LESSON 10: CONSIDER THE SOURCE

AIR & WASTE MANAGEMENT ASSOCIATION
Since 1907

OBJECTIVES

Students will do the following:

1. Name some significant natural and man-made sources of air pollution
2. Distinguish between stationary and mobile sources of outdoor air pollutants
3. Distinguish between point and area sources of outdoor air pollutants
4. Describe typical emissions points within and from different types of sources
5. Define "fugitive emissions"
6. Monitor the air for airborne particulate matter
7. Demonstrate that automobiles emit air pollutants
8. Demonstrate that natural substances can pollute the air.

TOPICS:
Sources of ambient air pollutants

SUBJECTS:
Science, language arts, environmental science, ecology, chemistry, human physiology

TIME:
5-6 class periods and 15 minutes on each of 7 other days

MATERIALS:
Microscope
Microscope slides
Petroleum jelly
Paper labels
Anemometer and wind vane
3 ft. x 4 in.. (1 m x 10 cm) piece of posterboard
Scissors
Ruler
White facial tissues
Masking tape
A variety of automobiles (pre-1968, early 1970's, late 1970's, 1980's, and diesel models), trucks, and motorcycles
Pinch-type clothespins
String

BACKGROUND MATERIAL

Most people depend on many modern conveniences in the course of a day. We have appliances that heat and cool our homes and heat water for bathing and cooking, and we use electricity to power our lights. Many of us use pharmaceuticals, cosmetics, furniture, and clothing made of synthetic materials and rely on services, such as dry cleaners and print shops, that use chemical solvents. We enjoy the convenience and freedom of driving cars and traveling by public transportation for business and leisure. But the availability of these conveniences comes at a price, because they all contribute to air pollution. When we think of human-generated sources of air pollution, some are quite obvious to us: factory smokestacks and vehicle tailpipes spewing exhaust. Yet there are many others.

There have always been natural sources of air pollution. Volcanoes have spewed particulate matter and gases into our atmosphere for millions of years. Lightning strikes have caused

forest fires, with their resulting contribution of gases and particles, for as long as storms and forests have existed. Organic matter in swamps decays, and wind storms whip up dust. Trees and other vegetation contribute large amounts of pollen and spores to our atmosphere. These natural pollutants can be problematic at times, but generally are not as much of a problem as are human-generated pollutants.

Human-generated sources of air pollution are categorized in three ways: point, area, and mobile. A point source is a source that emits a significant amount of pollutants and that is at a fixed point (location). A smokestack or a leaking storage tank would be considered a point source. An area source, on the other hand, is a group of sources that together contribute a significant amount of pollutants, even if one or more of the sources alone would not be very significant. For example, a community of homes using woodstoves for heating would be considered an area source, even though each individual home is contributing small amounts of various pollutants. Mobile sources, as the name implies, are sources that move. Cars, trucks, planes, boats, buses, and trains are all mobile sources.

Mobile sources emit both criteria pollutants (see fact sheet "Criteria Pollutants") and other hazardous substances and account for more than half of all the air pollution in the United States. The primary mobile source of air pollutants is the automobile. Automobiles emit large amounts of carbon monoxide and significant, but lesser, amounts of nitrogen oxides and hydrocarbons. Although emission controls have greatly reduced the amount of lead and other pollutants emitted by individual vehicles, there are increasingly more and more vehicles taking to the highways and back roads of North America, so automobiles continue to be the primary mobile source of pollution. Although automobiles are powered by gasoline, most trucks, buses, and trains are powered by diesel fuel. The burning of diesel fuel produces high quantities of particulate matter and nitrogen oxides. It has been estimated that 850,000 diesel trucks produce as much nitrogen oxides in a given year as do 8,000,000 automobiles. Jet planes burn yet another type of fuel: jet fuel. Jet engines emit primarily nitrogen oxides, but also emit carbon monoxide and unburned hydrocarbons. EPA set the emission standards for all mobile sources. Some states have additional programs to deal with emissions from cars.

Stationary sources are non-moving sources, such as power plants, chemical plants, oil refineries, manufacturing plants, and other industrial facilities. There are hundreds of thousands of stationary sources of air pollution in North America. As do mobile sources, stationary sources emit both criteria pollutants and HAPs. There are two primary activities that produce air pollutants from stationary sources: (1) the combustion (burning) of fuel and (2) industrial processes. Electric-power plants burn a lot of coal and oil and produce nearly 75 percent of all sulfur dioxide emissions in the United States. Refineries, chemical manufacturing facilities, and smelters are examples of industrial facilities that contribute large amounts of pollutants. For example, chemical plants are responsible for many HAPs emissions and for large quantities of volatile organic compounds (VOCs).

Within a stationary source there are many possible emission points. An emission point is the specific place or piece of equipment from which a pollutant is emitted. Air pollutants can be emitted not only from smokestacks, but from process vents, storage tanks, process wastewater handling and treatment areas, loading and unloading facilities, and equipment leaks. Although storage tanks are usually covered, pollutants can leak through the roofs, and can leak through tank openings when liquids expand or cool because of outdoor temperature changes. Also, air pollutants can escape during the filling and emptying of a storage tank. There are usually

many places within a stationary source where wastewater comes into contact with the outside air. If the water contains volatile organic chemicals, the chemicals will evaporate when they contact the air. Equipment leaks can be a significant source of air pollution emissions. Leaking equipment can include valves, flanges, pumps, and relief valves, and there might be thousands of these in a given facility.

In addition to the aforementioned categories of point sources and area sources, the Clean Air Act Amendments of 1990 categorize sources of HAPs into two groups: major sources and area sources. A major source is any stationary source that emits 10 tons or more per year of a single HAP, or 25 tons or more per year of any combination of HAPs. An area source of HAPs is any source of HAPS that is not a major source. This does not include automobiles.

A source of air pollution that sometimes receives a lot of attention and complaints from the general public is "fugitive emissions." Fugitive emissions are particles or gases that have "escaped" (hence the name, fugitive) because of an external force (such as the wind) acting upon them. A common type of fugitive emissions is the dust that escapes on a windy day from a road- or building-construction site when there has been a lot of grading and the area has not been planted or covered. You've probably noticed construction crews putting up temporary fences in an attempt to minimize the fugitive dust before it can spread to surrounding areas. Leaking valves, seals, and pumps in a chemical plant or refinery are also sources of fugitive emissions of VOCs.

Sources of the Criteria Pollutants (See also Lesson 5)

Particulate matter (PM_{10}) is composed of very small solid or liquid particles that float in the air and settle very slowly. Particulate matter can be either a primary pollutant or a secondary pollutant. Natural (biogenic) sources of particulate matter include windstorms, volcanoes, and forest fires. Human-generated (anthropogenic) sources include smelters, grain milling operations, incinerators, and woodstoves.

Carbon monoxide is a colorless, odorless gas produced mostly by such human-generated sources as automobiles, gas stoves, woodstoves, faulty heaters, and passive smoking. It is a by-product of combustion, and forms when the combustion takes place without adequate oxygen present.

Sulfur dioxide is a colorless gas that forms when sulfur is burned. Sulfur is a "pass through" pollutant, which means that the amount of sulfur released into the atmosphere is the same as the amount in the sulfur-containing fuel that is burned. Volcanoes are a natural source of sulfur dioxide, and power plants, industrial facilities, smelters, and oil refineries are some human-generated sources.

Nitrogen dioxide is a gas composed of nitrogen and oxygen. The main source of NO_2 is the combustion of fossil fuels in automobiles, power plants, factories, gas stoves and ovens, and space heaters. Natural sources include volcanoes, decaying organic matter in swamps, and lightning.

Ozone is a unique criteria pollutant in that it is the only one that is almost always a secondary pollutant. That is, it isn't emitted from a source as ozone; it is formed in the atmosphere

through a chemical reaction involving other pollutants. Ozone is formed when nitrogen oxides and volatile organic compounds (VOCs) react in the presence of sunlight. Because much of the VOCs emitted are from mobile sources and because ozone formation is affected by the intensity of sunlight and heat, ozone concentrations tend to be highest in urban areas from about 10 am to 4 pm (when there is a lot of traffic and direct sun rays, and the temperature is warmest) and in the summer. VOCs and nitrogen oxides are emitted by a variety of sources, including motor vehicles, power plants, industrial boilers, painting and coating operations, refineries, chemical processes, toxic waste and landfill sites, and small sources such as dry-cleaners, furniture refinishing operations, lawn mowers, and solvent usage.

Lead is a heavy, malleable, grey metal that is derived from ore-bearing minerals. Lead emissions are almost always in the form of particulate matter. Gasoline used to be a major source of atmospheric organic and particulate lead in the United States. Lead emissions were greatly reduced, however, by the switch from leaded to unleaded gasoline. Lead in gasoline was banned in the United States as of January 1, 1996. Lead can also be released from lead smelting and refining plants, storage-battery manufacturing facilities, lead mines, and tetramethyl and tetraethyl lead plants. It is sometimes found in paint in older homes, ceramic glazing, contaminated soil, and drinking water.

Procedure

I. Setting the Stage.

A. Give each student a copy of the handout, "Air Pollution Scavenger Hunt."

B. Have students do independent research to find the answers to the questions.

II. Activity

A. Students will determine whether the concentration of particulate matter in our environment remains constant.

You will need the following materials:

- ☐ Microscope
- ☐ Microscope slides
- ☐ Petroleum jelly
- ☐ Paper labels
- ☐ Anemometer and wind vane

B. Select several sites in your community in which to monitor for the presence of airborne particulate matter. The sites should provide contrasts and comparisons in air quality. Several factors should be considered:

- Topography (valleys, mountains, waterways, etc.)
- Traffic-flow patterns
- Residential areas

- Sites of industrial plants, incinerators, and power plants
- Prevailing wind patterns

Be sure to include at least one site inside and one site directly outside the school.

C. At each site, place three glass slides. Each should be labeled and should be evenly covered with a thin layer of petroleum jelly.

D. For each day of the experiment, keep a record of the wind direction and rainfall.

E. Day 0 is the day that the slides are placed in position. On Day 1, collect one slide from each site. Label the slide with the date. Using a microscope, examine the slides as soon as possible after collection. Record your findings. Be sure to note the color, size, and amounts of particles on each slide.

F. After examining the slides, cover each slide with a clean slide and store in a safe place.

G. Repeat steps D and E on Day 3 and again on Day 7.

H. Make a chart or graph comparing the color, size, and amounts of particulate matter collected from each site. Note the location, wind direction, and length of exposure.

I. Try to determine the most probable source of the particulate matter collected at each site.

NOTE: Precipitation can wash away the petroleum jelly on the slides. If it rains, snows, etc., during the test period, you will probably need to repeat the test. To reduce chances of this happening, place the slides in locations that are sheltered from precipitation yet open to the air (for example, in an open area beneath a building overhang). Be aware, however, that this might shelter the slide from certain wind directions.

III. Follow-Up

A. Cars pollute the air from (1) the gas tank (VOCs), (2) the carburetor in older cars (VOCs), (3) the crankcase vent (VOCs), (4) the tailpipe (VOCs, carbon monoxide, nitrogen oxides, and small amounts of particulate matter and sulfur dioxide), and (5) the road surface (road dust, tire-rubber particles).

B. This activity will demonstrate that automobiles and other motor vehicles are a source of air pollution.

You will need the following materials:

- ☐ 3 ft. x 4 in. (1 m x 10 cm) posterboard
- ☐ Scissors
- ☐ Ruler
- ☐ White facial tissues (or Pellon® or other fusible interfacing material)
- ☐ Masking tape
- ☐ A variety of automobiles (pre-1968, early 1970s, late 1970s, 1980s, and diesel models, if you can find them), trucks, and motorcycles

1. Prepare a collector board by cutting a 2" x 2" (5 cm x 5 cm) hole three inches from one end of the posterboard or cardboard. Over the hole, place a 3" x 3" (7.5 cm x 7.5 cm) piece of white facial tissue and tape the edges with masking tape. Put the collector board on a long (approximately 3-foot or 1-meter) pole so that the teacher doing the sampling does not have to place his or her face near the exhaust.

2. Prepare a "results" chart listing the following:

   - Type of vehicle
   - Model year
   - Manufacturer
   - Type of fuel burned
   - Approximate length of time since last tune-up

3. **CAUTION: CARBON MONOXIDE EMISSIONS MAY BE DANGEROUS. POST A "SPOTTER" TO OBSERVE THE PERSON DOING THE SAMPLING. During these procedures, do NOT touch the vehicle's tailpipe because it will be hot when the engine is running. Also, keep your face as far away as possible from the exhaust, because invisible, toxic pollutants are emitted by running engines. Before you start, be certain to obtain permission from the operator of the motor vehicle to perform this test.**

4. To sample the tailpipe emissions, warm up the engine for five minutes before the sample is taken. Then, for one minute, the teacher should hold the collector board on the pole approximately 4 in. (10 cm) away from the mouth of the exhaust tailpipe of a vehicle while the engine is idling. (Hold the collector board so that the tissue is facing the tailpipe.)

5. Record the vehicle's information on the results chart. In addition, tape to the chart the facial tissue that was exposed to the exhaust.

6. For a different vehicle, mount a new 3" x 3" (7.5 cm x 7.5 cm) piece of white facial tissue to the board. Take a 1-minute sample while this vehicle is idling. Record the information and save the tissue paper.

7. Repeat Steps 4 and 5 for as many different vehicles as possible.

C. Analyze the results.

1. Compare the color of the particles on the facial tissue samples from the various vehicles.

2. Place the samples on a bulletin board, record the vehicle information that was collected (type and model year, etc.) on cards, and arrange each card under the appropriate sample.

3. Compare the information.

4. Answer the following questions:

   a. Obtain information on the types of air pollution control devices that automobile manufacturers have installed. Draw an automobile and label the points where pollutants are emitted. What has been done to reduce these sources? How much have they been reduced?

   b. What are some federal and state regulations regarding automobile pollution control devices? Discuss local inspection and maintenance programs.

   c. A properly tuned automobile emits substantially less pollution that one that is not. How often does your family automobile have its engine tuned and carburetor adjusted?

   d. What are some alternatives to using automobiles for transportation? Why are they valuable?

IV. Extension

A. Not all air pollution is a consequence of human activities. Natural air pollutants—such as pollen, spores, and VOCs from trees—are present in the air we breathe. This is especially true during seasons when vegetation is active. Students will discover natural pollutants in the ambient air.

You will need the following materials:

- ☐ Microscope
- ☐ Clean microscope slides
- ☐ Petroleum jelly
- ☐ Labels for the slides
- ☐ Pinch-type clothespins
- ☐ String

B. Cover several clean microscope slides with petroleum jelly and suspend them with pinch-type clothespins from fencepost stakes, clotheslines, etc., in several areas around the school and/or around students' homes. Make sure that the slides are suspended in areas free from obstruction and that precipitation is not in the forecast.

C. Label the slides with the location and leave the slides in place for 24 to 48 hours.

D. Collect the slides and examine them for the presence of pollens and spores.

E. Compile the data collected and present the information to the class.

References

Source Book on Air Pollution Topics for Grade and High School Teachers. Pittsburgh, PA: Air Pollution Control Association (forerunner to A&WMA), 1984.

United States Environmental Protection Agency, Education and Outreach Group, *Course SI:422, Air Pollution Control Orientation Course.* Research Triangle Park, 1992.

United States Environmental Protection Agency, Education and Outreach Group, *Course 452, Principles and Practice of Air Pollution Control.* Research Triangle Park, 1983.

Air Pollution Scavenger Hunt

1. List two human-generated (anthropogenic) sources of carbon monoxide (CO).

2. List two natural (biogenic) sources and two human-generated sources of particulate matter (PM_{10}).

3. List one natural source and two human-generated sources of sulfur dioxide (SO_2).

4. List the two major pollutants that contribute to ozone (O_3) formation and give their major source.

5. List two human-generated sources of lead (Pb).

6. List two natural sources and two human-generated sources of nitrogen dioxide (NO_2).

7. Distinguish between stationary sources and mobile sources of outdoor air pollutants.

8. Distinguish between point and area sources of outdoor air pollutants.

9. Describe typical emissions points within and from different the following types of sources:

   Automobiles

   Industrial/manufacturing plants

   Storage tanks

10. Define "fugitive emissions."

Air Pollution Scavenger Hunt
Answers

1. List two human-generated sources of carbon monoxide (CO).
   Human-generated: Burning of gasoline, natural gas, coal, oil, etc., (automobiles; woodstoves)

2. List two natural sources and two human-generated sources of particulate matter (PM_{10}).
   Natural: Forest fires, volcanoes, ocean, desert wind storms, pollen, spores
   Human-generated: Burning of wood, diesel, and other fuels; industrial plants; agriculture (plowing, burning off fields, crop dusting); unpaved roads, mining, quarrying

3. List one natural source and two human-generated sources of sulfur dioxide (SO_2).
   Natural: Volcanoes
   Human-generated: Power plants; industrial plants (paper, metals), diesel vehicles, oil refineries

4. List the two major pollutants that contribute to ozone (O_3) formation and give their major source.
   Pollutants: Nitrogen dioxide (NO_2) and volatile organic compounds (VOCs)
   Source: Burning of fossil fuels (automobiles)

5. List two human-generated sources of lead (Pb).
   Human-generated: Lead smelting and refining plants; battery manufacturing plants; lead mines; leaded gasoline; sanding lead-containing paint

6. List two natural sources and two human-generated sources of nitrogen dioxide (NO_2).
   Natural: Volcanoes; lightning; forest fires; decaying matters in swamps
   Human-generated: Burning of gasoline, oil, gas, and coal (automobiles; power plants)

7. Distinguish between stationary sources and mobile sources of outdoor air pollutants.
   Mobile sources are sources that move, such as cars, trucks, planes, boats, buses, and trains. Stationary sources are non-moving sources, such as power plants, chemical plants, oil refineries, manufacturing plants, and other industrial facilities.

8. Distinguish between point and area sources of outdoor air pollutants.
   A point source is a source that is at a fixed point (location) and that emits a significant amount of pollutants. An area source is a group of sources that together contribute a significant amount of pollutants, even if one or more of the sources alone would not be very significant.

9. Describe typical emissions points within and from different the following types of sources:
   Automobiles
      Carburetor, gas tank, crankcase, tailpipe
   Industrial/manufacturing plants
      Smokestacks, process vents, storage tanks, process wastewater handling and treatment areas, loading and unloading facilities, equipment leaks (valves, flanges, pumps, and relief valves)

Storage tanks

Through the roofs and tank openings, during filling and emptying, from leaks.

10. Define "fugitive emissions."
Fugitive emissions are particles or gases that have "escaped" (hence the name, fugitive) from open doors, cracks in buildings, etc., or because of an external force (such as the wind) acting upon them.

