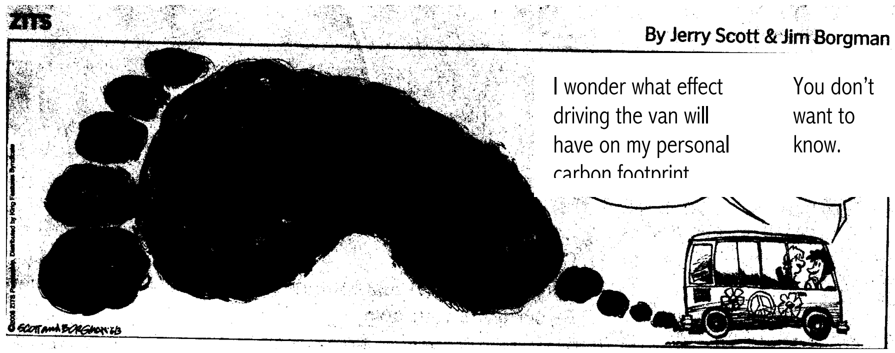
Air Pollution Lab



Overview

During the lab, you will explore air pollution resulting from combustion of fossil fuels. You will determine ozone and UV levels as you examine local conditions that contribute to the production of smog. Additionally, you will measure carbon monoxide and hydrocarbons in vehicle exhaust to quantify the contribution of combustion engines to air pollution. You will use the Air Quality Index to determine the health effects of carbon monoxide and ozone. With other students, you will discuss methods to reduce air pollution from fossil fuels.

Pre-lab Questions

1. What organization sets the national air quality standards in the United States?
2. What is the primary purpose of the Air Quality Index (AQI)?

Background

Fossil fuels are composed of organic carbon matter and are found in three forms: petroleum, natural gas, and coal. Pressure form the earth's crust, heat, and bacterial processes transform decayed plants and animals into carbon energy. The formation of fossil fuels takes millions of years. Fossil fuels are relatively inexpensive to extract, process, and ship, and their combustion is a straightforward process. A downside to dependence on fossil fuel is that fossil fuels are nonrenewable. In addition, fossil fuel combustion has been linked to global warming, and it negatively impacts air quality.

The components of fossil fuel air pollution include carbon dioxide, carbon monoxide, hydrocarbons (VOCs), particulate matter, nitrogen oxides, lead, and sulfur dioxide. These by-products of combustion are emitted into the air. They degrade air quality as they mix with other reactants in the atmosphere. Work as a group to investigate some components of fossil fuel air pollution and complete the lab.

Procedure

Make the following data table in your lab notebook. Follow the instructions that follow to fill in your table.

Variable	**Concentration or Degree**	**Date/Time**
Ozone (ppb)		
Ultraviolet radiation (index)		
Carbon monoxide (ppm) Make/model/year:		
Hydrocarbons (mL) Make/model/year:		
Outdoor temperature (°C)		

Sample Ambient Ozone
Based on prior knowledge, pick a location that your group believes would have a high ozone reading. Tape the ozone card at eye level, in a location that will stay out of the sun and rain for 8 hours. Record the start time and leave for 8 hours. After the reaction time is up, record the end time and put the ozone card into a plastic bag with a slip of paper recording the date, time, location, and relative humidity (see weather.com). Determine the ozone level using the card provided and record in your lab notebook. Keep the test card with your group for later analysis during the air pollutant calculations.

Determine the Current Index of Ultraviolet Radiation
Your instructor will pass around one UV indicator card to your group. Observe the color of the indicator and match it to the color scale on the card. Record the time and UV level in your lab notebook.

Measure Vehicle Emissions
List the make, model, and year of the vehicle. After recording the data, prepare the gas detector syringe with 3-way stopcock and tubing (see Figure 1). Now, start the car and proceed through the directions for each test. **NOTE:** Take the air pollutant readings <u>no more than 1 inch from the mouth of the tail pipe</u>. Use caution; *the tailpipe is very hot.*

Carbon monoxide (CO) sample

1. Connect the CO gas detector tube to the piece of tubing so that the <u>arrow on the detector tube points toward the syringe pump.</u>

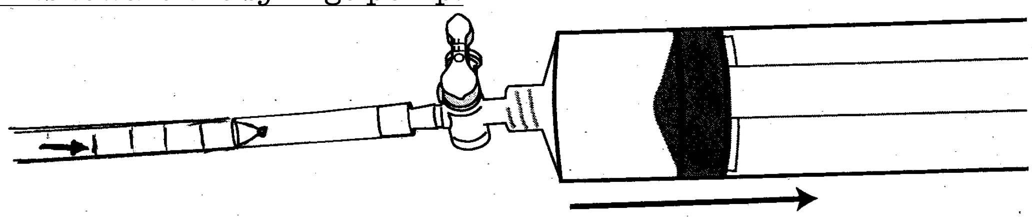


Figure 1. To pull air through the detector tube, orient the stopcock arm as shown and pull the syringe plunger.

2. Draw one air stroke sample using the following steps.
    a. Turn the stopcock arm toward the empty stopcock stem (see Fig. 1).
    b. Place the open end of the gas detector tube into the exhaust airstream. Ata reasonable rate, draw 50 mL of air into the syringe. Have a member of the group record the start time.
    c. Release the plunger. Note: If a partial vacuum is created, the plunger will draw back toward the gas detector tube. Wait until the plunger has stopped moving and then continue to pull back to the 50 mL mark, this time drawing the air through more slowly.
    d. Turn the stopcock arm toward the tube (Fig. 2) and expel the air out the side opening to clear the pump. (Make sure the stopcock arm is pointed correctly. Air must not pass back through the detector tube.)

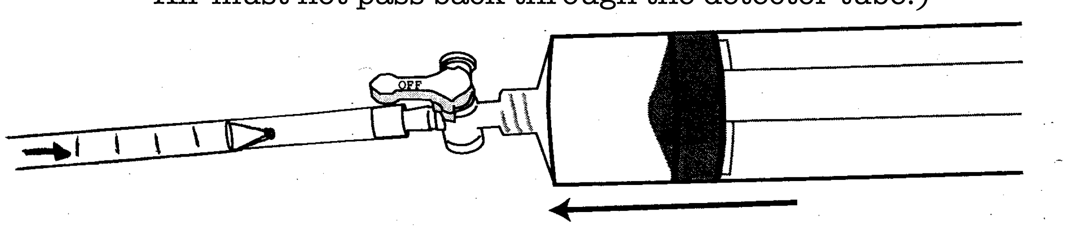


Figure 2. To expel air from the side, orient the stopcock as shown and push the plunger.

3. Repeat steps 2a-d.

CO is tested by taking two complete 50 mL syringe strokes.

4. Remove the gas detector tube from the piece of tubing.
5. Observe the percent volume at the point where the color change stops. In your lab notebook, record the concentration of the CO. If the color change line is slanted, take the value at the middle of the slanted region.

Hydrocarbon (HC) sample

1. Connect the HC gas detector tube to the tubing so that the arrow on the detector tube points toward the syringe pump (Fig. 1).
2. Turn the stopcock arm toward the empty stopcock stem (Fig. 1). Place the open end of the gas detector tube into the exhaust airstream. At a reasonable rate, draw air into the syringe until you see a color change. Have a member of the group record the start time.
3. In your lab notebook, record the volume of air that was needed to see the color indicator.

HC is tested by taking in exhaust until a color change takes place. The volume of exhaust that brings about the color change is recorded.

Outdoor Temperature

Record the current temperature in your lab notebook.

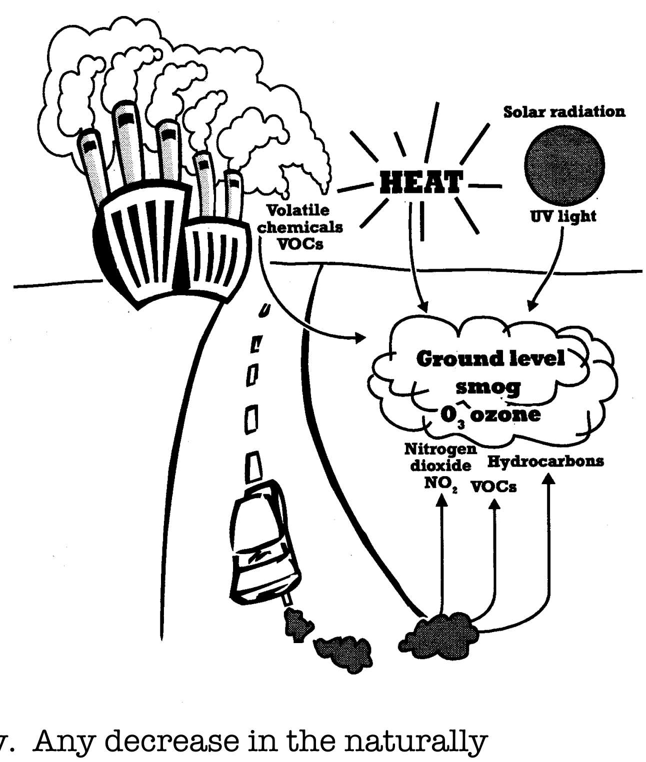
Discussion

Air pollution from fossil fuels produces hazardous conditions for living organisms. A combination of air pollutants and certain environmental conditions can produce smog, which reduces visibility and causes irritation to the lungs. Individual fossil fuel air pollutants are also toxic to targeted body processes, including cardiovascular activity and brain function.

Smog Formation

Ground level ozone is a type of air pollutant and a major component of smog, the hazardous, low-lying haze common during summer. When heat, nitrogen oxides (NO_x), volatile organic compounds (VOCs), and intense UV light come into contact, a chemical reaction takes place. Ozone and particles of solids and liquids are formed, producing smog.

Several variables influence the formation of smog. Vehicles emit nitrous oxide, which quickly transforms into nitrogen dioxide. Vehicles also emit VOCs. Hydrocarbons are specific types of VOCs that results from inefficient engine combustion. Propane and butane are hydrocarbon VOCs present in vehicle exhaust. The use of many types of everyday chemicals, such as paints, cleaners, and insecticides, is another source of VOCs. A third source is from industrial activity, such as chemical production and solvent usage.



Smog formation is also affected by environmental factors such as wind, temperature, topography, and ultraviolet light. An enclosed region such as a valley has reduced wind levels, allowing smog to accumulate. High outdoor temperatures tend to increase smog formation. UV light reacts with fossil fuel pollution to form smog. Cloud cover and other changes in the weather, the tilt of the earth at different times of the year, and the daily changes in position of the sun in the sky affect UV light intensity. Any decrease in the naturally occurring ozone in the upper atmosphere allows more UV radiation to penetrate. In the past, this protective ozone layer was reduced by human activities, mainly by chlorofluorocarbons that were used in coolants for many years. There is evidence that the layer has been recovering since those chemicals were replaced by alternatives.

The effects of smog on human health vary. Common effects are nose and throat irritation. A severe response includes lung inflammation. If the damage happens over long periods of time, lung function may be reduced permanently. The elderly, children, and people with lung ailments are particularly vulnerable to smog.

Data Analysis and Discussion Questions

Answer the following questions in you lab notebook.

1. a. Convert the carbon monoxide reading to ppm. Use the relationship, 1 volume-percent = 10,000 parts per million (ppm).

   b. Good air quality is between 0 and 4.4 ppm CO. How does yours compare?

2. Compare the typical results from the lab with another fossil fuel engine, a lawnmower.

Pollution Source	**Carbon Monoxide**	**Hydrocarbons**
Car exhaust	0.5-1.5%	5-300 mL
Lawn equipment	0.5%	100 mL

   a. Why are air pollutant concentrations similar from a car and a lawn mower?

   b. Name a factor that may influence the amount of pollution in vehicle exhaust. (Hint: you may want to look at another group's data for ideas)

3. Ground ozone and UV levels vary depending on location and human activity.

   a. Provide an explanation for the results of your samples. Did your results indicate a relationship between UV intensity and ozone levels? If so, what is it?

   b. Give specific examples from your area (environmental factors or activities) that influence ozone formation.

4. a. List the effects of poor air quality on individuals and on a community. Think about the impacts on the segments of the population most vulnerable to unhealthy air conditions (children, people with respiratory illness, the elderly).

   b. Provide two changes a family might have to make in order to accommodate a member with a long-term illness caused by air pollution.

5. Discuss some of the ways that you and other students can reduce air pollution. (Hint: think of ways that you and your peers' daily choices affect fossil fuel emissions.)

6. (Extra Credit) You can calculate the AQI of a pollutant if you know its concentration. Below, find the AQI range for a CO measurement of 6 ppm. Below the table, the exact AQI is calculated.

CO ppm	**Ozone ppb**	**AQI**	**Level of Health Concern**	**Colors**
0.0-4.4	-	0-50	Good	Green
4.5-9.4	-	51-100	Moderate	Yellow
9.5-12.4	125-164	101-150	Unhealthy for sensitive groups	Orange
12.5-15.4	165-204	151-200	Unhealthy	Red
15.5-30.4	205-404	201-300	Very Unhealthy	Purple
30.5-50.4	405-604	301-500	Hazardous	Maroon

The general formula for calculating the AQI is

[(upper AQI value – lower AQI value) divided by (pollutant concentration at upper AQI value – pollutant concentration at lower AQI value)] X (observed pollutant concentration – pollutant concentration at lower AQI value) + AQI value at lower pollutant concentration

AQI of air whose CO concentration is 6 ppm:
AQI = [{100-51)/(9.4 ppm – 4.5 ppm)] X (6.0 ppm – 4.5 ppm) + 51
AQI = 49/4.5 ppm X 1.5 ppm + 51
AQI = 63.38

a. Calculate the AQI value for 14 ppm CO:

b. Calculate the AQI value for 0.505 ppm ozone:

c. Calculate the AQI value for the ozone you tested.