ESA21
Environmental Science Activities for the 21st Century

Ground-level Ozone: Smog City

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Smog

In this exercise we will be examining ground-level ozone, commonly referred to as "smog" ("smoke" + "fog" = "smog"). Smog is formed by the combination of air pollutants and sunlight, and can have adverse effects on humans and other organisms. You have likely heard of ozone in a different capacity. Ozone also occurs high above the earth's surface in the stratosphere, where it serves a protective function by blocking harmful ultraviolet radiation from the sun. The ozone in each case is the same molecule (three bound oxygen atoms), but in one location (high in the atmosphere) it is beneficial to living things, and at another location (ground-level) is harmful. Realizing these "two faces" of ozone is important before proceeding, so look over the brochure below from the U.S. Environmental Protection Agency.

Ozone: Good Up High, Bad Nearby
Compares and contrasts ozone in stratosphere and troposphere
U.S. Environmental Protection Agency
http://www.epa.gov/oar/oaqps/gooduphigh/

npr Listen	Topic: L.A. Smog Date: December 26, 2000 Summary: NPR's Ina Jaffe reports that while the average weekday in Los Angeles brings traffic jams throughout the city and region, the air pollution is at its worst during the weekend. Scientists say the reasons for this are as hazy as the LA skyline (http://www.npr.org). (3:43) Link: http://www.npr.org/ramfiles/me/20001226.me.11.ram Requires RealPlayer

	Topic: Houston Smog Date: September 10, 2001 Summary: NPR's John Burnett reports on Houston's air pollution problem. Though Houston has the worst ground-level ozone in the country, business leaders have remained reluctant to tighten their emissions standards. But now these leaders are becoming more open to change, as they realize that Houston's reputation for poor air quality is making it harder to attract new businesses and talented employees (http://www.npr.org). (8:39) Link: http://www.npr.org/ramfiles/me/20010910.me.13.ram Requires RealPlayer
n p r Listen	

Forming Ground-Level Ozone

In this exercise we will be looking exclusively at ground-level ozone, also known as photochemical smog. The first step is for you to understand how photochemical smog is formed. View the animation below from the U.S. EPA and the Pima County (AZ) Department of Environmental Quality to learn about the process. When prompted, click the "Make Ozone" icon to continue the animation.

How Ozone is Formed
Animation shows process of smog formation
U.S. Environmental Protection Agency
http://www.airinfonow.org/html/makingozone/o3play.htm
Requires Macromedia Flash Player

Although visually appealing, this is a simplistic view of ozone formation. The actual process by which ozone forms and stays trapped at the surface is more complex. To examine this in greater depth, view material at the site below.

Thermal Inversions and Photochemical Smog
In-depth descriptions of smog formation and concentration with thermal inversions
The California Environment
http://daphne.palomar.edu/calenvironment/smog.htm

Effects of Ozone on Air Quality and Human Health

After reviewing this information, you should have a good understanding of the process by which ozone forms near the surface and how it can remain trapped there. But what does it do to you? As you would expect, ozone's effects occur primarily through the respiratory system. Let's examine the functioning of the human respiratory system with another Flash animation from the EPA-Pima County site. First view the "Normal Breathing" animation and then examine how ozone affects respiration. View the other pollutants and compare and contrast their effects with those of ozone.

Lung Attack
Animation of smog's effects on the human respiratory system
U.S. Environmental Protection Agency
http://www.airinfonow.org/html/lungattack/lungplay.htm
Requires Macromedia Flash Player

Finally, let's take a more comprehensive look at the effects of smog on humans, and on the mechanisms used to alert individuals to air quality issues. Review the EPA publication "Smog - Who Does It Hurt?" at the link below.

Smog – Who Does It Hurt? (PDF) (819 KB)
Smog's effects on humans
U.S. Environmental Protection Agency
http://www.epa.gov/airnow/health/smog.pdf

Activity: Smog City

There exists on the Internet an exceptional simulation of the factors involved in smog formation - *Smog City*. The simulation was produced by the Sacramento Metropolitan Air Quality Management District and allows users to change various parameters and observe the changes in air quality that result. The site has several pages with useful, concise information regarding the simulation, so comprehensive directions are not required.

Smog City
Interactive simulation of ground-level ozone formation
Sacramento Metropolitan Air Quality Management District
http://www.smogcity.com/welcome.htm

Weather Conditions

(1.)	Review the following sections in order listed: *Home*, *Visitors Tour Guide*, *Smog City Science*, *Help*, and *What You'll Learn*.
(2.)	After learning how to run the simulation, choose Run Smog City.
(3.)	Follow the directions provided on the activity sheet.

Graphing

In the first section of the Activity Sheet, you are asked to graph two smog profiles on one chart. Do this by distinguishing between the lines with different colors, or by drawing two different types of lines (dashed line vs. solid line). Make sure the reader is easily able to distinguish which line is which by adding a label to the chart identifying each line. An example is provided in Figure 1.
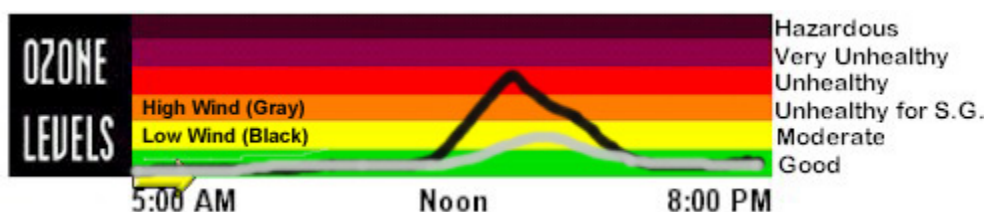

Figure 1. Graphing two smog profiles on one chart

Interpreting Ozone Profiles

When interpreting the severity of the ozone profiles the simulation returns, you must look at two characteristics. First, you should evaluate the maximum ozone concentration attained during the day, and the corresponding air quality level. If you change a parameter and the air quality reading goes from Moderate to Unhealthy, this represents a significant reduction in air quality. Second, you should also evaluate the length of time spent at different ozone levels. This is best exemplified by Figure 2, which shows two runs that both have peak ozone levels at the upper portion of the Unhealthy level. Note though, that in the second curve, air quality is at the upper portion of the Unhealthy range throughout the entire afternoon (note plateau shape of curve), while in the first curve the air quality is in the Unhealthy range for a much shorter period of time (note peak shape of curve). This has obvious implications for the individuals breathing the air, as adverse effects are dependent not only on the severity of exposure (the maximum ozone level attained), but also on the length of time individuals are exposed to these conditions (the shape of the curve).
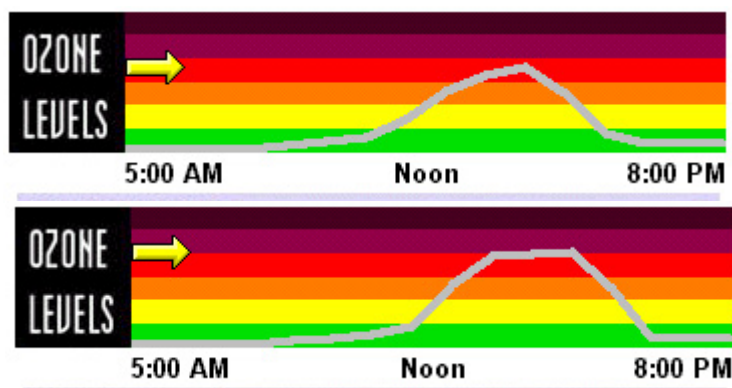

Figure 2. Comparing peak ozone concentrations and exposure durations

Pollutant Outputs

(1.)	Note that the factors we've examined so far aren't the only ones modeled in Smog City. The simulation also allows you to manipulate the sources of the compounds that form ozone, and this is done with the controls at the bottom of the screen. You can change the population size of your city, as well as pollutant inputs from passenger vehicles, off-road vehicles, industry, and consumer products. Follow the directions on the Activity Sheet to evaluate these outputs.
(2.)	While the weather conditions that affect smog formation are beyond human control, the release of the compounds that cause ozone formation is not. Model some approaches to reducing smog concentrations in Smog City by altering some factors we realistically could control, and observing the resultant changes in air quality with the simulation. Complete the exercise described on your Activity Sheet.

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Name:

Lecture Professor:

Examining Weather Factors:
For each of the following, vary only the parameter listed - keep the rest on the default setting. Make sure you hit the **Reset** button after each run to ensure the settings are returned to the default before the next run. For all of the charts except the Default, put both of the profiles (e.g. 80º F and 120º F) on the same chart, identifying each curve with a label and a different line type (solid line or dotted line) or color (red line or blue line).

Defaults:
100º F
Mild Inversion
Light wind
Partly cloudy

Temperature:
(a.) 80º F
(b.) 120º F

Inversion:
(a.) No inversion
(b.) Strong inversion
(lowest box)

Wind Speed:
(a.) No wind
(b.) Max wind

Sunlight:
(a.) Cloudy skies
(b.) Full sun

Evaluating the Factors:
Through your runs you've seen that some of these factors have a greater effect on ozone levels than others. List the four factors from most important to least important in the space below, and explain why you listed them in the order you did.

Most important --- **Least important**

The Ultimate Bad Smog Situation:
Describe the settings for each factor, and sketch the smog profile in the space below.

	Temperature	Inversion Layer	Wind Speed	Sunlight
Setting				
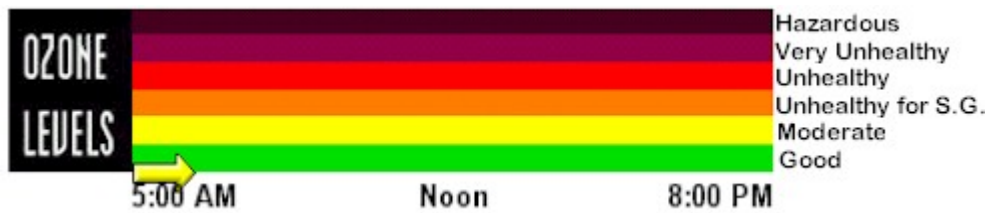
Examining the Sources of Pollutants:
Toggle the dials at the bottom of the page and observe how they affect the bar graph showing the relative contributions of the four different sources of pollutants. Once you've done this, increase or decrease the population, and see how the magnitude of the outputs are changed with greater or fewer people. Rank the four categories (dials) from greatest to least contributor, and describe the effects of population on pollutant outputs.

Greatest contributor --- **Least contributor**

The Value of Simulations:
Smog City is in trouble. True to its name, it has routinely exceeded federal air quality standards, and the city must take immediate steps to improve air quality. For the sake of this exercise, we will use the default settings as the current situation in Smog City (hitting **Reset** will restore these settings as before). Two competing proposals are on the table for improving air quality. Use the simulation to evaluate each one.

Proposal 1: The city develops a comprehensive mass transit system that reduces the number of passenger vehicles by developing a subway-rail system to ferry commuters around the city. This would reduce the **Cars and Truck** dial to its lowest setting, but increase the **Off Road** dial to its maximum setting.

Proposal 2: The city enacts a comprehensive plan that addresses pollution from multiple sources. The city's subway-rail system is modestly improved, and major initiatives are undertaken to reduce pollutant outputs from Industry and Consumer Products. This would reduce the **Cars and Truck, Industry, and Consumer Products** dials by one increment each, and increase the **Off Road** dial by one increment.

Run the simulations with the default weather conditions, show the profiles for each below, and make a recommendation to the city council on which proposal to adopt, providing justification for your answer. Be sure to address both maximum pollutant levels and length of exposure.

Proposal 1:
Cars -2
Off Road +2

Proposal 2:
Cars -1
Off Road +1
Industry -1
Consumer -1

Recommendation and Justification: