

ESA 21: ENVIRONMENTAL SCIENCE EXERCISES

Ozone: Ground-Level Ozone

Introduction

Ozone

In this week's exercise, we will be examining ground-level ozone, commonly referred to as "smog". Smog is formed by the combination of air pollutants and sunlight, and can have adverse effects on humans and other organisms. In next week's lab, you will be looking at stratospheric ozone, which exists high above earth's surface and helps to block harmful ultraviolet radiation from the sun. The ozone in each case is the same molecule, but in one location (high in the atmosphere) it is beneficial to living things, and at another location (ground-level) is harmful.



There exists on the Internet a wide variety of top-quality resources and simulations on ground-level and stratospheric ozone, and we will be utilizing these materials over the next two lab exercises. Because these sites are not located on the KSU servers, we do not have control over their availability. While they do reside on "stable" servers (government and educational institutions), it is *possible* that there may be temporary delays in accessing the pages during periods of peak Internet activity. If you experience trouble connecting to any of the sites, you should revisit the site at a later time and try again. While it is highly unlikely that this will be a problem, it is nonetheless important to mention it up front so you are aware.

To begin, let's review the major differences between stratospheric and ground-level ozone. Click on the link below to view a publication on ozone from the United States Environmental Protection Agency entitled "[Ozone: Good Up High, Bad Nearby](#)". View the page by clicking on the title link, or entering the web address below. As is the case with all of the links in this exercise, the new page will open in a separate window. When you are done viewing the information on the new page, close the new window and return to the window with the lab manual pages. Closing the window isn't absolutely necessary though, so feel free to jump between windows if you so desire.

Now that you are familiar with ground-level ozone, listen to the National Public Radio clips below to learn more about this issue.



[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](#)

 <p style="text-align: center;">Listen</p>	<p>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</p> <p>Requires RealPlayer</p>
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Internet Addresses of Linked Sites:

Ozone: *Good Up High, Bad Nearby*: <http://www.epa.gov/oar/oaqps/gooduphigh/>

Introduction

Forming Ground-Level Ozone

In this week's 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. Let's do this through a Flash animation entitled "[How Ozone is Formed](#)" from the EPA and the Pima County (AZ) Department of Environmental Quality (viewing the animation requires [Macromedia Flash Player](#) for your browser).

How Ozone is Formed:	
1.	Click Make Ozone to start the animation.
2.	Note the two ingredients for ozone -volatile organic compounds and NOx (nitrogen oxides), and their sources.
3.	Click the Make Ozone button to view the animation of smog formation.
4.	Note how the compounds interact in the presence and absence of sunlight by clicking on Lights On/Off .

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 on [Thermal Inversions and Photochemical Smog](#) from *The California Environment* web site.

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 site mentioned above entitled "[Lung Attack](#)".

Lung Attack:	
1.	Learn how your lungs operate normally. Click on Normal breathing and advance the animation when prompted.
2.	Now examine how ozone affects this process by choosing the Ozone bar and going through the animation.
3.	For the sake of comparison, note how the other pollutants (big/small particles, CO) affect gas exchange.

Next, 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?" in either [pdf](#) (recommended) or [html](#) format. Once you've read this, proceed on to the next page.

Internet Addresses of Linked Sites:

How Ozone is Formed: <http://www.airinfnow.org/html/makingozone/ozonecreation.swf>

Flash Player: <http://science.kennesaw.edu/biophys/gened/1101labs/plugins/index.htm>

CA Env. site:

<http://daphne.palomar.edu/calenvironment/smog.htm#Links%20to%20websites%20about%20photochemical%20smog>

Lung Attack: http://www.airinfnow.org/html/lungattack/lung_control.swf

EPA Smog (html): <http://www.epa.gov/airnow/health/index.html>

EPA Smog (pdf): <http://www.epa.gov/airnow/health/smog.pdf>

Simulation

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 I will forego additional comments and refer you straight away to the [Smog City](#) simulation.

Smog City: 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.	Print out the Activity Sheet and place it nearby to record the results of your simulations.
4.	The first step is to examine the weather factors that influence smog levels, and see each one's contribution to smog concentrations. Vary each of the factors as listed on the Activity Sheet and draw the resultant smog profile. Make sure you hit Reset after each run to return to the default settings before altering any parameters.
5.	Following this, complete the portions of your Activity Sheet that ask you to evaluate the relative contribution of each factor, and to design a "worst case" weather scenario for smog concentrations.

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.

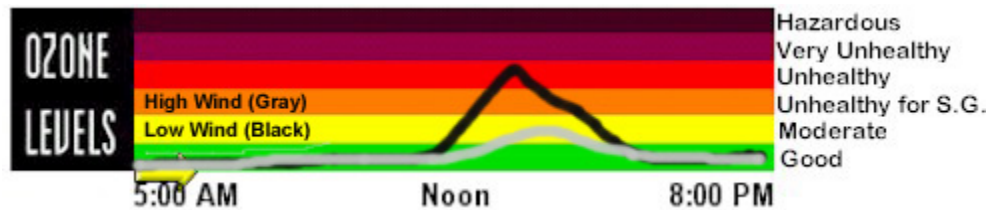


Figure 1. Graphing two smog profiles on one chart

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).

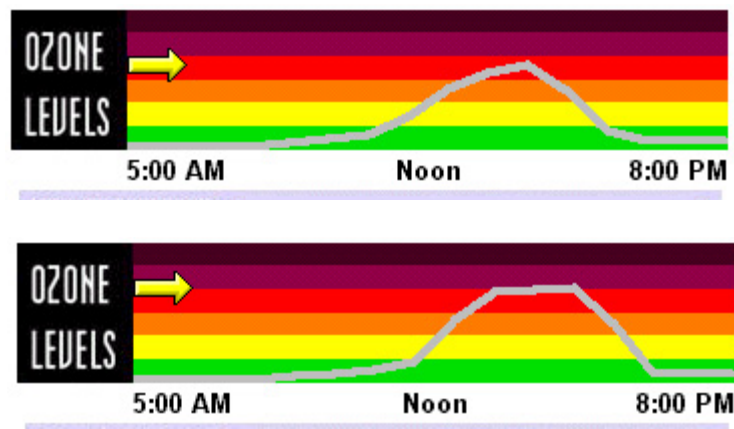


Figure 2. Comparing peak ozone concentrations and exposure durations

Smog City: Pollutant Outputs

6. 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.
7. While the weather conditions that affect smog formation are beyond human control, the release of the compounds that cause ozone formation is not. Let's 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.

Internet Addresses of Linked Sites

Smog City: <http://www.smogcity.com/welcome.htm>

ESA 21: Environmental Science Activities

Activity Sheet
Ground-Level Ozone

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. 80° F and 120° 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:

100° F
Mild Inversion
Light wind
Partly cloudy



Temperature:

(a.) 80° F
(b.) 120° 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 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: