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The Atmosphere and the Environment: Four Environmental Problems

Curriculum Unit 93.05.02
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In this curriculum unit I will be discussing three environmental problems, all relating to our atmosphere and the air we breath. Although this unit can be taught at any time during 8th grade Earth Science, it is particularly appropriate right after the required curriculum unit on the atmosphere.

The unit will use a variety of teaching techniques and emphasis is placed on hands-on experiences. How Connecticut and New Haven are affected by these three problems (ozone, global warming and acid rain) will be emphasized. Also, the realities and myths of each problem will be discussed. Furthermore, an appendix of data supporting each problem will be included. This enables the unit to be adaptable to different student abilities and also provides practice in a critical area of science and math-interpretation of data.

Ozone (stratospheric) Background Information

In 1985, a hole in the ozone layer the size of the continental United States was discovered over Antarctica. This hole has appeared each subsequent spring and the amount of ozone depletion over this continent is up to 40%. Ozone in the stratosphere blocks out harmful ultraviolet rays from the sun and if such protection did not exist, there could not be life on Earth as we know it. As a matter of fact, until the atmosphere could build up the ozone layer around the Earth, life did not exist, The Environmental Protection Agency predicts there will be an increase of 20,000 skin cancer cases for every 1% decrease in ozone. (Environmental Defense Fund, 1990)

Ozone is a molecule consisting of three atoms of oxygen and is found in a layer where the concentration is only a few parts per million. This layer occurs in the atmosphere at altitudes of between 12-and 25 kilometers. In the spring of 1987, the mean ozone concentration over Antarctica was down 50%. (Shea, 1988)

Why are these reductions happening? During the long, sunless Antarctic winter (March-August) air over the continent becomes isolated in a swirling polar vortex that causes temperatures to drop below -90C. This is enough for the little water vapor present in the upper atmosphere to freeze and form polar stratospheric clouds. Chemical reactions on the surface of the cloud ice crystals convert chlorine from nonreactive forms such as hydrogen chloride and chlorine nitrate into active chlorine atoms (that are very sensitive to sunlight) . Furthermore, gaseous nitric oxide ordinarily able to inactivate chlorine is transformed into frozen and nonreactive nitric acid. (Shea, 1988)

A history and overview of ozone formation and subsequent problems can be found in the appendix pages 1-3. (Earthquest, 1991)

Spring sunlight releases the chlorine, starting a virulent ozone-destroying chain reaction that proceeds unimpeded for five to six weeks. Molecules of ozone are transformed into ordinary oxygen. The chlorine keeps attacking more ozone in this chain reaction. Global warming—a problem that will be presented in the last part of this unit encourages the ozone destroying process by increasing the formation of stratospheric clouds over Antarctica. (Shea, 1988)

What is causing the breakup of all this ozone? The answer is Chloroflourocarbons (CFC's), Halons, carbon tetrachloride, nitric oxides, and methyl bromide—are the main culprits. (Environmental Protection Agency(EPA),1992)

CFC's have gotten the most media attention and are the main ozone-destroying chemicals. CFC's are very stable molecules and are not destroyed in the lower atmosphere. Hence, once released, CFC's go upward and in six to eight years reach the stratosphere. Once in the stratosphere, they can survive for up to 100 years.

Each chlorine atom from a broken down CFC molecule is capable of destroying tens of thousands of ozone molecules due to the aforementioned chain reaction. (Shea, 1988)

CFC's were developed in 1928 and their usage became widespread in the 1950's-1980's. In certain countries their usage is still growing. Worldwide CFC's are used in the following ways; Aerosols (banned in the U.S.)—25%, rigid foam insulation—19%, solvents—19%, air conditioning—12%, refrigerants—8%, flexible foam—7%, and other uses total 10%. (Shea, 1988)

Scientists and finally politicians eventually realized the danger from CFC's and in 1987 the Montreal Protocol was signed which states that the United States and other countries will cease CFC production by the year 2000. The U.S. will actually cease production earlier—in 1995. The Montreal Protocol has set aside a special \$240 million fund to help developing nations switch to CFC- free technology. (NOAA & OIES, 1992)

The Hughes Corporation now uses a chemical derived from lemon juice in place of CFC's to assist in its weapons manufacturing process. Northern Telecom has also ceased to rely on CFC's. Unfortunately, countries like China are not ceasing their production of CFC's. (Flavin, 1989)

Interestingly enough, scientists from the U.S. Geological Survey have discovered bacteria that eat CFC's. The bacteria can only live in the absence of oxygen (anaerobic environments) such as in wetlands and soil where some CFC does penetrate. (Popwatch, 1992)

Halon, another problem, contains bromine—a more effective destroyer of ozone than chlorine (found in CFC). Halon was developed by the U.S. Army Core of Engineers at the end of World War II and is used extensively in fire fighting and fire extinguishers because it does not cause damage or leave a residue. Most Halon though, is kept for emergency purposes and stored. (Shea, 1988)

The EPA is concerned with Methyl Bromide, a soil fumigant developed as a pesticide in 1932. Estimates say that this chemical could be the cause of up to 15% of the total predicted global ozone depletion by the year 2000. Methyl Bromide is a new target of ozone protection efforts. (EPA, 1993)

Even if we stopped production of all ozone depletion chemicals today, the problem would go on for years. CFC's once released into the atmosphere have a lifetime of 75-400 years. This means that they could break up

ozone molecules through chain reactions that would go on for centuries. As another example, Nitrous oxide has a lifetime of 100-175 years in the atmosphere. (Gawell, 1989)

An interesting note, the 1991 Mount Pinatubo volcanic eruption spewed ozone—unfriendly chlorine compounds (eg. HC1) into the air and researchers believe that these were partly responsible for the record-breaking ozone hole over Antarctica in 1992. (Time Magazine, 1993)

In addition, there has been a decrease in the amount of ozone over the northern hemisphere at a rate of 1.7—3% in the past 25 years. This depletion happens mostly during the winter and at higher altitudes. (U.S.D.C. & NOAA, 1989)

Additional problems due to the decrease in stratospheric ozone aside from the increased risk in skin cancer include; a decrease in soybean crop yield and a decrease in phytoplankton productivity of oxygen (phytoplankton produce most of the world's oxygen). (Shea, 1988)

Ozone (Tropospheric) Background Information.

While we can't live without ozone in the stratosphere, it is very difficult to live with it in the troposphere. We live our lives in the troposphere or bottom layer of the atmosphere, yet this ground level ozone is the major constituent of photochemical smog. (EPA, 1992)

Ozone, a colorless gas, forms in the lower atmosphere as a result of chemical reactions between oxygen, volatile organic compounds and nitrous oxide, in the presence of sunlight, especially during hot weather. (EPA, 1992)

Sources of ground level ozone include; vehicles, factories, industrial solvents, gas stations, and farm equipment, to name a few. (EPA, 1992)

According to Connecticut's Department of Environmental Protection (DEP), tropospheric ozone is Connecticut's worst air pollution problem and we're not alone. See appendix page 4-5. In 1992, Connecticut exceeded the federal ozone standard on 8 days—mainly in the summer when winds blow from the southwest. (DEP, 1993)

In 1989, the ozone level was above the health standard for 13 days. In the past 10 years, ozone levels exceeded the standard for 33 days in Connecticut—21 of those days occurring in the last 5 years. Ozone gas has a faint blue color and is monitored in 10 sites around Connecticut between April 1-October 31. (DEP, 1990)

To make air pollution reporting uniform throughout the country, a national "Pollution Standards Index" has been developed. See appendix pages 6-7. (DEP, 1990)

For additional information on the history of Connecticut's air quality see appendix pages 8-11. (DEP, 1990)

Tropospheric ozone, aside from playing a key role in air pollution, also contributes to the greenhouse effect and is one of the six pollutants used by the EPA to set the national ambient Air Quality Standard. Ozone causes foliar plant damage, affects the human respiratory system and damages materials such as rubber and paint. (EPA, 1989)

Ozone is also an oxidant and through chemical reactions contributes to other pollutants such as sulfuric and nitric acids. In reality, it controls the chemical processing of all global emissions. (EPA, 1989)

Ground level ozone damage is estimated to reduce crop yields from 2-5%. (NAPAP, 1991)

During the July heat wave of 1993, unhealthy ozone (smog) levels were front page stories due to health risks, especially for people with respiratory problems. (Katz, 1993)

Acid Rain—Background Information

Acid Rain is another atmospheric problem that is worth investigating. Some of the same pollutants that are involved with ozone affect this problem too. Discussion of acid rain can be enhanced by the use of the SEPUP kits that will become part of the 8th grade curriculum starting in 1993.

In order to understand acid rain, one must first learn about pH. pH is the measure of the chemical activity of the acid and alkali dissolved in water and is measured on a negative logarithmic scale numbered 0-14. A number less than 7 is acidic, 7 = neutral and a number greater than 7 is alkaline (basic). The lower the number, the more acidic and the higher the number, the more basic. Another way to look at pH is; the lower the pH the greater the concentration of hydrogen ions. (American Chemical Society, 1991)

Acids and bases(alkaline substances) are two extremes that describe chemicals- just like hot and cold describe temperature. A substance that is neither acidic nor basic is considered neutral. Pure water is neutral. Vinegar and lemon juice, for instance, are acidic and laundry detergents and ammonia are basic. Chemicals that are very basic or very acidic are reactive and dangerous. A dangerous acid is automobile battery acid (contains acid similar to that causing acid rain). Household drain cleaner often contains lye which is very alkaline. (EPA, 1990)

Some common pH values are; human gastric juice 1.3-3.0, lemon juice 2.1, orange juice 3.0, black coffee 5.0, milk 6.9, egg white 7.6-9.5, baking soda in water 8.4 and household ammonia 11.9. (Barber, 1991)

Part of this curriculum will contain lesson plans that will enable a student to have a good understanding of the concepts of pH, acids, bases and reactions of and between both.

Acid rain affects the climate and the environment we live in. Fish are affected if water is pH 6 or lower. Buildings and paint are affected at a pH of 5.5 or lower. Trees and plants are affected if acid rain is pH 3.5 or lower. (EPA, 1990)

If acidity is increased, nutrients are leached from the soil and nitrogen-fixing bacteria are killed, and toxic metals are released. (EPA, 1988) Also, acid rain creates a cation imbalance in the soil which effects tree growth because the trees don't get the minerals they need. (Leaf, 1990) These are some of the problems caused by acid rain and acid deposition—more will be discussed later.

Acid rain is rain that is more acidic than normal due to pollution put into the air by man. Sulfur dioxide and nitrogen dioxide are the main pollutants that cause acid rain. Acid rain forms high in the clouds where sulfur and nitrogen dioxides react with water, oxygen and oxidants. Here a mild solution of sulfuric and nitric acids are formed. Sunlight increases the rate of most of these reactions. Rainwater, fog and other types of precipitation contain sulfuric and nitric acids. (EPA, 1990)

Interaction between water droplets and carbon dioxide in the atmosphere gives rain a pH of 5.6, so clean, pure rain is normally acidic. (EPA, 1990)

About one half of the acidity in the atmosphere falls back to earth through dry deposition as gases and dry

particles, with wind scattering them about. If acidic enough, these gases and particles can eat away the things they settle on. Also, these gases and particles get into runoff water. The combination of acid rain and dry deposition is called acid deposition and it has the potential to be even a larger problem than acid rain by itself. (EPA, 1990)

Wind carries pollutants for hundreds of miles before they become joined with water droplets to form rain and thus acid rain can be a problem in areas hundreds of miles away from polluting smokestacks. Dry deposition though is usually greater near the source of the pollutants. (EPA, 1990)

Natural sources of acids are volcanic gases and hot springs usually recycled in nature by absorption and breakdown to different substances which contribute to a small portion of acid rain. Actually, in these normal, natural amounts help to dissolve minerals and nutrients from the soil for plants to use as food. Pollution overloads this natural system. (EPA, 1990)

Sources of the two major acid rain pollutants are as follows; sulfur dioxide comes primarily from coal burning power plants and nitrogen dioxide comes primarily from motor vehicles and coal burning power plants. (EPA, 1988)

Over 80% of the sulfur dioxide emissions in the United States originate in the 31 states east of or bordering the Mississippi River and these pollutants are transported elsewhere by prevailing winds. (EPA, 1988)

Between 1940 and 1970, annual sulfur dioxide emissions had increased by more than 55% and nitrogen dioxide emissions had almost tripled. Ten percent of the lakes in the Adirondacks of New York and in the Upper Peninsula of Michigan were found to be acidic. Also, 2.7% of total stream reaches in the Mid-Atlantic and southwest were found to be acidic. The National Acid Precipitation Assessment Program (NAPAP) found also through a ten year federal research program that though some waters were affected, there was no measurable consistent effects on crop yields. (EPA, 1988)

In the late 1960's and 1970's scientists made the connection between acid deposition and acidification of certain lakes and sports fisheries (eg. the Adirondack Lakes). The extent of damage depends on the total acidity deposited and the sensitivity of the area on which it falls. Areas with acid-neutralizing compounds (eg. calcium carbonate) in their soil have a buffer against acid damage, but thin soils do not. (EPA, 1989) A buffer is a substance that has the ability to (partially) neutralize acid precipitation in soils and waters. (National Wildlife Federation, 1983)

Nitrogen dioxide is a light brown gas at lower concentrations, in high concentrations, it becomes an important component of unpleasant-looking brown urban haze. As stated previously, it results from the burning of fuels and motor vehicle emissions. Nitrogen dioxide is a major component of smog and acid rain, and can impair human health (eg. for asthmatics, it can increase breathing difficulty). (EPA, 1992)

Note—nitrogen dioxide is an oxidant and helps to speed up chemical reactions in both the troposphere and stratosphere. It is not only involved in the acid rain dilemma, but contributes to the ozone hole and ground level ozone pollution. In addition, this gas contributes to global warming. (EPA, 1992)

Sulfur dioxide is a colorless gas, odorless at low concentrations, pungent at high. It's sources include; industrial, utility, and apartment house furnaces, boilers, petroleum refineries, smelters, paper mills and chemical plants. It is a major contributor to smog. Also, sulfur dioxide contributes to low visibility and can harm vegetables and metals. Like nitrogen dioxide, it causes human pulmonary problems. (EPA, 1992)

Acid rain is speeding up the weathering process by dissolving the mineral cement that glued sediments into rocks. As a result, brownstone buildings throughout the United States are slowly crumbling and many brownstone tombstones are becoming faceless monuments—their epitaphs erased by erosion due to acid rain. (Bell,1986)

The statue of Liberty, the Gettysburg Battlefield, and maple trees in New England, all feel the effects of acid rain. (Bell, 1986)

Acid rain and its effects also contribute to politics. One half of Canada’s acid rain originates in the United States and this has led to politics between the two countries and an agreement to lower the pollutants causing acid rain. (American Chemical Society, 1991)

In order to reduce acid rain in the U.S. and Canada, Title IV of the Clean Air Act amendment of 1990 establishes the Acid Rain Program. The goal of this program is to cut sulfur dioxide emissions in half and to substantially reduce nitrogen oxide emissions from electric utility plants. Sulfur dioxide is to be reduced by 10 million tons below the 1980 levels and nitrogen oxide by 2 million by the year 2000. Phase I begins in 1995. Also, starting in 1995, there will be a pollution allowance transaction and trading system set up. (EPA, 1992)

In addition to the above, other principles of the Acid Rain Program are as follows:

Free trading of emission allowance.

Permits and compliance plans.

Energy efficiency/pollution prevention incentives.

Reduction of acid deposition. (EPA, 1991)

For a history of government responses to acid rain see appendix pages 12-15. (EPA, 1989)

A chart that shows estimates on just how much sulfur dioxide can be found in the air can be found in the appendix on page 16. (EPA, 1992)

Acid rain seems to be one environmental problem that the government, politics or not , is taking seriously.

Global Warming—Background Information

Since the beginning of the industrial revolution some 200 years ago, machinery and fossil fuels have saved inestimable amounts of time and labor, while substantially raising the standard of living around the world. It is perhaps ironic that the same technology could change the Earth’s climate and threaten its future.

In 1896, a Swedish chemist, Svante Arrhenius estimated that the carbon dioxide concentration would double and the Earth’s surface would warm by approximately five degrees. Today we realize that his estimate and concern for the environment may not have been very far off the mark. In 1990, the U.S. government had allocated five hundred million dollars for research into global warming. (Davies, 1990)

Global warming is a great topic to include in a curriculum unit. Aside from the fact that global warming has

received wide media coverage and all students have heard or read about it in the news, analysis of the problem also shows that pollutants affect more than one part of our environment. Substances which may contribute to global warming include; CFC's, methane, nitrogen oxides and carbon dioxide (this has received the most press). Lastly, students will be able to see how a basic principle supporting life on Earth can go "haywire." See appendix page 17.

The surface of the Earth is heated by incoming solar radiation. The earth then emits some of this energy as infrared radiation (ex. radiation of much lower frequency). Some of this infrared radiation escapes directly into space, but much is absorbed by gases in the atmosphere like water vapor, carbon dioxide and ozone. The absorption process traps energy and heats the atmosphere much like a greenhouse traps heat. Therefore, this atmospheric process is known as the "greenhouse effect." The amount of energy trapped by greenhouse gases is equivalent to sixty-five percent of the energy received from the sun, and is therefore critical for establishing the average surface temperature of the Earth. The average temperature on earth is 15 degrees centigrade. (U.S. D.C. & NOAA, 1989)

If we didn't have an atmosphere, the temperature on earth would be 33 degrees centigrade cooler (60 degrees Fahrenheit) colder. Venus with a thick atmosphere of carbon dioxide has an average surface temperature of 470 degrees centigrade. Mars, with a thin atmosphere has an average surface temperature of -60 degrees centigrade. (NOAA & UCAR, 1991)

A greenhouse effect is essential to life. If there were no global warming or trapping of radiation by the greenhouse gases, our planet would be covered by ice. Past temperature fluctuations on earth before the industrial age have occurred naturally, and have included ice ages and desertification. Most scientists foresee a doubling of carbon dioxide occurring in the next century and are concerned about the resulting global warming leading to great changes in the earth's climate. (Albritton, 1990)

Due to increases in the greenhouse gases, some computer models show a possible rise of 1-3 degrees centigrade (1.95.7 F) in temperature. (UDC & NOAA, 1989)

According to the World Resources Institute, various human activities involving energy use (49%), industrial processes (24%), deforestation (14%) and agriculture (13%) all contribute to global warming by increasing the amount of the following greenhouse gases: methane, ozone, carbon dioxide and the man-made gases CFC's and nitric oxide. (World Resources Institute, 1990-1991)

Carbon dioxide today comes into the atmosphere from the burning of fossil fuels, deforestation, soil processes, and wood burning. It has a lifetime in the atmosphere of 2-3 years and is increasing at a rate of .3% per year. Carbon dioxide contributes 49% to global warming. (Gawell, 1989)

Methane comes from rice paddies, cattle and other livestock, termites, deforestation, wood burning and landfills. It has a lifetime of 5-10 years. Methane is increasing by .8-1.0% per year and contributes 18% to global warming. (Gawell, 1989)

CFC's, chemicals used in refrigeration, insulation, foams, aerosol propellants and in other parts of industry, have a lifetime of 75- 400 years and are increasing by 4% per year and contribute to heating by 14%. (Gawell, 1989)

Nitric oxide comes from fertilizers, land-use changes, wood burning, coal and oil combustion. It has a lifetime of 100- 175 years. It is increasing by .2% per year and contributes to warming by 6%. (Gawell, 1989)

Ozone (tropospheric) at lower elevations adds to the warming process. Its formation is catalyzed by other gases such as nitric oxide. In the troposphere, ozone has a lifetime of 5 months and is increasing by .2-1% per year. Ozone is responsible for 3% of the total global warming. (Gawell, 1989)

We need the greenhouse effect and global warming to live, but what if these artificial increases in the greenhouse gases (caused by man) raise the earth's temperature? Is this already occurring? This is where the controversy lies.

The years 1987 and 1988 were the hottest on record. (atmosphere, 1992) With the heat wave and floods of 1993 the question of global warming will take center stage again.

The earth does have a natural buffering or neutralization system to get rid of carbon dioxide, but will it be enough or be able to work fast enough? The oceans contain 95% of the carbon actively circulating in the biosphere and the carbon cycle found within it provides the main long-term control of atmospheric carbon dioxide. This determines the strength of the natural greenhouse effect and has been closely involved in previous climate changes. (American Chemical Society, 1990)

Presently, the net oceanic uptake of carbon is not keeping pace with the increasing carbon dioxide emissions, and is causing great uncertainty. Human activities currently release about 7-8 GT (1 GT=10¹² kg.) of carbon per year and the atmosphere accumulates around 3.5 GT per year. Net oceanic absorption is approximately 1-3 GT per year. (American Chemical Society, 1990)

Carbon dioxide is withdrawn from the ocean's surface by photosynthesis (phytoplankton). Also, the ability of the ocean to absorb carbon dioxide is strongly related to ocean temperature. Thus, oceans are key players in future global warming. (American Chemical Society, 1990)

While the jury's still out on whether the increase in carbon dioxide in the atmosphere will add to the warming of the earth should we take the chance? Global warming receive attention in the media until a couple of years ago Pinatubo exploded. Mt. Pinatubo spewed gases into the atmosphere and cooled the atmosphere by a degree or two. With its gases now dissipated, and a very hot and dry spring/summer in 1993, will this controversy be renewed in the media?

What if the oceans and other parts of the biosphere cannot absorb all the extra gases? Do we really need to find out and shouldn't we get rid of all the possibilities? Many articles and even a TV movie this past year have focused on the possible consequences of a rise in the earth's temperature. These possibilities include extinction of plants and animals, failed crops, deforestation, a rise in sea levels and thus flooding, droughts, tropical diseases, monsoons and hurricanes. (Gawell, 1989)

The media has been giving much attention to the disappearing rainforests in South America, but what about other places on earth. Each tree absorbs as much as 36 pounds of carbon dioxide per year and thus are vital to maintaining the earth's climate. (World Resources, 1990-1991)

As stated previously, our government as well as some others are trying to reduce air pollution and thus greenhouse gas emissions through a variety of laws and regulations; but not every country is pursuing the same goal. An example is China. China's fast growing economy is primarily due to the burning of coal. Carbon emissions in China have increased by 65% in the past decade and China now contributes 11% of global carbon emissions. (Lenssen, 1993) See appendix page 18

CFC's are 10,000 times better at blocking radiation than carbon dioxide, but there are 35,000 times more carbon dioxide molecules in the atmosphere. The U.S. is responsible for the

largest portion of man-made contributions to the greenhouse effect—21%, USSR- 14%, Europe- 14%, China 7% (this figure all gases), Brazil—4%, India-4% and others 36%. (Morgenstern & Tirpac, 1990)

Cows, coal mines and landfills are major sources of methane which is second only to carbon dioxide in contribution to the greenhouse gases. 1 gram of methane in the atmosphere absorbs infrared radiation about 70 times more effectively than one gram of carbon dioxide lifetime of 10 years and is considered an excellent target for reduction. More than 3 billion animals (cattle, sheep, goats, buffalo, camels, and others) account for 15-20% of the annual methane emissions. Recommendations include ; better control of animal feed and waste. In coal mining there is capability to recover 50% of the methane produced. Removal of methane from landfills is also suggested. Reduction of methane from-rice paddies by better irrigation, fertilizer practices and cultivation is also possible. (Gibbs & Hogan, 1990)

Skeptics of global warming include Richard S. Lindzen a professor at MIT. He believes that the present fluctuations in the earth's temperature are part of normal patterns and should not be a concern. (Lindzen, 1990)

Should we take the chance?

Lesson Plans

Day 1

Objectives:

Students will be able to understand the composition and layout of the atmosphere.

Students will be able to understand the chemical reactions and formations that lead to the breakdown of ozone and why these chemicals persist in the atmosphere for years.

Activities:

1. Class review of the atmosphere, its composition and lay-out using the student's science book

Evaluation:

Students will answer questions orally or on paper pertaining to the atmosphere.

Examples

- a. List and describe each layer of the atmosphere.
 - b. Where is the ozone layer found?
2. Class lecture/discussion using the provided background information on
- a. What is ozone and why is it important to have an ozone layer in the stratosphere?
 - b. What are the chemical reactions that lead to the formation of ozone?
 - c. What are the chemical reactions that lead to the breakdown of ozone and why these chemicals persist in the atmosphere.

Evaluation

Create a review ditto based on the background information and your class level, for today's lesson.

Day 2

Objective

Students will compare and contrast Nimbus-7 TOMs images from NASA (these have to be ordered from NASA and are about \$15 each), and be able to understand Dobson units to form a conclusion.

Activity

Divide the students into groups of 2-3 and have them answer the following questions using the TOM'S images and the material from NASA that comes with them.

- a. What are Dobson units?
- b. Describe the color code.
- c. Which year had the highest ozone concentration and which the lowest?
- d. What month were the images taken and why?
- e. Where is the thinnest area of ozone located?
- f. Form a conclusion from these images.
- g. What do you think might happen to the ozone layer in the future?

Evaluation

Go over and discuss answers to the above questions.

Day 3

Objectives

Students will be able to compare the effect of ozone in the stratosphere, with its effects in the troposphere.

Students will be able to understand smog and ozone warnings given by DEP and the news media.

A homework assignment (an environmental questionnaire) will be explained and due on day 4. Its purpose being to check public perceptions .

A take-home lab on air pollution will be passed out and explained

Activities

1. Discussion of tropospheric ozone, its formation and consequences that will occur.
2. Current media articles on ozone/smog will be discussed. These can easily be found in the school or public library.
3. Demonstration (teacher) of the effects of ozone using an ultraviolet lamp with objects placed under it a week prior to class. Also, demonstrate ozone damage to foliage by using live plant samples or pictures (the cooperative extension agency should be helpful in getting these)
4. Discuss public perceptions of the stratospheric and tropospheric ozone problems. Assign a homework assignment using a take-home questionnaire to be filled out by an adult of their choice.

Examples of questions could include:

1. What is ozone?
2. Why is it important to life on Earth?
3. Where is it found?
4. What is destroying the ozone layer and how?
5. What is the number one air pollution problem in New Haven and Connecticut?
6. What is (are) the causes of this pollution?
7. How does it affect our health?

Evaluation

Class review questions based on today's lesson.

Activity/ Homework

Assign a take-home lab due in 1 week, where students, using 2 plastic cups smeared with vasoline compare the amount of dust/pollution left on the cup. One cup will be placed in their home, while the other cup will be placed outside (somewhere it won't get rained on). After one week, students are to compare the amount of dust left on both cups with that of their classmates. Also, for this assignment, students should answer the following questions:

- a. Which cup looks dirtier?
- b. What did this dirt look like?
- c. Where might this pollution come from?
- d. How does it compare to your classmates?

Day 4**Objectives**

Students will discuss the results of their environmental questionnaires.

Students will find out how the media handles environmental problems and the public perceptions resulting from this.

Students will find and discuss articles from a media source relating to ozone and acid rain.

Activity

Hold class in the school's library and split the students into groups of 2.

Have students pretend they are aliens, visiting from another planet doing research on Earth's atmosphere and its effects on life.

Then have aliens/students form an opinion on the problems of our atmosphere (concentrating on ozone and acid rain) caused by humans using either magazines, newspapers or other references.

Also, have the aliens/students check out the health effects caused by acid rain and ozone on animals and plants.

Evaluation

Have each student (alien) write a 2 page report on their findings due at the end of class.

Discuss these findings, if there is time or do this tomorrow.

Day 5- Week 2**Objectives**

Students will compare and contrast their findings from yesterday's research.

Students from a video presentation, will be given an introduction to acid rain.

Activities

1. Discussion/comparison of the research from the last class and how the media affect our viewpoints.
2. Have students watch the video "Acid Rainbows," a PBS video that is 28 minutes long. Copyright 1988 by KRMA in Denver, Colorado.
3. Have students write down 15 facts about acid rain, they hear while-watching the video.

Evaluation

Discuss and collect the video facts. Students will have a general understanding of acid rain.

Day 6

Objectives

In order to understand acid rain, students will first gain knowledge of water as a resource using the SEPUP kit on chemical survey and solutions and pollution. These kits are part of the 8th grade science curriculum (starting in September 1993) and each middle school will have them.

Activity

SEPUP activity #1 from the chemical survey & solutions & pollution kit.

Evaluation

Students will be able to understand the difference between: solutions, solvents, solutes, dilute and concentrated.

Day 7

Objectives

Students will be able to understand the concept of pH.

Students will learn the differences between acids, bases and neutral substances using the SEPUP kit, Chemical survey & solutions & pollution kit.

Activities

1. Lecture/discussion on the concept of pH using the background information provided.
2. SEPUP activity from the chemical survey & solutions & pollution kit. Activity #3.

Evaluation

Make up review worksheet based on today's class and level of students.

Day 8

Objectives

Students will be able to understand how a pH indicator works using an acid, base and neutral substance.

Students will be able to determine the pH of some common substances.

Activity

Taken from the EPA's: "Acid Rain A Student's First Sourcebook," Copyright July 1990.

Materials

pH paper, garden soil pH testing kit (available from any garden center at a cost of between \$15- \$20), distilled water, white vinegar, household ammonia or baking soda mixed with water, 3 small clear cups per group, 3 measuring cups and spoons per group (spoons should be 1/4 teaspoon size, cups should be 1/4 & 1/2 cups), and each group should make up a chart for recording.

Procedure

1. Rinse each cup with distilled water and label 1 cup vinegar, 1 cup ammonia or baking soda and 1 cup water.
2. Pour (1 cup distilled water in each cup).
3. Add a teaspoon white vinegar to the vinegar cup and stir with a clean spoon.
4. Add a teaspoon ammonia or baking soda to the next cup and stir with a clean spoon.
5. Don't add anything to the water cup.
6. Dip an unused, clean strip of pH paper in the vinegar cup for about 2 seconds and using the color chart that comes with the pH paper, record the results. If using a garden pH tester kit, pour a teaspoon of the contents of the vinegar cup into the test container and shake once or twice, then compare with the color chart provided. Record the result.
7. Repeat step 6 for both ammonia (or baking soda) and water and record the results.

Evaluation

Have students answer the question—Which substance is acidic, basic, or neutral.

Activity

Also, taken from the EPA's "Sourcebook."

Materials:

Garden soil test kit, 3 fresh whole fruits (ex. lemons, oranges or melons), 3 beverages (ex. cola, 7-Up, milk), borax, measuring spoons 4 clear cups, stirring spoon, chart for recording data.

Procedure

1. Cut each fruit in half, dry knife off after each cut.
2. Squeeze 1/4 teaspoon of juice from the cut fruit into the test container and add 1/4 teaspoon of test solution. Cover and shake, or stir solution. Compare with the color chart and record the results.
3. Repeat step 2 for the other 2 fruits.
4. Pour 1/4 teaspoon of cola into the test container and add 1/4 teaspoon of the test solution. Cover and shake or stir. Compare with the color chart provided in the kit and record the result.
5. Repeat step 4 for the other 2 beverages.
6. Add one-eighth teaspoon borax to 1/4 cup distilled water and stir for about 2 minutes. Pour 1/4 teaspoon of the borax/water mixture into the test container, and add 1/4 teaspoon of the test solution. Cover and shake or stir. Compare with the color chart provided in the record the result.

Evaluation

After the lab, have students answer the following questions:

1. What was the pH of each substance tested?
2. Which ones were acids? Which ones were bases?
3. Using your results, explain why borax is a good cleaning agent.

Optional activity

In place of, or in addition to the garden pH test kit, use red cabbage juice, which is a natural pH indicator. To make it boil a red cabbage (cut up into pieces) in water for 30 minutes. Use the resulting juice left in the pot after boiling the cabbage. Cabbage juice (red) contains a chemical that changes its natural deep purple color to red in acids and blue in bases. Students really seem to like working with this.

Homework

Allow students to bring home red and blue litmus paper, in order to check 4 substances (other than those used in class). Have them record which substances were basic and which were acidic. Collect their results in class the next day.

Day 9-week 3

Objectives

The students will be able to understand the formation of acid rain and acid precipitation.

The students will be able to analyze the causes of acid rain/acid precipitation.

The students will be able to understand the effects that acid rain has on the environment and living organisms—including man.

The student will understand how and why our government has gotten involved in helping to solve the acid rain problem.

Activities

1. Class lecture/discussion on acid rain and the aforementioned objectives using the background information provided.
2. Class demonstration using chalk or limestone or sea shells added to vinegar or hydrochloric acid.

Evaluation

- a. Review ditto on today's class. Make up ditto based on background information presented and student levels.
- b. Collect air pollution assignment that was assigned a week ago and discuss results. Relate to acid rain and acid precipitation accumulating in our area and where they might have come from.

Day 10

Objectives

Students will understand the concept of buffering as it relates to the reducing of effects from acids and bases, including reduction in the effects of acid rain.

Students will understand that calcium carbonate(limestone) acts as a buffer in Connecticut's waters, so we don't see the problems acid rain can cause in our waters.

Activities

1. Taken from the EPA's "Acid Rain A Student's First Sourcebook," Copyright July 1990.

Materials:

pH paper (range pH 2-7) and color chart or garden pH test kit, white vinegar, distilled water, measuring cup and spoon, 2 stirring spoons, 1/2 cup crushed hydrated limestone or spray limestone, 2 cereal bowls (about 2-cup size), plastic wrap and recording chart.

Procedure

1. Label one bowl vinegar and the other vinegar & limestone.
2. Pour 1/4 cup crushed limestone into one bowl.
3. Pour 1 teaspoon of vinegar into 2 cups of distilled water. stir well and check the pH with either pH paper or garden test kit or use a pH meter. The pH of the vinegar/water mixture should be about 4. If it is below 4, add a sprinkle of baking soda, stir well and recheck the pH. If the pH is above 4, add a drop or 2 of vinegar and again recheck the pH.
4. Pour 1/2 of the crushed limestone into the other bowl that has the same vinegar/water mixture as in step 3. Check the pH and record the results.
5. Add the rest of the limestone to this mixture and record the pH.

Evaluation/Conclusion

Have the students answer the following question:

- a. What was the pH of the vinegar/water mixture?
- b. What happened during this experiment?

Activity 2

Using cabbage juice have students add a few drops (enough to change the color) of the following substances placed in clear plastic cups: cola, baking soda/water mixture, lemon juice, vinegar, crushed aspirin in water, borax/water mixture. Determine by the color changes which ones are acids and which are bases. Record the results.

Then have students add some of the bases to the acids and record the color changes. Substances should change to a more neutral color.

Evaluation/Conclusion

Design a questionnaire on buffers, and how to neutralize and lessen the effects of acids, bases and thus acid rain. Discuss the results of the two experiments and how processes like buffering and neutralization occur naturally. Lastly, using oral questions and answers check to see if students understand these processes. See appendix p.19-20 for extra review activities.

Day 11

Objectives

Students will be able to understand the “greenhouse effect” that keeps us alive on this planet.

Students will be able to understand the consequences if global warming occurs and increases the greenhouse effect here on earth.

Students will realize how the greenhouse gases form and interact, and how pollution has increased the amount of these gases in the atmosphere.

Activity

Lecture/discussion on global warming pertaining to the objectives listed above.

Evaluation

Students will be able to orally answer questions pertaining to the greenhouse effect and global warming.

Day 12

Objectives

Students will observe the greenhouse.

Students will review and compare the ozone dilemma, acid rain and global warming.

Activity 1

Using terrariums made for extra credit by students using inverted and cut soda bottles, students will observe and record the temperatures inside the terrariums. One which is placed in sunlight and one placed out of sunlight. Students will also record the conditions of the plants inside the terrariums.

Evaluation

Students will be able to answer the questions:

- a. How does the greenhouse effect and global warming enable us to live?
- b. What would happen if global warming increased on our planet?

Activity 2

Open book quiz on the environmental problems discussed in the past three weeks. Develop a quiz based on class discussions and labs. Go over quiz before the end of class.

EarthQuest: The Ozone Layer and Homo Sapiens

Ozone is a pungent gas naturally present in small amounts at ground level and in much larger abundance in the stratosphere, where it forms a layer that plays a critical role in the earth’s ecological balance. Ozone is produced from atmospheric oxygen by the action of sunlight. In turn, ozone absorbs certain kinds of ultraviolet light that are potentially harmful to living things. Life as we know it on the planet’s surface is possible in part because of the protection afforded by the stratospheric ozone layer.

Since the discovery of ozone and the recognition of its unique importance to life, much has been learned about the nature and chemistry of this atmospheric component. Gradually it has become clear that the ozone layer can be affected all too easily by other molecules some of which are products of human activity.

Chlorofluorocarbons, once thought to be miracle compounds completely benign to their environment, are now recognized as ozone destroyers. Scientific evidence has established that large-scale ozone losses over the Antarctic are caused by these compounds.

Recognizing this problem, many nations have taken collective action to eliminate the production and use of the most harmful of these compounds. Industry is seeking safe substitutes.

This timeline (see EarthQuest picture) depicts the history of ozone—its science and its relationship to mankind—from its discovery in 1840 to the present.

Source: Reprinted from EarthQuest, Fall 1991, UCAR Office for Interdisciplinary Earth Studies

(figure available in print form)

1. Ozone Discovered. A letter entitled “Research on the nature of the odor in certain chemical reactions” was presented to the Academic des Sciences in Paris by C.F. Shoenbein in 1840. Shoenbein was unable to determine the origin of the chemical species that he had found or to characterize its structure, but named the mysterious pungent-smelling molecule “ozone.” A few years later, J.I. Soret identified the compound as O₃.
2. UV-Ozone Cutoff Discovered. In 1879, W.N. Hartley and A. Cornu measured the ultraviolet radiation reaching the surface of the earth and found a sharp cutoff, which they correctly attributed to ozone. These pioneering measurements also showed that the bulk of the ozone must be in the upper atmosphere rather than near ground level. The ozone layer had been discovered.
3. Ozone and Meteorology. During the late 1920s, G.M.B. Dobson and his colleagues presented the first systematic measurements of the distribution and variability of the ozone layer. While it might be anticipated that ozone’s production by the action of sunlight on oxygen would lead to a tropical maximum, the measurements revealed the surprising result of a maximum during spring at high latitudes. Dobson correctly concluded that stratospheric winds must play an important role in transporting ozone around the globe. Thus, via ozone studies he formulated a general picture of the circulation of the stratosphere that has endured largely unchanged into contemporary scientific thought.
4. CFCs Invented. In 1928, an industrial chemist named T. Midgley was asked to develop a nonflammable, nontoxic compound to replace the hazardous compounds (such as ammonia) then used in home refrigerators. Within two days, he selected a chlorofluorocarbon (CFC) as the ideal refrigerant. In a dramatic demonstration of its complete safety for living things, Midgley personally inhaled the compound.
5. Pure Oxygen Chemistry. In 1930, S. Chapman presented the first theory of ozone chemistry. He postulated a simple three-step mechanism involving production of atomic oxygen via sunlight, followed by reaction of atomic oxygen with oxygen molecules (in the illustration, “M” indicates any molecule) to produce ozone, in chemical balance with destruction via the reaction of atomic oxygen and ozone. This series of “oxygen-only” reactions became known as the Chapman cycle and broadly explained why the ozone layer forms at stratospheric altitudes.
6. CFC Usage Grows. During the 1950s, chlorofluorocarbons came into widespread use in a variety of applications, particularly for refrigeration and later in air conditioning, spray cans, and foams, and as solvents. The chlorofluorocarbons were hailed as miracle chemicals.
7. Hydrogen-Ozone Chemistry. Scientific studies in the 1950s began to reveal that the pure

oxygen chemistry envisioned by Chapman was not sufficient to explain the observed distribution of atmospheric ozone. In the mid-1960s, J. Hampson postulated a series of reactions involving hydrogen compounds produced from water vapor that are capable of rapidly destroying ozone. It became clear that the chemistry that establishes the ozone layer is dependent upon more than just oxygen.

8. The International Geophysical Year. The IGY in 1957 was marked by intense international research programs on the earth and its environment. A network of ground-based instruments for continuous monitoring of ozone using the technique pioneered by Dobson was established worldwide (the Dobson network). The one installed by the British Antarctic Survey at their remote site at Halley Bay, Antarctica, was to play a fateful role in the interaction of humankind and the ozone layer.

9. Nitrogen-Ozone Chemistry. Concern about the possible use of supersonic transport planes led to the discovery of an ozone-destroying catalytic cycle involving nitrogen compounds by P. Crutzen and H.S. Johnston in 1970-71. Although the initial projections of large ozone decreases due to these aircraft were later shown to be excessive, the discovery revealed yet another chemical mechanism for rapid ozone loss. It also provided the first stimulus to public awareness regarding the importance and fragility of the ozone layer.

10. Chlorine-Ozone Chemistry. Measurements taken in the early 1970s revealed a growing abundance of chlorofluorocarbons at ground level, prompting M. Molina and F.S. Rowland to wonder where exactly these miracle chemicals end up. They studied the problem in detail and concluded that their eventual fate must be to rise up into the stratosphere, break down, and begin to destroy the ozone layer in like manner to the action of hydrogen and nitrogen. While hydrogen and nitrogen compounds are naturally produced in large quantities in addition to manmade contributions, the chlorine perturbation was recognized as potentially more disturbing, since the natural source of chlorine to the atmosphere is small.

11. CFC Aerosol Ban. Theoretical calculations suggested that continuing use of CFCs might cause about 5% depletion of the ozone layer in 100 years or so. Concern over the possible future depletion of the earth's ozone layer by the action of chlorofluorocarbons led the United States, Canada, Norway, and Sweden to ban their use in nearly all spray cans in their countries. Global use of chlorofluorocarbons slowed significantly.

12. CFC Usage Grows Again. Chlorofluorocarbons use began to increase again in the early 1980s, due in part to their use as cleaning agents in the rapidly expanding electronics industry. Home insulation and foam-blowing applications were also booming. Growing populations and worldwide industrial development created an expanding market.

13. Ozone Hole Discovered. In 1985, scientists from the British Antarctic Survey reported their observations of a deepening depletion in the springtime ozone layer above Halley Bay, Antarctica. Their work was quickly confirmed by measurements from satellites and from other Antarctic research stations, including the South Pole (United States) and Syowa (Japan). The phenomenon became known as the "ozone hole." The observed change in ozone was about 40% in 1985, as compared to projections of about 5% in 100 years, raising fears that ozone depletion may have been drastically underestimated.

14. National Ozone Expedition (NOZE). In response to the discovery of the ozone hole, a National Ozone Expedition was dispatched to McMurdo Station, Antarctica, from August to November 1986. A series of ground-based and balloon-based measurements were carried out that pointed toward chlorine and bromine compounds as the likely cause of the ozone hole.

15. Montreal Protocol Signed. On 16 September 1987, the United Nations adopted the Montreal

Protocol on Substances that Deplete the Ozone Layer. It required a freeze on the annual use of CFCs as early as 1990, with decreases leading to a 50% reduction by the year 2000. A freeze on halon annual production would occur in 1993. Progress in science and technology would set the pace for future changes in the provisions.

16. Airborne Antarctic Ozone Experiment (AAOE). In August-September 1987, a series of high-flying aircraft flights probed the stratosphere from South America to Antarctica under AAOE. This sequence of direct measurements clearly confirmed that chlorine and bromine compounds were the primary agents responsible for the Antarctic ozone hole.

17. Ozone Depletion Not Confined to Antarctica. Observations of trends from ozone measurement stations worldwide along with satellite data were carefully analyzed by an international group of experts in 1988. They came to the alarming conclusion that ozone decreases that could not be explained by known natural effects were already occurring not only in Antarctica, but also in the Northern Hemisphere midlatitudes and in the Arctic. Moreover, the decreases were larger than what could be explained by the current global models.

18. Montreal Protocol Amended. The participating countries are required to periodically assess the adequacy of the protocol's provisions in light of new scientific and technical advances. Because CFCs and halons were identified as the cause of the Antarctic ozone hole and in view of the downward trends in global ozone, the contracting parties substantially strengthened the protocol. The new provisions broadened the scope of the chemicals that are controlled, called for accelerated reduction in emission, and required complete phaseout of CFCs, halons (except essential uses), and other major ozone-depleting substances by the turn of the century.

19. U.S. Clean Air Act Amendments of 1990. While the Clean Air Act focuses mainly on urban pollution and acid rain, it also addresses the protection of the ozone layer. Because of recent scientific findings, Congress enacted amendments that are even more stringent than the updated Montreal Protocol. Notably, these include requirements for recycling CFCs and limitations on the time that CFC replacements can be used. The Clean Air Act also recognized that progress in research is essential and requires periodic reports on the health of our ozone shield.

Reprinted from EarthQuest Fall 1991 Science Capsule, UCAR office for Interdisciplinary Earth Studies.

Classification of Areas Violating the Ozone Standard

Category	Relative Ranking	Location/Area
EXTREME	1	Los Angeles
SEVERE	2	Houston
	3	NY/NJ/Southwestern CT
	4	Baltimore
	5	Chicago
	6	San Diego
	7	Philadelphia
	8	Milwaukee
SERIOUS	9	Muskegon, WI
	10	Sheboygan, WI
	11	Greater Connecticut
	12	Bakersfield, CA
	13	Fresno, CA
	14	El Paso, TX

CRITERIA FOR SELECTING EMISSION REDUCTION STRATEGIES

Connecticut will have to make considerable reductions in the emissions of VOC and NOx. With the understanding that reducing our ozone pollution will not be easy, the Connecticut Department of Environmental Protection has established the following guidelines for evaluating various control strategies.

A strategy must be

1. effective in reducing emissions,
2. cost effective,
3. equitable (i.e., the people creating the pollution should bear the brunt of the cost of control),
4. easy to implement, administer and enforce,
5. consistent with existing law, and
6. consistent with other social goals, such as energy conservation.

For further information, contact Vic Yanosy, DEP Bureau of Air Management, 566-2690 Hartford, Connecticut

1/27/93

Department of Environmental Protection: 1993

Curriculum Unit 93.05.02

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(figure available in print form)

Describing the air quality, and was developed by the federal government for use throughout the nation. The rationale was to convert the various pollutant readings to a common index which has a value of 100 equivalent to the health standard for all pollutants.

The index of 0-500 is divided into 5 categories with corresponding descriptor labels (see Fig. 2).

DESCRIPTOR		
RANGE	CATEGORY	EFFECTS
0=PSI=50	“Good”	No significant effects
50PSI100	“Moderate”	Human health not affected unless such levels continue for many days. Some damage to materials and vegetation.
100PSI200	“Unhealthful”	High risk individuals experience mild aggravation of disease symptoms; those with lung or heart disease should reduce physical exertion and outdoor activity. Healthy individuals notice irritations.
200PSI300	“Very Unhealthful”	Lung and Heart disease patients experience significant aggravation of disease symptoms and decreased exercise tolerance. These individuals should stay indoors and reduce physical activity. Widespread irritation symptoms in the healthy population.
300=PSI=500	“Hazardous”	(300 to 400) High risk individuals should stay indoors and avoid physical activity. Significant aggravation of symptoms and decreased exercise tolerance in healthy persons; premature onset of certain diseases. General population should avoid outdoor activity. (401-500) Premature death of some members of the “high risk” group. Healthy people will experience symptoms that affect their normal activity. All people should remain indoors with windows and doors closed, minimize physical exertion and avoid vehicular traffic.

As can be seen, the health standard (PSI=100) is the division between acceptable air and unacceptable air.

The Daily PSI Report is available each working day at approximately 3:00 p.m. by calling:

—Governor’s Information Office: 1-800-842-2220

—Recorded Message: 566-3449

—The American Lung Association: 289-5401

DEP, 1990, “Connecticut’s Air Quality”

Figure 1. Good Old Days v. Present

(figure available in print form)

Figure 2. The Air Quality Index

(figure available in print form)

Connecticut 1989 Air Quality by County (# days)

(figure available in print form)

Connecticut’s Air Monitoring Network by County (# sites)

(figure available in print form)

Actions To Date

To promote the use of clean-burning fuels, such as ethanol and methanol, to reduce hydrocarbon, carbon monoxide, and toxic air emissions from cars, buses, trucks, and motor fuels.

Require factories and plants emitting toxic compounds into the air to employ the best technology currently available in order to achieve in the near term a significant reduction in pollutants suspected of causing cancer. Taken together with efforts to reduce cancer-causing emissions from cars and trucks, it is estimated that the plan will eliminate by 1995 over three-fourths of the annual cancer deaths that air toxins are expected to cause.

The following chronology traces EPA, U.S. Government, and international achievements through the years in the fight against acid rain. A discussion of current acid rain-related activities follows.

1970: The Clean Air Act passed by Congress establishes a process for EPA to set national ambient air standards for SO₂, NO_x and other pollutants, requires State implementation Plans for meeting the standards, and requires New Source Performance Standards for coal-fired utility plants.

1972: Two Canadian scientists, R.J. Beamish and H. H. Harvey, report declines in fish populations due to acidification of Canadian lake waters.

1975: Scientists gather at Ohio State University for the First International Symposium on Acid Precipitation and the Forest Ecosystem.

1977: The U.N. Economic Commission for Europe sets up a Cooperative Programme for Monitoring and Evaluating the Long-Range Transmission of Air Pollutants in Europe.

August 1980: The United States signs a Memorandum of Intent with Canada to begin negotiations toward an agreement on transboundary air pollution.

December 1980: The National Acid Precipitation Assessment Program (NAPAP) is authorized by Congress under the Acid Precipitation Act of 1980 to establish a 10-year federal research effort on the causes and effects of acid rain.

1981-1983: U.S./Canadian working group reports and peer reviews are completed in accordance with the Memorandum of Intent.

1983: Under NAPAP, EPA begins the National Surface Water Survey to study the chemical status of lakes and streams in the United States.

August 1983: Canada and the United States sign a scientific agreement for the Cross-Appalachian Tracer Experiment to demonstrate the predictability of the long-distance airborne transport of acid rain pollutants over eastern North America.

January 1984: President Ronald Reagan, in his State of the Union address, calls for accelerated research into the causes and effects of acid rain, as well as into new control technologies.

June 1984: EPA Administrator Ruckelshaus and Canadian Minister of Environment Caccia confer at the Munich Conference on the Causes and Prevention of Damage to Forests and Water through Air Pollution.

Fall 1984: The Eastern Lake Survey, including samples from the Northeast, Upper Midwest and the Southeast, is conducted as part of the National Surface Water Survey.

1985: The NAPAP forest research program is expanded. Largely a joint effort of EPA and the Forest Service, the program is conducted regionally through four regional forest research cooperatives (eastern spruce-fir, southern commercial, eastern hardwood, and western conifer).

March 1985: President Reagan and Prime Minister Mulroney meet in Quebec City and agree to appoint h-level Special Envoys to examine acid rain issues. EPA announces the first in a series of grants to states for exploring solutions to problems they expect to face should a national acid rain control program be adopted. Known as the newly formed STAR—State Acid Rain—program, these grants are funded by a \$3 million Congressional appropriation.

August 1985: A report on the preliminary results of Phase I of the Eastern Lake Survey describes lakes that are, or are likely to become, susceptible to acid precipitation in the eastern United States.

Fall 1985: EPA conducts Phase I of the Western Lake Survey.

November 1985: The first national State Acid Rain (STAR) workshop is held in Pittsburgh.

January 1986: The Special U.S./Canadian Envoys' Report on Acid Rain is submitted to President Reagan and Prime Minister Mulroney. The report's major recommendation calls for a five-year, \$5 billion joint government/industry program to demonstrate commercial acid rain control technologies.

March 1986: Following a second meeting in Washington, Reagan and Mulroney officially endorse the Special Envoy's Report concluding that acid rain is a serious environmental and transboundary problem.

March 1986: EPA begins sampling streams in the mid-Atlantic and South, following a pilot survey in the Blue Ridge.

August 1986: The Department of Energy awards its first grants under the Clean Coal Technology Program.

September 1986: The final report on Phase I of Eastern Lake Survey is released.

October 1986: The second national STAR workshop is held in Asheville, NC.

January 1987: The final report on Phase I of Western Lake Survey is issued.

April 1987: President Reagan and Prime Minister Mulroney meet for a third time. Reagan announces that he would consider a bilateral accord with Canada to control sources of acid rain.

September 1987: NAPAP's Interim Assessment of the Causes and Effects of Acid Deposition is made public.

December 1987: Congress appropriates \$575 million for government/industry programs that will accelerate demonstrations of the retrofit and emission-reduction technologies recommended by the Special Envoys.

June 1988: EPA's Report on the National Stream Survey is released.

October 1988: The plan and schedule for the 1990 NAPAP Assessment is published.

February 1989: President Bush, in an address to Congress, announces that he will submit legislation for a more effective Clean Air Act. The legislation will include a plan to reduce, by date certain, the emissions which cause acid rain.

July 1989: President Bush announces his legislative proposal for Clean Air Act revisions to reduce acid rain, toxic air pollutants, and ozone.

August 1989: EPA proposes a new national program that will help reduce acid rain by requiring refiners to lower the sulfur content of diesel fuel.

EPA releases the final report of the four-year State Acid Rain Program which finds that existing federal and state air-pollution-control programs do not appear appropriate for carrying out the solutions being proposed to control acid rain.

EPA, (1989), "Environmental Backgrounder Acid Rain."

Canada/US SO₂ Emission Estimates (10⁶ tonnes/tons/year)

(figure available in print form)

How the Greenhouse Effect Works

(figure available in print form)

Reprinted from the World Resources Institute from "The Teacher's Guide to World Resources," Copyright 1990-1991.

The Greenhouse Index: 25 Countries with the Highest Greenhouse Gas Emissions, 1989

(figure available in print form)

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Contributions to Global Warming.

(figure available in print form)

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Acid Rain Crossword Puzzle

(figure available in print form)

GLOSSARY

Acid: A material with a pH of less than 7.0.

Adirondacks: A mountainous lake area in New York State where acid rain has caused over 200 lakes to be fishless.

Air Quality Standards: Federal and state government-prescribed levels of a pollutant in the outside air that cannot be exceeded during a specified period of time in a specified geographical area.

Alkaline: Capable of neutralizing acid and producing hydroxyl (OH) ions in solution.

Aquatic life: Plants or animals living in water.

Bedrock: The solid rock found on the surface of the land or just below the soil.

Buffer: The ability to (partially) neutralize acidic precipitation in soils and waters.

Buffering capacity: The degree to which soils or water bodies can neutralize acidification.

Carbonate: A mineral, soluble in acid, the chemical composition of which contains CO₃.

Carbon monoxide (CO): A colorless toxic gas produced by incomplete fossil fuel combustion, notably in motor vehicles.

Ecosystem: A community of independent organisms together with the environment with which

they live and interact.

Emission: Substances discharged into the air through smokestacks and car exhaust.

EPA: The Environmental Protection Agency is the governmental agency that enforces Federal regulations concerning pollutants.

Fossil fuels: Fuels derived from organic substances such as coal, petroleum, and natural gas.

Ion: An electrically charged atom or group of atoms.

Lake liming: Dumping alkaline compounds into a lake to neutralize the acidity of its water.

Molecule: The smallest particle of an element or compound that can exist alone and retain the characteristics of the substance.

Nitrogen oxides (NO_x): Gases formed in great part from atmospheric nitrogen and oxygen when combustion occurs at high temperatures.

Organism: Any animal or plant which can maintain life on its own.

Osprey: A large, fish-eating bird of prey.

Ozone (O₃): A form of oxygen that is reactive chemically and an irritant to the eyes and respiratory system.

Percolation: The downward movement of water through soil.

pH: The measuring unit for specifying the acidity of a substance.

Precipitation: Moisture that falls to the earth such as snow, rain, sleet, etc.

Scrubber: A device (attached to a utility or industrial smokestack) that uses a liquid spray to remove aerosol and gaseous pollutants from an airstream.

Standards: The amount of pollutants allowed by state and Federal governments.

Sulfur dioxide (SO₂): A pungent, colorless gas formed primarily by combustion of fossil fuels.

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