is exposed to their emissions. Also, as the pollution gets worse, pollution controls are required for smaller sources. Strategies that may be required by law to reduce and control these toxic emissions include state permitting programs, changes in the composition of gasoline, use of alternative fuels (such as natural gas and electricity), and use restrictions imposed by individual communities.

Many new and innovative approaches are being taken by local governments across the country to reduce air pollution in non-attainment areas. Some of these options include:

- Banning charcoal barbecues and wood burning in stoves or fire places when pollution levels are high
- Developing high-occupancy vehicle (HOV) programs for local highways to encourage car pooling
- Restricting traffic in specific areas of the city
- Providing incentives for citizens to use public transportation systems
- Expanding public transportation systems using clean-fueled vehicles,

such as municipal buses that use compressed natural gas (CNG) or electric trolley buses

- Eliminating payments by employers that reduce parking costs of employees who do not car pool
- Requiring employers to contribute to employee mass transit costs
- Assessing "smog fees" on cars in proportion to the number of miles driven and vehicle emissions produced
- Requiring more stringent vapor recovery at gas stations
- Requiring large companies to purchase fleet cars that run on clean fuel
- Buying and scrapping older cars

## WHAT TO DO

### Class #1

1. Explain that the class is going to act out a situation that illustrates the difficult process of making clean air choices. For the exercise, students are to assume that there has been a proposal brought before the city (town) council to close the downtown commercial district to automobile traffic because of the pollution level and traffic congestion. Under the proposal, only fire and police emergency and public transit (buses) vehicles would be allowed on downtown streets between the hours of 8:00 am and 6:00 pm.

2. Divide the class into 8 teams. Explain that each team will represent one of the "players" in this drama: three city (town) council members, two citizens, two downtown business owners, and one impartial expert that has been paid to evaluate the impacts of the proposal and report to the council (you may choose to be more specific about the roles to approximate the makeup of your community). Assign a role to each team and explain that each team will have to choose (not now) one team member to be the actor when the drama is played out at next week's class (give a specific date but allow a few days to prepare).

3. Explain that in order to act out the role they have been assigned, each team will have to define the characteristics and views of that person. Does the character live in the city (town) or out in the suburbs (in a rural area)? What does the person do for a living and where does he or she work? How does the person get to and from work? Does the person have a family? Where does the person shop? The last page of this activity is a sample "Character Attribute" worksheet that each team can fill out to help define its role.

4. Explain that once each team has defined its character, the team should define the character's concerns related to the proposal. Stress that this should go beyond deciding whether the character would be "for" or "against" the proposal and should include defining why this particular character might feel one way or the other. Encourage students to talk to their parents, local city (town) council members, and business owners to help develop these perspectives.

5. Explain that for the role-play activity, the actor from each team will have to describe the team's character and make a statement about that person's views on the proposal as if the character were addressing the council members during a meeting. (Remind the council members that they have a broader responsibility to the community and should be prepared, if necessary, to make a choice between their own individual views and what's best for the community as a whole.)

6. Give students the remainder of the class to work together and assign them to continue work outside of class in order to be prepared for the role-play activity.

### Class #2

1. Arrange desks or a table at the front of the room with chairs to accommodate the three city (town) council members. Place a lectern, desk, or small table somewhere else in the room from which the expert, citizens, and business owners will make their statements.

2. Instruct the actor from each team to describe the team's character (based on the worksheet completed by the team). Have the expert deliver his or her impartial report to the council members and audience at the council meeting. Have the citizens and business owners state their views on the proposal. Have each council member make a similar statement.

> **TAKE NOTE!** In the event that all teams take the same position on the proposal, be prepared to offer an opposing argument yourself, so that both sides of the issue will be heard by the class.

3. Ask the council members to vote. Examine the results. How did each member vote? How did they decide what to vote? Discuss the results and the choices involved with the class.

## SUGGESTED EXTENSIONS (OPTIONAL)

- Have students bring in examples throughout the year, from the newspaper or local television news, of real air pollution-related decisions made by your local government or major local businesses. Set aside time periodically to discuss the choices involved in these decisions and their impact on the quality of life.

## SUGGESTED READING

Asay, Gregory. "Acting Locally (Students and College Administration Work Together on Environmental Programs)." *Environmental Action Magazine,* 24 (December 1993) p. 21.

Becklake, John. *Thinking for the Future: Pollution*. New York: Gloucester Press (1990).

*Environmental Crisis—Opposing Viewpoints*. San Diego, CA: Greenhaven Press (1991).

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Watson, Bates, and Kennedy. *Air Pollution, the Automobile, and Public Health*. National Academy Press (1988).

Willis, Terri, and Wallace B. Black. *Cars: An Environmental Challenge*. Children's Press (1992).

*Worldwatch Paper 98: Alternatives to the Automobile*. Washington, DC: Worldwatch (1990).

# STUDENT WORKSHEET 1
# DECIDING TO CLEAN THE AIR
## CHARACTER ATTRIBUTES

Name: ______________________________

Family Members (include ages of children, if any): ______________________________

______________________________

Occupation (include type of business, if any): ______________________________

Where Do You Live (in the city, suburbs, rural area)? ______________________________

Where Do You Work (in the city, suburbs, rural area)? ______________________________

How Do You Get To And From Work? ______________________________

How Long Does Your Commute Take? ______________________________

Where Do You Do The Shopping? ______________________________

Are There Other Occasions You Need To Be Downtown During The Restricted Hours? ________

______________________________

What Do You Like About The Proposal? ______________________________

______________________________

What Don't You Like About The Proposal? ______________________________

______________________________

______________________________

Are You For Or Against The Proposal? How Strongly Do You Feel About It? ______________

______________________________

Are There Any Modifications To The Proposal You Want to Suggest to the Council? __________

______________________________

# ACTIVITY 16

# CHOOSING A BETTER FUTURE

This activity is designed to illustrate how students' choices today can impact future air quality. It lets them trace how the choices of earlier generations have increased air pollution over the last 40 years. It is related to the "Making Decisions" warm-up. Related activities include "Lifestyles and the Environment" and "Deciding To Clean the Air."

## CRITICAL OBJECTIVES

- Appreciate the differences between lifestyles today and 40 years ago
- Realize that the lifestyle choices made by previous generations have impacted the current air quality and air pollution problems
- Understand the increase in demand for selected manufactured goods, automobiles, and energy sources over the last 40 years and its impact on air pollution
- Determine practical and useful alternatives for reducing negative impacts
- Understand the cumulative nature of pollution problems

## SKILLS

- Researching
- Comparing ideas and situations
- Considering alternatives
- Making decisions
- Making oral presentations

## GUEST PRESENTERS

Guest presenters could include conservationists, economists, environmental scientists, or EPA environmental protection specialists.

## BACKGROUND

Air pollution levels have grown over the years because our demand for manufactured goods, automobiles, and energy, among other things, has grown. Overall, demand for goods and services continues to increase. Air pollution is an important concern because it causes sickness and damage to property and the environment. In order to ensure that we have the resources needed to sustain life into the future, measures need to be taken now to cure some of the problems we created over time. This will involve sorting out conflicts and making choices between the things we need and the things we want. (See reading materials on "Air Pollution," "Health Effects," and "Indoor Air Quality.")

**RELATED WARM-UPS**
G

**REFER TO READING MATERIALS**
"Air Pollution"
"Health Effects"
"Indoor Air Quality"

**TARGET GRADE LEVEL**
7th - 12th

**DURATION**
2 class periods (80-90 minutes), plus library research outside class

**VOCABULARY**
Demand
Energy
Manufactured goods
Natural gas

**MATERIALS**
Chalk
Chalkboard

## WHAT TO DO

### Class #1

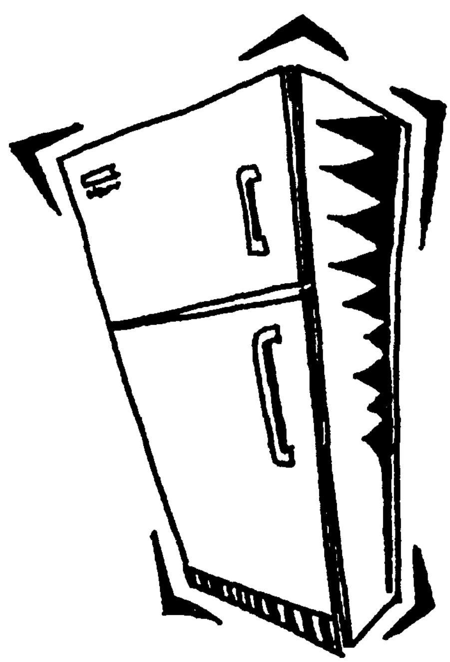
1. Start by asking students what they think life was like when their parents were children. What were their houses like? How many cars did they have? What was the traffic like? Do you think they worried about air pollution? Why (or why not)? What about your life is different than your parents'? What made things change? How did the choices your parents made influence how you live today? Explain briefly that our lives are influenced by a constant series of choices—some made by each of us as individuals, some made by our parents, and many made by people we don't even know. The combinations of all of these choices determine the quality of each of our lives.

2. The combination of choices made by individual citizens, business and industry owners, and government over the years has had a sizeable impact on the quality of the air we breathe and the air pollution problems the world faces today. Ask the class to name a few of these choices.

3. Explain that the class is going to look more closely at how things have changed since their parents were children, the air pollution problems that are the result of those changes, and what options we have for fixing those problems so the environment is healthy for future generations.

4. Divide the class into five teams. Assign each team a topic: refrigerators, computers, automobiles, electricity, natural gas.

5. Assign the teams to do research in their topic area to answer four questions: (1) How has the need and demand for it changed in the last 40 years? (2) How was the demand met? (3) What, if any, impact has that had on the environment, on the level of air pollution in particular, in the community (the nation) (the world)? (4) What alternatives are available for reducing the impact (or reversing the effect)?



6. Allow teams to organize themselves and distribute the work. Suggest that each team appoint a representative who will be responsible for making a short (5-minute) presentation during another class (give specific date but allow several days preparation time) to summarize the team's research findings. Encourage the teams to interview

their parents (and, possibly, grandparents), local government officials, and business owners in addition to doing research in the library.

7. Give students the remainder of the class to work together and assign them to continue work outside of class in order to be prepared for the second class.

**Class #2**

1. Have each team representative present the research findings from his or her team. Following each, open discussion to the class and allow students to suggest and discuss environmental (air pollution) impacts and options for improving the situation that may not have been mentioned in the presentation.

2. After all presentations have been made and discussed, have students make a list of the most useful and practical measures for reducing air pollution (at home, at school, in the community, in the nation, in the world). Record these on the chalkboard. Ask how students think the community will be different when their children are in school? Have students discuss which of these measures they will take at home and at school. Also discuss which measures students could help get started in the community (in the Nation) (in the world). Explore how they would accomplish that.

## SUGGESTED EXTENSIONS (OPTIONAL)

- Have students track, using the newspaper or television news, real air pollution-related decisions made by government and industry. Set aside time periodically to discuss these actions and their potential impact on improving the environment in the future.

## SUGGESTED READING


Becklake, John. *Thinking for the Future: Pollution.* New York: Gloucester Press (1990).

Miller, Willard E. *Environmental Hazards: Air Pollution, A Reference Handbook.* Santa Barbara, CA: ABC-Clio (1989).

Rock, Maxine. *The Automobile and the Environment.* New York: Chelsea House Publishers (1992).

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# ACTIVITY 17

# THE BUSINESS OF CLEAN AIR

This activity uses a structured discussion with the class to help educators introduce the concept that air pollution control is caused by a combiNation of market incentives and government regulation. While nobody "likes" air pollution, or causes it intentionally, there are tradeoffs associated with pollution control. Businesses are motivated by profit, and will change their way of doing business if they can see a demonstrated benefit. This activity is related to the warm-up called "Making Decisions." Related activities include "The Greenhouse Effect," "Climate and the Greenhouse Effect," and "The Cost of Polluting."

## CRITICAL OBJECTIVES

- Realize that businesses exist to make profits for their owners
- Recognize that governments make rules for individuals and businesses in order to establish minimum standards to protect society (human health and well being, ecology)
- Understand that businesses change as a result of market forces and regulations
- Appreciate that pursuing environmental concerns and realizing a profit can be competing objectives for a business
- Realize that pursuing environmental concerns and realizing a profit can be complementary objectives for a business

## SKILLS

- Observing
- Collecting data
- Computing

## GUEST PRESENTERS

Guest presenters for this activity could include air quality engineers, business administrators, economists, industrial engineers, lawyers, or mechanical engineers.

## BACKGROUND

Air pollution in this country is largely a result of business decisions, set in motion many years ago, that emphasize profit without balancing environmental concerns. In the 1960s, the federal government began to regulate pollution. The Clean Air Act was one of the first laws intended to govern the release of certain pollutants into the atmosphere. In recent years, many businesses have embraced the "green" approach to marketing, recognizing the image value of environmen-

**RELATED WARM-UP**
G

**REFER TO READING MATERIALS**
"The Greenhouse Effect"
"Air Pollution"

**TARGET GRADE LEVEL**
8th - 12th

**DURATION**
1 or 2 45-minute class periods, depending on the depth of discussions

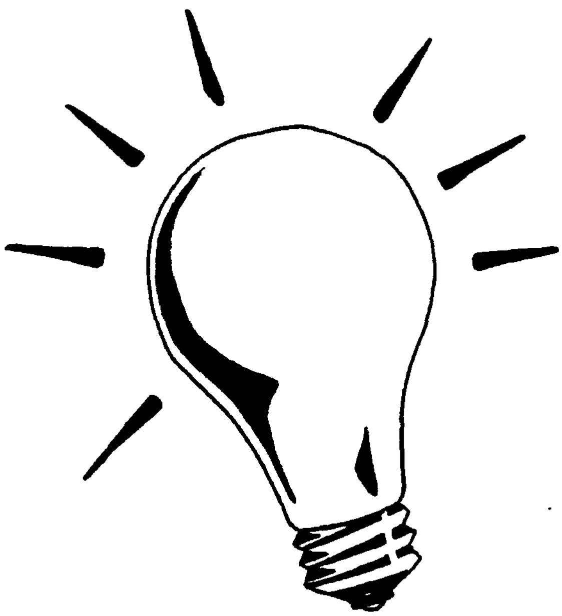
**VOCABULARY**
Amortization
Capital costs
Kilowatt-hour
Lumens
Market forces
Mitigation
Pollution
Power consumption
Profit
Regulations

**MATERIALS**
Chalk
Chalkboard

**WORKSHEETS INCLUDED**
1

tal consciousness. However, the primary motivation for business is to make a profit.

Pollution control and environmental improvement is big business. An estimated $115 billion is spent annually on environmental protection. The federal government will spend $1.9 billion during the six-year period 1994-2000 to implement its *Climate Change Action Plan.* This plan, which is expected to save the government $2.7 billion during that same period, is designed to slow the greenhouse effect, reduce air emissions, and stimulate the economy.



EPA and other organizations have instituted voluntary compliance programs using the "penny-saved, penny-earned" principles of business to encourage wholesale improvements in energy efficiency and waste minimization. Such initiatives as the "Green Lights" program, which encourages businesses to cut back on electric lighting, are estimated to have a potential National savings of $16 billion in electricity bills and reduce carbon dioxide, sulphur dioxide, and nitrogen oxides (the principle ingredients of air pollution and smog) by 12 percent, thereby slowing the greenhouse effect. What's in it for business? The obvious answer is significantly reduced costs of operation, providing capital for new jobs and increased productivity. In addition, in return for signing an agreement with EPA to upgrade its lighting, a business will receive technical advice, free publicity, and possible financial support. EPA's newer "Energy Star" program is a sequel, encouraging business to improve energy efficiency throughout the building—beyond just installing energy-saving light bulbs. (See the reading materials called "The Greenhouse Effect" and "Air Pollution.")

## WHAT TO DO

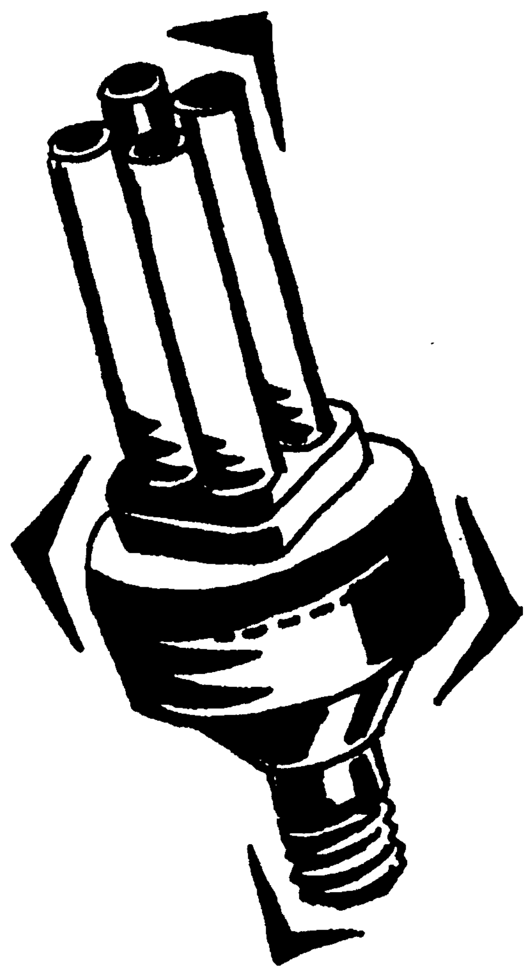
1. Tell the class to consider all the reasons why air pollution exists, why it isn't cleaned up, and what the possible roles of government, the public, and businesses are as forces in the issue. Write the responses on the chalkboard. Suggest that someone volunteer a couple of industries that might be associated with air pollution. (Common examples might be electric power generation, pulp and paper manufacturing, or oil refining. Less common, but also good, examples are surface mining (dust), steel manufacturing (coke/coal burning), agriculture (dust and chemical aerosols), or airlines (fuel vapors and exhaust).

2. As one example of how businesses can contribute to reducing air pollution, tell the class about EPA's voluntary "Green Lights" program. This program encourages businesses to conserve electricity by identifying and implementing lighting upgrades in their buildings wherever

it is "profitable" within five years. "Profitable" means, in this case, that the savings are greater than about six percent per year. In return for their participation in the program, EPA helps businesses obtain the most current information about energy-efficient lighting technologies, assists them in deciding which technologies are best for them, and provides guidance on how to finance the upgrades.

3. Explain that, for the purpose of this activity, students are to pretend that the school building is a commercial business building. Have them identify any "costs" to the "business" involved in conserving electricity that might offset any savings realized. For example, shutting down the school totally, while a popular suggestion that would certainly save electricity, would prevent the school from conducting its business. Ask the class to identify the beneficiaries of this "profit." Ask them to identify the secondary effects if such a practice were really implemented widely in their community (less generation costs, fewer brownouts, less pollution, less fuel used to produce electricity, etc.)

Energy efficiency is based on "getting something for nothing." For electric lighting, we want to obtain the same level of light (usually measured in lumens) for less consumption of power (usually measured in watts). The student worksheet called "Light Conversion" is formatted for conversion of incandescent lights to compact fluorescents, but the same principle applies for replacing older, low-efficiency fluorescents with high-efficiency fluorescent lighting. The same principle applies in turning off electrical devices when they are not in use, such as computers, televisions, air conditioners, and motors.



4. Hand out the worksheet. Divide the class into workable groups to identify all the electric lights in the school. The groups should look at common rooms such as the auditorium, gym, and cafeteria as well as the classrooms. The teacher may wish to assign certain rooms or locations to different groups to check at a time when rooms are not occupied by students. Students should not overlook spotlights or floodlights. Have the class compile a list of electricity reductions that could be accommodated within the school. For each reduction, have them identify what the potential savings could be, or at least how they could measure the savings. Get them to talk about the need to invest money up-front (for example, replacing incandescent lamps with fluorescent ones) in order to realize a long-term payback.

5. It obviously costs money to buy more energy-efficient equipment, even lightbulbs. In order to determine the true savings of such devices, have the class calculate a "payback" period for some devices. For example, a 60-watt bulb costs 89¢ and will last for 1,000 hours. A 13-watt compact replacement tube costs $6, but will last 10,000 hours. What is the savings, and what is the payback period? Explain to the class about two types of costs: *capital costs* and *operating costs*. *Capital Costs* are costs involved in purchasing or building something that is necessary to have. For example, a business's capital costs include the purchase prices of the furniture and equipment needed to provide the services or produce the goods it sells. Capital costs are usually divided by the expected life-span of the equipment to get an annualized cost. *Operating Costs* are the day-to-day costs involved in providing the services or producing the goods. For example, the total cost of transportation includes buying a car and then keeping it running. The capital (one-time) cost might be $15,000. If the car is expected to last 5 years, the annualized capital cost would be $3,000. Operating (recurring) costs include gasoline, oil, tires, insurance, normal repairs, and anything else needed to keep it running.

6. Have the class calculate the payback period of investing in high-efficiency light bulbs to replace existing bulbs throughout the school.

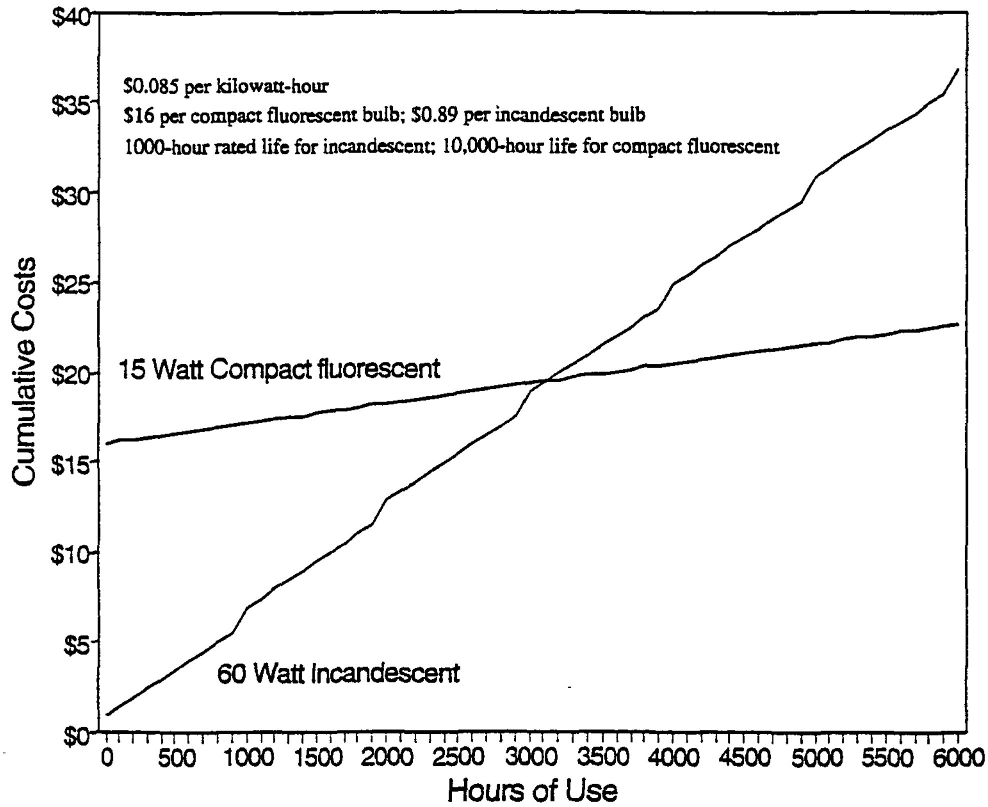
   Purchasing one high-efficiency tube requires a capital investment of $16, but lasts as long as 10 of the 89¢ bulbs.

   To obtain 1,000 hours of light from the incandescent bulb, it costs:
   60 watts x 1000 hours ÷ 1000 = 60 kilowatt-hours x 8.5¢/kWh =
   $5.10 (operating cost) + $0.89 (capital cost) = $5.99

   To obtain 10,000 hours from the high-efficiency bulb, it costs:
   13 watts x 10,000 hours ÷ 1000 = 130 kilowatt-hours x 8.5¢/kWh =
   $11.05 (operating cost) + $16.00 (capital cost) = $27.05

   Put another way, it will have cost us about $60 to obtain the same lighting from 60-watt incandescent bulbs as we could get for about $27 from one compact fluorescent tube.

   For example, the chart below shows the costs for each type of bulb measured against hours of use. While the compact fluorescent costs more to start, its lower operating costs allow the incandescent bulb to catch up and become more expensive after about 3,100 hours of use. This "payback" graph shows how long it will take to amortize the higher




capital cost of the fluorescent. If we use about 250 hours per month, our payback time will be about 12.4 months or just over one year.

7. Compile the "Green Lights" suggestions and audit results and forward them to the Principal and the School Board with an explaNation of how and why they were developed.

## SUGGESTED EXTENSIONS (OPTIONAL)

- Organize the class into several groups. Each will role-play a particular segment of business or industry. The groups could include: the local electric power utility, the local car dealer, a major local industry (let's say an airplane manufacturer or shipbuilder), and the local downtown business council. Tell them that their community is in danger of violating the federal and state air pollution standards for hazardous air pollutants. No one knows where the pollutants are actually coming from, but it is known that they exist in the aircraft/shipbuilding industry and as a by-product of automobile and truck emissions.

  Have each group write down a list of actions that should be taken by each of the groups and the reasons why. Instruct them to focus on the actions that their own group should take first, then the others. The groups should work independently, and should not exchange views until the end. Caution the groups that they should anticipate the actions that they think the other groups will expect them to take and be prepared to explain (defend) their choices. This activity could take portions of several days, or be done as homework over a weekend.

When the groups are ready, have them present to the class their "action plans" to solve the problem. Write down the key actions for each group on the chalkboard. Have the class compare and discuss them.

- Have students find a large business in your community that has an energy-conservation program in place like "Green Lights." Select a team of students to contact the company and ask them for data and computations on the savings they are realizing. Ask how the company is investing the savings realized from lower electricity bills. Have the students report back to class and discuss the information obtained.

- Does your local utility ever have a "brownout?" A "brownout" is when the power company reduces the line voltage from the normal 110 to 90 or even 80 volts. Most household equipment will work at the lower voltage. Have students contact the local power company and ask why and when the power company uses "brownouts?" Does this save wattage? How much?

- Have selected students contact a lighting supplier or lighting contractor (look in the *Yellow Pages*) and ask them for pricing data and specifications for "T-8 Lamp-ballast upgrades" for the standard 40-watt fluorescent tube systems in your school. Based upon the number of fixtures and the number of lamps, have the students calculate the annual savings in operating costs and the payback period for the conversion, taking into account the initial capital investment for the new lighting.

## SUGGESTED READING

Bhargava, Sunita Wadekar. "Growing Clean Air Down on the Algae Farm." *Business Week*, (24 February 1992) p. 72.

Brooks, Philip L., Laura J. Davidson, and Jodi H. Palamides. "Environmental Compliance: You Better Know Your ABCs." *Occupational Hazards*, 55 (February 1993) p. 41.

*Business and the Environment: Toward Common Ground.* Washington, DC: Conservation Foundation (1984).

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Nelson-Horchler, Joani. "Greening or Greenwashing? Industry Efforts Get Praise and Punches." *Industry Week*, 239 (16 April 1990) p. 77.

O'Hara, Gregory P. "Compliance Audit Can Keep Firm Out of a Tangled Web of Regulations." *Business Journal*, 9 (17 February 1992) p. S18.

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Ruckelshaus, William D. "Towards a Sustainable World." *Scientific American* (September 1989) p. 166.

Sheridan, John H. "Pollution Prevention Picks Up Steam." *Industry Week*, 241 (17 February 1992) p. 36.

U.S. EPA. *Green Lights: An Enlightened Approach to Energy Efficiency and Pollution Prevention.* Washington, DC: U.S. EPA, Office of Air and Radiation EPA/430/K-93/001 (July 1993).

Weinstock, Matthew P. "Environmental Auditing: A Measure of Safety." *Occupational Hazards*, 55 (May 1993) p. 73.

# STUDENT WORKSHEET 1
# THE BUSINESS OF CLEAN AIR
## LIGHT CONVERSION

Electric Lighting Savings Audit Worksheet (Example)

Starting with:

| Quant. | Device | Existing Unit Wattage | Replacement Unit Wattage | Unit Savings (Watts) | Total Savings (Watts) [1] | Avg. Daily Use (Hrs.) | Savings in Kilowatt-Hours/Year [2] | Savings/yr @ 8.5¢/kWh [3] | |
|---|---|---|---|---|---|---|---|---|---|
| 16 | Std Incandescent | 60 | 13 | 47 | 752 | 8 | 2,196 | $187 | [4] |
| 16 | Std 40-watt fluorescent | 40 | 32 | 8 | 128 | 8 | 374 | $32 | [5] |
| ___ | Std Incandescent | 15 | 5 | ___ | ___ | ___ | ___ | ___ | |
| ___ | Std Incandescent | 60 | 13 | ___ | ___ | ___ | ___ | ___ | |
| ___ | Std Incandescent | 75 | 18 | ___ | ___ | ___ | ___ | ___ | |
| ___ | Std Incandescent | 100 | 27 | ___ | ___ | ___ | ___ | ___ | |
| ___ | Std Incandescent | 150 | 44 | ___ | ___ | ___ | ___ | ___ | |
| ___ | Std Incandescent | 300 | 150 | ___ | ___ | ___ | ___ | ___ | |
| ___ | Std Incandescent | ___ | ___ | ___ | ___ | ___ | ___ | ___ | |
| ___ | Std Incandescent | ___ | ___ | ___ | ___ | ___ | ___ | ___ | |
| ___ | Std Incandescent | ___ | ___ | ___ | ___ | ___ | ___ | ___ | |
| ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | |
| ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | |
| ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | |
| | | | | Totals: [6] | ___ | | ___ | ___ | |

Annual Reduction in Air Pollutants [7]

| | | |
|---|---|---|
| Carbon dioxide reduction (1.5 lbs per kWh) | ___ | pounds |
| Sulfur dioxide reduction (5.8 grams per kWh) | ___ | grams |
| Nitrogen dioxide reduction (2.5 grams per kWh) | ___ | grams |

Notes:
1. Total savings is estimated by multiplying Quantity by Unit Savings.
2. Example for 16 60-watt incandescent bulbs replaced by 16 13-watt compact fluorescent lamps.
3. Example for 16 40-watt standard 4' fluorescent lamps replaced by 16 34-watt argon-krypton lamps.
4. Kilowatt-Hours per Year is estimated by multiplying total wattage x average daily use in hours x 365 days/year divided by 1000.
5. Savings per year is estimated by multiplying 8.5¢ per kWh times kWh savings per year.
6. Add up the values for the three columns. Ignore the values for the examples shown on the first two lines.
7. To calculate annual reduction in pollution, multiply Total Savings in Kilowatt-Hours/Year by each of the pollutant values in the list below.

# ACTIVITY 18

# AIR POLLUTION ALLOWANCE TRADING

This exercise introduces students to pollution abatement measures based on free market trading of pollution allowances. The class is broken up into six groups, each representing an industry subject to a fictitious Air Pollution Allowance Trading System. They are given a set of facts and conditions and will be required to make a series of decisions in order to comply with environmental regulations, as well as determine the price of a pollution allowance, and whether to implement pollution control measures. This activity is related to the "Making Decisions" warm-up and the "Cost of Polluting" activity.

## CRITICAL OBJECTIVES

- Recognize the costs of pollution abatement
- Recognize how costs are allocated and can be shared
- Decide how to allocate scarce resources
- Recognize the benefits of the free market in pollution abatement (rewarding good behavior)
- Learn to analyze environmental issues

## SKILLS

- Computing
- Analyzing data
- Drawing conclusions
- Explaining results

## BACKGROUND

There are several different types of pollution control measures that the government imposes on polluters to achieve compliance with environmental regulations. "Point source" controls impose standards on the emissions coming out of a facility (such as a factory) without regard to the cost of achieving the standard or the mixture of that discharge with other point source discharges in the local environment. Another method concentrates on the level of pollution in the local area (such as a river segment or air within a city's boundaries), requiring some sort of pollution reduction measures when the area is out of compliance. This latter method is used under the Clean Air Act, but has been difficult to enforce given the large number of individual air pollution sources that exist (for example, automobiles).

Under an allowance trading system, large stationary sources of air pollution, such as power plants, receive a certain number of "pollution allowances" for a specified period of time, based on local clean

**RELATED WARM-UP**
G

**REFER TO READING MATERIALS**
"Air Pollution Allowance Trading"

**TARGET GRADE LEVEL**
7th - 12th

**DURATION**
45 minutes

**VOCABULARY**
Allowance
Bank
Compliance
Discharge
Point source

**MATERIALS**
Scratch paper
Calculators (optional)

**WORKSHEETS INCLUDED**
6

air standards and allocated to the sources according to their historic fuel consumption and a specified emissions rate for the source. Allowances are in units of pollutant emitted, so a polluter will use up its allowances as it pollutes. The key to the system is that these allowances may be traded between sources, or may be "banked." At the end of the period, each source must have enough allowances to balance its emissions for that period, otherwise a penalty on each excess unit of pollution is imposed. The goal of this system is to use market incentives of rewards and penalties to reduce pollution, allowing polluters to make their own decisions as to how to expend their allocation of pollution allowances.

**EXAMPLE**

An electric utility, Metropolis Power and Light (MP&L) wants to install a certain pollution reduction technology at one of its electricity generation plants that will cost $100,000. Without an allowance system, MP&L may not be rewarded for doing the right thing, and has no other incentive to do so. However, under an allowance trading system, MP&L would save four allowances if it installs the clean air equipment and reduces its emissions of pollution. MP&L can sell the allowances in the pollution allowance market and recover part or all of the money it spent on the equipment, or even receive compensation above the amount spent.

Another utility, Commonwealth Gas and Electric (CG&E) does not implement any pollution reduction measures. During the year, CG&E has used up all of its allowances and is going to pay $250,000 in fines for pollution in excess of its allowances. CG&E estimates that it is 4 allowances short for the period and is willing to pay MP&L up to $250,000 for four allowances. Hence, MP&L, by implementing pollution reduction measures at a cost of $100,00, is rewarded the difference between that cost and the market value of the allowances it saves (in this example, $250,000 - $100,000 = $150,000 to MP&L).

## WHAT TO DO

1. Discuss the material presented in the above background section. Discuss the different ways that air pollution laws are enforced, and the different methods that may be used to reduce pollution. Explain how the pollution allowance system can reduce pollution by using incentives and market forces to encourage pollution reduction. Present the above example on the blackboard.

2. Break the class up into six groups and distribute facts and conditions. Each group receives the one page sheet entitled "Pollution Allowance Trading Game." Each individual group also receives the appropriate "scor-

ing" sheet, labeled "Group 1," "Group 2," and so on. Briefly explain the concepts and rules of the game, reading the fact sheets along with the students. The goal of the game is to make the most money through the trading and saving of pollution allowances. Have students read the fact sheets and answer any questions. Tell them that the game will be played for five rounds. A round represents one year. Each year they will receive a number of allowances that may increase or decrease, but they do not know what those changes will be.

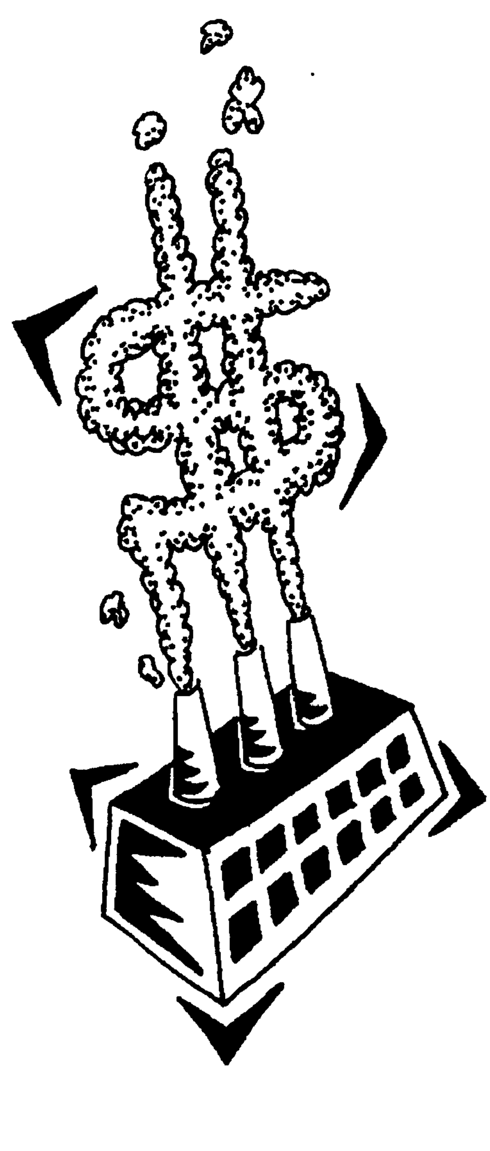
3. Have the groups complete questions 1 through 3 on each worksheet. After completing questions 1 through 3, each group will have to make three decisions: whether to sell or buy allowances; whether to pay for pollution abatement technology; and whether to bank allowances or pay fines. Remind the groups that pollution abatement technology is permanent, and will carry over year to year. Tally the number of allowances that are available from all groups. Have any groups complete question 4, and re-tally the number of extra allowances available. Then commence the trading of allowances through the auctioning of allowances (the teacher or a student may act as auctioneer). Have groups answer remaining questions. If allowances are bought and sold, how much does an allowance cost? Why?

4. For the second round, each group will again receive ten allowances. Repeat the steps from the previous round, making sure that they carry over any banked allowances and taking into account units of technology purchased. Has the price of an allowance changed? Why?

5. For the third round, each group receives only 8 allowances. Do not let students know that this change is coming. Repeat steps on worksheets. Record changes in allowance prices, technology purchasing patterns, fines paid out, and allowance banking.

6. For the fourth round (Year 4) distribute 11 allowances per group. Record changes as above.

7. Year 5 is back to 10 allowances per group. Record changes and determine the winner based on the value of the allowances in hand minus any fines paid. Have students discuss the results. Who did the best? Why? At the beginning of the game, Group 5 was in the best position. Did they maintain their lead? How did Group 4 fare? Why? Compare Groups 1 and 2, who began on even footing. Did one do better than the other? Why?



8. Have students discuss the usefulness of an allowance trading system, in particular the incentive to reduce emissions through the use of pollution reduction technology. Note that the number of allowances distributed for the first round was less than the total amount of emissions? Ask students how and why they think fines would be built into the game from the outset.

## SUGGESTED EXTENSIONS (OPTIONAL)

- Teachers should feel free to alter the facts. For example, the price of pollution abatement technology may change from year to year, or fines may change. The results need only reflect the current conditions and prices, and some results may be "unreasonable."

## SUGGESTED MODIFICATIONS

- For higher grades, have students consider alternatives to this system and consider the choices they would face and make if they were the regulator. Focus a class discussion on the topic or have students prepare and deliver oral presentations about their ideas.

## SUGGESTED READING

Kohn, Robert E. "Exposure Trading: An Approach to More Efficient Air Pollution Control." *Journal of Environmental Economics and Management*, 21 (July 1991) p. 82.

Mann, Eric. "Trading Delusions." *Environmental Action Magazine*, 25 (December 1994) p. 22.

Miller, William H. "Free Market Comes to Environmentalism." *Industry Week*, 242 (19 April 1993) p. 59.

"Pollution for Sale." *U.S. News and World Report*, 111 (29 July 1991) p. 9.

"Pollution Swap May Halve Utility Emissions." *National Geographic*, 184 (December 1993) p. 142.

Sheridan, John H. "Pollution Prevention Picks Up Steam." *Industry Week*, 241 (17 February 1992) p. 36.

# STUDENT HANDOUT 1

## AIR POLLUTION ALLOWANCE TRADING

### AIR POLLUTION ALLOWANCE TRADING GAME

For this exercise, each group has been given a role and an individual set of facts outlining the rules and circumstances going into the pollution allowance trading game. Each group represents a public utility that emits air pollution, however, the amount each can emit is limited by the government. A group will be penalized for exceeding air pollution limits. For each round of the game, each group will receive a certain number of air pollution allowances that represent a portion of the amount of pollution they are allowed to emit. If a group does not use up all of its allowances, it can trade or bank remaining allowances. For example, if a group receives 5 allowances, and each allowance permits 1,000 tons of pollution, then the group's factory can emit 5,000 tons of pollution. Any excess would be subject to a fine. If the group emits 3,000 tons, then it will only use up 3 of its allowances, and may then sell or bank the other 2. If the group emits 7,000 tons of pollution, it will be penalized unless it purchases extra allowances or has banked allowances.

There will be five rounds of trading. Each round represents one year. At the beginning of each round, each group will receive an allocation of allowances. For each round, the number of allowances received will be the same for each group, however, the number of allowances may increase or decrease from round to round. Extra allowances banked during one round may be used during subsequent rounds.

In addition to deciding whether to buy, sell, or bank allowances, a group may also decide to purchase pollution reduction technology. Technology units cost $2,000. Each unit provides 500 tons of annual pollution reduction. Technology units reduce pollution beginning in the year they are purchased and will continue to provide pollution reduction in subsequent rounds. In no event can a group emit less than 5,000 tons per year.

An allowance permits the emission of 1,000 tons of air pollution. The penalty for exceeding the allowance limit is $1 per ton per year.

TO RECAP:
5 rounds of trading.
Allowances are distributed at the beginning of each round.
An allowance permits 1,000 tons of pollution.
Extra allowances may be bought and sold, or banked (saved for use in future rounds).
Penalties = $1 per ton in excess of allowances.
Pollution reduction technology costs $2,000 per unit.
Technology reduces pollution by 500 tons per round.
Technology is permanent.
A group can not emit less than 5,000 tons per round

# STUDENT WORKSHEET 1

## AIR POLLUTION ALLOWANCE TRADING

### AIR POLLUTION ALLOWANCE TRADING GAME

### GROUP 1

You are a coal-burning electric power utility with a single power plant. You have received 10 pollution allowances for the first year. The number of allowances you will receive in future rounds is unknown. Based on your current projections, you will emit 10,000 tons of pollution annually in the coming 5 years.

1. Calculate your pollution emission allowance for the year.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

2. Do you have any extra allowances for the year (is your annual pollution emission less than your total allowances in hand)?
   a) NO, skip to question 3
   b) YES, how many (you can skip question 3)?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

3. Did you exceed your allowances (is your annual pollution emission greater than your total allowances in hand)?
   a) YES, how many extra allowances do you need?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

   b) Calculate any penalties you will pay if you are not able to purchase extra allowances.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

   c) How much would you be willing to pay for an allowance? Divide the penalty amount by the number of allowances you need.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

The auctioneer (your teacher) will now tally the number of allowances available.

4. Before trading begins, would you like to purchase pollution reduction technology? If yes, how many units?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

   Recalculate your annual pollution emissions.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

The auctioneer will now re-tally the number of allowances available. Now begin trading. Some groups have extra allowances that they may wish to sell, while others will be paying fines if they do not acquire extra allowances. Note that groups with extra allowances do not have to sell them if the selling price is not high enough. They can bank them for use or sale in later rounds.

5. How did your group end up at the end of the year (+/-)? (include money received for extra allowances sold, money paid in penalties or for extra allowances needed, money paid for pollution reduction technology, and the number of allowances banked)

Year 1: ________ Year 2: ________ Year 3: ________ Year 4: ________ Year 5: ________

6. What is the current price of an allowance?
Year 1: ________ Year 2: ________ Year 3: ________ Year 4: ________ Year 5: ________

Now go on to the next round. Your teacher will tell you the number of allowances each group will receive. Remember that this number may go up or down. For each round, fill in the above work sheet, recording the results of each round of trading. Be sure to keep track of your current account: the amount (+ or -) that your group has had earned or spent.

# STUDENT WORKSHEET 2

## AIR POLLUTION ALLOWANCE TRADING

### AIR POLLUTION ALLOWANCE TRADING GAME

**GROUP 2**

You are a coal-burning electric power utility with a single power plant. You have received 10 pollution allowances for the first year. The number of allowances you will receive in future rounds is unknown. Based on your current projections, you will emit 10,000 tons of pollution annually in the coming 5 years.

1. Calculate your pollution emission allowance for the year.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

2. Do you have any extra allowances for the year (is your annual pollution emission less than your total allowances in hand)?
   a) NO, skip to question 3
   b) YES, how many (you can skip question 3)?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

3. Did you exceed your allowances (is your annual pollution emission greater than your total allowances in hand)?
   a) YES, how many extra allowances do you need?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

   b) Calculate any penalties you will pay if you are not able to purchase extra allowances.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

   c) How much would you be willing to pay for an allowance? Divide the penalty amount by the number of allowances you need.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

The auctioneer (your teacher) will now tally the number of allowances available.

4. Before trading begins, would you like to purchase pollution reduction technology?
   If yes, how many units?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

   Recalculate your annual pollution emissions.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

The auctioneer will now re-tally the number of allowances available. Now begin trading. Some groups have extra allowances that they may wish to sell, while others will be paying fines if they do not acquire extra allowances. Note that groups with extra allowances do not have to sell them if the selling price is not high enough. They can bank them for use or sale in later rounds.

5. How did your group end up at the end of the year (+/-)? (include money received for extra allowances sold, money paid in penalties or for extra allowances needed, money paid for pollution reduction technology, and the number of allowances banked)
   Year 1: ________ Year 2: ________ Year 3: ________ Year 4: ________ Year 5: ________

6. What is the current price of an allowance?
   Year 1: ________ Year 2: ________ Year 3: ________ Year 4: ________ Year 5: ________

Now go on to the next round. Your teacher will tell you the number of allowances each group will receive. Remember that this number may go up or down. For each round, fill in the above work sheet, recording the results of each round of trading. Be sure to keep track of your current account: the amount (+ or -) that your group has had earned or spent.

# STUDENT WORKSHEET 3

## AIR POLLUTION ALLOWANCE TRADING

### AIR POLLUTION ALLOWANCE TRADING GAME

### GROUP 3

You are a coal-burning electric power utility with a single power plant. You have received 10 pollution allowances for the first year. The number of allowances you will receive in future rounds is unknown. Based on your current projections, you will emit 9,000 tons of pollution annually in the coming 5 years.

1. Calculate your pollution emission allowance for the year.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

2. Do you have any extra allowances for the year (is your annual pollution emission less than your total allowances in hand)?
   a) NO, skip to question 3
   b) YES, how many (you can skip question 3)?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

3. Did you exceed your allowances (is your annual pollution emission greater than your total allowances in hand)?
   a) YES, how many extra allowances do you need?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

   b) Calculate any penalties you will pay if you are not able to purchase extra allowances.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

   c) How much would you be willing to pay for an allowance? Divide the penalty amount by the number of allowances you need.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

The auctioneer (your teacher) will now tally the number of allowances available.

4. Before trading begins, would you like to purchase pollution reduction technology?
   If yes, how many units?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

   Recalculate your annual pollution emissions.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

The auctioneer will now re-tally the number of allowances available. Now begin trading. Some groups have extra allowances that they may wish to sell, while others will be paying fines if they do not acquire extra allowances. Note that groups with extra allowances do not have to sell them if the selling price is not high enough. They can bank them for use or sale in later rounds.

5. How did your group end up at the end of the year (+/-)? (include money received for extra allowances sold, money paid in penalties or for extra allowances needed, money paid for pollution reduction technology, and the number of allowances banked)

   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

6. What is the current price of an allowance?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

Now go on to the next round. Your teacher will tell you the number of allowances each group will receive. Remember that this number may go up or down. For each round, fill in the above work sheet, recording the results of each round of trading. Be sure to keep track of your current account: the amount (+ or -) that your group has had earned or spent.

# STUDENT WORKSHEET 4

## AIR POLLUTION ALLOWANCE TRADING

### AIR POLLUTION ALLOWANCE TRADING GAME

### GROUP 4

You are a coal-burning electric power utility with a single power plant. You have received 10 pollution allowances for the first year. The number of allowances you will receive in future rounds is unknown. Based on your current projections, you will emit 16,000 tons of pollution annually in the coming 5 years.

1. Calculate your pollution emission allowance for the year.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

2. Do you have any extra allowances for the year (is your annual pollution emission less than your total allowances in hand)?
   a) NO, skip to question 3
   b) YES, how many (you can skip question 3)?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

3. Did you exceed your allowances (is your annual pollution emission greater than your total allowances in hand)?

a) YES, how many extra allowances do you need?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

b) Calculate any penalties you will pay if you are not able to purchase extra allowances.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

c) How much would you be willing to pay for an allowance? Divide the penalty amount by the number of allowances you need.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

The auctioneer (your teacher) will now tally the number of allowances available.

4. Before trading begins, would you like to purchase pollution reduction technology?
   If yes, how many units?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

   Recalculate your annual pollution emissions.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

The auctioneer will now re-tally the number of allowances available. Now begin trading. Some groups have extra allowances that they may wish to sell, while others will be paying fines if they do not acquire extra allowances. Note that groups with extra allowances do not have to sell them if the selling price is not high enough. They can bank them for use or sale in later rounds.

5. How did your group end up at the end of the year (+/-)? (include money received for extra allowances sold, money paid in penalties or for extra allowances needed, money paid for pollution reduction technology, and the number of allowances banked)

Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

6. What is the current price of an allowance?
Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

Now go on to the next round. Your teacher will tell you the number of allowances each group will receive. Remember that this number may go up or down. For each round, fill in the above work sheet, recording the results of each round of trading. Be sure to keep track of your current account: the amount (+ or -) that your group has had earned or spent.

# STUDENT WORKSHEET 5

## AIR POLLUTION ALLOWANCE TRADING

### AIR POLLUTION ALLOWANCE TRADING GAME

#### GROUP 5

You are a coal-burning electric power utility with a single power plant. You have received 10 pollution allowances for the first year. The number of allowances you will receive in future rounds is unknown. Based on your current projections, you will emit 7,000 tons of pollution annually in the coming 5 years.

1. Calculate your pollution emission allowance for the year.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

2. Do you have any extra allowances for the year (is your annual pollution emission less than your total allowances in hand)?
   a) NO, skip to question 3
   b) YES, how many (you can skip question 3)?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

3. Did you exceed your allowances (is your annual pollution emission greater than your total allowances in hand)?
   a) YES, how many extra allowances do you need?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

   b) Calculate any penalties you will pay if you are not able to purchase extra allowances.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

   c) How much would you be willing to pay for an allowance? Divide the penalty amount by the number of allowances you need.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

The auctioneer (your teacher) will now tally the number of allowances available.

4. Before trading begins, would you like to purchase pollution reduction technology?
   If yes, how many units?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

   Recalculate your annual pollution emissions.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

The auctioneer will now re-tally the number of allowances available. Now begin trading. Some groups have extra allowances that they may wish to sell, while others will be paying fines if they do not acquire extra allowances. Note that groups with extra allowances do not have to sell them if the selling price is not high enough. They can bank them for use or sale in later rounds.

5. How did your group end up at the end of the year (+/-)? (include money received for extra allowances sold, money paid in penalties or for extra allowances needed, money paid for pollution reduction technology, and the number of allowances banked)

   Year 1: ________ Year 2: ________ Year 3: ________ Year 4: ________ Year 5: ________

6. What is the current price of an allowance?
   Year 1: ________ Year 2: ________ Year 3: ________ Year 4: ________ Year 5: ________

Now go on to the next round. Your teacher will tell you the number of allowances each group will receive. Remember that this number may go up or down. For each round, fill in the above work sheet, recording the results of each round of trading. Be sure to keep track of your current account: the amount (+ or -) that your group has had earned or spent.

# STUDENT WORKSHEET 6

## AIR POLLUTION ALLOWANCE TRADING

### AIR POLLUTION ALLOWANCE TRADING GAME

### GROUP 6

You are a coal-burning electric power utility with a single power plant. You have received 10 pollution allowances for the first year. The number of allowances you will receive in future rounds is unknown. Based on your current projections, you will emit 12,000 tons of pollution annually in the coming 5 years.

1. Calculate your pollution emission allowance for the year.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

2. Do you have any extra allowances for the year (is your annual pollution emission less than your total allowances in hand)?
   a) NO, skip to question 3
   b) YES, how many (you can skip question 3)?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

3. Did you exceed your allowances (is your annual pollution emission greater than your total allowances in hand)?
   a) YES, how many extra allowances do you need?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

   b) Calculate any penalties you will pay if you are not able to purchase extra allowances.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

   c) How much would you be willing to pay for an allowance? Divide the penalty amount by the number of allowances you need.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

The auctioneer (your teacher) will now tally the number of allowances available.

4. Before trading begins, would you like to purchase pollution reduction technology? If yes, how many units?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

   Recalculate your annual pollution emissions.
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

The auctioneer will now re-tally the number of allowances available. Now begin trading. Some groups have extra allowances that they may wish to sell, while others will be paying fines if they do not acquire extra allowances. Note that groups with extra allowances do not have to sell them if the selling price is not high enough. They can bank them for use or sale in later rounds.

5. How did your group end up at the end of the year (+/-)? (include money received for extra allowances sold, money paid in penalties or for extra allowances needed, money paid for pollution reduction technology, and the number of allowances banked)

   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

6. What is the current price of an allowance?
   Year 1: _______ Year 2: _______ Year 3: _______ Year 4: _______ Year 5: _______

Now go on to the next round. Your teacher will tell you the number of allowances each group will receive. Remember that this number may go up or down. For each round, fill in the above work sheet, recording the results of each round of trading. Be sure to keep track of your current account: the amount (+ or -) that your group has had earned or spent.

# ACTIVITY 19

# THE COST OF POLLUTING

Though there are laws restricting almost every type of pollution, there are still polluters. This activity sheds light on why this occurs, focusing on the decisions that lawmakers and regulators have to make on the severity of penalties for violation of environmental laws. It outlines the considerations leading up to the imposition of a non-compliance penalty that will help students understand how the government determines the severity of those penalties. This activity is related to the "Making Decisions" warm-up and the "Air Pollution Allowance Trading" and "Writing Environmental Laws" activities.

## CRITICAL OBJECTIVES

- Recognize the costs of pollution abatement
- Recognize why pollution is regulated
- Understand decision-making for penalizing violations

## SKILLS

- Computing
- Defining issues
- Interpreting data
- Making decisions

## GUEST PRESENTERS

Guest presenters for this activity could include environmental regulators, economists, or lawyers.

## BACKGROUND

There are several different types of pollution control measures that the government imposes on polluters to achieve compliance with environmental regulations. "Point source" controls impose standards on the discharge coming out of any facility (such as a factory), typically through the issuance of a permit and a compliance monitoring system. Other types of pollution control measures may focus on overall environmental quality or other measures, but the one thing all pollution control methods share are penalties imposed on violators of environmental laws and regulations.

Although most of the regulated community complies or intends to comply with environmental laws and regulations, each year there are cases where regulated entities violate regulations and risk being caught and penalized, or fail to make themselves aware of the laws and regulations and are penalized. Penalties usually serve three functions: restitution, retribution, and deterrence. Restitution, usually through

**RELATED WARM-UP**
G

**REFER TO READING MATERIALS**
"Air Pollution Allowance Trading"

**TARGET GRADE LEVEL**
7th-8th

**DURATION**
30-40 minutes

**VOCABULARY**
Compliance
Compliance monitoring
Deterrence
Permit
Point source
Restitution
Retribution

**WORKSHEETS INCLUDED**
1

compensation, serves to cover any damage caused by the violation. Retribution is the penalty imposed for the violation itself, while deterrence is meant to prevent future violations. In environmental regulatory practice, restitution can be difficult or impossible to quantify, since damage to the environment is not easily reduced to dollars. Most penalties for environmental law violations are meant to punish bad behavior and serve to deter others from the same behavior.

Monetary fines are the most common type of penalty for violating environmental regulations, though jail terms for more egregious violations (willful circumvention, outright fraud) serve as an important deterrent. Specific penalties are not written into the law, but are set by government officials that weigh a variety of factors in determining a penalty. To serve as an important deterrence signal to the regulated community, a penalty should reflect the degree of harm or potential harm to the environment. At a minimum, monetary penalties should recover any economic benefit a violator may have gained by ignoring the law. This type of penalty ensures that facilities are not economically disadvantaged for complying with the law. Other factors that may affect the amount of a penalty include the ability to pay, degree of cooperation with regulating agencies, whether the violation was self-reported, and the strength of the case if litigation is likely.

## WHAT TO DO

### Before class begins

1. Write the following "Problem Statement" on the chalk board:

   It has been discovered that Anytown Light and Power Company has been releasing nitrogen dioxide ($NO_2$) from its smokestack in concentrations of 75 parts per million (ppm) for the last 15 days. The company's permit allows the release of $NO_2$ in concentrations not to exceed 60 ppm.

### When class begins

1. Explain how environmental regulations are enforced like other laws, through the imposition of penalties, including fines and imprisonment.

2. Call students attention to the "Problem Statement," containing the basic facts and circumstances surrounding a fictitious violation of an environmental regulation. Explain that the students will serve as government regulators and use this class period to determine a penalty to be imposed.

3. Inform students that they will be limited to imposition of monetary fines. Ask the class to identify any other information that they would like to have about the situation before making this decision. List these on the chalkboard. If necessary, prompt students by suggesting they might want to know something about the seriousness of the violation. For example, did the violation cause potential or actual harm? The

completed list could include any or all of the following considerations (which are actually weighed in determining penalties):

Factor 1: Seriousness of the violation
- extent of deviation from requirements
- potential or actual harm

Factor 2: Economic benefit for non-compliance
- costs avoided
- costs postponed

Factor 3: Duration of the violation

Factor 4: Degree of cooperation with regulators

Factor 5: History of compliance

Factor 6: Ability to pay

4. After the students have completed their list, compare it with the factors actually used by government regulators. (Use the list above, but the presenter should feel free to supplement it based on his/her own experience.) Discuss how the lists differ (if they do) and why. Then come to a consensus on the factors to be used in this class to determine the penalty for the problem violation.

5. Hand out the worksheet. Divide the class into small groups if you wish. Explain that students should use the worksheet to compute the fine (or range of fines) to be imposed. In order to do that, however, discuss how to quantify or attach a value to each factor. For each step in this process, ask students to suggest appropriate values, discuss the pros and cons of suggestions, and come to a consensus on the amount to be used. (If the class is working in small groups, each group should come to its own consensus.) The presenter's role should be to facilitate the discussion. The presenter also may add facts and circumstances to the case study, if required, to introduce more real-world issues into the decision-making experience.

6. In facilitating the discussions, the presenter should introduce the following ideas if they do not surface on their own.

- In determining the seriousness of the violation, the class should consider what indicators or evidence it would use to determine potential harm. (More than any other element, this may be a judgement call since environmental damage is not easily quantified.) Students should recognize that seriousness is a function of personal judgement based on the two elements listed under Factor 1 above. On the chalkboard, you may want to draw the following payment calculation matrix bringing

the two elements together. Have students decide the penalty amount to enter in each box.

**Extent of Deviation from Requirements**

| **Potential or Actual Harm** | | **High** | **Medium** | **Low** |
|---|---|---|---|---|
| | **High** | | | |
| | **Medium** | | | |
| | **Low** | | | |

- In determining any economic benefits that may have accrued for non-compliance, the class should recognize the difference between avoided costs (for example, the cost of required pollution reduction equipment), and postponed costs. Students also may want to consider other recoverable costs: costs the government has incurred in enforcing the law or the value of other advantages the violator may have held over competitors that complied with regulations. All economic benefits are simply added together.

- To help students in determining the relevance of the duration of the violation, explain that some environmental laws apply "seriousness" penalties for each day of non-compliance. In some cases, the total penalty attributed to the seriousness of the violation may be discounted for the number of days of non-compliance. For this activity, students should assume that 10 percent of the penalty accrues for each day of non-compliance. This means that 30 days of non-compliance would triple the penalty assessed for the seriousness of the violation.

- The other factors listed in step #3 above are less important than the first three. The students should use them to fine-tune the penalty to reward good behavior or further punish bad behavior.

- It is important to understand that ability to pay is a baseline element. That is, it presumes that the violator has the ability to pay.

7. When students have completed the worksheet, ask students if their decision might have changed for a case in which a business was unaware of the regulations and the risks of failing to act. Explain why, in reality, "ignorance of the law" is not a valid excuse. (If an EPA employee is a guest presenter, he or she may wish to cite examples of actual penalties assessed and discuss the factors EPA considered in setting the penalties, especially if factors, other than those cited in this activity, were considered.)

## SUGGESTED EXTENSION (OPTIONAL)

- Have students discuss the following two questions, in addition to completing the activity above.

  •If no penalties could be imposed, why would a business comply with regulations?

  •Are there other "penalties" that may be associated with violating environmental regulations, such as damage to reputations, that serve as incentives for compliance?

  Discuss the implications of their answers in the broad context of "being a good citizen."

## SUGGESTED MODIFICATIONS

- For grades 10 through 12, ask students to consider and suggest alternatives to the current penalty system. For instance, why wouldn't all violators be automatically shut down? Why are environmental damages difficult to quantify?

## SUGGESTED READING

*The Oil Game (Apple II computer program).* AV System (1988).

Sheridan, John H. "Pollution Prevention Picks Up Steam." *Industry Week,* 241 (17 February 1992) p. 36.

U.S. EPA. *Principles of Environmental Enforcement.* Washington, DC: U.S. EPA, Office of Enforcement (February 1992).

# STUDENT WORKSHEET 1

# THE COST OF POLLUTING

## CALCULATE A MONETARY PENALTY

Facility Name: Anytown Light and Power Company

Money the Facility Saved by Not Complying with Regulations

| | | |
|---|---|---|
| Costs avoided | | ____________ |
| Costs postponed | | ____________ |
| Total | (a) | ____________ |

Seriousness of the Violation

| | | |
|---|---|---|
| Penalty required based on potential for harm and extent of deviation from requirement | (b) | ____________ |

Adjustment for the Duration of the Violation

| | | |
|---|---|---|
| Number of days of non-compliance | (c) | ____________ |
| Total = [(b) x (10%)] x (c) | (d) | ____________ |

SUBTOTAL

| | | |
|---|---|---|
| Subtotal = (a) + (d) | (e) | ____________ |

Penalty Adjustment Factors

| | | |
|---|---|---|
| 1. Degree of cooperation (+/-) | (f) | ____________ |
| 2. History of compliance (+/-) | (g) | ____________ |
| 3. Supplemental environmental projects (+/-) | (h) | ____________ |
| 4. Ability to pay (-) | (i) | ____________ |
| Total = [(f) + (g) + (h) + (i)] x (e) | (j) | ____________ |

TOTAL PENALTY

| | | |
|---|---|---|
| Total Penalty = (e) + (j) | | ____________ |

# ACTIVITY 20

# WRITING ENVIRONMENTAL LAWS

This activity walks students through the steps and decisions that are made when drafting an environmental statute. It examines the interplay of opinions, values, beliefs, and science in the development of law. It is related to the "Scales, Rules, Standards, Policy, and Science" warm-up. Related activities include "Deciding To Clean the Air," "Air Pollution Allowance Trading," and "The Cost of Polluting."

## CRITICAL OBJECTIVES

- Recognize why governments need laws and regulations
- Identify methods to obtain information for developing laws
- Recognize conflicts that may exist between what is wanted and what is achievable
- Translate objective and subjective data into laws

## SKILLS

- Comparing ideas
- Considering alternatives
- Writing reports
- Making decisions

## GUEST PRESENTERS

Guest presenters could include air quality engineers, environmental scientists, lawyers, or politicians.

## BACKGROUND

There are many approaches to managing environmental problems. Some approaches are voluntary and set goals, but do not require compliance. Other approaches are regulatory and impose requirements for compliance. Wholly regulatory approaches that both set goals and impose requirements are often called "command and control" regulations. An enforcement mechanism is needed to ensure compliance with requirements. Voluntary and other approaches, on the other hand, may use economic incentives to induce behavior or impose pollution control technologies on pollution sources.

The enforceability of requirements impacts the cost and effectiveness of enforcement and the ultimate degree of compliance. Requirements must be clear and practical, so that both the regulated community

**RELATED WARM-UP**
H

**REFER TO READING MATERIAL**
"The Clean Air Act"

**TARGET GRADE LEVEL**
7th-12th

**DURATION**
Two class periods (80-90 minutes)

**VOCABULARY**
Compliance
Regulations
Smog

**MATERIALS**
Chalk
Chalkboard

**WORKSHEETS INCLUDED**
1

and the enforcement authority understand "the rules of the game." They must be backed up by adequate enforcement authority in order to be effective. They also should rely on inexpensive, reliable, or available technology so that unreasonable or impossible burdens will not be placed on the regulated community. Requirements that are unclear, imprecise, ambiguous, inconsistent, or contradictory will be difficult or impossible to enforce. (See reading material on "The Clean Air Act.")

## WHAT TO DO

### Before class #1 begins

1. Write the following Problem Statement on the chalkboard:

> PROBLEM: Traffic congestion and smog levels in the downtown area of our community have increased substantially in recent years. Traffic is so bad most times during the day that local buses cannot keep their schedules. Emergency vehicles cannot get through the congestion either. There have been several incidents in which heart attack victims have died, and a delay in the arrival of the ambulance or fire department has been blamed. In addition, local health authorities have reported an increase in cases of asthma and upper respiratory problems among people who live or work in the downtown area.

### Class #1

1. Explain that the class is going to write legislation to deal with the problem described on the chalkboard.

2. Divide the class into 5 teams. Assign one of the teams to serve as the city (town) council. Explain that each of the other teams will write and present a proposal to the council. The council then will vote and choose one of the proposals.

3. Hand out the student worksheet to all but the city (town) council team. Explain that the teams should use this checklist in drafting their proposals. Allow teams the maximum flexibility in preparing their proposals, but no team should be allowed to propose maintaining the status quo. All proposals should include any needed enforcement mechanisms—for example, methods to be used to enforce the law (such as citations for violations), authorization for a specific party or group (such as local police) to carry out enforcement, penalties for violations, and so on. Encourage students to talk to their parents, local city (town) council members, and business owners to help develop their proposals.

4. Instruct each team to choose one team member to be the spokesperson and present the team's proposal at the next class (give a specific date but allow a few days to prepare)

5. Instruct the city (town) council team that they will be responsible for choosing a proposal to enact into law following the proposals. Indicate that they should be prepared to justify their choice and remind them that they have a broader responsibility to the community and should be prepared, if necessary, to make a choice between their own individual views and what's best for the community as a whole.

6. Give students the remainder of the class to work together and assign them to continue work outside of class in order to be prepared for the next class.

Class #2

1. Arrange desks or a table at the front of the room with chairs to accommodate the city (town) council team members. Place a lectern, desk, or small table somewhere else in the room from which the spokespersons for the other team can present their proposals.

2. Have the spokespersons make their presentations. (You may want to suggest that one of the council team members write the salient points from each presentation on the chalkboard to help in comparing the proposals.) Allow the council team to question spokespersons as necessary to be sure they understand the proposals.

3. When presentations have been completed, give the council team a copy of the student worksheet. Have team members deliberate on the sufficiency of the proposal, using the worksheet.

4. Ask the council members to vote. Examine the results. Have the council team explain why they made the choice they did. Let students discuss the results and the process involved in writing laws. Ask students whether any of the proposals would be applicable in your community and how they would proceed to bring their ideas to the attention of local legislators.

## SUGGESTED MODIFICATIONS

- For higher grades, have students research actual local laws related to smog prevention or other air pollution issues. Have them make short presentations of their findings.

## SUGGESTED READING

Bryner, Gary C. *Blue Skies, Green Politics: The Clean Air Act of 1990*. Washington, DC: CQ Press (1992).

Cushman, John H., Jr. "Clinton to Order Effort To Make Pollution Fairer." *New York Times*, 143 (10 February 1994) p. A1.

Hogan, Barbara. "M2/P2...A Better Pollution Control Approach." *Conservationist*, 48 (September 1993) p. 46.

Liroff, Richard A. *Reforming Air Pollution Regulations: The Toil and Trouble of EPA's Bubble.* Washington, DC: Conservation Foundation (1986).

Stevens, Leonard A. *How a Law Is Made: The Story of a Bill Against Air Pollution.* New York, NY: Crowell (1970).

Willis, Terri, and Wallace B. Black. *Cars: An Environmental Challenge.* Children's Press (1992).

## STUDENT WORKSHEET 1

# WRITING ENVIRONMENTAL LAWS

### PROPOSED LEGISLATION CHECKLIST

[ ] Does the proposal describe requirements clearly?

[ ] Is the regulated community adequately described?

[ ] Are the actions required or prohibited stated clearly?

[ ] Are requirements practical?

[ ] Can requirements be met by the regulated community?

[ ] Have exceptions or exemptions been included for extraordinary circumstances or contingencies? (In this example, groups may wish to allow ambulances and firetrucks to travel downtown as needed.)

[ ] Does the proposal include sufficient enforcement provisions?

[ ] Are any necessary enforcement bodies sufficiently authorized?

[ ] Have other enforcement mechanisms been described adequately?

[ ] Are penalties for violations included?

[ ] If so, are they stated clearly?

[ ] Has an appeal process been included?

# ACTIVITY 21

# TRANSLATING SCIENCE INTO PUBLIC POLICY

In this activity, the students will role-play participants at a panel on climate change and will represent either scientists or policymakers. "Scientists" will use the information they've learned in other classes and assignments to present information to "policymakers," who will weigh that information, develop their own opinions, and decide what—if anything—should be done about climate change. This activity is related to the "Scales, Rules, Standards, Policy, and Science" warm-up and the "Writing Environmental Laws" activity.

## CRITICAL OBJECTIVES

- Research, organize, and present information from the perspective of a scientist or policymaker
- Make informed decisions backed by evidence
- Describe the process and complexity of making policy decisions

## SKILLS

- Researching
- Comparing ideas
- Considering alternatives
- Making decisions

## GUEST PRESENTERS

Guest Presenters for this activity could include EPA Environmental protection specialists, lawyers, research scientists, conservationists, or journalists.

## BACKGROUND

Air quality laws and regulations attempt to govern behavior in order to improve the quality of life for people and protect nature. When people "know" that air pollution causes harm, or when regulations stipulate precise quantities of allowed or illegal pollutants, we take for granted that the numbers are based upon scientific research, and are not just made up. Thus, scientific research plays a major role in supporting laws and policies governing environmental pollution and natural resource management. Scientific research is often categorized into "basic" or "applied" science. Basic, or "pure" research usually refers to fundamental principles that do not have a specific result or application in mind, and is conducted mainly for the sake of improving knowledge. On the other hand, applied research is designed to solve a particular societal or commercial problem or collect information in order

**RELATED WARM-UP**
H

**REFER TO READING MATERIALS**
"The Greenhouse Effect"
"Air Pollution"

**TARGET GRADE LEVEL**
8th-11th

**DURATION**
3 class periods (120 minutes), plus library research outside class

**VOCABULARY**
Applied science
Policy
Pure science
Regulations

**MATERIALS**
Flip charts
Blank overhead transparencies
Marking pens
Projector
2-3 sheets of butcher paper
Note pads for student journals

**WORKSHEETS INCLUDED**
6

to enforce specific laws. Sometimes, research is hard to categorize this way, because the results can be both useful to the science in general as well as specifically destined to resolve some commercial or policy-related goal. In general, though, most applied research is based upon sound principles learned from "basic" research. While "policy" usually means government decisions or regulations, it can also include business or personal decisions. Scientists and policymakers each have critical roles to play in translating applied research results into sound government policies and actions. Scientists are trained in recognizing and describing the nature of the physical, chemical, and biological world, and in being able to predict natural behavior from certain facts or data. Scientists are also responsible for communicating their research to non-scientists. They must assist policymakers and others in understanding the relevance of the research, and to recognize the limitations of the conclusions. Scientists do not necessarily tell us what to do. Their role is to tell us what would happen if we did this or that. Policymakers, on the other hand, do more than just listen to scientists. They have to understand the conclusions that the scientists have reached, and they have to understand the limitations of the data. However, they must balance the scientific facts, principles, and uncertainties against social values and economic issues as well. They then have to make often-difficult or controversial public policy decisions. (See reading materials on "The Greenhouse Effect" and "Air Pollution.")

In our system of government, laws, regulations, and policies are generally determined by elected or appointed officials charged with balancing competing interests to the benefit of society or a constituency. In the environmental arena, policymakers usually rely upon recognized scientific or engineering experts to sift through the complex scientific data and (often) competing theories. In the activity below, the students will take the part of policymakers and technical experts in role-playing the type of hearings often held prior to policy decisions.

## WHAT TO DO

### First class

1. Divide the class into two groups. About eight of the students in the first group should be the "policymakers"—Members of Congress and their staff, and the Administrator of the Environmental Protection Agency and her staff—and the remainder of the class will be members of the expert scientific panel. Just as many different areas of scientific expertise are represented in the climate change research community, the "scientist" students should represent different scientific disciplines.
2. Divide the scientists into six or more teams, each representing a different discipline. Student worksheets are provided for the policymaker group and five possible scientist groups, but the students should be encouraged to identify and define additional interest groups (such as citizen groups, lobbies, or additional scientific communities). Team members should be encouraged to research their team's positions at the libraries or by discussions with real experts from government or

the community. You also may want to provide appropriate groups with copies of some of the reading materials included in this package.

3. Discuss with the class the description of each group, what information each group will need, the goals of the panel, and how the panel will be conducted. Stress that the presentations, questions and answers, and discussions are for the purpose of giving policymakers the best available scientific information to help them make decisions. The personal feelings of the scientists should not be allowed to affect the way the scientists present data; however, the conclusions the scientists reach based on those objective data may enter into the discussions.

4. Stress that groups should develop their own conclusions based on the data at their disposal. They may decide, for example, that there is insufficient scientific evidence to be concerned with climate change, or they may decide that the evidence for climate change is very strong and convincing and that severe problems will result. In either case, the scientist groups should be prepared to present their evidence and respond to challenges or questions from the policymakers who may be unconvinced.

5. Policymakers may ask for the scientists' "best professional opinion." The policymakers have to listen carefully to the information, making notes as they proceed, and consider their options. They have a particularly tough job because they have to consider not only the scientific evidence but also the effects their decisions will have on the economic and social welfare of the Nation.

6. Assign each of the scientist teams to prepare a 5-minute summary of the most important issues they want the policymakers to know about. (The presentations are to be made in a follow-up class.) Give them 15-20 minutes to begin deciding what they want to say and what visual aids they will need to support their positions and to select a spokesperson.

7. Have the policy group also select a chairperson, and study and discuss among themselves the list of possible policy options they may wish to consider. They must also consider the nature of the information they need from the scientists, and may wish to formulate questions for each scientist group. Some of the possible policy options include:

- Business as usual. Insufficient evidence that a problem exists at all.
- All-out control strategies. Stringent $CO_2$ controls, accelerated reforestation, careful monitoring of planetary health, inter-National cooperation demanded.
- Small concern. Some energy efficiency improvements,

**TAKE NOTE**
Spend some time helping students consider the economic and social implications of some of these choices.

but wait for more evidence before instituting controls that affect lifestyles.

### Class #2

1. Arrange the room so the policymakers are sitting at desks or tables facing the class. Set one desk facing the head table, near the center. This will be the "witness table" for the scientists to present their expert testimonies. Arrange the overhead projector, flip charts, or other visual aids nearby, so that everyone can see them. You may add to the official atmosphere by making a poster or banner with "U.S. Panel on Climate Change" printed on it, and by preparing place cards and name tags for each participant.

2. You, the teacher, or the guest presenter could serve as moderator and give opening remarks and introduce the scientist teams and policymakers.

3. Call on each teams' spokesperson to present their 5-minute summaries of the team's research to the policymakers. The teams should be encouraged to keep their presentations within the time limit, and to be very clear and direct in their summary remarks. In presenting their remarks, spokespersons should begin by stating the policy they recommend, and then present the scientific evidence for their position. For example, the Atmospheric Science team might decide to begin by urging immediate, drastic efforts to curb $CO_2$ emissions. They may cite the steady, measurable rise in $CO_2$ across the world and the known physical ability of $CO_2$ to absorb heat as their primary reasons to support the control policy. The policymakers should ask questions during and after the presentations, but the total time for each team should not exceed 8-10 minutes. If the policy group needs more information, they can request that the scientists provide it the following day. All the teams should be able to complete their presentations during this class period.

4. All students should take notes on the presentations in their journals.

### Class #3

1. Arrange the room as for Class #2

2. Allow about 20 minutes of the class period for the policymakers to confer and make their decisions. During this time, the scientist groups should quietly discuss what might happen if their recommendations were not accepted by the policymakers, and what kind of additional evidence might be important to fill in gaps from their presentations the day before.

3. Have the policy chairperson announce their decisions and their reasons, paying particular attention to missing or weak evidence that they

did not hear from the scientists. One of the policy group should write the decisions and reasons on a flip chart or butcher paper.

4. For the rest of the period, let the class as a whole explore the implications of the decisions, paying attention to the most convincing evidence the policymakers heard. Equal attention should be paid to reasons the policymakers did not accept certain scientific arguments, and whether additional data or evidence that was not heard might have changed the outcome. This consideration, in reality, would be a good reason for additional applied research.

5. Provide a wrap-up during the last five minutes, stressing the difficulties of the decision-making process and explaining that the 3-hour exercise would have taken many months in real life. (You also may choose to have the guest presenter provide the wrap-up.)

## SUGGESTED EXTENSIONS (OPTIONAL)

- Have students select aspects of the policy decisions and write a short essay to support or refute the decisions based upon the evidence presented, or upon the need for additional evidence (research).

## SUGGESTED READING


Barke, Richard. *Science, Technology, and Public Policy.* Washington, DC: CQ Press (1986).

Bryner, Gary C. *Blue Skies, Green Politics: The Clean Air Act of 1990.* Washington, DC: CQ Press (1992).

Cushman, John H., Jr. "Clinton to Order Effort To Make Pollution Fairer." *New York Times,* 143 (10 February 1994) p. A1.

Hiskes, Anne L., and Richard P. Hiskes. *Science, Technology, and Policy Decisions.* Boulder, CO: Westview Press (1986).

Hogan, Barbara. "M2/P2...A Better Pollution Control Approach." *Conservationist,* 48 (September 1993) p. 46.

Liroff, Richard A. *Reforming Air Pollution Regulations: The Toil and Trouble of EPA's Bubble.* Washington, DC: Conservation Foundation (1986).

Pringle, Laurence P. *Lives at Stake: The Science and Politics of Environmental Health.* New York, NY: Macmillan Publishers (1980).

Silverberg, Robert. "Greenhouse Effect: Apocalypse Now or Chicken Little." *Omni,* 13 (July 1991) p. 50.

# STUDENT WORKSHEET 1

# TRANSLATING SCIENCE INTO PUBLIC POLICY

## MEMBERS OF CONGRESS AND EPA'S ADMINISTRATOR AND STAFF

As policymakers and lawmakers, you are responsible for assuring that all interests are fairly represented and that no segment or sector of the population is unduly burdened by your decisions. There are, however, many influences on your decisions, and there are many checks and balances to protect the public from abuses of power or authority. Members of Congress, who are elected to represent the majority interests of a part of a single district within a state, may have different priorities and perspectives than the Administrator of the U.S. Environmental Protection Agency, who is responsible to the President for carrying out laws and setting policies Nationwide. Your role here is to determine the forces influencing your decision-making. These forces are outside of the testimony presented by the scientific panels. You should begin with a brief discussion summarizing the different motivations of the members of the group. You may decide to all be Members of Congress, or some of you may also represent the EPA Administrator as her senior policy staff.

You need not find the answers to your questions during the first session. Conduct your own research. Ask the guest presenter (if one was invited), or you may also contact the local office of your own Congressional Representative.

You will need to ask the scientific panelists questions to do your research. Use your questions to get to the root of the problem, and maintain a list of possible solutions as the testimony proceeds.

# STUDENT WORKSHEET 2

# TRANSLATING SCIENCE INTO PUBLIC POLICY

## ATMOSPHERIC SCIENTISTS

Your expertise is primarily in the composition and nature of the atmosphere (chemistry and physics—what's in the air and what the ingredients do), and the influence of the atmosphere on climate.

Clues for research: Atmospheric scientists could be expected to provide expert testimony on the greenhouse effect, what greenhouse gases are, how they are changing the atmosphere, and how that might affect climate over the short- and long term.

## STUDENT WORKSHEET 3

# TRANSLATING SCIENCE INTO PUBLIC POLICY

### ECOLOGISTS

Your expertise is in the structure and function of the Earth's living things; how plants and animals are distributed across the landscape, how they interact with each other and with the Earth's environment, and how plants and animals "make their livings."

Clues for research: Ecologists may provide expert opinions on the way climate influences important ecosystems, how changes in habitat may affect plants and animals, and how and why future climate changes might affect ecosystems.

## STUDENT WORKSHEET 4

# TRANSLATING SCIENCE INTO PUBLIC POLICY

### AGRICULTURAL SCIENTISTS

You are primarily interested in crop plants and their production in commercial quantities. You deal with issues of crop health and stress, soil fertility, water availability, farming practices, pesticides and fertilizers, and with economic issues affecting farms and food production.

Clues for research: Agricultural scientists would be expected to testify about the possible impacts of climate upon food production and food distribution.

## STUDENT WORKSHEET 5

# TRANSLATING SCIENCE INTO PUBLIC POLICY

### OCEANOGRAPHERS

You specialize in the physical and chemical makeup of the oceans, how they circulate, how they interact with the atmosphere, how they influence the Earth's climate, and how they store and exchange energy with the atmosphere. Oceanographers also are concerned with the biology of the seas, and with fisheries.

Clues for research: Oceanographers would be expected to provide information on the interactions of oceans with climate, the possibilities of sea-level rise, and the impacts of changing climate upon oceanic and coastal life.

# STUDENT WORKSHEET 6

# TRANSLATING SCIENCE INTO PUBLIC POLICY

## COMPUTER MODELERS AND MATHEMATICIANS

You are experts in producing complex computer simulations of natural physical and biological processes, often with hundreds of variables. These simulations can be used to predict the behavior of natural systems (such as climate) that cannot easily be experimented upon directly.

Clues for research: Computer modelers may give expert testimony on the way computer models are used to help the scientific community make predictions, and to discuss the strengths and limitations of these models and their data.

# READING MATERIALS

# READING MATERIAL
# AIR POLLUTION

## What Is Air Pollution?

The natural composition of air is mostly nitrogen and oxygen, along with water droplets, fine particles, and small amounts of other gases, such as carbon dioxide, nitrous oxide, methane, ammonia, and argon. These gases can be either free in the air or associated with water vapor.

Air pollution is any visible or invisible particle or gas found in the air that is not part of the normal composition of air. Natural air pollution has been around for millions of years, but during the last century, pollution created by humans started to become a major concern. We are most familiar with visible air pollution like smog; however, many other air pollutants, including some of the most dangerous, are totally invisible.

## Where Does Air Pollution Come From?

Natural air pollutants have always been a part of the earth's history. Particulate matter and a variety of different gases from volcanoes, forest fires, and decaying organic materials in oceans and swamps enter the atmosphere at irregular intervals, sometimes in amounts that have dramatic effects. Naturally produced "greenhouse" gases, such as methane from plant decay, may have contributed significantly to periods of global warming in the past. Carbon dioxide and water vapor react to form carbonic acid, which makes rain slightly acidic even without pollution from other sources.

Naturally produced pollutants are present in greater amounts than those of human origin. However, they do not present as serious a problem as man-made pollutants because they are not concentrated over large cities and many are less harmful than man-made pollutants.

Air pollution from man-made sources is the result of our increasing use of large quantities of fuel and high levels of industrial activity. Not only are some of these pollutants very harmful, but also tend to be concentrated in urban areas where many people live and work. Many of these air pollutants come from burning the coal, oil, wood, and other fuels we use to run factories, cars, and power plants that generate heat and light for our homes.

Once pollutants are added to the air, they can chemically react to form more dangerous pollutants. The interaction of nitrogen oxides and other components near ground level in the presence of sunlight forms another atmospheric gas—ozone. Ozone has two very important but different effects. The layer of ozone found in the upper atmosphere (stratosphere) provides a major protective barrier against harmful radiation from the sun. However, ozone near the Earth's surface can become a serious health problem when the ozone concentration becomes too high, usually on long, sunny, summer days.

Pollutants of any sort can ride the air currents for long distances. It has become very clear that the air around us and the pollutants it carries are never just a local concern but transcend regional, national, and hemispheric boundaries.

## What Are the Effects of Air Pollution on Plants, Animals, and Humans?

Plant and animal life has adapted to most natural pollutants except for the rare catastrophic occurrences that create worldwide climate changes. The most serious air quality concerns are the additional, often harmful, pollutants that humans add to the air.

Most of the water droplets carried by air eventually fall to earth as precipitation. Many of the small particles and chemicals are washed from the atmosphere when precipitation falls. Air pollution then becomes land and water pollution, which can influence the structure and function of ecosystems, including their ability for self-regulation. Numerous small lakes in the eastern United States are devoid of fish because of the effects of "acid rain."

The impact of air pollution on man is broad, causing symptoms ranging from itchy eyes to cancer. The absorption of inhaled chemicals can have direct consequences for health. However, public health also can be indirectly affected by the deposition of air pollutants on plants, animals, and water. These chemicals, by entering the food chain or being present in drinking water, constitute additional sources of human exposure.

## How Do We Detect Air Pollution?

Every year millions of tons of man-made chemicals are released into the atmosphere, mostly by industrialized countries. However, the toxic effects of these chemicals often are not recognized or understood until the chemicals have been widely used for considerable periods of time. A chemical compound that initially appears to have little or no effect on plants and animals may eventually produce extremely harmful results, often hidden for many years.

DDT and related chemicals are a classic case of such a situation. DDT is a very effective insecticide that showed great promise for fighting harmful insects all over the world. It wasn't until after many years of widespread use that DDT was discovered to have devastating toxic effects. The high DDT levels in bald eagles caused them to produce eggs so thin-shelled they were crushed during incubation. This caused a reduction in the population, putting bald eagles on the endangered species list. Similar disastrous repercussions can and are being repeated with other toxic chemicals in other food chains.

Governments around the world have established programs to measure and monitor levels of airborne pollution. For many years, cities in the United States developed and used their own indices for reporting air pollution levels to the public. These individual indices have now been replaced by the Pollution Standards Index (PSI) or the Air Quality Index (AQI), both recognized as standardized measures that allow comparison from city to city.

## How Do We Reduce Air Pollution?

Since little can be done by humans about natural pollution, our main concern has to be with the additional pollutants from human activity. Because of the increasing concern over toxic chemicals in the air we breathe, many laws have been passed to control emission sources.

Certain air pollutants are so pervasive that they show up wherever air quality is poor. Six have been designated "criteria pollutants:" particulate matter, sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, and lead. The U.S. Environmental Protection Agency has set national ambient air quality standards to protect health and welfare in connection with these pollutants. Where these standards are exceeded, the EPA takes steps to control pollutant emissions.

Identification and control of other hazardous air pollutants are critical steps to controlling air quality. Seven hazardous materials (arsenic, asbestos, benzene, beryllium, mercury, vinyl chloride, and radionuclides) already have U.S. standards. However, this start represents only a very small portion of the whole hazardous waste problem. An expanded list of 189 hazardous chemicals has been identified for regulation. They are listed in the Clean Air Act Amendments of 1990. Some states, even some cities, have been particularly aggressive in battling pollution of various sorts. New legislation is constantly being discussed. Alternative energy sources and alternative strategies, such as mass transit and energy conservation, are all part of the solution. Gradually, the international scope is being recognized and international agreements are being developed to try to deal with air quality problems on a global scale.

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READING MATERIAL

# INDOOR AIR QUALITY

## How Serious Is Indoor Air Pollution?

Most people are aware that outdoor air pollution can damage their health but may not know that indoor air pollution also can have significant harmful effects. The U.S. Environmental Protection Agency (EPA) studies of human exposure to air pollutants indicate that indoor levels of many pollutants may be 2-5 times, and occasionally more than 100 times, higher than outdoor levels. Also, people spend more than 90 percent of their time indoors. Tightly sealed buildings are an additional concern for the health of those who live and work in them. The Journal of the American Medical Association in 1988 reported that a population living in energy-efficient buildings contracted upper respiratory diseases at rates 46 to 50 percent higher than a comparable group living in older, more ventilated housing. The EPA and its Science Advisory Board rank indoor air pollution among the top five environmental risks to public health.

## Where Does It Come From?

There are many potential sources of air pollution in houses and other buildings. Gases like carbon monoxide, ozone, sulphur dioxide, nitrogen dioxide, lead, and particulate matter (less than 10 microns in size) flow into buildings from the surrounding automotive and industrial culture. Radon gas seeps indoors from the soil and rock around the foundation, and hundreds of other chemicals, dust, fibers, molds, bacteria, and metals are released into the indoor air primarily from carpeting, wood products made with synthetics, and combustion sources. Some examples include formaldehyde, xylene, vinyl chloride, ethylbenzene, trichloroethylene, methacrylic acid, asbestos, textile dust, and tobacco smoke. Old synthetic carpeting, which becomes brittle with age, gives off synthetic house dust. Unhealthy in itself, dust is even more dangerous when burned by the furnace or kitchen stove because it may produce gases such as hydrogen cyanide and forgene. Common sources of indoor pollutants include household cleaners, textiles, automotive supplies, furnaces, gas cooking appliances, pesticides, and paint.

## What Are The Effects of These Pollutants?

Some common indoor air pollutants are known to cause cancer and are relatively well characterized. Examples are tobacco smoke, benzene, vinyl chloride, trichloroethylene, and asbestos. Benzene is in fossil fuel and is used as a solvent in the manufacturing of paints, plastics, and pesticides. Vinyl chloride is used in plumbing and in manufacturing plastics. Trichloroethylene is used in dry cleaning and in the manufacturing of pesticides, paints, waxes, and paint strippers. Many indoor air pollutants cause non-cancer health effects (such as neurologic, reproductive/developmental, pulmonary, immune system) and generally are not understood as well as the cancer-causing ones. For example, the xylenes used as a paint and ink solvent and in some detergents are associated with liver, kidney, and nervous system disorders. Plasticizers may cause chromosome damage. Dust mites and mold may cause allergic reactions. Further research on indoor air quality is needed to identify and characterize the health risks associated with exposures to indoor air pollutants, individually and in combination. Not all potential indoor air pollutants have been identified.

## How Do We Detect Indoor Air Pollution?

With special equipment, a technician can test for airborne particulates, specific organic and inorganic gases, vapors, and dust in indoor air. Detecting radon gas is easy and relatively inexpensive. (See the reading material on "Radon.") Testing for carbon dioxide provides an index of the amount of outside air pollutants coming into a building.

### How Do We Reduce the Hazards?

Several strategies may be used to improve indoor air quality. A combustion furnace, if located indoors, should be efficient and atmospherically separated from the rest of the house. Solar heating and electric space heaters and kitchen ranges are better alternatives to kerosene and gas versions. Insulation of living spaces and metal conduits are recommended. Household cleaners, paints, and other products in the house should be sealed and stored properly to avoid leaking into the living area of the house. A ventilation controlled system can provide fresh air every day.

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# READING MATERIAL
# HEALTH EFFECTS

## Ambient Air Quality and Human Health

Ambient air quality, especially in highly industrialized and urbanized areas, is a growing concern to the health of the nation. The magnitude and variety of these pollutants across the country depends mainly on the number and types of air emission sources and meteorological conditions. To protect public health and welfare, the EPA has set national standards for six ambient pollutants that tend to reach unsafe levels. They are carbon monoxide, lead, nitrogen oxides, tropospheric ozone, sulfur dioxide, and particulate matter. However, there are other pollutants of concern, some of which occasionally reach dangerous levels under certain conditions or in accidental releases. The EPA is evaluating these pollutants and may require emission reductions for some of them. The EPA also is implementing programs to reduce emissions of chlorofluorocarbons and other pollutants that are depleting stratospheric ozone.

## Indoor Air Quality and Human Health

EPA studies of human exposure to indoor air pollutants indicate that pollution levels may be 2-5 times, and occasionally more than 100 times, higher than outdoor levels. Because most people spend at least 90 percent of their time indoors, indoor air quality is a growing concern. Virtually all ambient air pollutants can be found in indoor air, but some also are generated indoors. For example, carbon monoxide may be produced from tobacco smoking and faulty heating appliances, lead from old paint, and nitrogen and sulfur dioxides from coal-burning stoves. The major sources of indoor air pollution are carpeting, wood products made with synthetic glues, combustion appliances, and tobacco products.

## Determining Risk Associated with Air Pollution

To determine the risks to human health posed by air pollutants, the U.S. Environmental Protection Agency (EPA) obtains the best available toxicological data from animal studies and human studies. Risks associated with exposure to carcinogens (chemicals with cancer causing potential) are analyzed separately from those associated with exposure to non-carcinogenic chemicals (with the potential for causing pulmonary, liver, and kidney damage, nervous system changes, birth defects, immune system dysfunction, and other effects).

Even though some chemicals have the potential for generating both carcinogenic and non-carcinogenic effects, the means by which they produce them in the body is thought to be substantially different for most chemicals. In calculating the likelihood that someone will develop cancer, risk assessors assume there is some chance a person will get cancer even from extremely low exposures to a cancer causing substance. For a pollutant that causes non-carcinogenic health problems, risk assessors assume that there is a level of exposure below which people are not likely to experience adverse health effects over a time period, usually a lifetime. These assumptions are based on considerable evidence of adverse health effects in animal and human studies, such as occupational exposures.

Although air pollutants can enter the body by several routes, the primary route is through the lungs, which have a total surface area about 25 times greater than that of the body's skin surface. In the lungs, air pollutants may damage directly the lung tissue causing several types of diseases, including cancer. In addition, most air pollutants are absorbed into the blood and transported to sensitive organs throughout the body.

## Health Effects of Ambient Air Pollution

The pollutants for which EPA has set National Ambient Air Quality Standards produce a wide variety of health effects. Ambient carbon monoxide, which comes primarily from motor vehicles, enters the blood from the lungs and permanently binds to hemoglobin, preventing it from carrying oxygen needed to sustain life. Lead, from multiple sources including leaded gasoline, accumulates in the body and may cause neurological impairments such as mental retardation and behavioral disorders, especially in the very young. Even at low doses, lead is associated with changes in fundamental enzymatic and energy transfer mechanisms in the body. Nitrogen dioxide, mainly from coal burning power plants and motor vehicles, can irritate the lungs and lower resistance to respiratory infections. It also is a precursor to acid deposition and ozone. Ozone, formed mainly at ground level from other air pollutants in the presence of sunlight, damages lung tissue, reduces lung function, and sensitizes the lungs to other irritants. Decreased lung function can be accompanied by chest pain, coughing, and nausea. Ozone also causes agricultural crop loss. Sulfur dioxide, mainly from coal-burning power and industrial plants, is associated with decreased lung function, respiratory diseases, and lowered resistance to lung problems. It also damages plant life. Particulate matter (less than 10 microns in size) comes from a number of different sources such as diesel engines, burning wood, and windblown dust. It can aggravate lung and cardiovascular diseases, alter the body's defense systems, and cause cancer.

## Health Effects of Indoor Air Pollution

Indoor air pollutants may cause a wide variety of adverse health effects ranging from rashes and eye irritation to cancer, breathing difficulties, kidney failure, liver damage, and birth defects. The degree of toxicity depends on the physical/chemical characteristics of the air pollutant; the magnitude, frequency, and duration of exposure; and the overall health of those exposed. Some populations, such as children and the elderly, often are more susceptible to the adverse health effects of pollution. Tobacco smoke, benzene, vinyl chloride, trichloroethylene, and asbestos are common indoor pollutants with the potential for causing cancer. Some pesticides used or accidentally leaked indoors can cause cancer and a number of non-cancer effects including lung, kidney, liver, and nervous system dysfunction. Radon gas causes lung cancer. Formaldehyde, from the outgassing of particle board and similar products, not only irritates eyes, lungs, and skin, but also is a potential carcinogen. Even though the list of potentially dangerous indoor air pollutants seems endless, not all of the pollutants—for example, those produced during combustion or released during the outgassing of synthetic carpet—have been identified. Furthermore, the combined effects of air pollutants on human health are largely unknown.

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# READING MATERIAL
# RADON

## What Is Radon?

Radon is a naturally occurring radioactive isotope. Radon is colorless and odorless regardless of concentration and is the only member of a chain of decaying isotopes that is a gas. Radon is produced from radioactive disintegration reactions that begin with uranium-238, which is widely distributed throughout the Earth's crust. With a half-life of 3.8 days, radon has time to escape from soil and enter buildings before decaying into polonium-218, a radioactive particle (solid).

## Where Does It Come From?

The majority of radon that enters a building comes in through cracks in the foundation and basement floor, crawl spaces, floor drains, joints between walls and basement floor, water pipes, and electrical conduits. Other sources of indoor radon include water (primarily well water) and building materials made of rock, such as brick and concrete. Radon levels may vary a lot from one building to the next in a neighborhood. Radon levels are higher in the basement and lower floors, which are closer to the source, than the upper floors. They also tend to be higher in cold weather when doors and windows are closed.

## What Are Its Effects?

It is polonium-218, with a half-life of three minutes, and some of its solid decay products (such as lead-214, bismuth-214, and polonium-214) that present the greatest risk to human health. Alpha particle emissions from the radioactive disintegrations of these radon decay products are sufficiently powerful to penetrate lung tissue and damage the sensitive basal epithelial cells, which leads to lung cancer. Disintegration of the decay products outside the lungs is of little concern because alpha emissions are easily stopped by a couple of centimeters of air, and they are unable to penetrate the skin.

Although the number of deaths due to radon is disputable, the Centers for Disease Control, the American Lung Association, and other major health authorities agree that radon causes thousands of preventable lung cancer deaths each year. Radon is certainly a danger to uranium miners and others exposed to high doses. In the United States, estimates of the number of deaths from lung cancer caused by radon range between 7,000 and 30,000 per year, which is about 10 percent of the lung cancer deaths attributed to smoking. Evidence suggests that radon and cigarette smoking may act synergistically, increasing the cancer risk more than simply adding the risks of radon and smoking.

The U.S. Environmental Protection Agency (EPA) urges home owners to reduce their radon exposure if levels average greater than 4 picocuries per liter (pCi/L). The curie (Ci) is the basic unit of measurement most commonly used in the United States for radioactivity. One curie is equal to 37 billion radioactive disintegrations per second, which is a lot of radioactivity. The radioactivity released by radon and its decay products is usually measured in picocuries (pCi), or trillionths of a curie.

## How Do We Detect It?

Measuring radon levels in houses is easy and relatively inexpensive. There are several methods, but the three most common detection units are charcoal canisters, alpha track monitors, and electret ion chambers. The charcoal canister has a radon absorption device and can measure radon levels in 2-7 days. Usually, the canister is mailed to the manufacturer for analysis. Alpha track monitors require 3-12 months to measure radon by recording the tracks of alpha particles emitted when the radon decays. The electret ion chamber, which is designed for short- or long-term testing, contains a specially charged device that, when exposed to the air, reacts to the radioactive decay of radon. The recommended procedure is to begin with a short-term test, and if the results show high radon levels, add further tests.

### How Do We Reduce Its Effects?

If the radon detection tests indicate that radon levels are too high, one or more mitigation strategies may be implemented to decrease radon concentrations indoors. The best choice of a strategy depends on how much radon was detected, the design and air flow patterns in the house, cost considerations, and appearance. All strategies involve keeping radon from seeping into the house, and removing radon once it enters the house. Specific strategies may include:

- Sealing cracks and openings, including water and sewer lines and electrical conduits, in and around the foundation and concrete slab under the house;
- Increasing natural ventilation by opening windows to facilitate the flow of outside air into the house, especially to the basement and lower floors;
- Forced ventilation (fans) with or without heat recovery into (never out of) the house on the lower levels;
- Soil ventilation to draw soil gas away from the foundation of the house.

Air flows in the direction of least resistance. Consequently, if fans are used to ventilate the house, it is important to blow the air into, never out of, the house because radon is pulled into the house with the creation of a slight vacuum in the lower areas of the house.

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READING MATERIAL

# WEATHER AND AIR QUALITY

## What Is Weather?

Webster's Ninth Collegiate Dictionary defines weather as the "state of the atmosphere with respect to heat or cold, wetness or dryness, calm or storm, clearness or cloudiness." The term "weather" encompasses many factors, including temperature and precipitation conditions and air mass movements. Weather involves the daily variations of these factors. Knowledge about the basic elements of daily weather helps to explain how weather affects air quality.

The movement of huge air masses across the continent has the broadest impact on daily weather. In North America, these air masses, commonly termed weather systems, usually flow from west to east. The exact path of weather systems is determined by several factors, including the prevailing direction of "jet streams" and topographic features. The jet streams are enormous upper air currents of air that move across the continent at great speeds. The trends of weather systems depend upon whether the jet streams dip south or stay north. Topographic features, such as a mountain range, can alter the direction of air masses. The collision of different air masses also may affect the path of each air mass.

Weather systems typically are defined as being either a high- or low-pressure system. High-pressure systems are air masses with unique properties, such as warm or cool, or moist or dry. The winds of a high-pressure system rotate in a clockwise direction. Consequently, as a high-pressure system rotates, it will draw colder, northern air southward and warmer, southern air northward.

Low-pressure systems are pockets of air masses located between high-pressure systems. These systems flow in a counter-clockwise direction between two clockwise-rotating high-pressure systems. Since several weather systems (high- and low-pressures systems) occur at the same time over the North America, air masses are constantly colliding. When this occurs, weather fronts form, which often leads to some form of precipitation.

During the cooler seasons of the year, precipitation may encompass areas that are hundreds of miles across. Cold weather precipitation often falls as snow, sleet, or freezing rain. In the hotter seasons, precipitation often is limited to smaller areas. This precipitation ranges from rain showers to thunderstorms, and occasionally, hail.

Weather patterns also are affected by the sun and the position of the sun throughout the year. The amount of daylight and the angle of sunlight reaching the earth affects the temperature and the types of precipitation. During the winter, because the sun is situated in the southern sky, resulting in less daylight, temperatures are colder. As daylight slowly increases, as the sun shifts to the north, the temperature also slowly increases. The sun reaches its apex in the summer, resulting in the hottest temperatures, and starts to shift to the south again.

## How Does Weather Affect Air Quality?

Daily weather conditions directly affect the quality of the air. Shifting air masses and wind can move air pollutants from one location to another. Conversely, stagnant air can result in increased concentrations of harmful pollutants. All forms of precipitation wash pollutants from the air and onto the ground. Although this cleanses the air, it may create land and surface water pollution.

## What Is the Air Quality Index and How Does It Work?

The Air Quality Index (AQI) is a standardized index to classify and measure air pollution and is used to report air pollution levels to the public. The reason the public needs to be informed about air pollution levels is to warn people who may be susceptible to air pollution. These people may need to modify their behavior and take precautionary measures to protect themselves when air pollution is severe.

Once air monitoring data is collected, the AQI is used to convert the data to a scale that ranges from a 0 to 100 and over. The scale intervals indicate the potential health effects of measured daily levels of major air pollutants, including carbon monoxide, nitrogen dioxide, sulfur dioxide, particulate matter, and ozone. The AQI is based on the ambient air quality standards established by the U.S. Environmental Protection Agency. The AQI not only provides information about the health effects of air pollution, but also includes information about the effects of air pollution on property, vegetation, and aesthetic values.

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READING MATERIAL

# ACID DEPOSITION

## What Is Acid Deposition?

Acid deposition includes acid rain, snow, fog, humidity, and dust with an acidity level lower than pH 5.6. Normal rain, which has a pH of about 5.6, is about 25 times more acidic than "pure," neutral water. The acidity results from the conversion of atmospheric carbon dioxide in water vapor to carbonic acid, a weak acid. Most acid precipitation has a pH between 4.6 and 5.6, but scientists occasionally have measured pH values in acid rain in the eastern United States as low as 2.1 and 3.0, which is about 10,000 to 80,000 times more acidic than pure water.

## Where Does It Come From?

Nearly 95 percent of the acidity below pH 5.6 comes from atmospheric sulfur dioxide and nitrogen oxides, which are products of fossil fuel combustion. Acidified rainwater contains combinations of sulfuric and nitric acids that form when water vapor and sulfur dioxide and nitrogen oxides react. Most of the acid deposition in the eastern United States is attributed to the release of large amounts of sulfur dioxide and to a lesser extent nitrogen oxides from big midwestern power plants that burn coal. Paper and wood pulp processing plants also contribute to sulfur dioxide pollution. In the United States and Canada, sulfur dioxide contributes much more to acid deposition than nitrogen oxides, which come mainly from automotive emissions, but over the next few decades nitrogen oxides may catch up. Sulfur and nitrogen oxides may be transported by the wind in the atmosphere for many miles, crossing regional and international boundaries, before falling to Earth.

## What Are Its Effects?

The effects of acid rain may not be immediately apparent. For example, at a glance, a lake might look clear and beautiful, but a closer look may reveal few living organisms. Some species of fish cannot reproduce in water with a pH of less than 5. Clams, snails, crayfish, and other crustaceans, brook trout, walleyed pike, and bullfrogs are especially sensitive to acidification. However, the detrimental impact of acidification to animal life is not necessarily caused directly by the acidity. Trace metals such as aluminum, mercury, manganese, and cadmium, which are leached from sediment and rocks by the increased acidity, are toxic to life. Thus, the pH does not have to decrease very much before fish kills can occur. Because many insects cannot survive in strongly acidic streams and lakes, birds and mammals that depend on insects for food may suffer abnormally high mortality. Acidification also interrupts normal decomposition of dead plant and animal material in lakes and streams because many of the bacteria that assist in decomposition perish. Without the usual decomposition processes, dead material settles to the bottom, making the water look crystal clear.

The damaging effects of acid deposition on forests and other terrestrial systems are less well understood than on aquatic systems. Acid deposition can alter soil chemistry, nutrient availability, and plant growth. In their weakened condition, trees and shrubs become vulnerable to insects, diseases, and fungus infestations.

Although the Norwegians were the first to bring acid rain to the world's attention in the 1940s, one of the most severely impacted areas of the world is the industrialized Ruhr Valley in West Germany. There, white fir trees became defoliated and died in the early 1970s. Diseases in spruce and other sensitive conifers soon followed, and by 1985, the number of German trees visibly affected by acid deposition had risen to 52 percent. Forests in other parts of the world also display acid deposition damage. For example, the dominant tree in Vermont's Green Mountains, the red spruce, is suffering severe mortality and parts of the mountain range have become denuded. Sugar maples all over the northeastern United States and Canada are declining. In the Shenandoah and Great Smokey Mountains of the southeastern United States, spruce and fir are failing to reproduce and are dying. Pine also are impacted.

## How Do We Recognize It?

Particulate matter containing atmospheric sulfur dioxide and nitrogen oxide account for over 50 percent of the visibility problems in the eastern United States. In the West, these particles have been blamed for reducing visibility in the Grand Canyon of the Colorado River and other areas. Acid deposition contributes to the corrosion of metals and the deterioration and soiling of the stone and paint on buildings, statues, and other structures of cultural significance.

## How Do We Reduce Its Effects?

The federal government has undertaken a wide range of research programs, many through the National Acid Precipitation Assessment Program, to study the complex processes associated with acid rain. To measure acid deposition quantity and chemistry, scientists collect rainfall samples at monitoring stations throughout the United States. Monitoring dry deposition such as acid dust is difficult and, consequently, has not been as extensive as that for wet deposition.

The Clean Air Act Amendments of 1990 established an Acid Rain Program to reduce emissions of sulfur dioxide and nitrogen oxides at the lowest cost to society. To achieve reductions of 10 million tons of sulfur dioxide by the year 2010, the Act requires a two-phase tightening of the restrictions placed on fossil-fuel-fired power plants. Phase I begins in 1995 and affects 110 coal burning electric utilities in 21 midwestern and eastern states. Phase II begins in the year 2000 and tightens annual emissions on the large plants and also sets restrictions on smaller, cleaner plants burning coal, oil, and gas. To achieve reductions of 2 million tons of nitrogen oxides by the year 2000, the Act requires coal-fired utilities to install low-nitrogen-oxide technologies on their burners.

To reduce sulfur dioxide emissions, fossil fuel burning plants can burn low-sulfur coal, install flue-gas desulfurization equipment (scrubbers), and implement clean combustion technologies. Low-sulfur coal contains about one percent sulfur by weight and is found mainly in the western United States. High-sulfur coal contains sulfur in excess of three percent and is geographically concentrated in the Appalachians where coal utilization is greatest. Scrubbers are effective at reducing air pollution, but the sludge they produce creates a disposal problem. Also, they are expensive to build and operate. Clean combustion technologies involve mixing fuels with compounds that react with sulfur and either collect it or convert it to a marketable product that does not enter the stack. Many of these innovative technologies have the added advantage of removing nitrogen oxides as well. Because emissions from motor vehicles are a major source of nitrogen oxides, catalytic converters are used to reduce nitrogen oxides from automotive sources.

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READING MATERIAL

# THE GREENHOUSE EFFECT

## What Is the Greenhouse Effect?

The "greenhouse effect" is so called because it is analogous to the process that keeps the air inside greenhouses (and parked cars) warmer than the air outside. The glass in greenhouse windows is transparent to visible light radiated from the sun. This light heats the surface of materials inside the greenhouse, which emit longer wave-length infrared radiation. Infrared radiation cannot penetrate the glass and is trapped, causing the inside air to warm up.

Water vapor, clouds, carbon dioxide, and other gases in our atmosphere act like the greenhouse glass by preventing some of the infrared radiation emitted by the earth to escape into space. Because the levels of carbon dioxide and other "greenhouse gases" in the atmosphere are increasing, more and more of the heat radiated by the earth's surface may become trapped in the atmosphere. This may result in "global warming," or the gradual warming of the atmosphere around the world.

## Where Do Greenhouse Gases Come From?

Some greenhouse gases come from natural sources, such as volcanoes and forest fires. Because of the ability of these naturally formed gases to trap heat in the atmosphere, the Earth's surface is about 53°F (29°C) warmer than it would be without this trapping. This atmospheric heating makes the surface of the Earth warm enough for life.

Certain human activities can cause air pollution that magnifies the greenhouse effect in the atmosphere. The most important air pollutants that act as greenhouse gases are carbon dioxide, methane, nitrogen oxides, and chlorofluorocarbons. Methane is a product of natural decay from living (or once-living) things. Carbon dioxide and nitrogen oxides generally are a result of man-made burning, automobiles, and other internal-combustion engines. Nitrogen oxides also can enter the atmosphere from fertilizers spread on fields. Chlorofluorocarbons ("CFCs") are a class of chemicals often used in air conditioners and refrigerators and as the pressurizing gas in aerosol spray cans.

While all of these pollutants contribute to the greenhouse effect and other air pollution problems, such as smog, carbon dioxide is the most important of the greenhouse gases because there is more of it in the atmosphere. Also, carbon dioxide levels have risen over 25 percent during the past century.

Another source of carbon dioxide is the clearing of rain forests in countries near the equator. The burning of tropical trees to clear land for crops releases carbon dioxide to the atmosphere. At the same time, trees that use carbon dioxide for photosynthesis are being destroyed.

## What Will the Greenhouse Effect Do?

No one can predict for certain the impacts of the increasing levels of greenhouse gases in the atmosphere. Researchers think that the average temperature of the lower atmosphere will increase by 3°F to 9°F (1.6°C to 5°C) over the next 30 or so years. This may not seem like much, but the average world temperature during the last Ice Age was only 5.4°F (3°C) lower than it is now.

Researchers have attempted to predict the effects of increased global temperatures using sophisticated computer models. Most predict that warmer temperatures will be greater in winter than in summer and greater at higher latitudes than the equator. One thing seems certain, global warming of a few degrees Celsius will cause major shifts in global weather patterns. Tropical storms may become more severe or hit land in different places. Areas that now receive plenty of rain for crops may suffer more droughts. One area where rainfall is predicted to decrease is the central United States, which produces much of our food crops.

Global warming also may cause sea level to rise. The oceans are storehouses of heat. By storing some of the increased heat, ocean temperatures will rise, causing them to expand. In addition, warmer temperatures may melt the polar ice caps to some degree. A rise in sea level will flood low-lying areas where many people now live, for example low-lying parts of the state of Florida, many major cities around the world, and the country of Bangladesh.

The increased temperatures, changes in weather patterns, and sea level rise will have disastrous effects on many natural habitats and the plants and animals that live in them.

While most scientists believe that the greenhouse effect will gradually warm up the Earth's climate, some believe that warmer temperatures will increase cloud cover, reflecting more sunlight away from the Earth and eventually lowering the average temperature. This increased reflectivity is called the Earth's albedo.

### How Do We Detect the Greenhouse Effect?

During this century, the average global temperature has increased 1°F (just over 0.5°C). During the 1980s, the Earth experienced four of the hottest years ever recorded.

Governments and scientists around the world have been recording temperatures and levels of greenhouse gases in the atmosphere for years. Measurements are taken at the ground and aloft by airplanes and balloons. Remote sensing instruments in satellites also can be used to provide data on temperatures, winds, and other atmospheric and oceanic conditions.

### How Do We Reduce Its Effects?

We can reduce the effects of global warming by reducing or stopping the activities that cause greenhouse gases to enter the atmosphere. We should do our best to burn less fossil fuels by switching to alternative, cleaner sources of energy and ban the use of CFCs and other chemicals that increase the greenhouse effect. Protecting the world's forests and planting more trees also will help. A growing tree can take in more than 20 kilograms of carbon dioxide a year.

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# READING MATERIAL
# OZONE

## What Is Ozone?

Ozone is a colorless gas made up of three atoms of oxygen ($O_3$). Most of the oxygen in the atmosphere, the oxygen that supports life, is made up of only two atoms of oxygen ($O_2$).

Ozone can be beneficial or harmful depending on where it is found in the atmosphere. Ozone in the troposphere, the lower atmosphere that we breathe, is considered a pollutant and is harmful to human health and vegetation. Automobiles, power plants, and factories send gaseous pollutants into the troposphere that can react in the presence of strong sunlight to form ozone. Weather conditions and geography can then cause buildups in ozone levels that greatly increase its harmful effects. More information on the sources and harmful effects of ozone in the troposphere can be found in the reading materials on "Automobiles and Air Pollution" and "Smog."

Upper-level ozone is located in the stratosphere, a layer of the atmosphere nine to 31 miles above the Earth. Ozone gas in the stratosphere forms an important and very effective protective barrier against harmful radiation from the sun by absorbing ultraviolet radiation.

## Where Does Ozone Come From?

Ozone gas in the stratosphere forms when oxygen molecules interact with ultraviolet rays from the sun. Amounts of ozone in the stratosphere are changing all the time. Under normal circumstances, ozone is continuously being destroyed and regenerated by the sun's ultraviolet rays. The seasons of the year, changing winds, and even sunspots affect ozone levels.

## What Is the Problem?

In 1985, British scientists discovered a "hole" about the size of the United States in the ozone layer over Antarctica. The holes are not completely devoid of ozone, but the ozone concentrations in these areas are lower than under normal conditions, allowing more ultraviolet radiation to reach the earth's surface. The hole over Antarctica has reappeared each year during the Antarctic winter (our summer).

More recently, ozone thinning has been found in the stratosphere above the northern half of the United States. This hole extends over Canada and up into the Arctic. The hole was first found only in winter and spring, but more recently has continued into summer. Between 1978 and 1991, there was a four to five percent loss of ozone in the stratosphere over the United States.

Ozone holes also have been found over northern Europe. It has become clear that the ozone layer is thinning even more quickly than first feared.

## What Causes the Ozone Holes?

Ozone can be converted into the regular, atmospheric oxygen ($O_2$) by reacting with chlorine atoms in the stratosphere. The most common ozone-destroying pollutants are in a class of chemical compounds called chlorofluorocarbons (CFCs), which have a diversity of uses ranging from air conditioner coolants to aerosol spray propellants. CFCs are very stable compounds that do not react easily with other materials. These properties make them ideal for many industrial applications.

However, in 1974, scientists discovered that their stable properties enable CFCs to survive in the atmosphere long enough (up to one hundred years) to reach the stratosphere where they can break down and destroy ozone. Other common industrial chemicals that destroy ozone include halons, carbon tetrachloride, and hydro-CFCs (HCFCs).

When CFCs that are released into the troposphere rise into the stratosphere, ultraviolet light breaks them down into other chemicals. Eventually, chlorine is produced. Free chlorine atoms (Cl) are very unstable and will immediately react with the first ozone ($O_3$) molecules they find to form atmospheric oxygen ($O_2$) and chlorine monoxide (ClO). Chlorine monoxide also is unstable and will react with free oxygen atoms to form atmospheric oxygen and another free chlorine atom. The reaction is then repeated again and again. One chlorine atom has the potential to destroy 10,000 ozone molecules before it sinks into the troposphere.

### What Are the Effects of Depleted Ozone?

The ozone layer is an important protective screen for life on Earth, filtering out more than 99 percent of the ultraviolet rays before they reach the ground. Some scientist fear that the increasing ultraviolet radiation will tremendously increase such hazards to human health as skin cancer, immune deficiencies, and cataracts. In 1987, the EPA estimated that with a five percent increase in CFCs per year, 40 million Americans will get skin cancer over the next 88 years and of those, 800,000 will die. Even more serious is the fact that, since 1987, monitoring data indicate that the rate of ozone depletion for certain latitudes is now at levels predicted for the year 2050.

Damage to the ozone layer can reduce crop yields. Terrestrial and aquatic ecosystems also will be harmed, and plant life may be seriously affected to the point of threatening world food supplies.

### How Do We Reduce its Effects?

Scientists have been measuring the ozone layer since the mid-1970s, when concerns were first raised about the potentially harmful effects of CFCs on the ozone layer. The only practical approach to stopping the destruction of the ozone layer is reducing human-created pollutants that contribute to its depletion. Efforts to protect the ozone layer now involve many different nations and industries. An international agreement, called the Montreal Protocol, was established in 1987 requiring countries to cut CFC use in half by 1999. Over 90 countries have now signed the protocol. In addition, manufacturers of ozone-destroying chemicals have made major advances in CFC-alternative technologies. But even if all CFC use was halted today, the CFCs already released will continue to break down in the stratosphere and destroy ozone for decades.

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# READING MATERIAL

# SMOG

## What Is It?

The term "smog" was first used in London during the early 1900s to describe the combination of smoke and fog. What we typically call "smog" today is a mixture of pollutants but is primarily made up of ground-level ozone.

Ozone can be beneficial or harmful depending on its location. The ozone located high above the Earth in the stratosphere protects human health and the environment, but ground-level ozone is responsible for the choking, coughing, and stinging eyes associated with smog.

## Where Does Smog Come From?

Smog usually is produced through a complex set of photochemical reactions involving hydrocarbons and nitrogen oxides in the presence of sunlight that result in the production of ozone. Smog-forming pollutants come from many sources, such as automobile exhausts, power plants, factories, and many consumer products, including paints, hair spray, charcoal starter fluid, solvents, and even plastic popcorn packaging. In typical urban areas, at least half of the smog precursors come from cars, buses, trucks, and boats.

Major smog occurrences often are linked to heavy motor vehicle traffic, high temperatures, sunshine, and calm winds. Weather and geography affect the location and severity of smog. Because temperature regulates the length of time it takes for smog to form, smog can form faster and be more severe on a hot and sunny day. When temperature inversions occur (warm air stays near the ground instead of rising) and winds are calm, smog may stay trapped over your city for days. As traffic and other sources add more pollutants to the air, the smog gets worse. Smog is often more severe away from the pollution sources because the chemical reactions that cause smog occur in the atmosphere while the reacting chemicals are being moved by the wind.

Severe smog and ground-level ozone problems exist in many major cities, including much of California from San Francisco to San Diego, the mid-Atlantic seaboard from Washington, DC to southern Maine, and over major cities of the Midwest.

## What Are Its Effects?

Smog is made up of a combination of air pollutants that can injure health, harm the environment, and cause property damage. It has been estimated that about 90 million Americans live in areas with ozone levels above the established standards for health safety. These individuals can be severely influenced by pollutants on a daily basis.

Smog causes health problems such as difficulty in breathing, asthma, reduced resistance to lung infections and colds, and eye irritation. The ozone in smog also inhibits plant growth and can cause widespread damage to crops and forests, and the haze reduces visibility. This is particularly noticeable from mountains and other beautiful vistas, such as those in National Parks.

## How Do We Recognize/Detect It?

Smog is a visible example of air pollution. You can look at the horizon during the day to see how much haze there is in the air. In addition, most cities measure the concentrations of pollutants in the air and report the results to the public. Standardized measures have been established, like the Pollution Standards Index (PSI) or the Air Quality Index (AQI), which allow comparison of pollution levels from city to city.

## How Do We Reduce Its Effects?

The 1990 Clean Air Act establishes a comprehensive approach to reducing the widespread "criteria" pollutants, which include the ozone, nitrogen oxides, and particulates in smog. EPA sets national standards for criteria pollutants and the states must take action to ensure the standards are met. Areas that fail to meet the standards for at least one criteria air pollutant are called "nonattainment areas."

Areas of nonattainment for criteria pollutants have been classified according to the extent of pollution. The five classes for ozone range from marginal (relatively easy to clean up quickly) to extreme (will take a lot of work and a long time to clean up). The 1990 Clean Air Act uses these classes to tailor cleanup requirements to the severity of the pollution and set realistic deadlines for reaching cleanup goals. Many of the smog cleanup requirements involve motor vehicles (cars, trucks, buses). Also, as the pollution gets worse, pollution controls are required for smaller sources.

Strategies that may be required by law to reduce and control air emissions include state permitting programs, changes in the composition of gasoline, use of alternative fuels (such as natural gas and electricity), and use restrictions imposed by individual communities. Innovative approaches being taken by local governments across the country to reduce air pollution in nonattainment areas include: banning charcoal barbecues and wood burning in stoves or fire places when pollution levels are high; developing programs to encourage car pooling; restricting traffic in congested areas; expanding or improving public transportation systems; requiring employers to contribute to employee mass transit costs; assessing "smog fees" on cars in proportion to the number of miles driven and vehicle emissions produced; and even buying and scrapping older, "super-dirty" cars.

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# READING MATERIAL

# AUTOMOBILES AND AIR POLLUTION

Each of today's cars produces 60 to 80 percent less pollution than cars in the 1960s. More people are using mass transit. Per the Clean Air Act, leaded gasoline will be phased out completely as of January 1995, resulting in dramatic declines in air levels of lead, a very toxic chemical. Despite this progress, many types of air pollution that arise in part from mobile sources have not improved significantly. At present in the United States:

- Motor vehicles are responsible for at least half of the smog-forming volatile organic carbon (VOC) and nitrogen oxide pollutants in the air.
- Nearly 100 cities exceed the EPA National Ambient Air Quality Standard for ozone.
- Motor vehicles release more than 50 percent of the hazardous, cancer-causing air pollutants in the air.
- Motor vehicles release about 90 percent of the carbon monoxide found in urban air.

### What Went Wrong?

Although there has been significant progress since 1970 in reducing emissions per mile traveled, the number of cars on the road and the miles they travel almost doubled in the same time frame. As lead was being phased out, gasoline refiners changed gasoline formulas to make up for octane loss, and the changes made gasoline more likely to release smog-forming vapors into the air.

Another reason that pollution levels remain high is that emission control systems do not always perform as designed over the full useful life of the vehicle. Routine aging and deterioration, poor state of tune, and emission control tampering can increase vehicle emissions. In fact, a major portion of auto-related hydrocarbons can be attributed to a relatively small number of "super-dirty" cars whose emission control systems are not working properly.

### What Are the Most Dangerous Pollutants from Vehicles?

Air toxics are pollutants that cause adverse health effects. The EPA has focused a large part of its air toxics efforts to date on carcinogens, compounds that cause cancer. Motor vehicles emit several pollutants that EPA classifies as probable or definite carcinogens, including benzene, formaldehyde, acetaldehyde, 1-3-butadiene, and particulates (soot and smoke, especially from diesel vehicles).

Ozone is a form of molecular oxygen that consists of three oxygen atoms linked together. Ozone in the upper atmosphere (the "ozone layer") occurs naturally and protects life on earth by filtering out ultraviolet radiation from the sun. But ozone at ground level is the major component of smog and presents this country's most intractable urban air quality problem.

### What Are the Effects on Public Health?

Vehicles are such an integral part of our society that virtually everyone is exposed to their emissions. EPA estimates that mobile source (car, truck, and bus) air toxics may cause up to 1,500 cases of cancer each year, about half of the cancers caused by all outdoor sources of air toxics.

Ozone is responsible for the choking, coughing, and stinging eyes associated with smog. Ozone damages lung tissue, aggravates respiratory disease, and makes people more susceptible to respiratory infections. Adults with existing diseases and children are especially vulnerable to ozone's harmful effects. Elevated ozone levels also inhibit plant growth and can cause widespread damage to crops and forests.

## How Are Pollutants from Vehicles Formed?

Some air toxics are components of gasoline, such as benzene, which is added to gasoline to increase octane. Cars emit benzene as unburned fuel or as fuel vapors that evaporate during refueling. Formaldehyde, particulates, and 1,3-butadiene are not present in fuel but are by-products of incomplete combustion.

Ozone is not in fuels and is not a by-product of combustion, but is formed in the atmosphere through a complex set of chemical reactions involving hydrocarbons, oxides of nitrogen, and sunlight. In typical urban areas, at least half of those pollutants come from cars, buses, trucks, and boats. The rate at which the reactions proceed is related to both temperature and intensity of the sunlight. Because of this, high ozone levels occur most frequently on hot summer afternoons.

## What Has Been Done To Control Vehicle Emissions?

The Clean Air Act of 1970 gave EPA the primary responsibility for regulating "mobile sources," which include cars, trucks, and buses. The EPA vehicle emission control program has achieved considerable success in reducing both nitrogen oxide and hydrocarbon emissions. Cars coming off today's production lines typically emit 70 percent less nitrogen oxides and 80 to 90 percent less hydrocarbons over their lifetimes than their uncontrolled counterparts of the 1960s.

Pre-1975 vehicles without catalytic converters, and even pre-1981 vehicles with simple catalysts, emit far more pollutants than newer vehicles. Air toxics from motor vehicles will decrease during the 1990s as older cars wear out. However, without additional control, and with more cars driving more miles, overall emissions of air toxics will begin to increase again by the beginning of the next century.

## What Else Can Be Done?

Control of hydrocarbon and nitrogen oxide emissions is the most promising strategy for reducing pollution levels in most urban areas. EPA has established more stringent limits on gasoline volatility, tightened tailpipe emission standards, required improvements in inspection and maintenance programs, and required long-lasting catalytic converters.

In the most polluted cities, however, these measures will not be sufficient. Further exhaust emission controls for vehicles are approaching the limit of technology. The only way to ensure healthy air is to markedly reduce our use of cars or to switch to cleaner fuels.

Some fuels are inherently cleaner than gasoline because they emit less nitrogen oxides or hydrocarbons that are less likely to react in the atmosphere to form ozone. These fuels include alcohols, electricity, natural gas, and liquid petroleum (propane). Changes in the composition of gasoline itself (such as reducing fuel volatility or reducing benzene content) also can reduce emissions of most air toxics.

Unless we dramatically reduce the amount of pollution vehicles emit in actual use or drastically cut back on the amount we drive, smog-free air will continue to elude many cities.

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# READING MATERIAL
# CLEAN FUELS

## What Are Clean Fuels?

The most familiar transportation fuels in this country are gasoline and diesel fuel, but some vehicle fuels, called "clean fuels," create less pollution than today's conventional gasolines. These include alcohols, electricity, natural gas, and propane. There is still a degree of scientific uncertainty regarding the impacts of these "clean fuels," and, hence, a need to continue research on them.

## Why Switch to Clean Fuels?

Cars operating on conventional gasolines emit a complex mixture of compounds that are hazardous and toxic and can lead to the formation of smog. A lot has been done to reduce automobile pollution, including development of innovative emission control technologies and establishment of inspection and maintenance programs. These gains largely are being offset by an increasing number of cars on the road and people traveling more miles each year. Thus, the pollution control measures taken so far have not been sufficient to solve the smog problem in many large cities.

Clean fuels have a number of inherent properties that make them cleaner than conventional gasoline. In general, these fuels emit lesser amounts of hydrocarbons that are less reactive (slower to form smog) and less toxic. Emissions from electrical, natural gas, or alcohol-powered vehicles can be as much as 90 percent lower in toxics and smog-forming hydrocarbons than emissions from vehicles fueled with conventional gasoline. In addition, new gasoline formulations ("reformulated gasoline") may be able to reduce emissions from gasoline-powered vehicles by up to 25 percent.

Use of clean fuels also could help to slow the atmospheric buildup of carbon dioxide, a "greenhouse gas" that contributes to the potential for global warming. Combustion of any carbon-based fuel produces carbon dioxide, but in general, fuels produced from biomass ( such as crops and trees) and natural gas result in less carbon dioxide accumulation than fuels made from petroleum or coal.

Clean fuels have benefits that reach beyond their air quality advantage. New fuels in the marketplace give consumers new choices and could decrease our dependence on imported oil.

## Electricity

Battery powered vehicles give off virtually no pollution and offer one of the best options for reducing motor vehicle emissions in polluted cities. Power plants that produce electricity do pollute, but these plants are often in rural areas where the emissions do not drive pollution levels above health standards. Also, efficient emission controls can be installed and maintained more easily on individual power plants than on millions of vehicles. The driving range of today's electric cars is limited by the amount of power the battery can provide. Current batteries take hours to recharge and the cost of electric vehicles is high. Recent developments in electric vehicle technology show much promise for reducing these disadvantages.

## Ethanol

Ethanol ("grain alcohol") is the primary automotive fuel in Brazil, and ethanol/gasoline blends (known as "gasohol") have been used in the United States for many years. Pure ethanol fuel offers excellent performance plus low hydrocarbon and toxic emissions. It can be produced domestically from corn or other crops, potentially minimizing the accumulation of greenhouse gases. With current technology and price structures, ethanol is more expensive than gasoline, but new production technologies offer the hope of significantly reduced cost.

### Methanol

Methanol ("wood alcohol"), like ethanol, is a high-performance liquid fuel that emits low levels of toxic and smog-forming compounds. It can be produced from natural gas at prices comparable to gasoline, and also can be produced from coal or wood. All major auto manufacturers have produced cars that run on "M85," a blend of 85 percent methanol and 15 percent gasoline, and many auto manufactures have developed advanced prototypes that burn pure methanol ("M100"). Methanol has long been the fuel of choice for race cars because of its superior performance and fire safety characteristics.

### Propane

Natural gas is abundant and widely used for home heating and industrial processes. It is easily transported through pipelines and costs about the same or slightly less than gasoline. Compressed natural gas (CNG) vehicles emit low levels of toxics and smog-forming hydrocarbons, but CNG fuel must be stored in heavy, costly tanks. There are significant tradeoffs for CNG vehicles among emissions, vehicle power, efficiency, and range; however, natural gas already is used in some fleet vehicles and appears to have a bright future as a motor vehicle fuel.

### Reformulated Gasoline

The petroleum industry is developing gasoline formulations that emit less hydrocarbons, carbon monoxide, and toxics than today's fuels. These new gasolines can be introduced without major modification to existing vehicles or the fuel distribution system. The Clean Air Act requires some gasoline modifications to reduce carbon monoxide emissions as early as 1992 and use of reformulated gasoline in certain polluted cities beginning in 1995.

### Are Clean Fuels Feasible?

Clean-fueled vehicles have already been built and widespread use in the near future is feasible. To enable the transition, technologies must be refined so vehicles can achieve optimum emissions performance, consumers must accept the new vehicles and fuels, and government and industry must cooperate to ensure their availability. It will take a concerted effort by all parts of society, but a switch to clean fuels is the most viable way for many cities to attain clean and healthy air.

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READING MATERIAL

# AIR POLLUTION ALLOWANCE TRADING

There are several different types of pollution control measures that the government imposes on polluters to assure compliance with environmental regulations or otherwise achieve pollution reduction goals. This fact sheet briefly discusses the principal types of control measures, then presents an incentive-based pollution control system that allows the accumulation and trading of pollution allowances.

## Traditional Approaches

Most Federal pollution control programs take one of two general approaches to reduce pollution emissions: command and control of the source of pollution or standards for the local environment. "Point source" controls impose standards on the discharge coming out of a facility (such as a factory), usually through a permitting system. One source control method imposes standards and allows the permittee to select the method to be employed to achieve the standards. Other "technology-based" controls use standards related to the performance standards of a certain technology, and "force" the technology on polluters. Either of these "end-of-the-pipe" programs may be imposed without regard to the cost of achieving the standard or taking into account the effects of other pollution discharges on the local environment.

The "local environment" method concentrates on the level of pollution in a designated area (such as a river segment or air within a city's boundaries), requiring some degree of pollution reduction when the designated area is out of compliance. This latter method may be used under the Clean Air Act, which requires States to prepare State Implementation Plans (SIPs) that detail how the State plans to enforce air standards. However, the method has been difficult to enforce given the large number of small individual air pollution sources that exist (such as automobiles).

## Pollution Allowance Trading System

Under the Clean Air Act Amendments of 1990, the U.S. Environmental Protection Agency (EPA) established the Acid-rain Abatement Program that authorized the creation of a sulfur dioxide ($SO_2$) allowance trading system. An air pollution allowance trading program introduces market forces into pollution control, harnessing the incentives of the free market to reduce pollution.

The pollution allowance trading system program builds off both of the traditional approaches. The total amount of pollution to be allowed from certain similar sources (such as electric generation and other large "smokestack" plants) within the designated area for a specified period (typically one year) is determined based on local clean air standards and the goals of the emission reduction program. The total is then divided into allowance units, which are auctioned off to the sources. "Allowances" are in units of pollutant emitted, such that a polluter will use up its allowances as it pollutes.

The key to the system is that these allowances may be traded between sources, or may be banked. At the end of the period, each source must have enough allowances to balance its emissions for that period, otherwise a penalty on each excess unit of pollution is imposed. The program further penalizes a non-complying source by reducing its allocation for the next period by the number of excess units, which are removed from the program. Note that the system imposes ceilings on the total emission from any one source, regardless of the number of allowances held.

The allowance trading system contains an inherent incentive for utilities to conserve energy, since for each unit of pollutant that a source avoids emitting, one fewer allowance must be retired. Energy-efficient sources may then sell their surplus allowances at a profit. As an additional incentive, the government may set aside a reserve of allowances to stimulate efficiency. Extra allowances from the reserve may be available to sources that curtail emissions or invest in non-polluting technologies.

The following is a simple example of how the system operates. Utility X can implement a certain pollution control measure for $100,000. Without an allowance system, this cost would be passed on to consumers or paid for by shareholders, and may not be implemented since pollution reduction benefits are difficult to quantify. However, under an allowance trading system, this measure also will save 4 allowances. Utility Y (in the same region) does not implement reduction measures, and is going to pay $250,000 in fines after using up its allowances. Utility Y estimates that it is 4 allowances short for the period, and is then theoretically willing to pay up to $250,000 for 4 allowances. Hence, Utility X is rewarded when it implements pollution control measures and sells surplus allowances, in this example to the tune of up to $150,000 (the $250,000 fine Utility Y is facing minus the $100,000 invested in pollution reduction equipment).

The goal of this system is to utilize market incentives to reduce pollution by allowing polluters to select their own compliance strategy. An effective allowance trading system should have enough decision options open to sources to allow innovation and reduction. For example, under a program designed to reduce sulfur dioxide ($SO_2$) emissions from electric power plants that use fossil fuels, a participating source may choose to repower its units, switch to cleaner burning fuel (such as low sulfur coal), or shift some of its production from dirtier units to clean ones. The source also may choose to install pollution reduction technology or reduce output either through conservation of capacity or through increased efficiency. In any event, the program allows the participating source to combine options in any way they see fit to tailor their compliance plan to their present capabilities.

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# READING MATERIAL
# THE CLEAN AIR ACT

## What Is the Clean Air Act?

The original Clean Air Act was passed in 1963, but our national air pollution control program is actually based on the 1970 version of the law. The 1990 Clean Air Act Amendments revised the 1970 law.

The overall goal of the 1990 Amendments is to reduce pollutants in our air by 56 billion pounds a year—224 pounds for every person in the country—by the time the law is fully implemented in 2005. The new law builds on the strengths of the Clean Air Act of 1970 and the environmental lessons learned over the past 20 years. As the goals of the law are met, we will be breathing cleaner air every year.

## What Does the Clean Air Act Cover?

Two kinds of pollutants are regulated under the Clean Air Act. There are only six in the first group, which are called "criteria" pollutants. These pollutants—carbon monoxide, nitrogen dioxide, sulphur dioxide, ozone, lead, and particulate matter— are discharged in relatively large quantities by a variety of sources, and they threaten human health and welfare across broad regions of the country. EPA sets national standards for each of the criteria pollutants, and the states must take action to ensure the standards are met. Failure to meet the standards is called "non-attainment." Many urban areas are classified as "non-attainment areas" for at least one criteria air pollutant.

The other kind of pollutants—and there are hundreds in this group—are the ones that are immediately hazardous to human health and are associated with specific sources. Some of these air toxics are cancer-causing; some produce other health and environmental problems. The threat is highest for people living near large industrial facilities or in heavily polluted urban corridors.

The list of toxics emitted into the air is a long one, and it includes some familiar names. Benzene, for example, is a potent cancer-causing substance. Gasoline sold in the United States is, on average, 1.6 percent benzene. Eighty-five percent of human exposure to benzene comes from gasoline.

A second example is mercury. Mercury is a metal found in trace amounts in coal and is released to the air when the coal is burned. Mercury also is released by incinerators burning garbage. It is used in latex paints to prevent mildew, and as the paint weathers, substantial amounts of mercury may be released into the air.

Another aspect of air-toxics regulation focuses on the sudden and potentially catastrophic chemical accident. For the period 1982 to 1986, accidental releases of toxic chemicals in the United States caused 309 deaths, 11,341 injuries, and the evacuation of 464,677 people from homes and jobs. The most publicized accidental release of dangerous chemicals occurred at Bhopal, India, in 1984, when 3,000 were killed and over 200,000 injured.

## What Are the Requirements of the Clean Air Act?

Areas of non-attainment for criteria pollutants have been classified according to the extent of pollution. The five classes range from *marginal (relatively easy to clean up quickly)* to extreme (will take a lot of work and a long time to clean up). The 1990 Clean Air Act uses these classes to tailor cleanup requirements to the severity of the pollution and set realistic deadlines for reaching cleanup goals. If deadlines are missed, the law allows more time to clean up, but usually a non-attainment area that has missed a cleanup deadline must meet the stricter requirements set for more polluted areas.

States do most of the planning for cleaning up criteria air pollutants using a system of permits to make sure power plants, factories, and other pollution sources meet their cleanup goals. A variety of cleanup methods are required in non-attainment areas, many of which involve motor vehicles. Cleaner fuels, cleaner new vehicles, better maintenance programs for vehicles on the road, and mass transportation may be required. Also, as the pollution gets worse, pollution controls will be required for smaller sources of pollution.

The regulatory program for air toxics in the 1990 amendments reflects an entirely new approach. The new law names 189 toxic air pollutants. Typically, they are carcinogens, mutagens (substances that can cause gene mutations), or reproductive toxins, and their sources usually are specific industries. EPA must identify categories of the major sources of these chemicals and then develop "maximum achievable control technology" (MACT) standards for each category over the next 10 years. These standards are to be based on the best control technologies that have been demonstrated in these industrial categories. State and local air pollution agencies will have primary responsibility to make sure industrial plants meet the standards.

In setting the MACT standards, EPA will look only at pollution control equipment and pollution prevention methods, such as substituting nontoxic chemicals for the toxic ones currently in use. The new law favors setting standards that industry must achieve, rather than dictating equipment that industry must install. This flexibility will allow industry to develop its own cost-effective means of reducing air toxics emissions and still meet the goals of the act.

The law includes unique incentives for industries to reduce their emissions early, rather than waiting for federal standards. Sources that reduce emissions by 90 percent or more before the MACT standards go into effect will have six additional years to comply with them. This "early reduction program" should lead to significant reductions in air toxics both immediately and into the future.

Other parts of the Clean Air Act establish a program for the prevention of accidental releases of air toxics from industrial plants and create a Chemical Safety Board to investigate accidental releases of air toxics from industrial plants.

## What Happens If You Don't Comply?

The Clean Air Act establishes "enforcement" methods that can be used to make polluters obey the laws and regulations. Enforcement methods include citations (like traffic tickets) for violators of the law, fines, and even jail terms. The knowing violation of almost every requirement is now a felony offense. EPA and state and local governments are responsible for enforcement of the Clean Air Act, but if they do not enforce the law, members of the public can sue EPA or the states to get action. Citizens also can sue violators apart from any action taken by EPA or state or local governments.

Before the 1990 Clean Air Act, all enforcement actions had to be handled through the courts. Now, in some cases, EPA has the authority to fine violators without going to court first. The purpose of this new authority is to speed up compliance with the law and reduce court time and cost.

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# GLOSSARY

# GLOSSARY

**Acetaldehyde** A transparent, colorless liquid aldehyde with a characteristic smell, produced by the partial oxidation of ordinary alcohol.

**Acid** A solution that has a pH that is lower than 7.

**Acid Rain** Precipitation, in the form of snow, sleet, hail, rain, or fog, that has a low pH resulting from emissions of pollutants into the atmosphere, especially sulphur dioxide and nitrogren oxides.

**Acidic** A solution having properties of an acid.

**Air Pollution** The contamination of the atmosphere by industrial waste gases, fuel exhaust, particulate matter such as smoke, and the like.

**Air Quality Index** A guide used to classify and measure contaminants in the air.

**Air Quality Monitoring** Periodic or continuous surveillance or testing to measure particulates or other pollutants in the air.

**Air Quality Standards** The level of pollutants prescribed by law or regulation that cannot be exceeded during a specified time in a defined area.

**Albedo** The reflectivity of a planet. Incoming solar energy is reflected from clouds, particles in the atmosphere, and large ice caps. The greater the albedo, the more energy is reflected back into space. On Earth, about 30 percent of incoming or incident radiation is reflected.

**Allowance** An amount of pollution (for example, one ton of pollutant) that may be emitted before the allowance is used.

**Ambient Air** That portion of the atmosphere, external to buildings, to which the general public has access.

**Amortization** The process of averaging or prorating the start up or capital costs of new equipment over the expected life of the equipment.

**Amortize** To average the start up or capital costs of new equipment over the expected life of the equipment.

**Applied Science** Applying scientific concepts and knowledge for practical purposes and uses rather than theoretical.

**Aromatic** Of or belonging to a class of organic compounds, such as benzene.

**Audit** A methodical examination or review. For example, an **environmental audit** is an examination of how much energy and other resources are used or consumed for specific purposes and of conservation measures that could reduce that level of consumption.

**Auto Emissions** The release of pollutants into the air from a mobile source, such as an automobile or vehicle.

**Bank** To save unused air pollution allowances for a period that may be carried over into the next period.

**Base (Alkali)** A solution that has a pH value higher than 7.

**Baseline** An initial, stable characteristic against which future measurements are compared to determine changes. Baselines should be measured after the instruments have equilibrated.

**Basic (Alkaline)** A solution having properties of a base (alkali).

**Benefit** Anything that is useful or advantageous or promotes well being. For example, the benefit of reducing vehicle emissions is cleaner air.

**Benzene ($C_6H_6$)** A colorless, volatile, flammable liquid; the simplest aromatic hydrocarbon extracted from coal tar used as a solvent and intermediate in manufacturing organic chemicals; also called benzol.

**Biota** All the living things—plants and animals—within a system.

**Capital Costs** Costs involved in purchasing or building something that is necessary to have. For example, a business's capital costs includes the purchase cost of the furniture and equipment used to produce the goods it sells. Capital costs are usually divided by the expected life-span of the equipment to get an annualized cost. **Operating Costs** are the day-to-day costs of producing the goods, and which do not go to purchase long-lasting equipment. Operating costs are recurring, while capital costs are not.

**Carbon Cycle** The natural process whereby atmospheric carbon dioxide is converted to carbohydrates via photosynthesis in plants; animals then eat and metabolize the plants and return the carbon dioxide to the air via respiration and decay.

**Carbon Dioxide ($CO_2$)** A colorless, odorless gas that consists of one atom of carbon and two atoms of oxygen. It is the product of a chemical reaction between carbon-based materials (all life is based on carbon) and oxygen. Animals convert carbon in their food with oxygen and exhale carbon dioxide. This process is called respiration. Plants absorb carbon dioxide and produce sugars and oxygen in a process called photosynthesis.

**Carbon Monoxide (CO)** A colorless, odorless, poisonous gas, produced by incomplete burning of carbon-based fuels, including gasoline, oil and wood. Carbon monoxide is also produced from incomplete combustion of many natural and synthetic products. For instance, cigarette smoke contains carbon monoxide. When carbon monoxide gets into the body, the carbon monoxide combines with chemicals in the blood and prevents the blood from bringing oxygen to cells, tissues and organs.

**Carcinogen** Any substance or agent that produces or tends to produce cancer.

**Chlorofluorocarbons (CFCs)** Any of various gaseous compounds of carbon, hydrogen, chlorine, and fluorine. These chemicals and some related chemicals have been used in great quantities in industry, for refrigeration and air conditioning, and in consumer products. If CFCs and their relatives are released into the air, they rise into the stratosphere. In the stratosphere, CFCs take part in chemical reactions which result in reduction of the stratospheric ozone layer, which protects the Earth's surface from harmful effects of radiation from the sun.

**Cilia** Small, hairlike projections that extend from a cell surface and are capable of whiplike, rhythmic motions.

**Clean Air Act** The legislation, originally enacted in 1963, revised in 1970, and amended in 1990, which is the basis for the national air pollution control program.

**Clean Fuels** Low-pollution fuels that can replace ordinary gasoline. These are alternative fuels, including gasohol (gasoline-alcohol mixtures), natural gas and LPG (liquefied petroleum gas).

**Climate** The characteristic meteorological conditions, such as temperature, precipitation, and wind, that prevail in a particular area or region over a period of time.

**Climatology** The science of how the Earth's temperature and weather patterns are created and changed. Climatologists are interested in long-term changes to the energy balance of the Earth, and with the resulting impacts to the Earth's biota and other resources.

**Combustion** Burning, or rapid oxidation, accompanied by release of energy in the form of heat and light. A basic cause of air pollution.

**Compact Fluorescent** Energy efficient light bulbs that last ten times longer than traditional incandescent bulbs and emit more light per watt.

**Compliance** The full implementation of requirements, standards, or regulations.

**Compliance Monitoring** Periodic or continuous surveillance or testing to determine whether a factory or facility is complying with statutory requirements for limiting air particulates or other pollutants.

**Concentration** The amount of a substance contained in a specific quantity of another solution or a mixture.

**Consumption** An economic term meaning the utilization of goods and services to satisfy wants or to produce other goods.

**Contaminant** Any physical, chemical, biological, or radiological substance or matter that has an adverse affect on air, water, or soil.

**Convection** A meteorological term meaning a rapid upward movement of air that occurs through the strong heating of the Earth's surface and supportive atmosphere instability. Winds and currents are mainly driven by convection in the atmosphere and in the oceans.

**Cost** Anything that can be considered as a disadvantage, penalty, or loss associated with gaining something. For example, a cost or disadvantage of everybody driving a car to work is increased air pollution.

**Criteria (air) Pollutant** One of a group of air pollutants regulated by EPA on the basis of criteria (information on health and/or environmental effects of pollution). Criteria air pollutants are widely distributed all over the country.

**Data** Any factual information organized for analysis or as the basis for a decision.

**Demand** Economic term meaning the quantity of a commodity or service desired at a defined price and time; for example, demand for energy.

**Deterrence** An action or measures adopted to discourage people or companies from violating regulations or requirements.

**Discharge** A release of pollutants into the air.

**Electricity** A natural phenomenon known only by its effects, as electric charge, electric current, electric field, electromagnetism; the science that concerns itself with this phenomenon; the measurable existence or flow of subatomic particles more or less freed from their association from any particular molecule or atom.

**Emissions** Pollution discharged into the atmosphere from a source such as smokestacks, vents, and other areas of commercial or industrial facilities; from residential chimneys; and from motor vehicle, locomotive, and aircraft exhaust.

**Energy** The ability or capacity for doing work by a body or a system. More specifically, a measure of the total heat in a system. Energy can be converted between a number of forms that we can easily recognize, such as light, motion, electricity, and warmth. Energy is created by the sun through nuclear reactions, and is transmitted to Earth in the form of light waves. Plants and animals use the light waves directly and indirectly to produce food and sustain life. Living things are chemical reactors, converting stored energy from food or incident energy in the form of light waves into heat and motion. Energy is storable ("potential") because it can be so easily converted from one form to another.

**Energy-Efficient** The effective use and consumption of energy resulting in a minimal amount of waste. Energy-efficiency ratings are required for all new appliances. This rating indicates how much energy an appliance will use over a certain period of time.

**Equilibrate** To change to meet new conditions. For example, a thermometer reading a stable room temperature at 72°F (22.2°C), when put into a warm oven at 150°F (65.6°C), will rapidly read higher temperatures until it equilibrates at 150°F (65.6°C).

**Extrapolation** A scientific method of applying or transferring experimental observations from a model to the real world. Extrapolation is frequently necessary because effects in the real world are usually too slow or too minute to measure.

**Formaldehyde** A colorless gas with a sharp, irritating odor, used in a water solution as a disinfectant and preservative: Carbon monoxide and hydrogen have been photochemically excited with ultraviolet radiation to produce formaldehyde.

**Fossil Fuel** A combustible fossil material, such as coal, petroleum, and natural gas. Free Good A product or service that can be consumed without cost to the consumer, such as air or drinking water out of a stream, or the pleasure of observing a beautiful mountain scene.

**Free Good** A product or service that can be consumer without cost to the consumer, such as air or water from a stream.

**Greenhouse Effect** A term scientists use to describe the trapping of heat on the surface of the Earth by the atmosphere, which is a normal atmospheric occurrence. Because warm air is trapped, the Earth's surface is about 53°F (29.4°C) warmer than it would be without the greenhouse effect. This effect is magnified by certain greenhouse gases in the atmosphere, most notably carbon dioxide, methane, nitrogen oxides, and chlorofluorocarbons (CFCs). Methane is a product of natural decay from living things; nitrogen oxides are generally a result of man-made burning and automobiles and similar internal-combustion engines; and CFCs are a class of chemicals used often in air conditioners and as the pressurizing gas in aerosol spray cans. Scientists believe that concentrations of greenhouse gasses in the atmosphere will double over the next hundred years, producing average temperature rises of about 8-10°F (4.4-5.5°C).

**Hydrocarbons** Chemical compounds that consist entirely of carbon and hydrogen. Hydrocarbons make up a large part of vehicle emissions and contribute to smog.

**Hypothesis** A supposition, hunch or guess about what or why something happens. More specifically, a proposition put forth as a basis for reasoning; a supposition formulated from proved data and presented as a temporary explanation of an occurrence, as in the sciences, in order to establish a basis for further research.

**Incandescent** An object, such as a light bulb, that emits light as a result of being heated. In an incandescent light bulb, a filament is heated by an electric current to produce light. Incandescent light bulbs are less energy-efficient than fluorescent light bulbs.

**Intensity** The amount or degree of strength of electricity, heat, light, or odor per unit of area or volume. For example, odor intensity is the perceived strength of an odor stimulus.

**Kilowatt-Hour** The unit of electric power consumption in common use in this country. A kilowatt is 1,000 watts, and a kilowatt-hour is 1,000 watts of power in use for one hour. Electric power production contributes 35% of all U.S. emissions of carbon dioxide, 75% of sulfur dioxide, and 38% of nitrogen oxides.

**Lead** A heavy metal that may be hazardous to health if breathed or swallowed (for example, by a child eating soil or paint contaminated with lead). Lead occurs in the atmosphere as particulate matter originating from natural and artificial pollution sources. Lead's use in gasoline, paints, and plumbing compounds has been restricted or eliminated by Federal laws and regulations.

**Logarithm** The power to which a base number (usually 10) must be raised to produce a given number. Many scientific scales, such as pH are based on multiples of 10. Every whole increment of pH means a 10-fold increase of decrease.

**Lumens** A measure of how much light is emitted from a light source; a lumen is equal to the amount of light emitted through a solid angle by a source of one candle radiating equally in all directions.

**Manufactured Goods** Goods made or processed (from a raw material) into a finished product, especially by means of a large-scale industrial operation.

**Market Forces** The requirements that a business believes its customers want, and will pay for. Businesses will conduct research on their potential customers' needs, and will adjust their products or services to better respond to these perceived market forces.

**Methane** A colorless, odorless, flammable gas, the simplest of the hydrocarbons. Methane is formed naturally by the decomposition of plant or other organic matter, as in marshes, petroleum wells, volcanoes, and coal mines. It is obtained commercially from natural gas.

**Micrometer** A unit of measure. There are 1 million ($10^6$) micrometers or microns in 1 meter, in other words, one micrometer is one millionth of a meter; objects measured in micrometers are usually too small for the human eye to see.

**Mitigation** The reduction or offset of harm caused by pollution. Mitigation can include preventing the pollution, cleaning up the pollution, or reducing the pollution. Mitigation can be accomplished through engineering solutions (such as air pollution "scrubbers" on power plants) or process solutions (such as recycling).

**Monitoring** Periodic or continuous surveillance or testing to collect specific types of data. Air is monitored to measure air pollution. See Air Quality Monitoring.

**Mucus** A viscid, slimy substance that moistens and protects the mucous membranes located in the nose, throat, digestive tract, and other body passages and cavities open to the air.

**National Ambient Air Quality Standards** The levels of pollutants that cannot be exceeded as prescribed by law or regulation for outside air.

**Natural Gas** A natural fuel containing methane and hydrocarbons that occurs in certain geologic formations.

**Neutral** A solution that is neither acid nor alkaline (base). A neutral solution has a pH equal to 7.

**Nitrogen Dioxide ($NO_2$)** The result of nitric oxide combining with oxygen in the atmosphere. It is a major component of smog.

**Nitrogen Oxides ($NO_X$)** Gases formed in great part from atmospheric nitrogen and oxygen when combustion takes place under conditions of high temperature and pressure. Nitrogen oxides include nitric oxide (NO) and nitrogen dioxide ($NO_2$).

**Non-renewable Resources** Resources that exist in only finite or limited amounts in the Earth and atmosphere, such as coal, oil, metals, and minerals.

**Non-attainment Area** A region or area that fails to meet the national standards set by EPA for each of the six widespread criteria pollutants, which are ozone, lead, particulates, nitrogen oxides, sulfur dioxide, and carbon monoxide.

**Odor Detection Threshold** The minimum odorant concentration needed to perceive the presence or existence of a substance or pollutant. The concentration of a substance often is measured in parts per million or billion. For example, ammonia can be perceived when it has a concentration of 17 parts per million.

**Odor Recognition Threshold** The minimum odorant concentration needed to identify a particular substance or pollutant. The concentration of a substance often is measured in parts per million or billion. For example, ammonia has a recognition threshold of 37 parts per million.

**Outgas** To remove embedded gas from material by heating. Gases are released from furniture, carpet and other synthetic household items when those items are exposed to temperature increases.

**Ozone** A principal component of smog. Ozone can be either good or bad for living things, depending upon where it is. Ground-level ozone (where we breathe it) is harmful and causes health effects similar to asthma, and is known to harm trees and plants. However, an ozone layer that exists naturally in the stratosphere keeps out most of the dangerous ultraviolet rays from the sun that can cause skin cancer.

**Particulate Matter** Very small, separate particles, such as a particle of dust or fiber. The major source of atmospheric particulates include combustion of coal, gasoline, and fuel oil; cement production; lime kiln operation; incineration; and agricultural burning.

**Permit** An authorization, license, or equivalent control document issued by the federal, state, or local government to implement the requirements of a regulation. For example, the 1990 Clean Air Act introduced a nationwide permit system for air pollution control that requires permits for both the operation of power plants or other facilities and for construction of new plants or facilities.

**pH** A measure of acidity and alkalinity of a solution.

**Photochemical Reaction** A chemical reaction in the atmosphere that is triggered by sunlight. Pollutants often are created from a photochemical reaction.

**Photosynthesis** The process by which plant cells make carbohydrates by combining carbon dioxide and water in the presence of chlorophyll and light, and release oxygen as a by-product. It is the source of most of the oxygen in the air.

**Planning** To design or devise by drawing or making a graphic representation of something. For example, in planning a city, urban planners determine the arrangement of roads, buildings, and parks in a city.

**Point Source** A discrete, stationary source of pollution, such as a power plant, factory, or gas station.

**Policy** Any plan or course of action adopted by a government, business organization, or the like, designed to influence and determine decisions and actions. For example, Clean Air regulations constitute policy issued by the EPA to control air pollution.

**Pollutant** Any substance introduced into the environment that adversely affects the usefulness of a resource. Air pollutants are unwanted chemicals or other materials found in the air, such as gases, vapors, dust, smoke or soot.

**Pollution** An adverse impact upon the natural environment usually caused as a by-product of manufacturing or using a product. For example, air pollution can come from the stacks of power plants when they burn oil or coal to produce electricity or from the operation of automobiles. Air pollutants include carbon dioxide, the most important greenhouse gas and major cause of global warming; sulphur dioxide, a principal component of acid rain; and nitrogen oxides, precursors to both acid rain and smog. Some of these same pollutants occur naturally, and can come from volcanoes, forest fires, and other natural sources.

**Power Consumption** The amount of power utilized for a particular purpose, usually measured in watts per hour.

**Precipitation** A meteorological term meaning a deposit of moisture onto the earth in the form of rain, dew, mist, snow, hail, and sleet.

**Precursor** A condition or a chemical ingredient that signals another condition, such as smog or acid rain..

**Prediction** A projection in advance of an event based on observation, experience, or scientific reason.

**Probability** The likelihood that an event will occur, as measured by the relative frequency of the occurrence of events of the same kind.

**Profit** The difference between the cost to a business of producing a product or service and the income it makes when it sells its product or service.

**Pure Science** The study of fundamental scientific principles for the sake of improving knowledge; theoretical rather than practical.

**Radioactivity** The property possessed by some elements, such as uranium and radon, of spontaneously emitting alpha or beta rays and sometime also gamma rays by the disintegration of the nucleus of atoms.

**Radon Detector** A mechanical, electrical, or chemical device designed to discern the presence of radon in specific areas. Common detectors are the charcoal canister, alpha track monitor, and electret ion chamber.

**Rain Forest** A large, very dense forest, located mostly in tropical areas with an annual rainfall exceeding 100 inches, that is composed mainly of lofty broad-leaved evergreen trees that form a continuous canopy.

**Raw Material** Unprocessed natural materials that can be converted by manufacture or processing into a new product.

**Recyclable Resources** Resources that can be reused with further processing, such as aluminum and paper. Usually, the energy required and air pollution emitted in recycling a product are much lower than in making a product from virgin materials.

**Regulations** Rules that federal and local governments issue to govern how individuals and businesses may act or operate.

**Relative Humidity** A meteorological term meaning the ratio of the amount of water vapor actually present in the air to the greatest amount possible at the same temperature.

**Renewable Resources** Resources that can be replenished, such as agricultural crops and trees that can be harvested and replanted.

**Respiration** The physical and chemical processes by which an organism supplies its cells and tissues with the oxygen needed for metabolism and relieves them of the carbon dioxide formed in energy producing reactions.

**Restitution** A return to previous state or position.

**Retribution** The dispensing or receiving of punishment in compensation for an act perceived to be harmful to others.

**Risk** The possibility of suffering harm or loss either because of a hazardous and dangerous condition or from an action or a decision.

**Scale** A series of marks found along a line or curve and spaced at regular intervals to use in measuring weight, size, time, temperature, etc. An instrument to use for measuring.

**Scarce Good** A product or service that must be paid for, such as food, automobiles, and haircuts.

**Scientific Method** An iterative process in which a hypothesis is tested through experiments and compared to observation.

**Sea-Level Rise** An increase in the volume of the oceans. Scientists who believe the greenhouse effect will contribute to global warming have cited sea-level rise as a potential consequence of the melting of polar ice-caps as the temperature of the Earth rises. An average sea-level rise of just a few feet could be enough to flood many square miles of area.

**Smog** A mixture of pollutants, principally ground-level ozone, produced by chemical reactions in the air of smog-forming chemicals. Smog can harm health, damage the environment, and cause poor visibility.

**Smoke** The gaseous products of burning carbon-based materials; made visible by the presence of small particles of carbon.

**Soot** A fine, black powder formed by combustion or separated from fuel during combustion. It rises into the air as fine particles that settle on surfaces and covers them with a black layer. Often associated with burning of coal.

**Standard of Living** The necessities, comforts, and luxuries enjoyed by an individual, a group, or society in general.

**Standards** In the context of the Clean Air Act, a contaminant level established by EPA above which a contaminant presents unacceptable health or environmental risks.

**Stratospheric Ozone** Ozone located in the portion of the atmosphere that is 10-to-25 miles above the Earth's surface. Ozone at this altitude filters out harmful sun rays, including those that may cause health and environmental damage.

**Sulphur Dioxide** A colorless, irritating gas formed by the burning of sulphur-containing material. Sulphur dioxide can react with other atmospheric chemicals to form sulfuric acid.

**Supply and Demand** The relationship of the demand for a good or service to the supply, or availability, of that good or service. This relationship is a factor in pricing of goods and services. Since the supply of resources, including air and clean water is finite, increased consumption of these resources by humans decreases their supply and increases their price.

**Temperature** The degree of heat or cold of any substance or living organism measured on a definite scale, such as Celsius, Fahrenheit, Réaumur, or Kelvin.

**Thermal Inversion** A layer of warm air settling over a layer of cool air that lies near the ground. This condition prevents smog from rising and dissipating.

**Tidal Volume** The volume of air that a person ordinarily inhales and exhales at each breath. The tidal volume of the average adult is 0.5 liters.

**Total Minute Volume** The total volume of air a person inhales and exhales in a minute.

**Toxic Release Inventory** A computer database, maintained by the EPA, that contains information about toxic releases. The information in the database is collected from facilities that are required to report on an annual basis about any releases of toxic substances above a specified quantity into the air, land, and water.

**Toxicity** The degree of danger posed by a toxic or poisonous substance to animal or plant life.

**Trend** The general movement over time of a statistically detectable change; a prevailing tendency, inclination, or pattern.

**Vacuum** An enclosed space from which almost all the air or other gas has been removed. A vacuum permits experimentation without atmospheric disturbance.

**Variable** A condition that can change, such as temperature, humidity, or atmospheric pressure.

**Ventilation Rate** The rate at which a living organism breathes, expressed as a volume per unit of time.

**Volatile Organic Compounds (VOCs)** Organic compounds, such as gasoline, industrial chemicals (benzene), and solvents (toluene and xylene and tetrachloroethylene), that participate in atmospheric photochemical reactions. Many VOCs are hazardous air pollutants.

**Weather** Meteorological term meaning the condition of the atmosphere at a particular time or area with respect to temperature, moisture, clearness, and wind velocity.

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## FILMS, FILMSTRIPS, SLIDES, VIDEOS, AND KITS

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## COMPUTER SOFTWARE AND NETWORKS

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# PROJECT A.I.R.E. CONTACTS

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For scheduling guest presenters from the U.S. Environmental Protection Agency or to discuss the activities, call the EPA representative in your geographic area.

## REGIONAL CONTACTS

Paula Watson, Region 1
U.S. EPA
JFK Federal Building
Boston, MA 02203
617-565-3502

Barbara Giannacco, Region 2
U.S. EPA
26 Federal Plaza, Rm 1034
New York, NY 10278
212-264-9593

Carrie Dietzel, Region 3
U.S. EPA
841 Chestnut Street (3EA22)
Philadelphia, PA 19107
215-597-6728

Wesley Lambert, Region 4
U.S. EPA
345 Courtland St., NE
Atlanta, GA 30365
404-347-3004

Renee Kuruc, Region 5
U.S. EPA
77 West Jackson Blvd.
Chicago, IL 60604-3507
312-353-5574

Evelyn Daniels, Region 6
U.S. EPA
1445 Ross Aveue, Suite 1200
Dallas, TX 75202-2733
214-655-7543

Judith Robinson, Region 7
U.S. EPA, ARTX-ARBR-ARCP
726 Minnesota Avenue
Kansas City, KS 66101
913-551-7825

Judy LaVerdure, Region 8
U.S. EPA, 8-ART-AP
999 18th Street, Suite 500
Denver, CO 80202-2405
303-294-1092

Ida Tolliver, Region 9
U.S. EPA, E-2
75 Hawthorne Street
San Francisco, CA 94105
415-744-1581

Mish Vakoc, Region 10
U.S. EPA, AT082
1200 Sixth Avenue
Seattle, WA 98101
206-553-8578

## HEADQUARTERS CONTACTS

Linda Zarow, OAR
Program Coordinator
U.S. EPA, M.C. 6101
401 M Street, SW
Washington, DC 20460
202-260-6221

Deborah R. Miller
Assistant Program Coordinator
U.S. EPA
MD-15
Research Triangle Park, NC 27711
919-541-5552