Air Pollution

Introduction

Like water pollution, air pollution is becoming an increasing problem in our society. The detrimental effects of air pollution - poor visibility, eye and throat irritation, and damage to vegetation and property - are obvious to anyone who has ever visited or lived in or near a major urban area. Several US cities (such as Los Angeles, Denver and Houston) are already at the point of having to take decisive action to improve air quality, or risk subjecting their citizens to significant health risks.

Air pollution is defined as the release of harmful amounts of natural or synthetic materials into the atmosphere as a direct or indirect result of human activity. The severity of air pollution in a given area depends on several factors, including climate, topography, population density, and the number and type of industrial activities. Air pollution may be broken down into four categories. The first, **ambient**, or outdoor air pollution, is perhaps the most familiar and includes both natural (biogenic) and human-made (anthropogenic) sources. However, **indoor** air pollution is also of concern because, on average, most people spend up to 90 percent of a typical day indoors. **Occupational** air pollution is restricted to the workplace, but can involve potentially heavy exposures, often to more than one pollutant. Finally, **personal** air pollution includes voluntary exposures to consumer products, as well as those incurred through lifestyle choices (such as smoking).

Increases in ambient air pollution are due primarily to four factors: 1) population growth; 2) technological changes that create new products; 3) social changes (such as urbanization); and 4) a rising standard of living. In general, as energy use per person increases, so too does the potential for increased air pollution. Most ambient air pollutants are added directly to the troposphere, the lower layer of the atmosphere, as **primary pollutants**. In the troposphere, and in the presence of sunlight, they often mix and react chemically with each other or with natural components of the atmosphere, forming **secondary pollutants**. Eventually, most of these pollutants are washed out of the atmosphere and returned to both land and water by precipitation. Some contaminants, such as large particulates, settle out under the influence of gravity as fallout. Insoluble and nonreactive chemicals, on the other hand, may diffuse upward into the stratosphere, adversely impacting the ozone layer or contributing to global climate change.

In the US, ambient air pollution is regulated at the federal level under the Clean Air Act (CAA), which establishes standards for the following classes of air pollutants: carbon oxides (CO, CO_2), sulfur oxides, nitrogen oxides, photochemical oxidants (ozone), and particulate matter (PM).

Carbon oxides include carbon monoxide (CO) and carbon dioxide (CO_2). Carbon monoxide is a colorless, odorless gas that forms during the combustion of carbon-containing fuels and as a result of cigarette smoking. It is poisonous to air-breathing animals. Approximately 77% of the CO in the atmosphere comes from motor vehicle exhaust. Carbon dioxide is a natural component of the atmosphere and the basis of the carbon cycle. It enters the atmosphere as a result of natural processes such as cellular respiration and volcanic activity. However, it also enters the atmosphere as a result of human activities, primarily from the combustion of fossil fuels. While carbon dioxide constitutes <1% of the atmosphere, its atmospheric levels have been increasing steadily since the beginning of the Industrial Revolution. Increases in atmospheric CO_2 concentrations are thought to be enhancing the earth's natural greenhouse effect, leading to global warming.

Sulfur oxides include sulfur dioxide (SO_2) and sulfur trioxide (SO_3). Sulfur dioxide is produced when sulfur-containing fossil fuels are burned. It can irritate respiratory tissues and aggravate asthma and other respiratory conditions. In the atmosphere, it reacts with water, oxygen and other materials to form sulfur-containing acids which return to the earth as acid deposition.

Ozone (O_3) is a major component of photochemical smog. It forms in the troposphere as a result of the interaction between volatile organic compounds and nitrogen oxides (both of which mostly result from the emissions of cars and industrial processes), oxygen gas (O_2), and sunlight. Ozone can cause respiratory problems and eye, nose and throat irritation. It also can damage plants and man-made materials and contributions to the reduced visibility associated with smog.

Table 1. National ambient air quality standards (from "Environmental Science: A Study of Interrelationships", 9th ed., Enger & Smtih, 2004).

Pollutant	Standard	Value
CO	8-hour mean	9 ppm
	1-hour mean	35 ppm
SO_2	3-hour mean	0.50 ppm
	24-hour mean	0.14 ppm
	Annual mean	0.03 ppm
O_3	1-hour mean	0.12 ppm
	8-hour mean	0.08 ppm

Particulate matter represents approximately 5 percent of all air pollutants by weight, and includes a variety of components such as sulfate salts, sulfuric acid droplets, metallic salts, dust, and liquid sprays and mists. Biogenic sources of particulates include wind erosion, various pollens, volcanic eruptions, and forest fires caused by lightning. Anthropogenic sources of particulates include internal combustion engines, coal-fired power plants, boilers and industrial furnaces, and solid/hazardous waste incinerators. The amount and composition of particulate matter varies throughout the year, due partly to environmental factors such as wind and rainfall, human activities such as soil disturbance from agriculture or construction, and the life cycles of plants and fungi.

In this exercise we will determine the concentration of carbon monoxide, carbon dioxide, sulfur dioxide and ozone in air samples collected on campus. We will also examine the quantity and composition of dust particle samples collected on campus.

Materials

- Gastec® Gas Sampling Pump
- Gastec® Carbon Monoxide Gas Detector Tube
- Gastec® Carbon Dioxide Gas Detector Tube
- Gastec® Sulfur Dioxide Gas Detector Tube
- Gastec® Ozone Gas Detector Tube
- Adhesive dust particle collectors
- Microscopes

Procedure

Week 1

Gas Detection

1. The class will work together as a single group along with the instructor.
2. Before going to the field, the instructor and class will decide on sampling locations for four gases (CO, CO_2, SO_2, and O_3). You may sample for all 4 gases in a single location or you may chose separate locations in which to sample each gas.

3. Go to the field to the selected sampling location(s) and follow the directions below to sample for each of the four gases
   a. break both the tips off the detector tube by bending each tube end in the tip holder
   b. put a rubber cap on the detector tube tip, on the end marked "G", after the tip is broken off (choose the red or blue cap based on the size of the detector tube, selecting the one that fits best)
   c. make certain the pump handle is all the way in
   d. insert the tube securely into the rubber inlet of the pump with the arrow on the tube pointing toward the pump
   e. align the red guide marks on the shaft and pump body
   f. you are now ready to obtain the sample
   g. direct the tube end (which has a rubber cap on it) to the point of measurement
   h. pull the handle all the way out until it locks on 1 pump stroke (50mL) and then wait until staining stops (see Table 2 for approximate sampling time and expected color change for each gas)
   i. to return the handle to the starting position, first turn 1/4 turn in either direction and confirm that the handle does not retract inward
   j. disconnect the detector tube and read the concentration at the interface of the stained-to-unstained
   k. record the concentration in Data Table 1
   l. SAVE THE RUBBER CAPS, as they can be used again
   m. discard the detector tube after reading, as it can only be used one time

Table 2. Approximate sampling time and expected color change for each gas.

Gas	Sampling Time	Color Change
CO	1 minute	White to blackish brown
CO_2	1 minute	White to purple
SO_2	45 seconds	Purple to white
O_3	15 seconds	Pale blue to white

Dust Particle Collection

1. Work in groups by lab table.
2. Obtain 2 adhesive dust particle collectors.
3. Before going to the field, decide on two locations to place the dust particle collectors
   a. suggested locations include
      1) parking garage

2) interior of a building
3) adjacent to a road
4) adjacent to a parking lot
5) wooded area
6) open area
7) adjacent to a tree with blossoms
8) adjacent to an area planted with flowers

b. choose sites carefully to minimize the chance that the collectors will be disturbed by the wind or curious passersby

4. Write the location and group name in the space provided on the dust particle collector before removing the protective backing from the adhesive surface
5. To remove the protective backing from the dust particle collector, start at one corner. Handle only the edges. Do not let the adhesive surface to come into contact with anything, including your fingers.
6. Affix the dust particle collector to a surface at your chosen location. Be sure not to affix the collector to any surface that you think will be damaged by the adhesive.
7. The collectors will be left in place for a period of one week.
8. Make notes, if necessary, to ensure that you can locate your collectors next week.

Week 2

Dust Particle Collection

1. Return to the field and retrieve the two dust particle collectors that you placed last week.
2. Handle the collectors carefully as you return to the lab, touching only the edges and the non-sticky surface.
3. Obtain a microscope for examining the dust samples collected.
4. The dust particle collector is divided into three zones: white, cross-hatched in 1mm squares, and transparent. Some small, dark particles such as soot are most easily seen on the white area when viewed through a stereomicroscope. Other particles can be observed best from the transparent side.
5. Place the dust particle collector on the viewing stage of a stereomicroscope.
6. Begin with the white areas of the collector and adjust the magnification and focus to give the best possible view. Generally, 10X magnification works well for scanning an area, while 30X is better for close examination of individual particles.
7. Carefully examine the objects that are trapped in the adhesive.

a. record in Data Table 2 observations such as: identification; unusual shapes, colors, textures; objects or structures near the sampling site that might have contributed to this airborne debris; general size of the majority of particles (>1mm long, <1mm long).

8. Next, examine the portion of the dust particle collector that is printed with the grid of 1mm squares. Note that larger squares, measuring 5mm each direction, are outlined with heavier lines. These, in turn, are grouped into still larger blocks, measuring 10mm (1cm) on each side, or $1cm^2$ in area.
9. Count the total number of dust particles that lie within a $1cm^2$ block on the grid. If any portion of a particle lies inside the space, include it in the count. Record the total count in Data Table 2. Repeat the exercise two more times, using different grid blocks. Record these numbers in Data Table 2. Add the three counts together, then divide by three to obtain the mean dust particle density (expressed as particles per cm^2 or # particles/ cm^2). Record this value in Data Table 2.
10. The rate at which deposition of airborne particulate occurred at your collecting sites is a direct measure of how "dirty" or "clean" your collecting site is relative to other sites. To calculate the deposition rate for your sites, divide your calculated value for mean dust particle density by the number of hours that the dust particle collector remained at the collecting site (24 hours/day x 7 days = 168 hours). Record this value in Data Table 3 and on the transparency.
11. Repeat #5 through #10 for your second dust particle collector.
12. Record all data from the transparency for Data Table 3 to your Data Table 3.

Air Pollution LAB WRITE-UP Submit Pages 7-10

Student Name: ______________________________________Lab Date: _______
Lab Instructor: __________________________________ Lab Section: _______

Results (Data)

Data Table 1. Location and concentration of 4 gases in 4 air samples.

Pollutant	Sampling Location	Concentration
CO		
CO_2		
SO_2		
O_3		

Data Table 2. Individual group results for total number of dust particles per cm^2 for two dust particles collectors.

	# particles / cm^2	
	Collector #1	Collector #2
Sampling Location:		
Observations:		
Count #1		
Count #2		
Count #3		
Mean		

Data Table 3. Deposition rate by lab table and sampling location.

Lab Table	Collector #	Sampling Location	Deposition Rate ((# particles/cm^2)/hr)
1	1		
	2		
2	1		
	2		
3	1		
	2		
4	1		
	2		
5	1		
	2		
6	1		
	2		

Conclusions (Questions): *For full credit, these questions should be answered thoroughly, in complete sentences, in legible handwriting.*

1. Were you able to identify any of the particles found on the dust particle collectors? Thinking back to the collection site, were there any objects or structures that might have been responsible for this debris?

2. Were the majority of the particles larger or smaller than 1mm long? Would you expect the size of the particles to affect the distance that the particles can travel through the air? What features other than size might influence the distance the particle travels?

3. Compare the deposition rate data from the various collection sites (classwide). What statements can you make regarding the "cleanest" and "dirtiest" areas sampled? Was there a difference based on man-made versus natural sources? Were there any surprises? .

4. Discuss the results of the sampling for the four gases. Relate the concentration of each gas sampled to its sampling location. Did the results meet your expectations, and why or why not? Relate, if possible, the concentrations you obtained for the gases sampled to the values presented in Table 1. What odes this tell you about the quality of the air sampled relative to the 4 gases.