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6.1 Introduction

Balancing the goal of good air quality with maintaining the conveniences of modern life is a challenge requiring conservation and government policy. Students will learn about the effects of transportation, manufacturing, and consumption on air quality, know some of the policy alternatives, be able to discuss their costs and benefits, and seek ways to minimize their own impact on air quality.

Objectives

In this lesson students will:

- Identify the primary sources of air pollution in Virginia
- Identify the costs of air pollution
- Discuss preventive measures to protect air quality
- Identify and discuss cost/benefit tradeoffs of policies to improve air quality

SOLs

Science 6.1, 6.6, 6.9
Math 6.8, 6.10, 6.12

Key Terms/ Concepts

- Air pollution
- Particulates
- Smog
- Property rights
- Acid rain
- Fossil fuel
- Subsidize

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6.2 Student Information

While water is essential to the survival of humans and animals alike, we are even more limited in the duration of time we can survive without breathing in oxygen from the air. It is unsafe to go without air for little more than a minute. Thus the quality of the air you breathe is of major importance and can affect your health. The air we breathe is a mixture of gases, composed of mostly nitrogen, oxygen, and carbon dioxide. Other components such as dust and ash or chemicals (such as sulphur dioxide and nitrogen oxide) are considered air pollutants.

Air pollution can be generated either by natural or human activities. For example, volcanic eruptions, forest fires, and trees (pollen) all emit some form of air pollution. These and other components cause smog, acid rain, retarded plant growth, and respiratory illnesses.

In order to protect our environment and health, several measures may be taken to reduce air pollution. Using public transportation or walking is a great way to reduce the emissions produced from individual cars. Another way we can reduce pollution is by using less energy. A major source of energy is derived from the burning of fossil fuels, whose byproducts can harm the environment. Can you think of other ways to reduce pollution or clean up the air that has already been polluted? What effects might air pollution have on the quality of water in your area?

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6.3 Teacher Content

Defining Air Pollution

Look at photographs of Shenandoah National Park on a clear day versus a hazy day. *(See Activity I.)* Why is there a difference between the two pictures? What might have caused the differences between these pictures? Haze is caused by air pollution. Shenandoah National Park in Virginia is one of the places in our state most affected by poor air quality.

Air pollution includes any particles or gases that are not part of the air's natural composition. Air is mostly composed of nitrogen, with a smaller amount of oxygen. Small amounts of carbon dioxide, methane, ammonia, and argon also occur naturally in the air.

Air pollution can be generated either by natural or human activities. For example, volcanic eruptions, forest fires, and trees (pollen) all emit some form of air pollution. The forests in the Blue Ridge Mountains release a natural emission that causes the blue color of the range (Peirce, Weiner, and Vesilind 1998). While this air is not pure, the air pollution with the greatest environmental and health hazards is produced by human activities, and includes emissions from cars, farm equipment, industrial activities, and power plants. Cars and industry powered by burning coal, oil, wood, or gasoline release smoke and other gases into the air.

Identifying Pollutants

Several pollutants affect our environment and our lives. When someone says the word "ozone," we usually think of the atmospheric layer that protects the Earth from harmful solar radiation. However, ozone is also a form of air pollution that is different from the protective ozone layer in the upper atmosphere. The pollutant ozone forms in the lower atmosphere on hot, sunny days when nitrogen oxides react in the atmosphere with hydrocarbons from cars, power plants, and industrial emissions. Ozone is also the main ingredient in **smog**, a mixture of pollutants in the air that reduces visibility and can have negative effects on health and the environment. For smog to develop in the air, pollutants must "cook" in the sun. By the time the smog is formed, it may have blown far from the original source of the pollutants.

Volatile Organic Compounds (VOCs), including hydrocarbons, are another major contributor to smog. Some VOCs, released from car emissions, are linked to cancer.

The burning of **fossil fuels** such as oil, coal, and natural gas, results in other air pollutants as well. One is carbon monoxide, an odorless compound that can impede the delivery of oxygen to cells. While for health and environmental reasons it is wise for us to reduce the quantity of pollutants produced from fossil fuels, there is another reason for us to conserve. Fossil fuels are a non-renewable resource, which means no new oil or coal will form during our lifetimes. Developing technology for renewable sources of energy such as wind or solar power (we will not run out of sun or wind) would

reduce the drain on the resources we cannot replace, while cutting down on the pollution formed by fossil fuels.

Sulfur dioxide and nitrogen oxides released into the air are primary causes of **acid rain**. These emissions may also travel to the east coast from coal-burning plants in states in the Midwest. Sulfur dioxide reacts with water in the air and creates sulfuric acid that then falls to the Earth in the form of acid precipitation, such as acid rain and acid snow. To be considered acid rain, precipitation must have a pH lower than 5. Pure water has a pH of 7.0. Normal rain that has not been affected by sulfur dioxide is slightly acidic because carbon dioxide dissolves into it, so it has a pH of about 5.5. As of the year 2000, the most acidic rain falling in the US has a pH of about 4.3. (Bodnar). *Activity 2* tests the acidity of rainwater.

Sulfur is found in coal, and when burned, mixes with oxygen to create the sulfur dioxide. The other major cause of acid rain, nitrogen oxides, is created through the burning of any fossil fuel, including natural gas and oil. Nitrogen oxides are released into the air through the exhaust of most vehicles, making car emissions the primary source of nitrogen oxides. When weather conditions are right, these acids return to the earth in the form of rain, snow, fog, or mist, sometimes far away from where the chemicals were produced.

Significant improvements have been developed and utilized in sophisticated technology for pollution abatement. Power plants today have invested in scrubbers, baghouses, and/or precipitators that have dramatically reduced emissions.

Heavy metals are another form of air pollution. Lead and mercury are two examples of this kind of pollution, which can result in organ damage in humans, including brain damage, and can also harm wildlife. These metals can enter the air through the use of leaded gasoline, lead paint, metal refining, combustion of fossil fuels, and manufacture of lead or mercury batteries.

Besides specific chemical compounds, particulate matter in the air also poses a problem. Particulate matter, consisting of little particles of dust and soot, can be a cause of haze. It is sometimes responsible for bronchitis and lung damage. **Particulates** may enter the air through the burning of fossil fuels, but may also occur through burning wood. *Activity 3* measures the particulate matter in your area.

Mercury Mystery . . . ?

Dragon Run, one of Virginia's most pristine natural areas, contains some amounts of mercury – a highly toxic metal, sometimes found in fish tissue. How did it get there? Not naturally found in the Dragon Run Watershed, mercury must come from an external source. Since Dragon Run has experienced little human impact, some scientists are wondering about the origin of this metal pollutant. One theory focuses on atmospheric deposition, of mercury, from industrial sources.

What do you think? Help scientists solve the mystery. For more information see the following site:
http://www.deq.virginia.gov/fishtissue/pdf/vahg42004.pdf

Costs of Pollution

Air pollution imposes costs on human health, property, and the environment. Ozone has the potential to intensify respiratory ailments, make people cough or wheeze, and damage lung tissue. Children, asthmatics, and the elderly are particularly at risk to ozone exposure and the negative impacts of air pollution.

Humans are not the only creatures harmed by air pollution, however. Ozone retards the growth of many plant species. Acid rain reduces aquatic animal populations: many species of trout, bass, and clams are unable to survive in water polluted by acid rain. Acid rain can also dissolve limestone and marble in buildings and statues. *Activity 4* gives an example of how acids can damage structures.

Preventive Measures to Decrease Air Pollution

Air pollution can damage human health and the environment, but there are steps we can take to minimize its effects. While government agencies and industry may have different incentives to regulate and reduce air pollution, people in the community also have an interest in cleaner air. How can we improve air quality in our community, make wise decisions about health and the environment, and influence other people such as parents and friends to do the same? *Activity 5* offers some ideas on how to conserve at home, thereby reducing the output of two major sources of pollution: energy production and vehicle emissions.

Virginians drive their cars more each year; plus, as population increases in Virginia, there are more drivers. Loudoun County is the third fastest growing county in the nation, and Northern Virginia, Hampton Roads, and Richmond areas are also growing particularly fast. According to the Metropolitan Washington Council of Governments, the Virginia "outer suburbs" of Washington, D.C. will grow three times faster than the rest of the region over the next decade, which means many people may

live far from where they work. More public transit is now offered, but more planning will be required to keep up with the growing needs of the community. Most new vehicles have emission control devices of varying efficiency. In the meantime, we can choose to walk, bicycle, take public transit when possible, and/or install pollution abatement equipment on older vehicles.

Conserving energy is another way to limit air pollution by lessening the amount of fossil fuel that needs to be burned to provide our heat and electricity at home. Turning off lights and appliances when we are not using them, using heat and air-conditioning with care, insulating our homes, and limiting fires are a few places to start.

Policy Options to Decrease Air Pollution

The task of state government in regulating air pollution is a difficult one. First, air pollution can travel long distances, affecting residents of states far from where the pollution was first produced. Another problem lies in assigning property rights, or deciding who owns the right to produce pollutants, or who has the right to an unobstructed view of a clear skyline. For more explanation of property rights, see *Activity 6*.

While we can all help to lessen air pollution by practicing conservation at home, often the government needs to get involved in reducing it. Government has several options:

- It can engage in command and control, passing laws that ban or limit the quantity of pollution that power plants or other industry can produce, and punishing companies that produce more than the legal limit.
- Tax fossil fuels, making it more expensive to produce pollution.
- **Subsidize** energy-efficient equipment and appliances, by giving tax breaks or rebates to companies or consumers who choose to buy them.
- Issue permits to each polluter, giving them permission to produce a certain amount of pollution.

There are advantages to each of these choices.

Bans and Quotas

Suppose that the government decided that there should be zero sulfur dioxide pollution. All companies producing sulfur dioxide emissions, including power plants fired by coal, would not be allowed to operate by the government. There are benefits: first, there would be no more sulfur dioxide emitted, which would greatly reduce acid rain. Second, this would reduce the use of coal, which is a non-renewable resource. What are the costs? Many people depend on these power plants for electricity, and without their electricity, they could not use their lights, televisions, computers, or washing machines. Imagine if things such as hospital equipment and ATMs had to be turned off. While there

are costs to having sulfur dioxide in the air, there are also important benefits to having electricity available.

For another example, imagine that the government decided to reduce the amount of ozone in the air. Since much of ozone comes from vehicles, each car can only be driven every other day. Cars with odd-numbered license plates could be used on odd-numbered days, and cars with even-numbered license plates would be driven on even-numbered days. If people follow the rules, there will be less emissions and ozone. Because cars are driven fewer miles, less gasoline, which is a non-renewable resource, will also be used. What else would happen if people could only drive cars every other day? Some people would take public transportation when they could not drive their cars. Some people would buy another car so that they could drive every day, which would defeat the purpose of the legislation. Some people would lose their jobs because they could not get to work. Some people would probably try to get around the regulations, and the government would have to spend a lot of time and money enforcing them. The government's policy of telling people on which days they may drive has significant costs for the citizens, both to their convenience and their tax dollars.

Command and Control

Rather than ordering companies not to pollute, the government might command them to invest in technologies that reduce their pollution output. While implementing this policy will reduce pollution, it also has high costs. For some of the cleaner facilities, investing in new technology might be very expensive, and only reduce their pollution by a small amount, i.e., the marginal costs (MC) outweigh the marginal benefits (MB). Government also will have to spend money to enforce this law, monitoring the progress of each of the plants involved (Ellerbrock). For a demonstration of a basic technology to reduce air pollution, see *Activity 7*.

Taxes and Subsidies

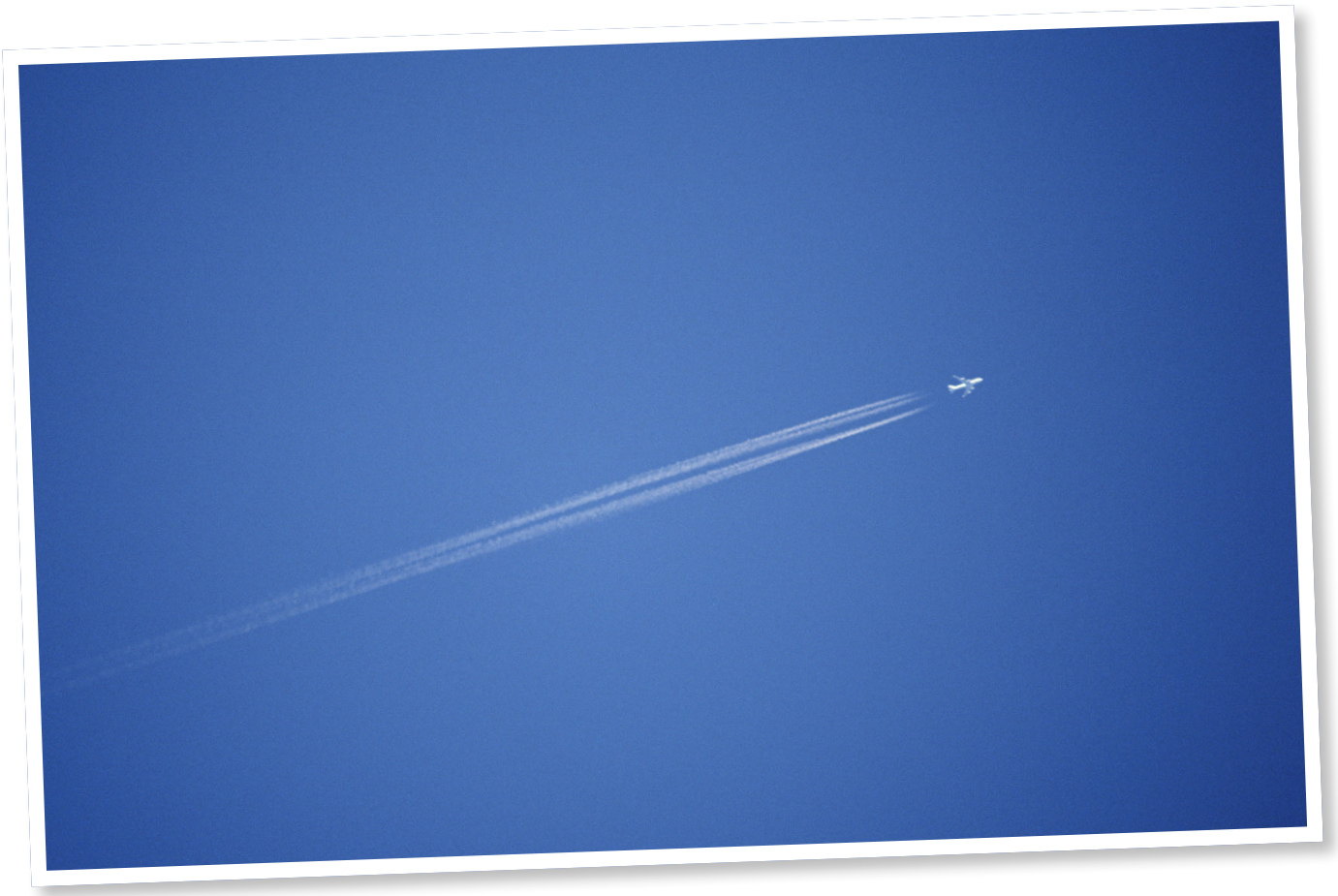
Another way government can influence the quantity of pollution is by changing incentives through taxes or subsidies. Government might tax plants for the amount of pollution they produce, or tax consumers in a way that causes them to use less energy. Imagine if there were a tax on electricity that doubled the electricity bill in your house each month. How might your family react? Since each kilowatt-hour costs twice as much as before, you will probably be more careful about turning off lights when you are not home, and unplugging appliances you are not using. If everyone has to pay more for their electricity, most people will probably reduce their electricity consumption. Instead of turning up electric heat, they might wear a sweater or use a wool blanket; instead of leaving the lights on when they go out, they will be sure to turn them off. Because less electricity would be needed, fewer fossil fuels would be burned, and less pollution would be created, along with fewer jobs in the power industry. Government would not have to send someone to make sure you use less electricity. See *Activity 8* for another illustration of the power of taxes to decrease pollution.

Besides using taxes to encourage conservation, government can promote better environmental practices through subsidies, or grants of money. For example, a power plant might consider upgrading

its facility, which would make its production cleaner and more efficient. Government might offer an additional incentive by paying for part of the upgrade. In the home, air conditioners are often the biggest users of electricity. By offering rebates to consumers who buy the more expensive, but more energy-efficient models, the total amount of electricity used would decrease, thus decreasing the amount of pollution it causes.

Pollution Permits

A third option government could choose to reduce pollution is to issue permits, allowing companies a certain amount of pollution. Government first decides what the total allowable amount of a particular pollutant should be in a region. Next, the government auctions just enough permits to equal that amount of pollution. All the firms operating in that area must then buy the right to continue polluting. Most companies will buy permits, while some of the highest-polluting companies may decide to close down because it would be too expensive to buy enough permits to cover their pollution. Once companies own these permits, they can also trade them. For example, if one company wants to open a new plant, it would have to buy a permit from another company. A company that decides to upgrade its plant, and make production cleaner or more efficient, would be able to sell some of its permits. It is in the firms' interest to operate more efficiently and cleanly so that they need to own fewer permits. At the same time, these companies make their own decisions about how best to reduce their pollution, based on their individual situations, thereby rewarding good management and corporate flexibility (Ellerbrock). For more discussion on allocating permits, see *Activity 9*.



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6.4 Materials List

6 – 1 *Introducing Sources of Air Pollution*

- Transparencies of Shenandoah National Park

6 – 2 *Measuring the Acidity of Rain*

- Clean glass jar
- pH paper
- Newspaper
- Rain water

6 – 3 *Measurement of Particulate Matter: Dust Fall Jar*

- Large jar with a lid
- Soil test kit
- Marker
- Scale
- Sticky material
- Masking tape
- Ruler

6 – 4 *Observing Effects of Acid Rain*

- Clear plastic cup
- Chalk
- Vinegar
- Paper clip

6 – 5 *Pollution Solutions*

- Copies of "Pollutions Solutions"

6 – 6 *The Role of Property Rights*

- Masking tape
- Dimes
- Dried beans
- Quarters

6 – 7 *Build a Wet Scrubber for Cleaning Emissions*

- Paper towels
- Flasks
- Hot plate
- Tubing
- Vacuum
- Glass tubing
- Impingers
- Rubber stoppers
- Ring stand

6 – 8 *Fuel Costs and Consumer Decisions*

- Copies of "Fuel Costs"

6 – 9 *Allocating Scarce Resources*

- Activity sheet

6 – 10 *Additional Air Education Resources*

- Activity sheet

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6.5 Activities

6 – 1 Introducing Sources of Air Pollution

Viewing pictures of Shenandoah National Park, classmates will see the effects of air pollution.

6 – 2 Measuring the Acidity of Rain

Students will collect rainwater and test the acidity of the water to learn the causes of acid rain.

6 – 3 Measurement of Particulate Matter: Dust Fall Jar

Students will make a Dust Fall Jar, historically used to measure particulate matter over various weeks and in different locations.

6 – 4 Observing Effects of Acid Rain

Classmates will perform an experiment with a paper clip and vinegar to see the effects of acid rain on statues.

6 – 5 Pollution Solutions

Many air pollutants are caused by burning non-renewable resources, such as fossil fuels. In groups, students will discuss these pollutants and possible sources.

6 – 6 The Role of Property Rights

Students will play a game with beans, quarter, and dimes to learn about the role of property rights among public and private land.

6 – 7 Build a Wet Scrubber for Cleaning Emissions

Students will set up an apparatus to act as a wet scrubber to demonstrate cleaning emissions.

6 – 8 Fuel Costs and Consumer Decisions

Cost/Benefit Analysis – Hybrid Cars vs SUVs

6 – 9 Allocating Scarce Resources

The Economic Challenge: Allocation of Scarce Resources

Additional Air Education Resources

Clean Air Partners – "On the Air" curriculum

Love-A-Tree – Fresh, Clean Air: Protecting Air Quality in Virginia
http://www.deq.virginia.gov/export/sites/default/education/pdf/lat05.pdf

Virginia Department of Environmental Quality – Air Quality Homepage – Specific information related to the implementation of the Clean Air Act in Virginia in regards to developing regulations, policy and guidance, and to pursue necessary enforcement actions.

6 – 1 *Introducing Sources of Air Pollution*

Purpose

Use visuals to illustrate air pollution and discuss possible sources.

Materials Needed

- Transparency of photographs of Shenandoah National Park, available at http://www.epa.gov/air/visibility/parks/shenan.html

Procedure

- Display the varying pictures of Shenandoah National Park for students to compare.

Reflection

What is the difference between the two pictures?

Answer: Less visibility in the lower photo.

What kinds of pollutants might cause haze? Where might these pollutants have originated?

Answer: Traffic, factories; wind currents may carry these pollutants from nearby cities or from even further away.

6 – 2 *Measuring the Acidity of Rain*

Purpose

Students will measure the acidity of rain water they collect.

Materials Needed

- Glass Jar
- Newspaper
- Rain Water
- pH paper

Procedure

- Place the glass jar outside until it collects rainwater.
- Cover a desk or table with newspaper.
- Place the glass jar on the newspaper.
- Use the pH paper to measure the acidity of the water. Acids turn pH paper red, and bases will turn the paper blue. If the rain is neither acid nor base, the paper will remain a neutral color.

Reflection

Was the rain acidic? How do you know?

What are some of the causes of acid rain?

Answer: sulfur dioxide, nitrogen oxide

Can pollution from other states cause acid rain in Virginia? Why or why not?

Answer: Yes, air currents can move pollutants.

More information can be found at

http://www.hcdoes.org/airquality/Outreach/Teacher%202%20-%20Acid%20Rain.htm

6 – 3 *Measurement of Particulate Matter: Dust Fall Jar*

Purpose

This is an activity that can be done for homework or as an ongoing in-class activity. The entire project will take a total of one month to complete.

Materials Needed

- 1 bucket and plastic wrap or 1 large jar with lid
- Sticky surface such as fly paper or double sided tape
- Masking tape
- Marker
- Ruler
- Scale

Procedure

- Have each student acquire a bucket or large jar (preferably with a lid) from home, thrift stores, junkyards, etc.
- Make sure the jar is completely clean and rid of any excess materials such as dirt or water.
- Measure the area of the sticky surface and record in Table 1.
- Place the sticky surface at the bottom of the jar.
- Cover immediately with the lid or with plastic wrap for the large bucket.
- Place masking tape on the outside of the jar for recording dates and times of collection.
- Weigh the entire jar with the sticky surface and record weight in Table 1.
- You have the choice of letting the students take their jars home and determine the amount of dust fall at their houses or place them at different points near the school.
- If they choose to take them home, make sure that they bring them to school the same time each week to be weighed. This assures precision in the sampling techniques so as to reduce possible error from uncalibrated or different measuring devices.
- Advise the students to place the jar under an overhang of some sort such as a front porch or open-air garage so as to avoid rain entering the jar. If no covered area exists, encourage the students to cover (so that particulate matter in the household air does not contaminate the sample) and move their jars inside if it is going to rain.
- Record the date and time that the jar is covered on the masking tape. Also write that date and time in Table 1 (see Student Page, VI:14).

Reflection

There are a number of ways to assess this experiment. If the students do this from home, and all get different results, you can assess meteorological parameters that might have affected their results, such as being downwind from power plants, being downwind from a major highway, or any other explanations the class might suggest. Discuss experimental sources of error such as rainwater, water vapor, or animal excrement caught within the jar. Results may be graphed to determine different amounts of particulate matter over various weeks and different dust jars' locations.

Example Test Question as quoted from Peirce, Weiner, and Vesilind (1998):

An empty dust jar with an area of 30 cm^2 weighs 2,000g. After sitting outside for 30 days, the jar weighs 2,020g. Report the dust fall in g/cm^2/month.

Student Page

6 – 3 Measurement of Particulate Matter: Dust Fall Jar

Record the weight of the jar with lid in Table 1 every 7 days (normally recorded as grams per cm² per 30 days).

Table 1

Area of sticky surface	Date and Time Measurement was taken	Mass of dust fall jar with sticky tape, lid, and masking tape	Mass of dust: Measurement X – Measurement 1
Measurement 1: Before being placed outside			
Measurement 2: Approximately 7 days later			
Measurement 3:			
Measurement 4:			
Measurement 5: After about 28 days to a month			

6 – 4 *Observing Effects of Acid Rain*

Purpose

Since all rain is naturally acidic, it affects buildings and statues. Highly acidic rain (pH below 5) does even more harm to buildings and statues. Conduct an acid rain experiment to demonstrate the effects acid rain has on buildings.

Materials Needed

- Paper Clip
- Chalk
- Clear Plastic Cup
- Vinegar

Procedure

- Use the paper clip to make a statue out of the chalk: write your name, draw a face, etc.
- Place chalk statue in the clear plastic cup.
- Add vinegar, to symbolize "acid rain," to the cup.
- Observe what happens to the chalk statue.

Reflection

What change did you observe in the chalk statue? Why do you think this change occurred?

What conclusions might you come to about the effect of acid rain on buildings?

Answer: structural damage, material degeneration, aesthetic degeneration, maintenance and repair costs

More information can be found at
http://www.hcdoes.org/airquality/Outreach/Teacher%202%20-%20Acid%20Rain.htm

Teacher Page

6 – 5 Pollution Solutions

Purpose

In groups of three or four, students will list the major air pollutants. Note that many of these pollutants also are connected to the use of non-renewable resources, especially fossil fuels.

Key

Pollution Solutions

Sources of Pollution	*Major Air Pollutants*	*Solutions: What we can do to decrease the pollution*
Cars	• Ozone • Carbon Monoxide • VOCs (Volatile Organic Compounds) • Nitrogen Dioxide	• Walk • Bicycle • Take public transportation • Carpool • Plan errands carefully to minimize car trips
Heat and Electricity	• Particulate Matter (dust, smoke, soot) • Sulfur Dioxide	• Turn off lights, computers, electronic devices when not in use • Choose energy-efficient appliances; • Limit wood fires

Procedure

Student Page

6 – 5 Pollution Solutions

Pollution Solutions

In groups, list the major pollutants resulting from car emissions or energy production, then come up with ways to decrease car emissions or the use of energy.

In 2006, the Hopewell Cogeneration Facility, which sells electrical power directly to Dominion Virginia Power and steam to a nearby manufacturing plant, changed its plant startup procedures to significantly **reduce its emissions of nitrogen oxides**, a precursor to ground level ozone and a green house gas. The first phase of the project **reduced NOx emissions** by about 16 tons or 5% per year, and the second phase increased that number to about 40 tons per year, saving the facility $36,000 a year, or 10%. Corporate Case Study – Hopewell Cogeneration Facility.

Pollution Solutions

Sources of Pollution	*Major Air Pollutants*	*Solutions: What we can do to decrease the pollution*
Use of Motor Vehicles	• Ozone • Carbon Monoxide • VOCs (Volatile Organic Compounds) • Nitrogen Dioxide	
Consumption of Heat and Electricity	• Particulate Matter (dust, smoke, soot) • Sulfur Dioxide	

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6 – 6 The Role of Property Rights

Adapted from http://fte.org/teachers/programs/efl/lessons/fri/eflfri2.htm

Purpose

This activity addresses the issue of property rights using a fishing location as the example.

Materials Needed

- Masking tape
- 15 dried beans
- 15 dimes
- 15 quarters (or other small rewards of differing value)

Procedure

- A pond full of fish is located on public land, and anyone may come there to fish. Another pond nearby is also full of fish, on a fisher's private land. The fisher sells fish from his pond. Soon, there are very few fish in the public pond but many fish in the fisher's pond. How can you explain this?

- Tape 2 large squares on the floor in the center of the room. Divide one of the squares into a number of smaller sections. Select 8-10 students to participate in the first round. Make sure that the squares are in a position where students observing the activity will be able to see.
- The taped area without sections is the "public pond," and any student may fish. Scatter the 15 beans (the "fish") on the public pond. Give the students standing around the square the following instructions:
  - When I say "Go," you may enter the square and pick up the beans.
  - I'll pay 10¢ for each bean picked up in the first round.
  - I'll pay 25¢ for each bean picked up in the second round.
- Say "Go" and keep time for one minute. Make sure no one hides beans. They must turn in all harvested beans at the end of the minute. Because students will not be able to trust others not to harvest the limited "resource," you will not have to play the second one-minute round.
- Ask students to return to their seats. Choose a new set of participants. You will be using the second square, so choose the same number of students as you have sections. After students line up around the edges, assign each student the "ownership" of a particular section. They each "own" a small pond, and can only fish in their particular section.
- Repeat your instructions from procedure #2. Play the 2 rounds and pay students for the beans.

Reflection

Why did the first group fish right away, while the second group saved their fish for the second round?

Answer: The first group had unlimited access to the pond.

Who owns the fish in the public pond? Would people fishing there have worried about preserving the fish population for the future? Why or why not?

Answer: No one, there is no incentive to conserve.

Who owns the fish in the fisher's pond? Do you think the fisher is concerned with preserving the fish for future years? Why or why not?

Answer: Fisher, yes, he has incentive (future profit).

Who owns the air we breathe? Who is responsible for preserving clean air for the future?

Answer: No one has ownership, everyone is responsible for preserving the air.

After completing this activity, do you think pollution permits would be effective? Why or why not?

6 – 7 *The Role of Property Rights*

Adapted from http://fte.org/teachers/programs/efl/lessons/fri/eflfri2.htm

Purpose

Students will build a model wet scrubber.

Materials Needed

- Paper towels
- 12-cm piece of glass tubing
- Three 2.5-cm pieces of glass tubing
- Three 55-mL flasks
- Two glass impingers (glass tubing drawn at one end to give it a smaller diameter so as to let out smaller bubbles)
- Heat source (burner or hot plate)
- Three 2-hole rubber stoppers (of a size to fit the mouths of the flasks)
- Two 30-cm pieces of rubber tubing
- Ringstand apparatus
- Vacuum source

Background Information

The wet scrubber is one of the most common pollution control devices used by industry. It operates on a very simple principle: a polluted gas stream is brought into contact with a liquid so that the pollutants can be absorbed.

Procedure

A diagram of the set-up can be found at the website listed above.

- Set up the apparatus as shown in figure 1. Put a paper towel in a 55-ml flask and place this above the burner.
- Using a 2-hole stopper that makes an air-tight seal with the flask, insert a 12-cm section of glass tubing through one of the holes. The tubing should reach to approximately 1.2-cm from the bottom of the flask.
- Insert a 2.5-cm piece of glass tubing into the other hole of the stopper.
- Connect a 30-cm piece of rubber tubing to the 2.5-cm piece of glass tubing, making sure an air-tight seal exists.
- Fill a second 500-ml flask approximately 3/4 full of water. Using a second double-hole stopper, put a 2.5-cm piece of glass tubing into one of the holes, and insert the glass impinger into the other.
- Construct a third flask like the second.
- Connect the rubber tubing and heat the first flask (combustion chamber) until smoke appears.
- Put a vacuum on the third flask to draw a stream of smoke through the second flask (the wet scrubber). If smoke collects in the second flask above the water, a second scrubber can be added.
- Ask the students if particles are the only pollutants produced by industry. Discuss how a wet scrubber collects not only particulate matter, but also captures waste gases. Demonstrate how the water scrubber works. Discuss that the white plume you see coming from a smokestack may really be steam coming from a water scrubber.
- After observing the wet scrubber, answer the questions listed in the Reflection section.

Website for estimated distance between major United States cities:
http://www.mapcrow.info/united_states.html

Reflection

Why does the water in the wet-scrubber change color?

Answer: particles being pulled in cause the color change

Why does the wet-scrubber have an impinger (in other words, why is it important for small bubbles to be formed)?

Answer: waste gases are being filtered also

What does the scrubber filter out of the air? Not filter out?

Suggest ways to dispose of the pollutants that are now trapped in the water.

What do you think might be some of the difficulties with cleaning larger amounts of pollution from the air?

Teacher Page

6 – 8 *Fuel Costs and Consumer Decisions*

Procedure

Sport utility vehicles and light trucks, which have been very popular in the United States, use more gasoline and produce more air pollution than smaller, more efficient vehicles. In the chart below, calculate the difference in cost for SUVs versus hybrid cars, which require less gasoline.

Hint: Price of gasoline divided by miles per gallon gives us cost of gasoline per mile. Cost per mile multiplied by miles per week gives total gas cost per week.

1. How much more per week does it cost to buy gasoline for a SUV than for a hybrid?

Weekly Gasoline Costs of Hybrid Cars and Sport Utility Vehicles

Vehicle	Price of Gasoline ($/gal)	Miles per Gallon (mi/gal)	Cost per Mile ($/mi)	Total Miles per Week (mi/week)	Gas Cost per Week ($/week)
Hybrid Car	$2.00	50	$0.04	200	$8.00
SUV	$2.00	20	$0.10	200	$20.00

Now, suppose that the government introduces a tax of $2.00 on each gallon of gasoline, raising the price drivers pay to $4.00.

Weekly Gasoline Costs of Hybrid Cars and Sport Utility Vehicles

Vehicle	Price of Gasoline ($/gal)	Miles per Gallon (mi/gal)	Cost per Mile ($/mi)	Total Miles per Week (mi/week)	Gas Cost per Week ($/week)
Hybrid Car	$4.00	50	$0.08	200	$16.00
SUV	$4.00	20	$0.20	200	$40.00

2 With the tax, what is the difference in gasoline cost per week between hybrid cars and SUVs?

3. Do you think drivers are likely to drive more, less, or the same number of miles?

4. What do you think will happen to the popularity of hybrid cars?

Student Page

6 – 8 *Fuel Costs and Consumer Decisions*

Sport utility vehicles and light trucks, which have been very popular in the United States, use more gasoline and produce more air pollution than smaller, more efficient vehicles. In the chart below, calculate the difference in cost for SUVs versus hybrid cars, which require less gasoline.

Hint: Price of gasoline divided by miles per gallon gives us cost of gasoline per mile. Cost per mile multiplied by miles per week gives total gas cost per week.

1. How much more per week does it cost to buy gasoline for a SUV than for a hybrid?

Weekly Gasoline Costs of Hybrid Cars and Sport Utility Vehicles

Vehicle	Price of Gasoline ($/gal)	Miles per Gallon (mi/gal)	Cost per Mile ($/mi)	Total Miles per Week (mi/week)	Gas Cost per Week ($/week)
Hybrid Car					
SUV					

Now, suppose that the government introduces a tax of $2.00 on each gallon of gasoline, raising the price drivers pay to $4.00.

Weekly Gasoline Costs of Hybrid Cars and Sport Utility Vehicles

Vehicle	Price of Gasoline ($/gal)	Miles per Gallon (mi/gal)	Cost per Mile ($/mi)	Total Miles per Week (mi/week)	Gas Cost per Week ($/week)
Hybrid Car					
SUV					

2 With the tax, what is the difference in gasoline cost per week between hybrid cars and SUVs?

3. Do you think drivers are likely to drive more, less, or the same number of miles?

4. What do you think will happen to the popularity of hybrid cars?

6 – 9 *Allocating Scarce Resources*

Background

One of the basic functions of economics is rationing goods: deciding who gets how much of the goods produced. When the government decides that people do not have the right to produce as much pollution as they want to, the right to pollute has to be rationed. In a parallel example, we look at and evaluate some of the costs and benefits of different ways of distributing bicycle permits.

Suppose there is only one bike rack at school, with room for only 10 bicycles. All bicycles must be parked on the rack. More than 10 students would like to bring bikes to school, so the principal decides to issue permits for bike parking.

Discussion

Think of some ways the principal might decide who gets a bike permit. Some possibilities:

- *First come, first serve:* the first 10 students who come to his or her office get the permits.
- *Lottery:* The principal could choose names from a hat to decide who gets the permits.
- *Geography:* The principal could give the permits to the students who live closest to the school.
- *Reward:* The principal could give the students with the highest grades the bike permits.
- *Auction:* The principal could sell the permits to the highest bidder.

Reflection

What are some of the benefits to each of these solutions? What are some of the costs?

In each case, is the person who wants the bike permit the most likely to get it?

Answer: No, except in the case of the first come first serve scenario.

Which person would give up the most for a bike permit? Why might other students not be willing to give up very much?

Answer: The person with the least alternatives and most income.

What do you think would be true of the highest bidder for a pollution permit?

Answer: The person with the least alternatives and most income.

6.6 References

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