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AQI Toolkit for Teachers

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

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Contents

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Notice

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Toolkit Overview

Toolkit Overview

Introduction to the AQI and This Toolkit

Children are one of the sensitive groups at risk for health effects from air pollution, in part because their lungs are still developing. The Air Quality Index (AQI) is an important tool for letting children know when air quality in their area is unhealthy and how they, their families, and communities can protect their health. The AQI uses a color-coded scale and maps to provide daily air quality information. Check the AQI at www.airnow.gov, download the AirNow App, or install the AirNow Widget on your website. Many local newspapers and television and radio stations also present the AQI. You can also sign up for air quality emails at: www.airnow.gov/enviroflash.

Compiled by the U.S. Environmental Protection Agency (EPA), this Toolkit provides teachers with easy-to-use and engaging lesson plans, additional activities, and other resources to teach students about the connections between air quality, health, weather, and other related science topics, as well as actions students can take to protect their health and reduce air pollution.

The lesson plans in this Toolkit meet Next Generation Science Standards and can be easily incorporated into school curriculums.

What's In This Toolkit?

This Toolkit includes:

- **Key messages—**Bullet point lists of key air quality messages for each age group.
- **Lesson plans** appropriate for:
  - Grades K through 2
  - Grades 3 through 5
  - Grades 6 through 8
- **Additional activities—**Brief descriptions of other activities about air quality that teachers can conduct with students.
- **Handouts—**Simple one-page, age-appropriate handouts for students on air quality that highlight how they can protect their health and the environment.
- **Background information** for teachers on air quality, the AQI, and related health impacts, including:

  — *Fact Sheets on:*

  - Air Pollution and Health
  - The Air Quality Index

  — *Bibliography* of curricula, lesson plans, activities, publications, and Web sites

Teachers' Guide

The Key Messages in the Toolkit provide an overview of air quality issues covered in the lesson plans. The Background Summary section of each lesson plan offers a brief synopsis of the lesson's topics and procedures; these sections are written in easy-to-understand language to assist teachers in communicating relatively complex environmental and health topics to students. For more information, teachers can review the Toolkit's fact sheets. The age-appropriate handouts can be distributed at the beginning or end of a lesson, or independently, to let students know "at a glance" what they can do to protect themselves and the environment when air quality is unhealthy.

Two pollutants in particular, ground-level ozone and particle pollution, are sometimes present at unhealthy levels in many parts of the United States. The Toolkit focuses on these two air pollutants, with information on sources of these pollutants, how to use the AQI to find out current levels of these pollutants in particular locations, and ways to improve air quality and protect our health.

Quick Prep

- Read the Key Messages and fact sheets in this Toolkit to familiarize yourself with air quality issues, the AQI, the health effects of air pollution, and ways to protect air quality.
- Visit EPA's AIRNow Web site at www.airnow.gov for further information about the AQI and to obtain local air quality information.
- Review the table of Next Generation Science Standards and Toolkit Lesson Plans (next page) to help you decide which lesson plan(s) to use.
- Read the *Background Summary* sections of the Toolkit lesson plans to help you select and prepare for lessons.
- Checklist:

  _____ Copy of lesson plan(s) you will be conducting with your class.

  _____ Copies of Student Worksheets, as needed, and Teacher Answer Sheets.

  _____ Internet access, as needed.

  _____ Copies of age-appropriate handout for each student.

  _____ Materials needed for the selected lesson plan(s).

Next Generation Science Standards

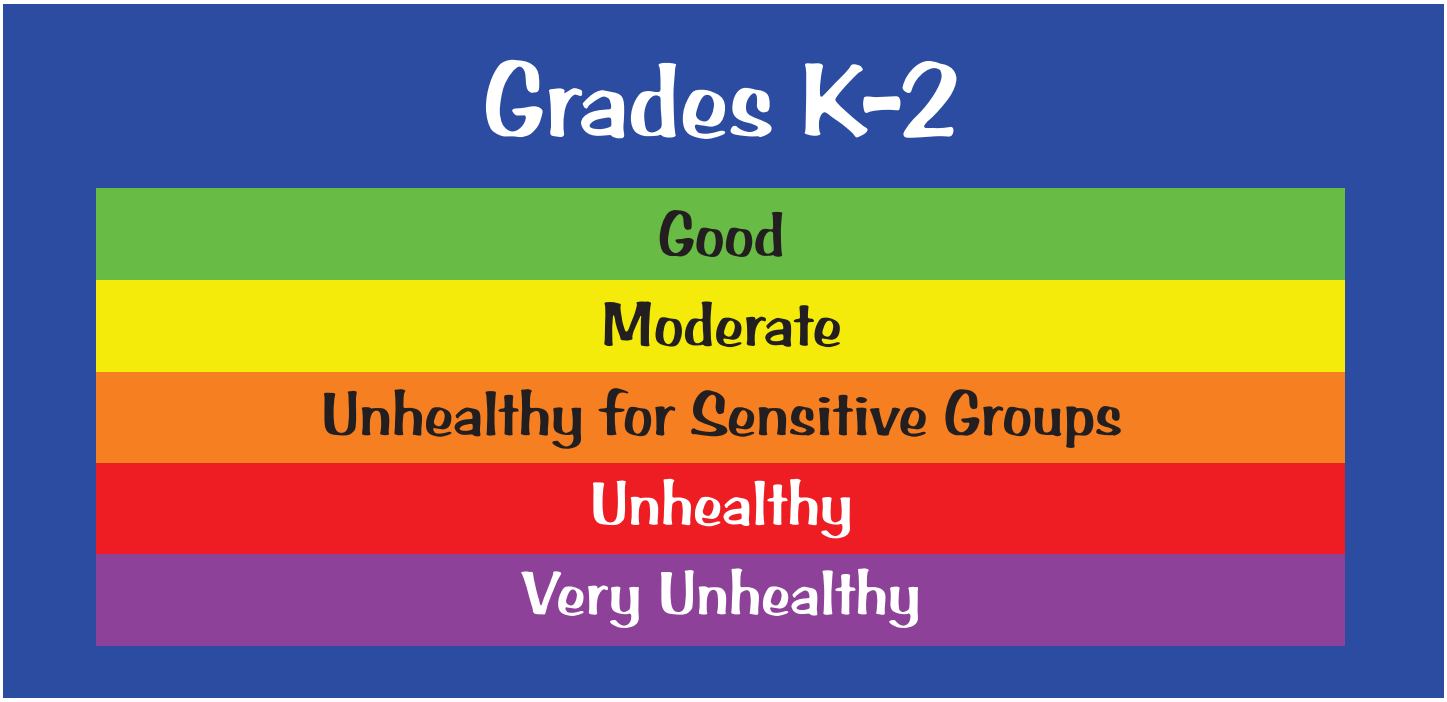
The lesson plans in this toolkit meet the following Next Generation Science Standards (www.nextgenscience.org/next-generation-science-standards), as verified by an education expert:

Lesson Plans	Next Generation Science Standards
Grades K-2	
What Color Is My Air Today?	Engineering Design Interdependent Relationships in Ecosystems
Now You See It, Now You Don't	Engineering Design Interdependent Relationships in Ecosystems
Breathing, Playing Outside, and Air Pollution	Engineering Design Interdependent Relationships in Ecosystems
How Dirty is the Air We Breathe?	Engineering Design Interdependent Relationships in Ecosystems
Grades 3-5	
The Ozone Between Us	Energy Interdependent Relationships in Ecosystems Matter and Energy in Organisms and Ecosystems Earth and Human Activity Engineering Design
The Cilia (not Silly!) Game	Energy Interdependent Relationships in Ecosystems Engineering Design Matter and Energy in Organisms and Ecosystems

Lesson Plans	Next Generation Science Standards
Grades 3-5 (continued)	
Traffic Tally	Energy Interdependent Relationships in Ecosystems Engineering Design
Trapping Air Pollution: Temperature Inversions #1	Weather and Climate Earth and Human Activity Engineering Design Matter and Energy in Organisms and Ecosystems
Save Smog City 2 from Particle Pollution	Weather and Climate Energy Interdependent Relationships in Ecosystems Engineering Design Matter and Energy in Organisms and Ecosystems
Grades 6-8	
Symptoms Scenario	Interdependent Relationships in Ecosystems Human Impacts Engineering Design
Tracking Air Quality	Chemical Reactions Human Impacts Weather and Climate Engineering Design

Lesson Plans	Next Generation Science Standards
Grades 6-8 (continued)	
Smog Alert	Human Impacts Earth's Systems Weather and Climate Engineering Design
Trapping Air Pollution: Temperature Inversions #2	Human Impacts Weather and Climate Engineering Design
What's Riding the Wind?	Human Impacts Engineering Design
Save Smog City 2 from Ozone	Human Impacts Engineering Design

Grades K-2


Good
Moderate
Unhealthy for Sensitive Groups
Unhealthy
Very Unhealthy

Key Messages: Grades K-2

- Breathing dirty air is not good for people. For example: You might feel like it's harder to breathe, you might cough, or your chest might feel tight.

- You can help protect your health when the air is dirty. Here are three things you can do.

  1. Find out how clean your air is each day.

     - You can do this by checking the AQI, just like checking the weather report. The AQI (or the Air Quality Index) uses colors to tell you how clean or dirty the air is. For example, green means the air is clean. Red means the air is unhealthy.

     - You can always find the AQI on the Internet at a site called AIRNow at: www.airnow.gov. You also might hear about the AQI on TV during the weather forecast or on the radio, or you might see it on the weather page in the local newspaper.

     - Tell your parents about the AQI so they can check how clean or dirty the air is.

  2. If you play outside when you know the air is polluted, you can protect your health by taking it easier. For example, walk instead of run, take breaks often, or play outside at another time or on another day when the air is cleaner.

  3. If you notice any signs when you are playing outside like coughing, pain when you take a deep breath, chest tightness, or wheezing, stop playing and tell an adult.

     - If you have asthma, pay special attention on polluted days. If you think you or a friend may be having an asthma attack, tell an adult.

Lesson Plans

What Color Is My Air Today?

Learning Objectives

Students will:

- **Understand how breathing the air can affect people's bodies and health.**
- **Describe how colors and numbers can represent different classifications of something, such as levels of air quality.**
- **Understand that air pollution, driving, and health are connected.**

Grade Level: Grades K-2

Estimated Time: 30 minutes

Background Summary

Some days, the air is clear and smells fresh and clean. Clean air is air that has no harmful levels of pollutants (such as dirt and chemicals) in it. Clean air is good for people to breathe. However, on a hot day with no wind—especially in some cities—the air can feel heavy and may have a bad smell. Sometimes, the air can even make your chest feel tight, or make you cough. When too much dirt or too many chemicals get into the air, the air is dirty, or polluted. Polluted air is not good for people to breathe.

Scientists measure pollution in the air across the country. Then they use something called the Air Quality Index, or AQI for short, to tell people how clean or dirty the air is each day in different places. The AQI uses colors, words, and numbers to tell you about the air.

Using EPA's online Air Quality Index color game, students will learn that air quality can be classified according to different levels of pollution, and that these levels can be represented by colors and/or numbers. They will also learn that they can find out what the Air Quality Index is on any given day and understand what it means for people's outdoor activities. This lesson also introduces students to different types of transportation and ways that transportation choices can affect air quality.

Materials Needed

- Internet access (preferable) (or, print version of AQI Color Game included with this lesson)
- Computer printer, preferably color, if not conducting activity online
- Chart of AQI colors and their meanings (simplified print version included)
- AQI color posters (online or printed, see Step 6)

Key Questions

- What is air pollution? (*Answer:* Air pollution is when too much dirt or chemicals get into the air.)
- What is the Air Quality Index, or AQI? (*Answer:* The AQI tells us how clean or dirty the air is each day.)
- How can you and your family help reduce air pollution? (*Possible Answers:* Walk more, ride bikes, or carpool. [Carpooling is when more than one person not related to each other share a ride somewhere.] People can also take the bus, train, or subway to reduce air pollution instead of driving in their cars.)

Vocabulary

Air Pollution—Occurs when too much dirt or too many chemicals get into the air and make it dirty.

Air Quality Index—Colors and numbers used to tell how clean or dirty the air is.

Steps

1. Have the class play the *AQI Color Game* online at: www.airnow.gov/index.cfm?action=aqikids.games easy or hand out copies of the game (Easy version).

   It may take a minute for the color chart to load onto your computer.

   (Note: The AQI Color Game is available online at different levels: easy, medium, and hard. First have students play the "easy" game, which discusses AQI colors only. Then add a discussion of the AQI numbers, as discussed in the "Steps" below.

The medium and hard versions of the game are appropriate for students in Grades 3-5.)

If printing, also print out the answer key for the teacher. It is best if the student game can be printed in color.

2. Discuss the AQI colors and their meanings with students. Tell students that each day, the AQI is one of these colors. The colors tell you how healthy the air is to breathe that day. The colors go from Green to Yellow to Orange to Red to Purple, with each color telling you that the air is less clean than the color before.

   (*Note:* If students ask, you can tell them that the last AQI color, Maroon, which represents the worst air quality, is usually not included with the other AQI colors because air quality in the U.S. has not been Maroon in many years. This is probably because people have been working hard to clean up the air.)

   Give students the following simplified chart of the AQI colors and their meanings, and read the chart to them.

3. Tell students to look at their AQI Color Game Student Worksheet. With the help of the chart of AQI colors and meanings you gave them in Step #2, tell students to draw a line from the AQI words on the left side to the correct color on the right side of the worksheet. For younger students (e.g., kindergarten), the teacher can read the words and ask students which words go with which colors. For older students (e.g, Grade 2), the teacher may need to assist students in reading and understanding some of the key words, as discussed in the table above.

4. Discuss the correct answers using the Teacher Answer Sheet.

5. Add a discussion of the AQI numbering system. An index uses numbers to tell people how good or bad something is. For example, you might say your school lunch is a 1 (very good) or a 5 (yucky). The Air Quality Index uses numbers from 0 to 500. These numbers are used to decide the AQI color for a particular day. On days measuring less than 100, the air is clean. If the air is dirtier, the numbers get bigger. On days measuring more than 100, the air can be bad for you to breathe.

If Color is...	What This Means for Outdoor Activity
Green	The air is **"good"** and it's a great day to be active outside!
Yellow	The air is **"moderate"** - it's fine for most people to be active outside. However, people who are unusually sensitive to air pollution may notice symptoms such as coughing or shortness of breath. These are signs to take it easier.
Orange	The air is **"unhealthy for sensitive groups."** This group can include people with heart or lung problems (such as asthma), kids, and older grown-ups, who should take it a little easier.
Red	The air is **"unhealthy."** Everyone should take it a little easier or spend less time being active outside.
Purple	The air is **"very unhealthy."** People should be active indoors on purple days.

For more complete Air Quality and Outdoor Activity Guidance for Schools, visit www.epa.gov/airnow/school_flag/school-chart-2013.pdf

Here is how the AQI numbers match up with the AQI colors:

AQI Numbers	AQI Colors
0 to 50	Green
51 to 100	Yellow
101 to 150	Orange
151 to 200	Red
201 to 300	Purple

6. Have students view the six AQI color posters online, or print out several sets of the posters and pass them around the class, available from the EPA AIRNow website at: www.epa.gov/airnow/aqikids/pdffiles/posters.pdf

   It is best if these posters can be printed in color.

7. Discuss the six posters in sequence (from Green to Purple), which will reinforce the lesson thus far, including both AQI colors and numbers.

8. Tell students how they and their families can help reduce air pollution. Most cars contribute to air pollution. To reduce air pollution, students and their families can walk more, ride their bikes, or carpool. (Carpooling is when more than one person share a ride somewhere.) People can also take the bus, train, or subway to reduce air pollution instead of driving their cars.

Adaptation

For older students (Grades 3-5), play the Medium and/or Hard versions of the AQI Color Game. Add more in-depth discussion from the EPA Web site at: www.epa.gov/airnow//aqikids/pdffiles/aqirefer.pdf

For Further Exploration

If using the Internet, go to www.airnow.gov and under the map find "Local Air Quality Conditions and Forecasts" and choose a state or click on "Select by map." Review the information for the nearest city with the students. You can click on a city name for more detailed information. Ask students what the air quality is for today and expected to be tomorrow.

Have students try to find and cut out the Air Quality Index in the newspaper and bring it in to class to discuss; the AQI can often be found on the weather page in newspapers.

Acknowledgments/Resources

U.S. EPA. Air Quality Index Kids Page at: www.airnow.gov/index.cfm?action=aqikids.games

Next Generation Science Standards

Engineering Design
Interdependent Relationships in Ecosystems

Student Worksheet: What Color Is My Air Today?

Name: _____

AQI Color Game

Easy Game

To play this game, first print this page and then draw a line from the AQI word(s) on the left side to the correct color on the right.

1. Good	Green
2. Moderate	Yellow
3. Unhealthy for Sensitive Groups	Orange
4. Unhealthy	Red
5. Very Unhealthy	Purple

Teacher Answer Sheet: What Color Is My Air Today?

AQI Color Game

Easy Game

1. Good →	Green
2. Moderate →	Yellow
3. Unhealthy for Sensitive Groups →	Orange
4. Unhealthy →	Red
5. Very Unhealthy →	Purple

Now You See It, Now You Don't

Learning Objectives

Students will:

- **Observe differences between gases and particles, in the context of air pollution.**
- **Identify common gases and particles in the air that can contribute to air pollution.**

Grade Level: Grades K-2

Estimated Time: 30 minutes

Background Summary

Sometimes the air is clean, and sometimes it's dirty. When the air is dirty, it's called pollution. There are different kinds of air pollution. Some air pollution is made of particles, such as small pieces of dirt or dust. This is called particle pollution. Other kinds of air pollution are gases, which usually you cannot see. Ozone near the ground where we can breathe it in is a harmful air pollutant that is a gas. But ozone many miles above the Earth (in the stratosphere) is good for us. It helps protect us from sunburn. You can't see ozone in the air. The cars that we ride in can make air pollution—both particle pollution and gases like ozone. If people walked, bicycled, or took buses or trains more often instead of driving places, fewer cars would be on the road. This is one way to make less air pollution.

In this lesson, students observe differences between gases and particles in the air. Water represents air. Milk in water acts like an air pollutant that is a gas. Pepper in water acts like particle pollution in the air. Students then identify common gases and particles in the air that can contribute to air pollution.

Materials Needed

- Two clear glass bowls (if teacher demonstrates) or 2 large clear plastic cups per group (if students perform activity)*
- One tablespoon of milk for one bowl or cup
- One teaspoon of pepper for the other bowl or cup
- One plastic spoon for each bowl or cup
- Water
- Student Worksheet (included)
- Teacher Answer Sheet (included)

**Note:* If the teacher does this as a demonstration with the clear glass bowl, it helps to have a light or white paper behind the pepper so it is easier to observe. Alternatively, students can do this in small groups using clear disposable cups instead of the glass bowl.

Key Questions

- What is the water supposed to be in this experiment? (*Answer:* Air.)
- (During Step 2)—What kind of air pollution do you think the milk is like when it combines with the water: a gas, or particle pollution? (*Answer:* A gas)
- (During Step 3)—What kind of air pollution do you think the pepper is like when it combines with the water: a gas, or particle pollution? (*Answer:* Particle pollution)

Vocabulary

Gas—Something that is not a solid or a liquid. A gas doesn't have a particular shape, and usually is invisible.

Particle—A small bit of something, such as dirt or dust.

Pollution—Harmful substance put into the environment, for example into the air, water, or soil.

Ozone—A gas. When ozone is near the ground, it is bad, and is air pollution. Ozone high up in the atmosphere is good, and helps protect us from sunburn.

Steps

1. Review vocabulary as needed and age-appropriate. Divide the class into small groups (if the teacher is not conducting the activity for the entire class). Fill the clear glass bowl or clear disposable cups half full with water. Tell students to think of the water

as "air." Tell students to carefully look at the bowls (or cups) to see what happens as you add things to the water.

2. Add one tablespoon of milk to one of the bowls or cups of water and stir to mix. Then ask: What happened to the milk when it was added to the water? (*Answer:* It mixed with the water, or a similar answer.) Then ask: What kind of air pollution did the milk act like in the water—air pollution that is a gas, or particle pollution in the air? (*Answer:* Gas.)

3. Now add one teaspoon of pepper to the other bowl or cup of water and stir. Then ask: What happened to the pepper when it was added to the water? (*Answer:* It did not mix with the water; it stayed separate from the water, or a similar answer.) Then ask: What kind of air pollution did the pepper act like in the water—air pollution that is a gas, or particle pollution in the air? (*Answer:* Particle pollution.)

4. Ask students: If the bowls or cups were left on a shelf all day, which do you think would sink to the bottom of the bowl or cup—the pepper or milk? (*Answer:* Pepper.) Ask: Would it be easier to get the milk or the pepper out of the water? (*Answer:* Pepper.) Remind students that the milk is like air pollution that is a gas, and the pepper is like particle pollution in the air.

5. Ask students: Do you think it would be easier to get gases or particles out of the air? (*Answer:* Particles.) Why?

6. Use the Student Worksheet, first for word recognition, then have students fill out the Worksheet as best they can, with teacher assistance.

   (a) Begin this step as a word recognition task: For older students who can read (e.g., Grade 2), tell students to highlight or circle some of the words they recognize on the Student Worksheet. For younger students, the teacher can use an overhead transparency or make word cards to read, and lead a class discussion.

   (b) Next, tell students to fill out the Worksheet for the highlighted or circled items. Tell them to check off whether they think the things listed in the first, left-hand column can make particle pollution (2nd column), a gas that is air pollution (3rd column), or both particle pollution and a gas (last column).

Review the Student Worksheets with the class. (The Teacher Answer Sheet provides the correct answers.)

Adaptation

Students could receive a star or sticker for answering correctly.

For older students, introduce the concepts of solutions (i.e., milk and water) and suspensions (i.e., pepper and water) in scientific terms. Also, see the lesson plan, "Parts Per Million," on the Rutgers University Web site listed below.

For Further Exploration

Have the students research some of the types of air pollution listed on the Student Worksheet.

Acknowledgments/Resources

Suspended Particulates Lab Lesson Plan. Rutgers Engineering, contributed by D. Gioffre, Hillsborough Middle School, Hillsborough, NJ 08844 at: www.engineeringplanet.rutgers.edu

Next Generation Science Standards

Engineering Design
Interdependent Relationships in Ecosystems

Student Worksheet: Now You See It, Now You Don't

Name: _____

Air Pollution from...	...is particle pollution?	...a gas?	...both particle pollution and a gas?
Car tail pipes			
Cow burps			
Dirt			
Dust			
Factory smoke stacks			
Fireplaces			
Forest fires			
Volcano ash			

Teacher Answer Sheet: Now You See It, Now You Don't

Air Pollution from...	...is particle pollution?	...a gas?	...both particle pollution and a gas?
Car tail pipes			✓
Cow burps		✓	
Dirt	✓		
Dust	✓		
Factory smoke stacks			✓
Fireplaces			✓
Forest fires			✓
Volcano ash	✓		

Breathing and Air Pollution

Learning Objectives

Students will:

- Observe how breathing changes with physical activity.
- Learn how air pollution can affect breathing and our health.

Grade Level: Grades K–2

Estimated Time: 30 minutes

Background Summary

Most living things, including people, need the oxygen in air to breathe. When we're more active, like when we're running, bicycling, or jumping, our bodies need more oxygen and air. We may notice that our breathing is faster and we take deeper breaths when we're active. This faster and deeper breathing is how our body takes in more oxygen and air when needed, which can help make us healthier.

Breathing dirty, or polluted, air is not good for people. For example, it might make you cough, or you might feel like it's harder to breathe. If an adult tells you the air is polluted while you're playing outside, you can protect your health by taking it a little easier. For example, walk instead of run, take breaks often, or play outside at another time or on another day when the air is cleaner. If you have trouble breathing on days with a lot of air pollution, tell an adult.

This lesson involves having a few students count their breaths while at rest and again after jumping up and down. The class will discuss differences in breathing when at rest and after jumping, and how students can protect their health from air pollution.

Materials Needed

- Stopwatch, watch, or clock with second hand
- Blackboard
- Handout (included)

Key Questions

- Does a person breathe faster when active or when sitting still? (*Answer:* When active.)
- How can faster and deeper breathing improve our health? (*Answer:* It gives our bodies more oxygen.)
- How can we protect our health from air pollution? (*Answer:* We can take it easier on days when there is a lot of air pollution. We can walk instead of run, take more breaks, or play outside when the air is cleaner. It you have trouble breathing on days with a lot of air pollution, tell an adult.)

Vocabulary

Pollution—Things put into the air that can make the air dirty.

Improve—To make better.

Protect—To keep from being hurt.

Steps

1. Tell the class that they are going to see how being active affects breathing.
2. Pick three student volunteers. (*Note:* Do not pick students who are not feeling well or have health conditions that restrict exercising.) Write their names on the blackboard horizontally so you can add information in columns under each name.
3. Have all three student volunteers seated at the front of the class. Tell the volunteers to breathe normally. Tell the volunteers and the class that when you say "Go," the volunteers are going to count how many breaths he or she takes in 30 seconds, when he or she is just sitting and is not active, until you say "Stop." Remind the volunteers to take normal breaths.
4. Say "Go," remind the volunteers to start counting, and watch the clock for 30 seconds.
5. After 30 seconds, say "Stop" and ask the volunteers how many breaths each of them took. Record the numbers on the blackboard under the students' names.

6. Now tell the volunteers and the class that when you say "Go" this time, the volunteers are going to jump up and down for 30 seconds. Tell the volunteers that when you say "Stop jumping and start counting," they should stop jumping and immediately start counting their breaths until you say "Stop counting."

7. Say "Go." Student volunteers should start jumping. Watch the clock.

8. After 30 seconds, say "Stop jumping and start counting."

9. After another 30 seconds, say "Stop counting." Ask volunteers for the number of breaths they counted, and write these numbers on the blackboard under the students' names.

10. Ask the class what they notice about the results. Discuss how the results are the same and different, and how the results show that breathing is faster and deeper when people are active than when they are not active. Also discuss how faster and deeper breathing when we're active is good for our health because it brings more air and oxygen into our bodies when our bodies need it.

11. Tell students that breathing dirty, or polluted, air is not good for people, and can make people not feel well. For example, it might make you cough, or you might feel like it's harder to breathe.

    Tell students that on days when there is a lot of air pollution outside, they can help protect their health by taking it easier. They can walk instead of run, take more breaks, or play outside when the air is cleaner. If they have trouble breathing on days with a lot of air pollution, they should tell an adult.

12. Distribute the handout, *Breathe Smart! Four Things Kids Can Do.* (See Grades K-2 Handout in this Toolkit.)

Adaptation

Have all students in the class count their breaths at rest and after jumping. Take a few responses from the class, write them on the blackboard, and discuss the differences in breathing at rest and after jumping. (*Note:* If you feel that your classroom does not have enough room for jumping, or that it might be too disruptive, students can instead stand up and sit down repeatedly for one minute.)

Have students play a quick game of basketball or walk quickly up and down a flight of stairs a few times rather than jumping up and down in place.

For Further Exploration

Explain that cars use gasoline and are one big source of air pollution. Discuss that one way to reduce air pollution is by going places with adults in ways other than cars, such as walking, bicycling, or taking a bus or train. This would reduce the number of cars on the road, which would reduce the amount of air pollution from cars.

Acknowledgments/Resources

Adapted from the California Air Resources Board, The KnowZone at: www.arb.ca.gov/knowzone/knowzone.htm

Also see: U.S. Environmental Protection Agency's AQI (Air Quality Index) for Kids at: www.airnow.gov/kids

Next Generation Science Standards

Engineering Design
Interdependent Relationships in Ecosystems

How Dirty Is the Air We Breathe?

Learning Objectives

Students will:

- Make a simple air pollution tester.
- Collect and observe air pollution and discuss the findings.

Grade Level: Grades K–2

Estimated Time: 30 minutes (indoors), 30 minutes (outdoors)

Background Summary

The air around the Earth is mostly invisible. Sometimes the air is dirty, or polluted. Most of the time polluted air is also invisible, but sometimes you can see air pollution. Air pollution that you can see comes from things like the tailpipes of cars and the smokestacks of factories. Sometimes you can see air pollution near busy roads and factories. Air pollution can also come from burning wood in fireplaces and wood-burning stoves, and even from forest fires and volcanoes. Sometimes the wind can blow air pollution from where it was created to other places far away. Breathing polluted air is not good for people's health—it can make it harder to breathe, and for people with heart or lung problems, it can make their problems worse.

In this activity, students will make pollution testers, collect samples of air pollution outdoors, and discuss how air pollution can affect health and what we can do to reduce air pollution.

Materials Needed

- Double-sided masking tape
- Half gallon or larger milk cartons filled with sand (optional)
- White paper for each child or group of children
- Adult assistants for outdoor placement of tape (and milk cartons if using them)

Key Questions

- Do you think air pollution is invisible or can you see it? (*Answer:* Both. Some air pollution is invisible, some you can see.)
- Do you think that people's health can be affected by air pollution? How? (*Answers:* Yes. People might have more trouble breathing. Some pollutants can make heart or lung problems worse.)
- How can we help keep the air clean? (*Possible answers:* Instead of driving places, we can walk, bicycle, or take a bus or train, with an adult, when it's safe to do so.)

Vocabulary

Invisible—Impossible to see.

Visible—Possible to see.

Steps

1. Tell students: As we look outside, we often see a clear blue sky. Where is air pollution? If using milk cartons, tell students that they are going to make a simple tester for air pollution so we can see it. If using double-sided tape only, tell students that the class is going to go outside to test the air to see air pollution.
2. Have students make the milk carton testers, if using them. Divide the class into groups with adult assistants and give the groups their materials. With the double-sided masking tape, have each group wrap the tape around the sand-filled milk carton, and make sure the tape is securely attached. If using double-sided masking tape only (no milk cartons), give each group's adult assistant a roll of the tape.
3. Take the class outside. With adult assistants, have students place the milk cartons outdoors on posts, fences, walls, and/or window sills in various locations. If using pieces of double-sided masking tape only, place tape on trees in various locations and on other surfaces on which the tape will stick. If you can, place some milk cartons or double-sided tape near a road and some in a protected location away from roads. Try to pick places where the milk

cartons won't be knocked over by pets or children's play. Leave them for 24 hours.

4. The next day, collect the milk cartons and double-sided pieces of tape, and make labels of the tester locations. Help students remove the tape from the milk cartons and lay the tape, exposed side up, on white paper. Place location labels next to each corresponding sample.
5. Have the class examine the air pollution collected on the testers.
6. Discuss the findings. *Ask:* Did your tester collect any air pollution? How does your tape compare to those of the other groups? In what places does the air seem to be the dirtiest? (*Possible answers:* Near busy roads, near factories.) Why do you think those areas might have the most air pollution? (*Possible answers:* Because cars and factories make pollution.)
7. Discuss possible health effects of breathing air pollution. *Say:* We have seen air pollution where we first didn't see any. Clean air is important for us to breathe to be healthy. Breathing in dirty, or polluted, air can make us less healthy—it can make it harder to breathe, and some pollutants can make heart or lung (especially asthma) problems worse.
8. Discuss what people can do to reduce air pollution. *Ask:* What can we do to keep the air clean? (*Possible answers:* People could drive less and walk more, such as to school, with adults. We can turn off lights, TVs, and computers when we're not using them; this saves energy and keeps the air cleaner. Factories could reduce their pollution.)

Adaptation

For Grades 3-5, students can write a paper and explain the differences they observed among the pieces of tape.

For Further Exploration

Have students take their tester home (along with instructions for parental assistance) to test for pollution for 24 hours. Students can then report their findings to the class the next day.

Ask students to leave the tester outside for a week (sheltered from precipitation); students can report results to the class each day and at the end of the week.

Acknowledgments/Resources

Texas Commission on Environmental Quality at: www.tceq.state.tx.us

Next Generation Science Standards

Engineering Design
Interdependent Relationships in Ecosystems

Student Handout

Breathe Smart! Four Things KIDS Can Do

1

Find out what AQI color for today is where you live.

- Visit the AIRNow Web site at www.airnow.gov.
- Tell your parents about the AQI so they can help you.

2

Protect your health when the air is dirty.

- Take it easier when you play outside.
- If it feels harder to breathe, tell an adult.

3

Help reduce pollution.

- Turn off lights, TVs, and computers when not using them.
- Walk, bike, or take a bus or train with an adult. But remember, your safety always comes first!

4

Visit the AQI kids' site at www.airnow.gov
(click on "Kids" in the "Learning Center")

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Grades 3-5


Good
Moderate
Unhealthy for Sensitive Groups
Unhealthy
Very Unhealthy

Key Messages: Grades 3-5

- Breathing dirty air is not good for people. For example: You might feel like it's harder to breathe, you might cough, or your chest might feel tight.

- You can help protect your health when the air is dirty. Here are three things you can do.

  1. Find out how clean your air is each day.

     - You can do this by checking the AQI, just like checking the weather report. The AQI (or the Air Quality Index) uses colors to tell you how clean or dirty the air is. For example, green means the air is clean. Red means the air is unhealthy.

     - Check the AQI at www.airnow.gov, download the AirNow App, or sign up for air quality emails at www.airnow.gov/enviroflash. Many local newspapers and television and radio stations also present the AQI.

     - Tell your parents about the AQI so they can check how clean or dirty the air is.

  2. If you play outside when you know the air is polluted, you can protect your health by taking it a little easier. For example, walk instead of run, take breaks often, or play outside when the air is cleaner.

  3. If you notice any signs when you are playing outside like coughing, pain when you take a deep breath, chest tightness, or wheezing, stop playing and tell an adult.

     - If you have asthma, pay special attention on polluted days. If you think you or a friend may be having an asthma attack, tell an adult.

Lesson Plans

The Ozone Between Us

Learning Objectives

Students will:

- **Discover that ground-level ozone occurs in many areas of the country.**
- **Discover that ground-level ozone problems are often associated with high-population centers.**

Grade Level: Grades 3-5

Estimated Time: 30 minutes

Background Summary

Ozone is a gas consisting of three oxygen atoms. Ozone can be good or bad depending on where it is in the atmosphere. "Good" ozone occurs naturally in the stratosphere approximately 10 to 30 miles above the earth's surface. This good ozone forms a layer that protects life on earth from too much of the sun's harmful ultraviolet rays.

Ozone at "ground-level"—that is, in the earth's lower atmosphere—is bad because it pollutes the air. Ozone pollution can cause people to have breathing problems. An easy way to remember these differences about ozone is: "good up high, bad nearby."

Ground-level ozone comes mostly from motor vehicles that we drive, factories that make products we use, and power plants that produce our electricity. Ozone pollution is not produced directly from these sources. Rather, heat and sunlight "bake" certain other chemicals (nitrogen oxides, or NO_x, from vehicles and power plants; and volatile organic compounds, or VOCs, from gasoline-powered cars, factories, and products such as paints), which causes a chemical reaction and produces ozone. Weather is an important factor in ozone formation—more ground-level ozone usually is formed in summertime, when there is the most heat and sunlight. Also, wind can transport ozone "downwind" to other areas far from where it was formed, and pollute those areas.

This Internet activity allows students to explore the different concentrations of ground-level ozone in various areas of the country and develop an understanding of why more ground-level ozone may occur in certain areas.

Materials Needed

- Printed color copies of the two AQI color charts on the *Air Quality Index (AQI)—A Guide to Air Quality and Your Health* Web page; or, students can access the charts from the Internet at: www.airnow.gov/index.cfm?action=aqibasics.aqi
- Internet access or color copies of the Ozone Map at: http://ciese.org/curriculum/airproj/airquality-map/
- Student Worksheet (included)
- Teacher Answer Sheet (included)

Key Questions

- Do people contribute to ground-level ozone pollution when they drive or ride in cars? (*Correct answer:* Yes) When they ride bicycles? (*Correct answer:* No) When they walk? (*Correct answer:* No)
- In what parts of the country do you think ozone pollution might be the worst? Why? (*Possible answers:* In cities; in places where the wind has blown the ozone pollution; in places with a lot of cars and/or factories.)

Vocabulary

Chemical reaction—A change that takes place when two or more substances interact to form a new substance.

Ozone—A gas that occurs both in the Earth's upper atmosphere and at ground level. Ozone can be "good" or "bad" for people's health and the environment, depending on its location in the atmosphere. High up in the atmosphere, ozone helps protect people's health from too much ultraviolet radiation from the sun. Near the Earth's surface, ozone is an air pollutant that can result in breathing difficulties.

Air Quality Index (AQI)—A color-coded scale that provides daily air quality and health information.

Steps

1. If you are using printed color copies of the AQI color charts on the *Air Quality Index (AQI)—A Guide to Air Quality and Your Health* Web page, hand them out to the class. If you are using the Internet to access the charts, tell students to go to: www.airnow.gov/index.cfm?action=aqibasics.aqi (The rest of the page can be used for additional background information.)

2. Explain to the class what the Air Quality Index (AQI) is while having them look at the AQI Color Chart. Tell students that the Air Quality Index, or AQI, is an index for reporting daily air quality. It uses a simple color-coded scale to tell you how clean or polluted the air in a particular location is, and how you can protect your health at different levels of pollution. There is an AQI for five pollutants, one of which is ground-level ozone, which we are discussing in this lesson. The AQI is like a yardstick that runs from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 represents good air quality with little potential to affect public health, while an AQI value over 200 represents very unhealthy air quality. (Note: More information on the AQI is available on the rest of the Guide page and at www.airnow.gov.)

3. If you are using printed color copies of the Ozone Map, hand them out to the class. If you are using the Internet to access the map, tell the class to go to: http://ciese.org/curriculum/airproj/airquality-map/

   Tell students that the AQI colors on the map represent one day only; the AQI, and air quality, can change daily.

4. Have students answer Questions 1-5 on the Student Worksheet, using the AQI color charts and the Ozone Map.

5. Review students' answers for Questions 1-5 on the Student Worksheet with the class.

6. Give students time (approximately 5 to 10 minutes) to answer Questions 6 and 7.

7. As a class, discuss students' answers to Questions 6 and 7.

Adaptation

For Grades K-2, use the first and second paragraphs of the *Background Summary* and simplify the third paragraph to: "Ground-level ozone comes mostly from motor vehicles that we drive, factories that make products we use, and power plants that make our electricity." Also assist the class in answering the Student Worksheet questions #1-6 verbally instead of writing the answers, and skip question #7.

For Further Exploration

- Have students explore more information about ground-level ozone on the AIRNow Web site (www.airnow.gov).
- Have students explore "nitrogen oxides" (NO_x) and "volatile organic compounds" (VOCs) on the Internet.

Acknowledgments/Resources

Air Pollution: What's the Solution? project, developed by the U.S. EPA, the Northeast States for Coordinated Air Use Management, and the Center for Innovation in Engineering + Science Education. See: http://ciese.org/curriculum/airproj/

AIRNow program. The Air Quality Index (AQI) is always available at the AIRNow Web site at: www.airnow.gov

Walking for Health and the Environment Curriculum, by Walk Boston and ERG. Web site: www.walkboston.org/what-we-do/initiatives/safe-routes-school

Next Generation Science Standards

Interdependent Relationships in Ecosystems
Matter and Energy in Organisms and Ecosystems
Earth and Human Activity
Engineering Design

Student Worksheet: The Ozone Between Us

Name: _____

Ozone Map

Look at the two AQI color charts on the page titled *Air Quality Index (AQI)—A Guide to Air Quality and Your Health*, then look at the "Ozone Map" and answer the following questions:

1. Next to each Air Quality category listed below, write the name of the color that is used on the map for that category:

Air Quality Category	Color Used
Good	
Moderate	
Unhealthy for Sensitive Groups	
Unhealthy	
Very Unhealthy	

2. Find Los Angeles, CA on the Ozone Map. What is the air quality in Los Angeles? Circle:

Good Moderate Unhealthy for Sensitive Groups Unhealthy Very Unhealthy

3. Find another city on the map that has the same air quality as Los Angeles. Write the city and state below.

4. Find two cities on the map where the air quality is "unhealthy for sensitive groups." Write the city names and states below.

(continued)

Student Worksheet: The Ozone Between Us

Name: _____

5. Are there any cities on the map with good air quality? If so, list three.

6. Where are most of the red and orange areas on the map, near or far away from cities?

7. Write a sentence that compares the kinds of places where good air quality is found, and the kind of areas where unhealthy air quality is found. Why do you think that is?

Teacher Answer Sheet: The Ozone Between Us

Ozone Map

Look at the two AQI color charts on the page titled *Air Quality Index (AQI)—A Guide to Air Quality and Your Health*, then look at the "Ozone Map" and answer the following questions:

1. Next to each Air Quality category listed below, write the name of the color that is used on the map for that category:

Air Quality Category	Color Used (answers below in italics)
Good	*Green*
Moderate	*Yellow*
Unhealthy for Sensitive Groups	*Orange*
Unhealthy	*Red*
Very Unhealthy	*Purple*

(If students ask, or you wish to inform them, tell them that the color "Maroon," which represents "Hazardous" air quality, is not listed on the chart above because air quality has not been "hazardous" in the U.S. for many years.)

2. Find Los Angeles, CA on the Ozone Map. What is the air quality in Los Angeles? Circle:

Good Moderate Unhealthy for Sensitive Groups Unhealthy Very Unhealthy

(Answer: Unhealthy)

3. Find another city on the map that has the same air quality as Los Angeles. Write the city and state below.

(Answer: Several correct answers—Houston, New York City, Boston)

(continued)
Teacher Answer Sheet: The Ozone Between Us

4. Find two cities on the map where the air quality is "unhealthy for sensitive groups." Write the city names and states below.

(Several correct answers: Sacramento, Charlotte, Richmond, Albany)

5. Are there any cities on the map with good air quality? If so, list three.

(Several possible answers: Seattle, Tuscon, Dallas, Jackson, Miami, Atlanta, Orlando, Detroit, Denver)

6. Where are most of the red and orange areas on the map, near or far away from cities?

(Answer: Near cities)

7. Write a sentence that compares the kinds of places where good air quality is found with the kinds of areas where unhealthy air quality is found. Why do you think that is?

(Answer: Good air quality is found mostly in areas away from cities, in rural areas, where fewer cars and factories are. Or similar answer.)

(Additional information that teachers may want to include: Some cities also have good air quality. This may be because they have taken steps to reduce air pollution, such as having good public transportation so that people take buses or trains instead of driving places, and high-occupancy vehicle lanes to cut down on rush-hour traffic. Or, it could be that wind blew air pollution away from certain cities.)

The Cilia (not Silly!) Game

Learning Objectives

Students will:

- **Learn what particle pollution is.**
- **Understand how particle pollution can affect people's health.**
- **Observe through role playing how our bodies (cilia in particular) help protect us from particle pollution.**
- **Understand the sources of particle pollution (see For Further Exploration).**
- **Learn what people can do to reduce particle pollution (see For Further Exploration).**

Grade Level: Grades 3-5

Estimated Time: 30 minutes

20 minutes—For Further Exploration

Background Summary

One type of air pollution is called particle pollution, which is made up of tiny particles of dust, dirt, smoke, and liquid droplets. Particle pollution comes from things like cars and other vehicles, smokestacks from factories and power plants, fireplaces and wood-burning stoves, volcanoes, and forest fires. When there's a lot of particle pollution in the air, people can get sick from breathing it in. Our bodies help protect us from particle pollution. Cilia, which are tiny hair-like structures that line our respiratory system, try to keep foreign objects like particle pollution out of our lungs. Sometimes the cilia are successful, but not all the time. When particle pollution reaches our lungs, we might feel sick.

Certain people are particularly sensitive to particle pollution, including children, the elderly, people with asthma and other respiratory problems, and people with heart problems. Particle pollution may make people cough or have difficulty breathing, and can make asthma and heart disease worse. People visit hospitals more often when there is a lot of particle pollution. There are things that we can do to help protect our health from particle pollution, such as finding out how clean or dirty the air is, taking it easier outside if the air is not good, and telling an adult if you have trouble breathing on days when the air quality is bad. It's also a good idea to stay away from school bus tailpipes because particle pollution comes out of them.

Tell the class that they are going to play a "Cilia Game" that shows how cilia keep particle pollution out of the lungs, and how some particle pollution gets through to the lungs.

Materials Needed

- Flour (about a handful)
- Flashlight
- Student Handout: Human Hair and Particle Pollution (included)
- 75 (approx. 3-4 per student) pre-made newspaper balls (wadded up newspapers to size of tennis balls, wrapped in masking tape)
- Cilia Game Set-Up (Included)
- 4 orange traffic/sports cones, or other similar size safe objects
- Name tags (optional, that say "Cilia", "Particle Pollution", and "Lung"—see Step 9)
- Sources of Particle Pollution poster (included) (see "For Further Information" section)
- Flip chart and marker

Key Questions

- What is particle pollution? (*Answer:* Particle pollution is made up of tiny particles of dust, dirt, smoke, and liquid droplets in the air.)
- Where does particle pollution come from? (*Answer:* Particle pollution comes from cars and other vehicles, smokestacks from factories and power plants, fireplaces and wood-burning stoves, volcanoes, and forest fires.)

- How can particle pollution affect our health? (*Answer:* Particle pollution may make people cough or have difficulty breathing, and can make asthma and heart disease worse.)
- What can we do to protect our health from particle pollution? (*Answers:* Find out how clean or dirty the air is. Take it easier outside if the air is not good. Tell an adult if you have trouble breathing on days when the air quality is bad. Stay away from school buses' tailpipes.)
- What can we do to reduce particle pollution? (*Answer:* Use fireplaces and wood stoves less often, or not at all. Make sure you have a clean-burning, EPA-certified wood stove. Carpool or use public transportation when possible instead of driving. Turn off lights when not using them.)

Vocabulary

Cross section—A cut through a substance, at a right angle.

Particle pollution—Air pollution that consists of tiny, often microscopic particles of dust, dirt, smoke, and liquid droplets.

Cilia—Small hair-like structures that line the airways in the lungs and help clean out the airways.

Steps

1. Darken the classroom. Gently throw a handful of flour into the air, keeping it away from students.
2. Quickly shine a flashlight on the flour as it is falling. Ask students to describe what they see.
3. Discuss how the flour floats in the air, separating into tiny pieces, like dust. Tell students that these tiny pieces are called "particles." Explain that many different kinds of particles float in the air and can be inhaled into our lungs, sometimes making people cough.
4. Explain that when tiny particles of dust, dirt, or smoke mix with liquid droplets in the air, scientists call this "particle pollution." When there is a lot of particle pollution in the air, people can get sick from breathing it into their lungs. They may have trouble breathing and become more tired. Particle pollution can aggravate heart or lung disease. Breathing particles has been linked to heart attacks and even death.
5. Have one student come up to the blackboard and draw a large circle on it. Tell students to pretend that the circle is a strand of hair, cut open—a "cross section." Have the student label the diameter "70 microns."
6. Have two other students draw two tiny circles inside the large circle and label their diameters "2.5 microns." Explain that microns are very, very small units of measurement. Tell students that particles can be very tiny—we may not be able to see them, but they may still be there.
7. Distribute the Student Handout: Human Hair and Particle Pollution and observe it with students.
8. Explain what cilia are and the role they play in our health and air pollution.

   (*Background information on cilia:* Tell students that cilia (pronounced: sih-lee-uh) are tiny hair-like structures in our respiratory system. The job of cilia is to protect our respiratory system by keeping foreign matter—like particles—from entering our lungs. Cilia do this by moving back and forth to remove particles that enter our nose with the air we breathe. As air is inhaled, the cilia wave around, pushing any foreign matter away from the lungs.)
9. Tell students they are going to play a "Cilia Game." (Not a "Silly" game!) Ask for student volunteers, as follows:
   - Two students as the "Lungs"
   - Half the class, plus a few more, as "Particle Pollution"
   - The remaining students as "Cilia"

   If you are using name tags for the above roles, pass them out now.
10. See the enclosed graphic for the Cilia Game Set-Up. In an open area, set up the boundaries of the game in a trapezoid shape, using 4 traffic cones or similar size (and safe) objects, leaving approximately 15 feet between the "Lungs" boundary and the "Particle Pollution" boundary.
11. Read the game rules to the class.

    (a) The "Lungs" students stand on the short side of the trapezoid.

    (b) The "Particle Pollution" students line up along the longer edge of the game area.

    (c) The "Cilia" students stand in between the "Particle Pollution" and the "Lungs." Tell the Cilia students that they can stretch and wave their

arms like cilia to keep Particle Pollution from entering the Lungs, but they must stand still with their feet together, and must not hit other students. Have the Cilia students practice this movement.

(d) Place some of the pre-made particle pollution newspaper balls near each of the "Particle Pollution" students. Explain that the "Particle Pollution" students will throw the particle pollution balls towards the "Lungs" students, and the "Cilia" students will try to defend the Lungs by waving their arms and batting the particle pollution balls away from the Lungs. Emphasize that the balls should NOT be thrown too hard and not anywhere near anyone's face. Demonstrate by having a Particle Pollution student throw one of the newspaper balls at you.

(e) Tell students to take a deep breath and feel the air moving into their own lungs.

12. Begin the game by declaring the day bright and clear, with little particle pollution, and tell two Particle Pollution students to throw two balls each towards the Lungs. The Cilia students should try to bat the balls away from the Lungs.

    Ask the "Lungs" how they are feeling.

13. Explain that now it is a day with lots of particle pollution. Tell students that when you say "Go," all of the Particle Pollution students should throw all of their balls, one at a time, towards the Lungs, and the Cilia students should try to stop the balls from reaching the Lungs by waving their arms. Then shout out "Go!"

14. When all the balls have been thrown, stop the game and allow time for students to calm down. Then ask the Lungs students how it felt to have all of that particle pollution thrown at them. Tell the Lungs students to count how many Particle Pollution balls reached them. Ask the Cilia students how they felt during the game.

15. Review with students what happened in the Cilia Game: when there was just a little particle pollution, it was easier for the cilia to keep the particle pollution away from the lungs. When there was a lot of particle pollution, it was much harder for the cilia to keep the particle pollution away from the lungs, and the lungs may have felt attacked by the particle pollution.

16. Explain/review that at certain levels, everyone can be affected by particle pollution. Some groups of people are more sensitive, including children, the elderly, people with asthma and other respiratory problems, and people with heart problems. Breathing in particle pollution may make people cough, make it harder to breathe, and can make asthma and heart disease worse. People visit hospitals more often when there is a lot of particle pollution.

17. Discuss with the class what they can do to protect their lungs and hearts from particle pollution in the air. Tell them they can:

    (a) Find out how good or bad the air quality is each day from the Air Quality Index, or AQI. The AQI is often in the newspaper on the weather page, sometimes on the TV news, and always on the Internet (at www.airnow.gov).

    (b) If the air quality is not good, take it easier if you're outside—walk instead of run, and take breaks often.

    (c) If it feels harder to breathe when the air is not good, tell an adult.

    (d) Stay away from the tailpipes of school buses —you don't want to breathe in the particle pollution that comes out of those.

    In addition to the *Human Hair and Particle Pollution* handout included with this lesson, you can also distribute the general student handout in this Toolkit, *Breathe Smart! Four Things Kids Can Do* (see Grades 3-5 Handout in this Toolkit).

    Note: See "For Further Exploration" below for a discussion of sources of particle pollution and ways to reduce particle pollution.

For Further Exploration

If time permits, have a discussion with students about where particle pollution comes from. Share with the class the *Sources of Particle Pollution* poster at the end of this lesson. Ask students if they or their families ever create particle pollution and how. Record answers on a flip chart.

(*Teacher discussion information:* There are many sources of particle pollution created by people's activities. Cars and trucks, factories, and power plants that produce electricity release particle pollution. Unpaved roads, and construction projects that grind or crush rocks or soil, also cause particle pollution. Wood-burning stoves and fireplaces, outside burning of branches or trash, smoke from cigarettes and cigars, and off-road vehicles such as ATVs and lawn mowers also create particle pollution. Sometimes nature

can pollute the air, too. Forest fires and volcanoes can pollute the air with particles. If you lived near a forest fire, what do you think it would feel like to breathe the air that day? *[Wait for an answer or two.]* The air would be very smoky, and it might make you cough, or you might find it harder to breathe.)

Continue the discussion by asking students what they think they, their families, and their communities can do to reduce particle pollution. Write the answers on the flip chart. Guide the class discussion to include the following categories:

- Use fireplaces and woodstoves less often or not at all. Some town or city governments already ban such burning when there's a lot of air pollution. Also, if your family uses a woodstove, make sure it's a clean-burning, EPA-certified unit, which produces less particle pollution than older units. Use only dry seasoned wood; wet wood or plastics cause more smoke and that's not good for you to breathe, indoors or outdoors.
- Use public transportation such as buses, trains, and subways whenever possible instead of driving in cars and trucks.
- Companies and governments can develop cleaner (less polluting) fuels (gas or other fuels) and cars, and people can buy these cleaner cars and fuels.
- Power plants can use cleaner ways to make electricity (such as water, wind, or solar power; cleaner coal; and special equipment to reduce pollution).
- Factories can use cleaner ways to make their products, and special equipment to reduce pollution.

Acknowledgments/Resources

Adapted from Clean Air Campaign, Georgia Learning Connections.

Next Generation Science Standards

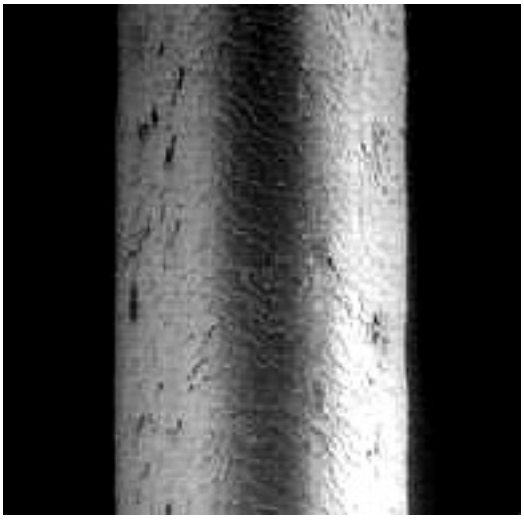
Energy
Interdependent Relationships in Ecosystems
Engineering Design
Matter and Energy in Organisms and Ecosystems

Student Handout: The Cilia (not Silly!) Game

Human Hair and Particle Pollution

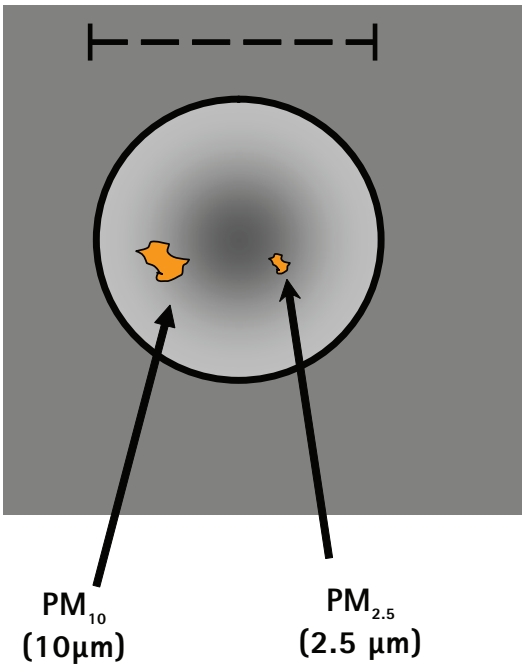
Average Human Hair =

70 microns



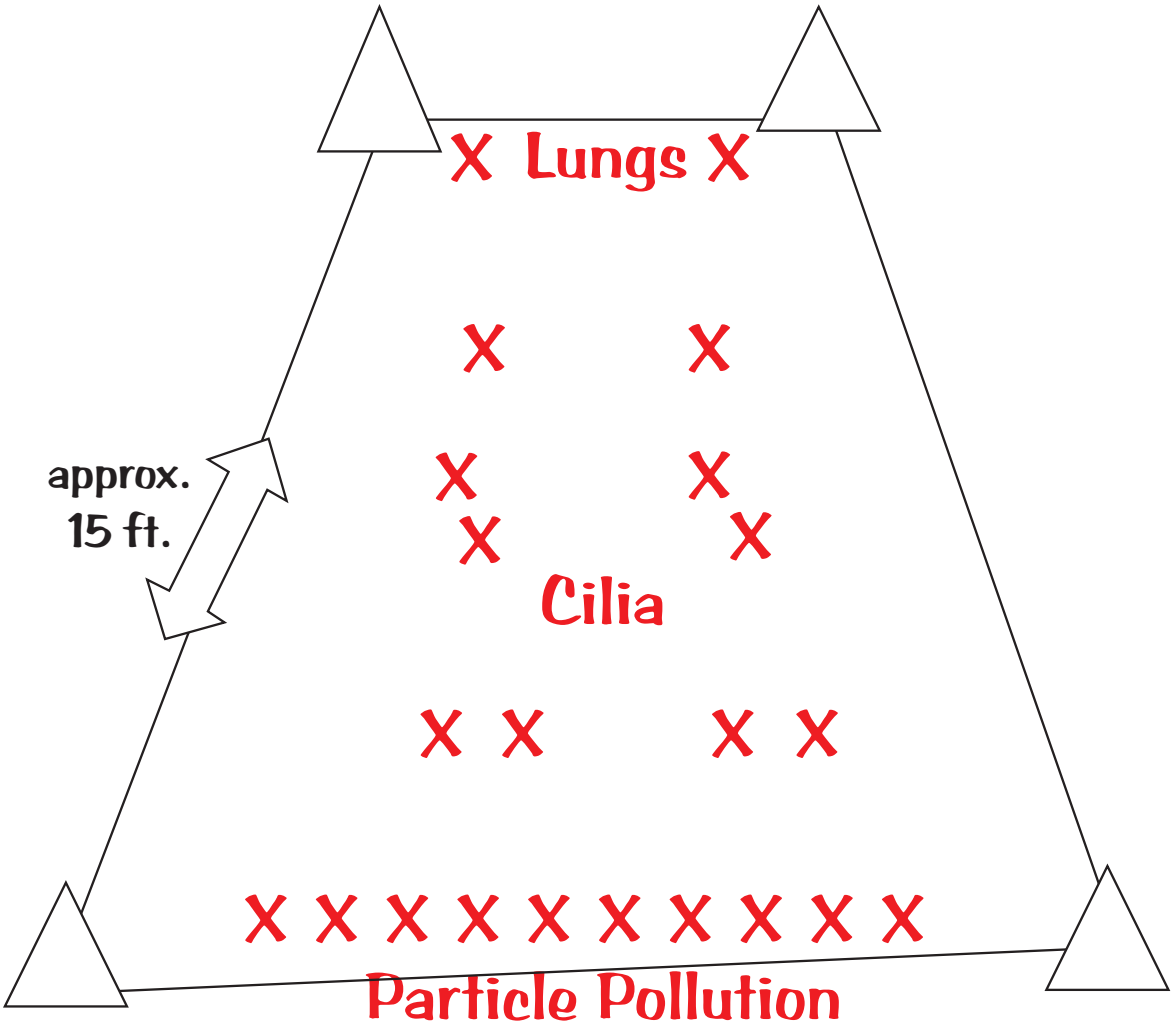
Particle Pollution

(shown as 10 and 2.5 microns)

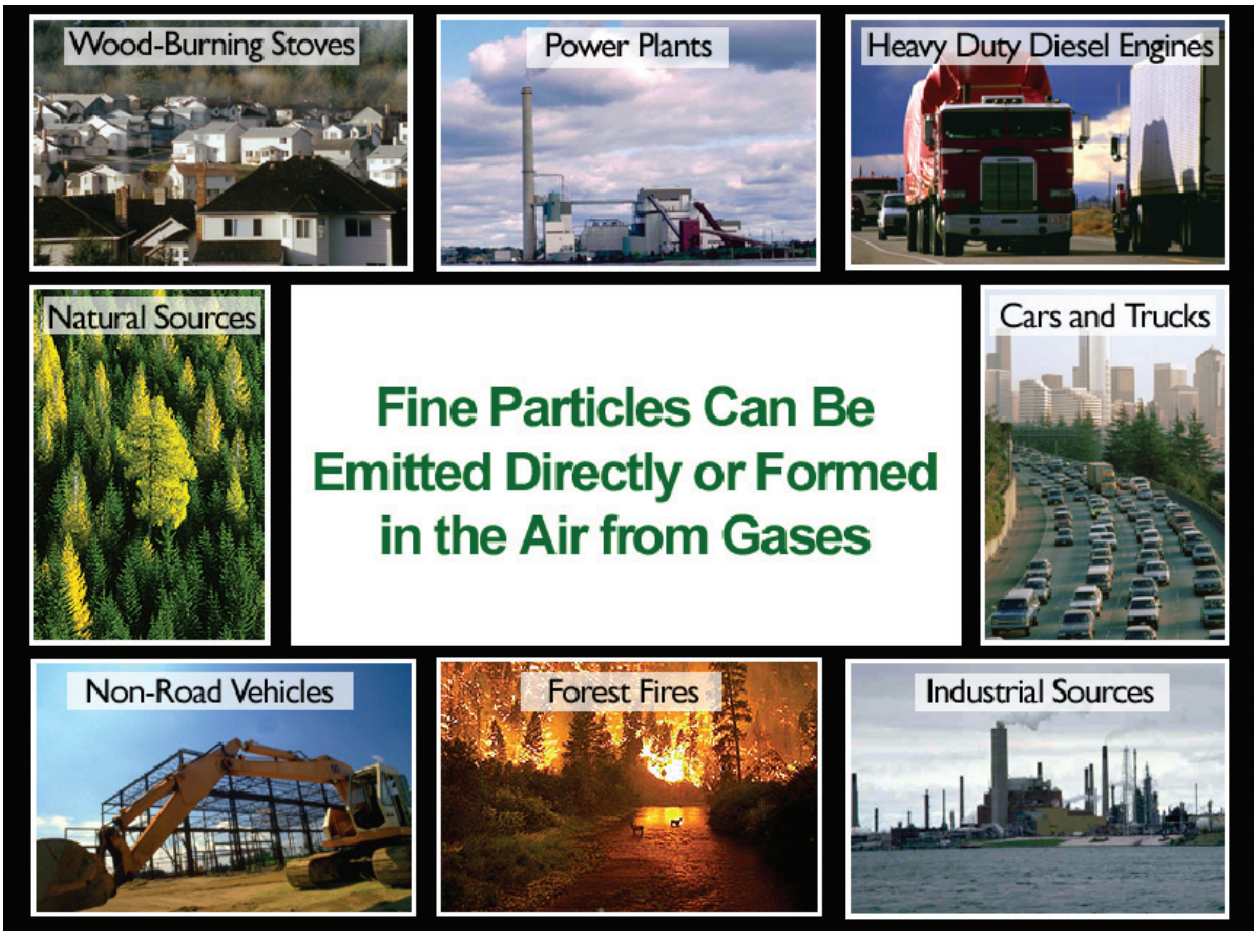


(Particle pollution is also known as particulate matter, or PM)

Cilia Game Set-Up



Sources of Particle Pollution



Source: U.S. EPA, Office of Air Quality Planning and Standards.

Traffic Tally

Learning Objectives

Students will:

- **Design and conduct a traffic survey to explore traffic volume on key local roads.**
- **Collect and analyze observational data.**
- **Understand the connection between traffic volume, modes of transportation, air pollution, and health.**

Grade Level: Grades 3-5

Estimated Time: 1.5-2 hours (2-3 sessions)

Background Summary

Increased traffic is an ongoing problem in many local communities, for several reasons. An increase in traffic often increases accidents, safety problems, traffic jams, and the time it takes to get places. Increased traffic is also a health and environmental concern: more vehicles on the road means more air pollution, since gasoline-powered vehicles release, or emit, several air pollutants (called vehicle emissions). Increased air pollution can cause people to have breathing problems and aggravate heart and lung disease. Also, driving more, instead of walking or bicycling, means we get less exercise, which can potentially contribute to health problems such as obesity, heart disease, and diabetes. Traffic is an environmental and economic concern for another reason as well: more cars on the road means more gasoline is used to run those cars. Gasoline is made from oil, of which there is a limited amount in the world.

This activity is a mini-field trip that provides students with hands-on experience in conducting a traffic survey in their own community, analyzing their data, and exploring the connection between traffic and air pollution. If time permits, students can create presentations of their data.

Materials Needed

- Pencils and erasers
- Watches with minute/second hands, stopwatches, or clicker counters
- Clipboards (if available)
- Additional staff support (classroom assistants or parent volunteers)
- Signed parental consent forms (if taking students off school premises)
- Student Worksheets (included)

Key Questions

- Do you think there is too much traffic along the main (2-lane) roads in your community? If so, how many vehicles do you think travel along these roads during morning rush-hour traffic? How many people do you think are typically in each vehicle?
- How might the amount of traffic be reduced? (*Possible answers:* People could walk, bicycle, carpool, and take subways, trains, and buses more often.)
- How might the amount of air pollution from traffic be reduced? (*Possible answers:* Having fewer vehicles on the road; more people walking, bicycling, carpooling, and taking subways, trains, and buses; driving low-emission vehicles.)
- What might some of the benefits be of reducing traffic and air pollution from vehicles? (*Possible answers:* Fewer traffic jams; safer streets to walk and bike on; fewer health problems from air pollution, such as breathing problems [e.g., asthma], and heart disease, and possibly healthier people because more people might be walking and getting exercise.)
- What things might affect the accuracy of a traffic survey's results? (*Possible answers:* If on the day of the survey there was bad weather or the day was a holiday, the amount of traffic would not represent the usual traffic. Also, the traffic survey results would not be as accurate if: (1) different

groups started counting traffic at different times; (2) some people missed counting some vehicles; (3) some people put some vehicles into the wrong categories; (4) some people "double-counted" some of the vehicles.)

- What vehicles produce the most pollution per person? *(Possible answer:* Cars and trucks with just one person in them.) What vehicles produce the least pollution per person? (*Possible answer:* Bicycles. Or, buses or trains that carry a lot of people.)

Vocabulary

Tally—Counting using marks rather than names or numbers.

Emissions—Substances discharged into the air. Releases of pollutants from a variety of sources and activities, including vehicles, factories, power plants that make electricity, and wood-burning stoves and fireplaces, among others.

Steps

1. Preparation.

- Make important arrangements, such as obtaining parental permission slips to go to off-school premises, and getting commitments from adult classroom assistants and/or parent volunteers to accompany the class groups. (Note: If going offsite is problematic, you can instead conduct the traffic survey on school premises, near the driveway to the school.)

- Choose the roads on which the class will survey traffic volume and vehicle types. Choose a minimum of two roads, for comparison purposes. Choose roads that are within easy walking distance of the school, and are busy two-lane (one travel lane each direction) roadways. Select a time of day when the roads have moderately busy traffic, such as morning rush hour.

  The number of roads chosen will depend on how many groups you want to divide the class into (which in turn will depend in part on how many adult assistants/volunteers you have, and the size of your class). (Note: The class will not be surveying major four-lane or larger highways; the purpose is to determine local/community traffic impacts.)

- Give students an overview of the traffic survey. Inform students that the class will conduct a traffic survey to explore traffic volume on key local roads, and the connection between vehicle traffic and air pollution. Discuss the "Key Questions" above with the class if you have not already done so. Tell the class that they will divide up into groups of at least 8 students per group, and will stand safely by the sides of different busy roads. For a fifteen-minute period (e.g., during morning rush hour), some students will count the number of vehicles driving by, while other students will identify the type of each vehicle (e.g., car, truck, etc.), or the number of people in each vehicle.

- Explain a tally chart. Tell students that to conduct the survey, they will make tally charts that keep track of the number and types of vehicles and the number of people in each vehicle, and that the class is first going to practice making these charts. On the chalkboard, illustrate tally marks.

2. Practice a traffic tally in class. Tell students to use the back of their Student Worksheets to practice recording the number and types of vehicles that you will be calling out to them. For simplicity, tell students to consider SUVs and vans as "trucks" and to ignore motorcycles. Then call out the names of the vehicle types listed below; do it quickly to simulate rapid traffic flow so that students can practice performing quick tallys, which they will need to do by the roadside.

Car	Car	Car	Truck	Bicycle
Truck	Car	Truck	Car	Truck
Car	Car	Truck	Bus	Truck
Bicycle	Car	Car	Car	Car
Car	Car	Bicycle	Truck	Car
Car	Car	Bicycle	Truck	Car
Truck	Car	Car	Car	Truck
Car	Car	Bicycle	Truck	Truck
Car	Car	Car	Car	Truck
Truck	Bus	Bus	Car	Car
Car	Truck	Car	Bicycle	Truck
Car	Car	Car	Car	Truck
Bus	Car	Truck	Bicycle	Car
Car	Car	Car	Car	Car

   Tell students to swap tally sheets and check for correct answers for each type of vehicle as you read aloud the totals listed below:

   Totals: Bicycle = 7, Car = 41, Truck = 18, Bus = 4

3. Explain to students that they will conduct the traffic survey in four pairs. The first and second pairs will focus on the number and types of vehicles;

the third and fourth pairs will focus on the number of people in each type of vehicle:

- **1st Pair:** One person will call out loud to their partner the type of the vehicle (e.g., "car," "truck") each time a vehicle passes in *one direction* (one side of the street), while the other partner will record the data on Student Worksheet #1.
- **2nd Pair:** One person will count vehicles passing in *the other direction* (on the other side of the street), while the other partner records the data (as described in "1st Pair" above).
- **3rd Pair:** One person will call out the number of people in each vehicle in *one direction* and identify the type of vehicle, while the other partner will record the number of persons per vehicle and the vehicle type. Tell students that it may be difficult to identify the number of people, and to do the best they can. For buses, have the students discuss and agree on an estimate of the number of people they will use (e.g., average of 15 people per bus) and make sure all students are using the same number.
- **4th Pair:** One person will call out the number of people in each vehicle in *the other direction* and the vehicle type, while the other partner will record the number of persons per vehicle and the type of vehicle. Again, tell students that it may be difficult to identify the number of people, and to do the best they can. For buses, use the same estimated average number of people as discussed in "3rd Pair" above, and make sure all students are using the same number.

4. Explain ways that conducting the survey can help make it more accurate. That is, it is important for each group and each pair of students to do things exactly the same way. For example, each group must start the survey at the same time, and each group must conduct the survey for exactly 15 minutes—not longer and not shorter.

5. Assign the students to survey groups, and assign an adult assistant to each group. Have students in each group divide up into pairs; help them decide who will be an "announcer" (calling out the type of each vehicle that passes, or the number of people in each vehicle) and who will be the "recorder" in each pair. Assign one person (e.g., the adult assistant) to be the timekeeper, who will tell students when to begin and end the survey and record the exact starting and ending times.

6. Conduct the traffic survey at the designated locations, using Student Worksheet #1. If possible, have students stand in locations where they do not have to cross any streets. Be sure to remind students to practice safety: stand back from the roadway; if crossing a street is necessary, do so carefully when the adult assistant says it is safe to do so. Make sure students are standing in such a way that allows other pedestrians to pass easily, and that they are polite to people. Have adult assistants help students as needed as they count vehicles and people in them.

7. After the survey has been conducted, in class (on the same day or another day), have the student groups compile their survey results, and discuss and analyze the results as a class.

- **Calculate totals**. Back in the classroom, in the top half of Student Worksheet #2, have each group add up the totals for their group, including the total number of each type of vehicle and the grand total number of vehicles. Ask a spokesperson from each group to read aloud the totals for their group, write these on the chalkboard, and add up the totals for the entire class.
- **Calculate data for different vehicle types**. Of the total traffic, have the class calculate the portion of each vehicle type (e.g., cars, trucks, buses, bicycles). For younger students, this might be calculated as fractions. For older students, this might be calculated as fractions and percentages.
- **Discuss results thus far**. Which roadway had the most traffic? Why does the class think this is so? Compare and contrast the numbers of different types of vehicles for each group.

8. Explain the Air Pollution Values table on Student Worksheet #2 to the class. Tell students that you have assigned an "air pollution value" number to each type of vehicle. The number is an estimate of the degree of air pollution each type of vehicle releases for every person it carries, compared to the other vehicle types—the higher the number, the more air pollution. On Student Worksheet #2, in the Air Pollution Values table, tell students to look at the numbers in the "Air Pollution Value Per Person" column.

   Explain the rationale behind these numbers: Trucks with one or two people in them release the most pollution per person, so they are assigned the highest pollution value of "10." Cars with one or two people in them release the next most pol-

lution per person, so they are assigned the next highest pollution value of "9." Cars and trucks with three or more people can be considered carpools (sharing rides) for this exercise; because more people are in the vehicle, it releases less air pollution per person, and is assigned a lower value of "3"—about one-third the pollution values of 9 or 10. (This is because a vehicle with three people in it would release about one-third of the pollution compared to three separate vehicles each carrying one person in it). Because buses can carry many more people than cars and trucks, the pollution value per person for buses is much lower ("0.2") than for cars and trucks. Bicycles don't release any air pollution, so their air pollution value is "0".

9. Tell students to fill in the "Total Number of People" column in the Air Pollution Values table in Student Worksheet #2. Ask students if they know where to get this information. If no one offers the correct answer, tell students they recorded this information on the bottom of Student Worksheet #1 during the traffic survey, in the "Number of People in Each Vehicle" box. Assist students as needed in adding up the data in Student Worksheet #1 and transferring it to the Total Number of People column of the Air Pollution Values table in Student Worksheet #2 (e.g., placing the numbers in the correct "Vehicle Type" rows in the table).

10. Next, demonstrate on the board how to calculate numbers for the "Estimated Air Pollution Value" column in the Air Pollution Value table. For one of the vehicle types listed, ask a student to give you his or her answer for the "Total Number of People" for that vehicle type. Multiply the total number of people for that type of vehicle by the "Pollution Value Per Person" number assigned to that vehicle type. Have students enter this answer in the "Estimated Air Pollution Value" column of the table. Have students work in groups to calculate the Estimated Air Pollution Value for the other vehicle type categories and record these numbers in the Air Pollution Values column in the table.

11. Discuss the results of the Air Pollution Values table. Which vehicle type had the highest air pollution value? Which vehicle type had the lowest air pollution value? Discuss the results for the other categories, and compare the numbers for all five vehicle types. If no buses were identified in the traffic survey, provide a hypothetical scenario for comparison purposes (e.g., two buses, each with 15 people in them, would result in an Estimated Air Pollution Value of 6: Total Number of People [30] x Air Pollution Value Per Person [0.2] = Estimated Air Pollution Value [6]).

12. Discuss the relationship between traffic volume, air pollution, and health.

    Ask: If the number of vehicles on the road were reduced, might this reduce air pollution? (*Correct answer:* Yes). Why? (*Correct answer:* Because gas-powered vehicles release air pollutants, and fewer vehicles would mean less pollution.)

    Ask: How might the number of vehicles on the road be reduced? (*Correct answers:* Carpooling and using public transportation [buses, trains, subways] would reduce the number of vehicles on the road, which would reduce air pollution. Walking and bicycling would also reduce air pollution. You can also mention that new laws requiring vehicles to release fewer emissions would also help vehicles reduce the amount of air pollution.

    Ask: What are some benefits from reducing air pollution? (*Correct answer:* Less breathing problems and fewer asthma attacks and heart problems. People might also be healthier because they might get more exercise by walking or bicycling instead of driving. Also, trees and plants would be healthier if there was less air pollution.

13. Discuss the accuracy of the traffic survey methodology and results. Identify any potential problems regarding the data collection methods: Did one group collect data for 20 minutes instead of 15? Did some people miss counting some vehicles (e.g., because they weren't paying attention, because they sneezed, etc.)? Did some people "double-count" one or more vehicles? Could students really see the number of passengers inside vehicles? Did some people put certain types of vehicles in the wrong categories (e.g., did they remember to count SUVs and vans as trucks)? Did one group start earlier or later than another group? Did the weather suddenly change during the tally? Inform the class that any of these or other factors can affect the accuracy of the survey results. Ask the class if they have any ideas about how the survey could have been done more accurately. (Then tell students they did a great job, given the many things that can affect the accuracy of survey results.)

14. If time permits, have students create a presentation of the traffic survey and air pollution results. Depending on time available, either assign how the class should present the data, or, if more time is

available, have the class discuss different ways of presenting the data and determine the best way to present the information (e.g., line graph, pie chart, pictogram, and/or bar graph). If time permits, you may want to have different groups present their data results in different ways.

Building on prior classroom experience with different graphic presentation formats, explain to the class how to develop the type of presentation format you choose. Decide what units, scales, colors, symbols, spacing, etc. to use, as appropriate. If computers are available, consider having students use the Internet or relevant software to create charts or graphs.

Discuss which type(s) of chart or graph conveys the information most effectively and why.

Adaptation

For Grades K-2, conduct the traffic survey as a whole class instead of dividing up into groups (with enough adult classroom assistants). Have the teacher and adult assistants, rather than the students, count the number of vehicles and people in the vehicles. Back in class, the teacher can call out the totals for the students to record. The teacher can calculate the estimated air pollution values and tell students that the higher the number, the more air pollution that type of vehicle produces. For presentation purposes, help the students develop pictograms and/or pie charts (instead of more complex bar graphs, etc.).

For Further Exploration

- Have students explore the mean and range of the different groups' data sets and of the grand totals.
- Have students develop a database, computerized if possible, of the data collected.
- Conduct an in-class simulation instead of, or in addition to, a traffic survey field trip. See the Traffic Jams lesson at Web site: www.cleanaircampaign.org/Your-Schools/Resources/Air-Quality-Lesson-Plans/Elementary-School. (Step 7 of the Traffic Jams lesson on pollution values was adapted and incorporated into this Traffic Tally lesson).

Acknowledgments/Resources

UK Department of Transport Primary School Teaching Resource – Numeracy: Local Traffic Survey.

The Beacon School Interactive Website—Geography Department at: www.geogweb.com

Traffic Jams. The Clean Air Campaign, Georgia Learning Connections at: http://www.cleanaircampaign.org/Your-Schools/Resources/Air-Quality-Lesson-Plans/Elementary-School

Walking for Health and the Environment Curriculum. WalkBoston and ERG at: http://walkboston.org/resources/maps

Next Generation Science Standards

Energy
Interdependent Relationships in Ecosystems
Engineering Design

Student Worksheet #1: Tally Sheet for Traffic Survey

Location (name of road, and main intersection if appropriate):

_____

_____

Number of Each Vehicle Type

Type	Tally	Totals
Cars		
Trucks		
Buses		
Bicycles		

Number of People in Each Vehicle (keep separate results for each individual vehicle)

Cars	Trucks	Bicycles	Buses (estimate)

Student Worksheet #2: Survey Results and Air Pollution Values

Location (name of road, and main intersection if appropriate):

_____

_____

Using your results in Student Worksheet #1, fill out the following information in the classroom after conducting the survey:

Total number of cars: _____

Total number of trucks: _____

Total number of buses: _____

Total number of bicycles: _____

Total number of all types of vehicles: _____

After your teacher discusses the Air Pollution Values table below with the class, complete the table.

Air Pollution Values

Vehicle Type	Total Number of People	Air Pollution Value Per Person	Estimated Air Pollution Value
Trucks with 1 or 2 people		10	
Cars with 1 or 2 people		9	
Cars and Trucks with 3 or more people (Carpool)		3	
Bus		0.2	
Bicycle		0	

If your teacher instructs you to do so, present your survey results (as a line graph, pie chart, bar graph, and/or pictogram, as your teacher tells you).

Trapping Air Pollution: Temperature Inversions #1

Learning Objectives

Students will:

- **Observe simulations of normal weather conditions compared to conditions during temperature inversions.**
- **Understand how temperature inversions can trap air pollutants and impact health.**

Grade Level: Grades 3-5

Estimated Time: 45 minutes

Background Summary

Air temperature can play an important role in air pollution. Under normal weather conditions, air temperature is cooler as you move upward in the atmosphere; the air closer to the Earth is warmer than the air above it. The word "inversion" means that something is reversed or turned upside down. So when a temperature inversion occurs, the opposite is true about the air. During a temperature inversion, cool air is "trapped" under warmer air above it. Any pollutants in the cooler air are also trapped under the warmer air, and cannot rise and move away, until the weather changes, such as a wind carrying the air pollution away. While the temperature inversion is occurring, air quality in that particular location can get worse if there is a lot of pollution there.

Materials Needed

- Photos showing clean air and air with trapped pollutants (included)
- 4 identical small, clear glass jars (baby food jars work well)
- Very hot tap water
- Ice water (about 500F)
- 2 index cards
- Red food coloring
- Medicine dropper (e.g., eye dropper) (optional)
- 2 shallow pans or baking dishes, each long enough (to hold 2 of the small jars)

Key Questions

- Do you think different layers in the atmosphere have different temperatures?
- Do you think temperature differences in the atmosphere could affect air pollution? How?

Vocabulary

Atmosphere—The mass of air surrounding the Earth.

Inversion—A reversal of the usual order.

Temperature inversion—A layer of warm air that prevents the rise of cooler air and pollutants beneath it.

Steps

1. Show the class the photos of a city with clean air and a city with trapped air pollutants.

Demonstrate normal weather conditions to the class (Steps 2-6):

2. Place two of the jars in one of the shallow pans.
3. Fill one of the jars with hot water and the other jar with ice water. Fill jars to the brim. If you use ice cubes to cool the water in the ice-water jar, do not leave any ice in the jar.
4. Put several drops of red food coloring in the jar with the hot water, and explain to students that the food coloring represents air pollution.
5. Place an index card over the top of the jar with the cold (clear) water and quickly flip this jar on top of the jar with the hot (red) water.

   Align the jar openings.
6. Carefully pull the index card out. Leave the jars one on top of the other for later observation.

Next, demonstrate a temperature inversion (Steps 7-11):

7. Place the last two jars in the other shallow pan.
8. Fill one jar with hot water and the other jar with ice water. Fill jars to the brim. Again, if you use ice cubes to cool the water in the ice-water jar, do not leave any ice in the jar.
9. This time, add several drops of red food coloring to the jar with the ice water, and explain that the food coloring again represents air pollution.
10. Place an index card over the top of the jar with the hot (clear) water and quickly flip this jar on top of the cold (red) water jar.

    Align the jar openings.
11. Carefully pull the index card out. Leave the jars one on top of the other for observation.
12. Discuss the results with the class.

    A. Ask the class: What happened in each experiment? (*Answers:* In the first experiment, the hot [clear] water in the bottom jar and the cold [red] water in the top jar mixed immediately, and water in both jars turned red. In the second experiment, the cold [red] water in the bottom jar was trapped and could not escape upward, and the jar on the top [hot water] stayed clear.)

    B. Which of these experiments do you think reflects normal weather conditions, and why? Which reflects a temperature inversion, and why? (*Answer:* The first experiment reflects normal weather conditions because the colder temperature was above the warmer temperature. The second experiment reflects a temperature inversion because the colder temperature was trapped below the warmer temperature above it.)

    C. What happens to air pollutants under each of these conditions, and how do you think this might affect people's health? (*Answer:* In the first experiment [normal weather conditions], the water in the jars and any pollutants [red coloring] in them mixed together, showing that the air and pollutants can move upward and away. In the second experiment [temperature inversion], the warmer water above trapped the cooler water below and any pollutants [red coloring] in it. This shows that a temperature inversion prevents cool air and pollutants from rising and traps them closer to the Earth in the air that we breathe. Breathing trapped pollutants can make it harder to breathe and can make people feel sick.)

Adaptation

For a more advanced lesson on temperature inversions, see "Trapping Air Pollution: Temperature Inversion #2" (for Grades 6-8) in this Toolkit.

Acknowledgments/Resources

Adapted from Alamo Area Council of Governments (AACOG) Air Quality Curriculum at: www.aacog.com/documentcenter/view/247

Next Generation Science Standards

Weather and Climate
Earth and Human Activity
Engineering Design
Matter and Energy in Organisms and Ecosystems

Clean Air

Pollutants Trapped In Air

Save Smog City 2 from Particle Pollution

Learning Objectives

Students will:

- **Understand how weather and people's activities affect air pollution.**
- **Explore how changes in key variables can affect air pollution.**
- **Learn how air pollution can affect our health.**
- **Identify things people can do to reduce air pollution.**

Grade Level: Grades 3-5

Estimated Time: 1 hour

Background Summary

Air pollution is not good for our health. Particle pollution is one type of air pollution that is made up of tiny particles of dust, dirt, smoke, and liquid droplets that may contain chemicals. Particle pollution "emissions" come from cars and trucks, power plants, and factories. Particle pollution can also come from natural sources, such as fires and volcanoes.

(*Make sure the class understands what emissions are*, since this is an important concept of this lesson and the Smog City 2 Web site used as the basis for this lesson.) *Ask the class* if they know what emissions are. Based on their responses, guide the class to understand that emissions are releases of pollutants from cars and trucks, factories, power plants that make electricity, and even activities we do at home, such as using wood-burning stoves and fireplaces.

Weather can also affect particle pollution. Wind can blow particle pollution away from where it was produced to distant areas. Particle pollution can occur at any time of year, but is often especially bad in the winter, when the winds are calm and when temperature inversions occur. An inversion is when a layer of warm air traps cold air beneath it, including any pollutants in the cold air.

Tell the class that the Air Quality Index, or AQI, tells how clean or polluted the air is in a specific location each day. The AQI has six categories for air quality: Good (green), Moderate (yellow), Unhealthy for Sensitive Groups (orange), Unhealthy (red), Very Unhealthy (purple), and Hazardous (maroon). Tell students that you will discuss the AQI more as the lesson continues.

Particle pollution can be part of "smog"—a term that originally meant a combination of smoke and fog. These days, smog refers to a combination of chemicals and particles. Tell students that they will be playing an online computer game called Smog City 2 about particle pollution that lets them change things like the weather, emissions from cars and power plants, and population to see how these changes affect particle pollution.

Materials Needed

- Internet access
- Teacher Answer Sheet (included)
- Student Worksheet (included)

Key Questions

- What is particle pollution? (*Answer:* Particle pollution is one type of air pollution that is made up of tiny particles of dust, dirt, smoke, and liquid droplets that may contain chemicals.)
- Can people's activities affect air pollution? How? (*Answer:* Yes. Vehicles, power plants, and factories are major sources of air pollution.).
- Can the weather affect air pollution? How? (*Answer:* Yes. See the third paragraph under *Background Summary* above.)
- Can particle pollution affect people's health? How? What can people do to protect their health from air pollution? (*Answer:* Particle pollution can irritate the eyes, nose, and throat; cause coughing, chest tightness, and shortness of breath; and can make asthma and heart disease worse. When particle pollution levels are "Unhealthy"—a "red" air quality day according to the Air Quality Index (AQI)—people with heart or lung disease (including asthma) and older adults and children are advised to avoid strenuous activities. The AQI also provides other health messages for other air quality conditions.)

- What can people do to reduce air pollution? (*Answers might include:* Drive less; take buses, trains, and subways; walk and bicycle. If you drive, drive a hybrid or other car that produces fewer emissions. Use lawnmowers that don't use gasoline or electricity. Reduce use of wood-burning stoves or fireplaces. Also, power plants could use wind power, solar power, or hydroelectric power instead of coal, oil, or natural gas. Factories can use cleaner technologies that produce fewer emissions. Companies can make and sell fuels for cars from waste products instead of gasoline.)

Vocabulary

Emissions—Substances released into the air that may contain pollutants from a variety of sources and activities, including vehicles, factories, power plants that make electricity, and wood-burning stoves and fireplaces, among others.

Particle pollution—Tiny particles of dust, dirt, smoke, and liquid droplets in the air.

Air Quality Index (AQI)—A color-coded scale that provides daily air quality and health information.

Steps

1. Tell students to access the Smog City 2 Web site at www.smogcity2.org and click on "Save Smog City 2 from Particle Pollution." Then have the class minimize the instructions box at the top right of the screen and ignore the "Information" box at the bottom of the screen; they will be exploring several of these concepts in this lesson.

2. Tell the class not to click on anything until you tell them to (it's tempting!). Point out the main categories on the left of the screen with the class, including Weather, Emissions, and Population. Also tell students to notice how each of the settings under these categories are pre-set to a certain level. Tell them that they will explore what happens when they change some of these settings.

   (If students ask, you can mention to students that the "Total Emissions" graph towards the bottom of the page reflects all the different types of emissions at the levels you set when you play the game. Tell them that you will be discussing Emissions later in the lesson. You can also mention that "Random Events" refers to natural events such as fires.)

3. Tell students to look at the black sign in the picture. The signs tells the current temperature and AQI, or Air Quality Index. Remind students that the AQI tells how much air pollution there is.

   Tell students to record the current temperature and the AQI on their Student Worksheet in Question #1—for the AQI, have students enter the AQI under the "Number" column only for now.

4. Tell students to observe the AQI (Air Quality Index) box in the lower right corner of the screen. Tell the class that the default setting is "Red". (Define default for students.) Tell students that the matching health level for a red AQI color is "Unhealthy" (see just below the colored graph where it says "Health.") Under this health level is a corresponding health message.

   Review the health message in the box for a Red, Unhealthy AQI with the class: "People with heart or lung disease, older adults, and children should avoid prolonged or heavy exertion. Everyone else should reduce prolonged or heavy exertion."

5. Tell students to add the "Color" and "Health Level" for the AQI in Question #1 of their Student Worksheet (based on the information reviewed in Step 4).

6. Tell students that it's winter in Smog City 2, so they should change the temperature setting to 30 degrees F (lowest setting, farthest to the left).

   Note: Tell students that settings can be changed by clicking on the new level they want. Remind them to wait until you tell them to change any of the settings.

7. Tell the class that the "Population" setting refers to total population in an area, and it can also refer to the number of people using wood-burning stoves and fireplaces. Keeping the same setting established in Step 6 (that is, tell students not to press the Reset button), have students increase the Population to the highest setting (far right), since more people in Smog City 2 are using their wood-burning stoves and fireplaces this winter.

8. Tell students to record the AQI in Question #2 on their Student Worksheet after they lowered the temperature and raised the Population.

   Ask students: What happened to the AQI when you lowered the Temperature and increased the Population setting? Why do you think this happened?

(Answer: The AQI increased from 157 to 184. This occurred because the increase in wood stove and fireplace use produced more particle pollution. Also, while particle pollution can occur at any time of year, it is often higher in the winter. Note that while the AQI increased, it remained in the same —Unhealthy—category.)

9. Tell the class that the mayor of Smog City 2 has just restricted the use of wood-burning stoves and fireplaces this winter to reduce the Unhealthy level of particle pollution. The west side of the city can burn wood on even calendar days, the east side on odd calendar days.

   Keeping the setting established in Step 8 (don't press Reset), tell students to reduce the Population setting to the second to lowest setting (second from left)—remind students that you are using this setting to represent the number of people using wood stoves and fireplaces.

10. Tell students to record the AQI in Question #3 on their Student Worksheet after they reduced the Population using wood-burning stoves and fireplaces.

    Ask students: What happened to the AQI when you lowered the Population? Why do you think this happened?

    (Answer: The AQI decreased from 184 to 119. The AQI category changed from Unhealthy to Unhealthy for Sensitive Groups. Read the Health Message for "Unhealthy for Sensitive Groups" to the class in the box on the lower right. The AQI decreased because reducing the use of wood stoves and fireplaces reduced particle pollution.)

11. Have the class press the "Reset" button on the lower left side so that everything returns to the original settings.

12. Tell students to observe the current Emissions level for "Cars and Trucks" and record the current AQI on Question #4 of their Student Worksheet.

13. Tell students that the mayor of Smog City 2 has just purchased a whole new fleet of hybrid cars and other fuel-efficient cars and trucks to replace all older cars used by city government workers. Therefore, tell students to decrease the Emissions level from Cars and Trucks to the lowest level to reflect this change.

14. Tell students to record the AQI after they made the change in Cars and Trucks emissions in Question #5 on their Student Worksheet.

    Ask students: What happened to the AQI when you lowered the emissions from Cars and Trucks? Why do you think this happened?

    (Answer: The AQI decreased from 157 to 113. The AQI category changed from Unhealthy to Unhealthy for Sensitive Groups. Read the Health Message for "Unhealthy for Sensitive Groups" to the class in the box on the lower right of the Web page. The AQI decreased because the newer fleet of vehicles purchased by the city produced fewer emissions than the older vehicles.)

15. Tell students that particle pollution can irritate the eyes, nose, and throat; cause coughing, chest tightness, and shortness of breath; trigger asthma attacks; and make heart disease worse.

    (Note: If the class is also studying ozone pollution, you can mention that some of the health symptoms of particle pollution and ozone pollution are similar, such as irritation of the throat, coughing, and aggravating asthma, but some health symptoms are different. For example, particle pollution can make heart disease worse. Particle pollution has been linked to heart attacks.)

16. Tell students to look at the top of the column on the left side of the Save Smog City 2 from Particle Pollution page and click on "Air Quality Index (AQI)" (the second heading).

    Look at the color chart at the bottom of this AQI page with the class and read each different color's health message so that students understand how changes in air pollution, as reflected by changes in the AQI, can affect people's health.

17. Ask students what steps they think they or other people could take to reduce emissions and particle pollution. Add to and discuss the answers, as indicated below, and the rest of the Student Worksheet.

    (Correct answers might include: Drive less; take buses, trains, and subways; walk and bicycle. If you drive, drive a hybrid or other vehicle that releases fewer emissions. Use lawnmowers that don't use gasoline or electricity. Reduce use of wood-burning stoves or fireplaces. Also, power plants could use wind power, solar power, or hydroelectric power instead of coal, oil, or natural gas. Factories can

use cleaner technologies that produce fewer emissions. Companies can make and sell alternative fuels for cars from waste products instead of depending so much on gasoline as a fuel.)

(The class can also have a discussion of electricity and emissions. Tell students that generally, the more electricity that we use, the more electricity that power plants need to produce, which produces more emissions of air pollutants. If we use less electricity, power plants will need to produce less electricity, and will produce fewer emissions. So, turn off lights when you're not using them, and also appliances such as computers, TVs, fans, and air conditioning, and turn down the heat when leaving the house [talk to your parents about this first]).

For Further Exploration

Change some of the other settings in Save Smog City 2 from Particle Pollution, such as Wind, Consumer Products, and Industry, and discuss with the class how these changes can affect particle pollution, the AQI, and health.

To challenge students, conduct the "Save Smog City 2 from Ozone" lesson (or portions of it) in this Toolkit (see Grades 6-8).

See the Temperature Inversion lesson(s) in this Toolkit (one for Grades 3-5, another for Grades 6-8) for information on how temperature inversions can affect air pollution.

Acknowledgments/Resources

Smog City 2, U.S. EPA and the Sacramento Air Quality Management District at: www.smogcity2.org

Next Generation Science Standards

Weather and Climate
Energy
Interdependent Relationships in Ecosystems
Engineering Design
Matter and Energy in Organisms and Ecosystems

Student Worksheet: Save Smog City 2 from Particle Pollution

Name: _____

1. Record the current temperature and AQI in "Save Smog City 2 from Particle Pollution":

   Current temperature:

   Current AQI:

Number	Color	Health Level

2. Record the AQI when you lowered the temperature to 30° F and raised the Population to the highest level:

Number	Color	Health Level

3. Record the AQI after you reduced the "Population" that uses wood-burning stoves and fireplaces.

   Current AQI:

Number	Color	Health Level

4. Record the AQI at the current Emissions level for Cars and Trucks:

Number	Color	Health Level

(continued)

Student Worksheet: Save Smog City 2 from Particle Pollution

Name: _____

5. Now record the AQI when the Emissions level for Cars and Trucks was changed to reflect government use of a new fleet of low-emission cars and trucks (changed to lowest level):

Number	Color	Health Level

Teacher Answer Sheet: Save Smog City 2 from Particle Pollution

1. Record the current temperature and AQI in "Save Smog City 2 from Particle Pollution":

   Current temperature: 50° F

   Current AQI:

Number	Color	Health Level
157	Red	Unhealthy

2. Record the AQI when you lowered the temperature to 30° F and raised the Population to the highest level:

Number	Color	Health Level
184	Red	Unhealthy

   Ask: If the AQI changed when you lowered the temperature and raised the Population, why do you think this occurred?

   Answer: The AQI increased from 157 to 184. This occurred because the increase in wood stove and fireplace use produced more particle pollution. Also, while particle pollution can occur at any time of year, it is often higher in the winter. Note that while the AQI increased, it remained in the same—Unhealthy—category.

3. Record the AQI after you reduced the "Population" that uses wood-burning stoves and fireplaces.

   Current AQI:

Number	Color	Health Level
119	Orange	Unhealthy for Sensitive Groups

Teacher Answer Sheet: Save Smog City 2 from Particle Pollution

Ask: If the AQI changed when you reduced the Population using wood-burning stoves and fireplaces, why do you think this occurred?

Answer: The AQI decreased from 184 to 119. The AQI category changed from Unhealthy to Unhealthy for Sensitive Groups. The AQI decreased because reducing the use of wood stoves and fireplaces reduced particle pollution.

4. Record the AQI at the current Emissions level for Cars and Trucks:

Number	Color	Health Level
157	Red	Unhealthy

5. Now record the AQI when the Emissions level for Cars and Trucks was changed to reflect government use of hybrid cars (changed to lowest level):

Number	Color	Health Level
113	Orange	Unhealthy for Sensitive Groups

Ask: If the AQI changed when you reduced Emissions from Cars and Trucks to reflect the city's purchase of a fleet of newer low-emission cars and trucks, why do you think this occurred?

Answer: The AQI decreased from 157 to 113. The AQI category changed from Unhealthy to Unhealthy for Sensitive Groups. Read the Health Message for "Unhealthy for Sensitive Groups" to the class in the box on the lower right of the Web page. The AQI decreased because the newer fleet of vehicles purchased by the city produced fewer emissions than the older vehicles.

Student Handout

Breathe Smart! Four Things KIDS Can Do

1

Find out what AQI color for today is where you live.

- Visit the AIRNow Web site at www.airnow.gov.
- Tell your parents about the AQI so they can help you.

2

Protect your health when the air is dirty.

- Take it easier when you play outside.
- If it feels harder to breathe, tell an adult.

3

Help reduce pollution.

- Turn off lights, TVs, and computers when not using them.
- Walk, bike, or take a bus or train with an adult. But remember, your safety always comes first!

4

Visit the AQI kids' site at www.airnow.gov
(click on "Kids" in the "Learning Center")

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Grades 6-8


Good
Moderate
Unhealthy for Sensitive Groups
Unhealthy
Very Unhealthy

Key Messages: Grades 6-8

- Breathing polluted air is unhealthy. For example, you might find it more difficult to breathe, you might cough or wheeze, or your chest might feel tight.
- You can't always tell if the air is polluted by how it looks. The Air Quality Index, or AQI, can help.
- Two main types of air pollution are ozone pollution and particle pollution.
- The ozone we breathe at ground level is bad. But very high in the atmosphere (the stratosphere) is a natural layer of ozone that is good because it helps protect us from the sun's harmful ultraviolet rays. A rhyme that can help you remember this is: "Ozone: Good up high, bad nearby."
- You can protect your health in three ways when the air is polluted:

  1. Find out the air quality each day.

     - You can do this by checking the AQI (the Air Quality Index), just like checking the weather report. The AQI uses color-coded maps and health messages to tell you how clean or polluted the air is. For example, green means the air is clean. Red means the air is unhealthy for everyone.
     - You can always find the AQI on the Internet at a site called AIRNow at: www.airnow.gov. You also might hear about the AQI on TV during the weather forecast or on the radio, or you might see it on the weather page in the local newspaper. Download the AirNow App to get the AQI on your smartphone.

  2. If you're outside when you know the air is polluted, you can protect your health by taking it easier. It's important to exercise and be active to maintain good health. But when the air is polluted, you can reduce the time you spend exercising, walk instead of run, take frequent breaks, or go outside at another time or on another day when the air is cleaner.
  3. If you notice any symptoms when you're outside like coughing, pain when you take a deep breath, chest tightness, or wheezing, stop your activity and tell an adult. This is especially important if you have asthma.

- Both people's activities (such as transportation, energy use, and materials production) and nature (such as forest fires and volcanic eruptions) can cause air pollution.
- You can help reduce pollution. For example, turn off lights and equipment that use energy when you don't need them. Walk, bike, carpool, or use public transportation when possible instead of having someone drive you.

Lesson Plans

Symptoms Scenario

Learning Objectives

Students will:

- **Identify some of the health symptoms associated with specific air pollutants (ozone and particle pollution).**
- **Identify preventive measures that people can take to protect their health.**
- **Understand which segments of the population are most at risk from air pollution.**

Grade Level: Grades 6-8

Estimated Time: 2 hours

Background Summary

Breathing clean air is important to maintain our health. Millions of Americans live in areas where the air is sometimes considered unhealthy to breathe because it is polluted. One common air pollutant is ground-level ozone. The effects of ground-level ozone pollution are different than the effects of the ozone layer high up in the atmosphere, which helps protect us from receiving too much of the sun's ultraviolet radiation. At ground level, ozone can cause breathing difficulties, aggravate lung diseases, such as asthma, and may cause permanent lung damage. An easy way to remember the different types of ozone is: "Good up high, bad nearby." Ground-level ozone pollution is formed when certain pollutants, known as precursors, are released from vehicles, industries, and power plants, and in the presence of sunlight and heat react together to form ozone.

Another common air pollutant is particle pollution, which can cause breathing difficulties, aggravate heart disease as well as lung disease, and may cause chronic bronchitis or reduced lung function in children. Particle pollution consists of tiny particles of dust, dirt, smoke, and liquid droplets that contain chemicals.

In this lesson, students first read background materials about the health impacts of air pollution, followed by a teacher-led discussion. Students then role-play realistic case studies, as patients with health symptoms and their family members. The rest of the class interviews the patient and family members to try to determine which air pollutant may have caused the symptoms. The class then discusses what they can do to protect their health when air quality is poor.

Materials Needed

(one copy of each of the following materials is included in this lesson)

- Background Reading: What Are the Health Impacts of Air Pollution? (one for each student)
- Pollutants Chart: Sources and Effects of Air Pollutants (one for each student)
- Group Task Cards (one set for each of three groups; cut to card size before distributing)
- Symptoms Scenarios A, B, and C (a different scenario for each of the three groups)
- Student Worksheet #1: What Are the Health Impacts of Air Pollution? (one for each student)
- Student Worksheet #2: Which Pollutant? (one for each student)
- Teacher Answer Sheet #1: What Are the Health Impacts of Air Pollution?)
- Teacher Answer Sheet #2: Which Pollutant?

Key Questions

- Do you think that air pollution levels in your area could be high enough to affect people's health? If so, what might some sources of air pollution be in your area? (See Step 1 below.)
- What do you think some of the health effects are that people living in areas with high levels of air pollution might experience? (*Answer:* Ozone can cause breathing difficulties, aggravate lung diseases, and may cause lung damage. Particle pollution can cause breathing difficulties, aggravate heart disease or lung disease, and may result in chronic bronchitis or reduced lung function in children.)

Vocabulary

Ethical—Behavior considered good or right.

Susceptible—Vulnerable or predisposed to certain effects. A member of a population who is at risk of getting a disease or illness if exposed to something that causes the disease or illness.

Ozone pollution—Ozone is an air pollutant when near the Earth's surface. (In contrast, in the Earth's upper atmosphere, ozone protects people from receiving too much ultraviolet radiation from the sun.)

Particle pollution—Tiny particles of dust, dirt, smoke, and liquid droplets in the air.

Precursor—A compound that participates in a chemical reaction that produces another compound.

React—When two or more chemicals interact and form a new product.

Steps

1. If you haven't already done so, ask students if they think air pollution levels in your area could be high enough to affect people's health. If so, what might some sources of air pollution be? Hold a brief class discussion of their answers.

   (*Possible answers:* Cars and other vehicles, dust from construction sites, smokestacks from factories and power plants, yard burning, fireplaces and wood stoves. Also see the enclosed Pollutants Chart: Sources and Effects of Air Pollutants.)

2. Either as homework the night before or in-class, have students read Background Reading: What Are the Health Impacts of Air Pollution? and Pollutants Chart: Sources and Effects of Air Pollutants. Then have them complete Student Worksheet #1: What Are the Health Impacts of Air Pollution? Tell students to keep all three of these items for future use.

3. Hold a brief class discussion of the reading, chart, and students' Worksheet #1 responses. Discussion could include teacher prompts such as: Did you know about the health effects of air pollution discussed in the Background Reading and the Pollutants Chart? Were you surprised at any of these health effects? Have you or anyone you've known experienced any of these effects?

4. Select 12 students and divide them into three groups of four students each for role-playing.

   Distribute materials (below), some to the groups and others to the rest of the class, as indicated:

To the three groups of role-playing students:

- Symptoms Scenario (hand out Scenario A to one group, Scenario B to a second group, and Scenario C to the third group)
- Group Task Cards (after cutting them to size, give a full set of 4—Patient, Family Member (or Second Patient), Class Monitor, and Scribe—to each group)

To the rest of the class:

- Student Worksheet #2: Which Pollutant? (one for each student)
- Background Reading, Pollutants Chart, and Student Worksheet #1 (previously distributed; provide to students who don't have these with them, if done as homework)

5. While the rest of the class is reviewing the materials distributed in Step 4, explain to students in the three role-playing groups that each member of their group will choose and assume a specific responsibility, as defined on the Group Task Cards, and will present their Scenario to the class.

   Explain that one "patient" and one "family member" (or, "second patient") from each group will introduce themselves to the class (acting skills welcome!) based on the information in their Symptoms Scenario. Another group member will act as class monitor, maintaining order during questions and answers; and another will act as scribe, writing answers on the board. Each of the cards describes the tasks in more detail.

6. Give the groups time to prepare (5 to 10 minutes), allowing them to briefly read and discuss their Symptoms Scenario and Group Task Cards amongst themselves to prepare for their presentations, while the rest of the class continues to review the materials distributed in Step 4 and proceeds with Step 7.

7. Tell students in the audience that they are going to be "doctors" trying to determine the pollutant most likely associated with or causing the symptoms presented. Tell them to listen carefully to each of the three presentations and make doctor's notes on Worksheet #2: Which Pollutant? as they listen. Tell them they will be asking the patient and family member in each group questions to help the class come up with answers.

8. Have the first group present its Symptoms Scenario to the class. Assist the group as needed.

9. After the presentation, tell the rest of the class to go ahead and ask "doctor" questions to try to determine possible causes of the symptoms. Tell them they can use their Student Worksheet #2: Which Pollutant?, the Pollutants Chart, and the background reading as guides. Have the presenters respond. Assist the class as needed in asking targeted questions to obtain pertinent information included in the Symptoms Scenarios.

   Each presenter should respond as best they can, based on their Scenario. Other members of their group (e.g., family member, class monitor, scribe) can help them answer questions.

10. At the beginning of this Step, give the role-playing groups the Pollutants Chart and Student Worksheet #2 so they have the same information as the rest of the class.

    After a reasonable amount of time questioning the Scenario presenter group, have the class as a whole (presenting group, other groups, and audience) together continue to try to determine the pollutant associated with or causing the symptoms, as well as identify health prevention measures, with teacher guidance—but don't tell students yet which pollutant it is or possible preventive measures.

    See Teacher Answer Sheet #2: Which Pollutant? for information on symptoms and other "hints" of information that might be shared with the class at this point.

    Discourage students from arriving at answers too quickly. Encourage questions about other aspects of the patient's life (e.g., cigarette smoking) that could also be an influence. Inform students that even when air pollution is a primary factor, many other factors can still influence our health.

11. Have students write down their answers on Student Worksheet #2: Which Pollutants?

12. Using Teacher Answer Sheet #2: Which Pollutants?, share and discuss the answers with the class, including the pollutant most likely associated with or responsible for each group's symptoms/illness, and precautions that people can take to protect their health.

13. Repeat Steps 8 through 12 with each of the other two groups.

Adaptation

If time is limited, have only one or two groups make presentations. (Note: Two groups, one group illustrating ozone symptoms and a second group illustrating particle pollution symptoms, is preferable.)

For Further Exploration

1. Imagine that you and a friend started working out and running together a few weeks ago, meeting each day at 5:00 p.m. Today your friend proposes trying a new jogging route. One possibility is at a large park on the outskirts of town, and another is along a major highway. Explain which route you prefer and why.

   Answer: The park would be preferable. This would help avoid exposure to high levels of air pollutants, especially from motor vehicles.

2. Imagine that you have been training for a bicycle race, and the day of the race is here. The Air Quality Index (AQI) value for today in the area where the race is taking place is 215, based on ground-level ozone. One group of cyclists is asking the race committee to reschedule the race. Another group of cyclists is upset that the race may be rescheduled. Explain which group you agree with, and why the group requesting rescheduling might be asking for this change in plans.

   Tell students to look at the AQI chart in the Background Reading material, What Are the Health Impacts of Air Pollution? to help them make a decision about the bike race.

   Answer: Many athletes would probably want the race to be rescheduled so they could avoid strenuous exercise when the AQI has reached a value of 215, which is considered "Very Unhealthy"—see the AQI chart in the Background Reading material, What are the Health Impacts of Air Pollution? According to the AQI chart, "health alerts" begin at an AQI value of 201, up to 300. At this level, the chart tells us that "everyone may experience more serious health effects." EPA guidelines for the "Very Unhealthy" AQI category for ground-level ozone suggest that "active children and adults, and people with lung disease such as asthma, should avoid all outside physical activities. Everyone else, especially children, should significantly cut back on outside physical activities."

Acknowledgments/Resources

Adapted from *Students for Clean Air*, Clean Air Program, Pima County Department of Environmental Quality, Tuscon, Arizona.

Next Generartion Science Standards

Interdependent Relationships in Ecosystems
Human Impacts
Engineering Design

Background Reading: What are the Health Impacts of Air Pollution?

Air Pollution and Our Health

Every minute of every day, we breathe six to ten liters of air. If the air carries unhealthy levels of pollutants, those pollutants can enter our bodies and affect us in many ways. Millions of Americans live where the air is often unhealthy to breathe. Enough people are affected so that the health impacts of air pollution costs us millions of dollars every year.

Air pollution is especially harmful to the very young and old. Infants and children are at risk because their lungs are not fully developed until they are about 18 years old and because they breathe faster. The elderly are at risk because they are more likely to have undiagnosed heart or lung disease.

Since the respiratory system comes in direct contact with the air we breathe, it is the body system most likely to be affected by air pollutants. People who already have asthma, emphysema, or other respiratory conditions, as well as people with heart or other circulatory problems, are especially susceptible to the effects of air pollution.

Even healthy people can be affected by air pollution. Air pollution can affect anyone. Healthy teenagers, young adults, and strong athletes can suffer negative effects from high pollution levels, especially when exercising outdoors.

A Tricky Question

It's a real challenge for scientists to study the health effects of different air pollutants. It wouldn't be ethical for researchers to put people in a lab and expose them to high levels of a pollutant. Also, outside the lab, people who live in heavily polluted areas are exposed to not just one pollutant but to many pollutants. And, the concentration of each pollutant changes during the day. All of this makes it difficult to separate out the effects of each pollutant.

In addition, how susceptible people are to the effects of air pollutants can vary widely. Think about a roomful of healthy people who are all exposed to the same cold virus. Some will develop a bad cold, others a mild cold, and others no cold at all. In a similar way, susceptibility to pollutants can vary greatly even among a group of healthy individuals.

Finally, there are always many influences on our health. If you develop symptoms that might be caused by air pollution, it's often difficult to be sure that pollution was "the"

cause. Just as with other health problems, there are likely to be several factors affecting your health.

How Much Do We Know?

One way to study the relationship between air pollution and health is to compare hospital records and death records to pollutant levels. Researchers have found that during extreme air pollution events, hospital admissions for respiratory problems increase. Death rates also increase, especially among the elderly and those who already have circulatory or respiratory problems.

Another type of research involves evaluating the physiological effects of exposure to pollution. In general, we know that exposure to irritants in the air can cause inflammation and bronchioconstriction of the airways and reduce the effectiveness of bacteria-destroying white blood cells. Irritants can also increase production of mucous, which, although annoying, helps the cilia clear out the airways. Normally, the cilia of the epithelial cells in the airways make sweeping movements to keep the airways clean. The cilia move mucous, along with germs and dirt caught in the mucous, out of the respiratory tract. Air pollutants can irritate or kill the cells with cilia, so that the cilia's protective action slows down or even stops. This leaves sensitive tissues unprotected. Then microorganisms and bits of foreign matter in the air are more likely to remain in the lungs and can cause infections.

Although the part of our bodies most affected by air pollution is the respiratory system, the circulatory system can also be affected. Exposure to unhealthy levels of air pollutants can result in low oxygen levels in red blood cells, abnormal heart rhythms, and increased risks of blood clots and narrowing of blood vessels. These effects can lead to worsening of heart diseases such as heart failure and increased risks of heart attacks or strokes.

The *Pollutants Chart: Sources and Effects of Air Pollutants* summarizes the sources and health effects of two air pollutants: particle pollution and ground-level ozone. When we inhale particle pollution (dust, soot, dirt, and liquid droplets, which may or may not be visible), tiny bits of foreign matter can travel deep into the lungs where they become lodged in the alveoli, which are small balloon-like sacs in which oxygen exchange occurs. This is where carbon dioxide from the blood is exchanged for oxygen from the air. Some particles can be exhaled or moved out by the cilia; other particles may sink into underlying tissue or move into the blood stream. Health effects from particles range from coughing and aggravated asthma to chronic bronchitis and even premature death. For people with heart disease, exposure to particle pollution can cause serious problems in a short period of time—even heart attacks—with no warning signs.

Ozone pollution, which is invisible, can irritate the respiratory system, reduce lung function, inflame and damage the lining of the lungs and the cilia, and cause structural damage of the lungs. Ozone pollution can also reduce the number and functioning ability of bacteria-destroying white blood cells. Ozone pollution can aggravate asthma and increase people's susceptibility to respiratory illnesses like pneumonia and bronchitis. Symptoms to watch for when ozone is in the air include coughing, pain when taking a deep breath, and breathing difficulties, especially when active or exercising outdoors. But ozone damage can also occur without any noticeable signs. For some people, several months of repeated exposure to ozone can permanently damage the lungs.

It is important to know that ozone can have two very different effects, depending on where it is in the atmosphere. "Good" ozone occurs naturally high up in the atmosphere (the stratosphere), where it helps protect us from receiving too much of the sun's harmful ultraviolet rays. "Bad" ozone at ground level is air pollution, as we have been discussing, and can result in health and environmental problems. An easy way to remember the difference is: "Ozone: good up high, bad nearby."

The Air Quality Index (AQI)

The Air Quality Index (AQI) provides information about the current day's and the next day's air quality and includes descriptions of associated health effects. Ground-level ozone and particle pollution are two of the five pollutants for which the U.S. Environmental Protection Agency calculates an AQI. The AQI is like a yardstick that runs from 0 to 500. The higher the number, the greater the air pollution. The AQI has six color-coded categories ranging from "Good" to "Hazardous." Each category corresponds to a different level of health concern. The chart below lists the AQI categories, their corresponding colors and numerical values, and associated health concerns for each category.

(Source: *Students For Clean Air. Clean Air Program*, Pima County Department of Environmental Quality, Tucson, Arizona)

Air Quality Index (AQI)

The Air Quality Index (AQI)

AQI Category	Color	Numerical Value	Health Concerns
Good	Green	0-50	Air quality is considered satisfactory, and air pollution poses little or no risk.
Moderate	Yellow	51-100	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	Orange	101-150	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	Red	151-200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	Purple	201-300	Health alert: everyone may experience more serious health effects.
Hazardous	Maroon	>300	Health warnings of emergency conditions. The entire population is more likely to be affected.

More information about the AQI is available at www.airnow.gov

Pollutants Chart:
Sources and Effects of Pollutants

Pollutant	Sources	Possible Effects on Humans	Other Effects	Comments
Particle pollution (also called particulate matter, or PM)	• Dust • Motor vehicle exhaust • Factories • Burning of coal for power • Natural sources: forest fires, volcanoes	• Irritates nose & throat • Difficult or painful breathing • Coughing, chest tightness • Reduces lung function • Lowers resistance to respiratory infection • Aggravates asthma and existing lung & heart disease • Chronic bronchitis or reduced lung function in children (long-term exposure) • Premature death	• Reduces visibility • Discolors statues, buildings, painted surfaces • Interferes with photosynthesis, may damage crops • May alter climate	• 75% from motor vehicles • Usually refers to particles less than 10 (PM_{10}) or 2.5 ($PM_{2.5}$) microns 1 micron = 1/1,000,000 of a meter) Particle pollution is often worse in winter, and near busy roads or factories.
Ground-level Ozone (O_3)	• Formed when nitrogen oxides (NO_x) and volatile organic chemicals (VOCs) react in heat and sunlight • Sources of NO_x and VOCs include vehicle exhaust, industrial emissions, gasoline vapors, and chemical solvents.	• Coughing, wheezing, pain with deep breathing, shortness of breath • Nausea • Irritates respiratory system, chest tightness • Damages lung tissue • Reduces lung function • Aggravates existing lung diseases, including asthma • Structural changes (long-term exposure) • Premature death	• Deteriorates rubber, paint, some building materials • Damages fruits and seeds • Injures crops and trees • Affects whole ecosystems by altering wildlife habitat	Ozone pollution is often worse in warmer weather, in late afternoons and early evenings. Ozone is good up high in the upper atmosphere where it helps protect us from too much of the sun's harmful ultraviolet rays. Ozone is bad at ground level where it can result in health and environmental problems. Remember: "Ozone: good up high, bad nearby".

Symptoms Scenario A

Patient: Francisco (if man) or Francesca (if woman) Grijalva
Family Member: Jorge Grijalva (cousin)

Patient—*Use this information to introduce yourself and your family member to the class:*

My name is Francisco (or Francesca) Grijalva. I used to be a runner years ago. I stopped for a few years, but took it up again last year. Lately I've been feeling short of breath in the middle of my run. This is my cousin Jorge, who is also my roommate. He'll tell you that I'm a pretty serious runner.

Patient and Family Member—*Use this information to answer class questions about the patient:*

- 34 years old
- Lives and works in _____ [fill in name of nearby city or town]
- Works as a computer programmer
- Works with a small, independent company
- The office building he works in is well-ventilated
- Running is an important personal interest
- Other hobbies include hiking, bird-watching, and surfing the Net
- Smoked from age 14 to 16, but "I quit when I got smart enough to know better"
- Roommate smokes, but only outside, so Francisco is not breathing Jorge's smoke
- Ran pretty regularly from age 20 to around age 30
- Started running again last year, in December
- Ran in the early morning, about 6:00 to 6:30 a.m., all winter
- In April, started working an early schedule and running after work, around 2:00 pm
- Last winter, felt refreshed and really "up" after running, just like years ago
- Has been running very regularly and is confident he's in good shape
- Lately has been feeling short of breath halfway through a run
- He also notices that he seems to cough and needs to spit while running, which didn't happen before
- Has never had any lung or respiratory problems in the past
- Cousin Jorge will vouch that Francisco has been running as regularly as he says—five or six times a week, for over a year—so this can't be happening because he's in poor shape

Symptoms Scenario B

Patient: Chris Chapman
Family Member: Rose Chapman (his wife)

Patient—Use this information to introduce yourself:

My name is Chris Chapman. I have been having chest pain and chest tightness for the last two or three months. Since these problems don't seem to be going away, I went to see my doctor last week. She told me that I have arrhythmia, which is an irregular heartbeat. I had a minor heart attack when I was 56, but have felt pretty good since then.

Patient and Family Member—Use this information to answer class questions about the patient:

- Chris is 62 years old
- He retired early, at age 50
- Never smoked cigarettes or anything
- Used to work for the city as a technician installing and repairing traffic lights
- They live in the city of _____ [fill in nearby city] because they like living near their children and grandchildren
- Love kids
- Every Monday through Friday, ever since retiring, Chris volunteers as a school crossing guard at a busy intersection, helping kids get across the street
- He does this for an elementary school and a middle school, that start at two different times, so he's out there almost two hours early each morning and two hours each afternoon
- Likes to wear white shirts, even though they always look really dirty after doing the crossing guard work
- They live in an apartment near the same intersection
- Several factories are nearby
- His hobbies include bowling, going to grandchildren's soccer and softball games, babysitting for the youngest granddaughter, and staying in close touch with world news
- Not really into exercise or working out
- Rose and Chris take a walk around the neighborhood a couple of times each week, usually right after he finishes crossing guard duty

Symptoms Scenario C

Patient: Jerry Wolak
Second Patient: Dot Wolak

Patient: *Use this information to introduce yourselves:*

My name is Jerry Wolak and this is my wife Dot. We live in _____ [fill in nearby city or town]. We came back from our afternoon walk feeling just awful.

Patient and Second Patient: *Use this information to answer class questions about the patients:*

- He's 58 years old
- She's 48 years old
- They take a brisk walk together almost every day, in mid-afternoon
- Usually walk two miles, along a local canal, where it's quiet and there's no traffic
- Jerry's interests include cooking, woodworking, and fishing
- Dot's interests include painting and playing drums with a jazz band
- Today was a beautiful sunny day and the first really hot day of spring
- Today they took a different route than usual
- The traffic was backed up for several blocks on one road, and they were curious why, so they decided to turn up that road and see for themselves
- Ended up sitting by the road for an hour in the middle of the walk, talking with a friend who was stuck in the giant traffic jam
- Near the end of the walk, both Jerry and Dot started wheezing and coughing
- Dot was feeling some nausea
- Jerry felt like his asthma was acting up for the first time in years

Group Task Cards

GROUP TASK CARD

PATIENT

You will play the role of the primary character described on the Symptom Scenario card. Using information on the card, you will introduce yourself to the class and then answer questions from them. A member of your family will help you answer questions. After some time has passed, if you feel that there is important information on your Scenario card that has not been covered by the questions, you may decide to volunteer that information.

GROUP TASK CARD

FAMILY MEMBER (or SECOND PATIENT)

You will play the role of someone in the patient's family. The patient will introduce you to the class, using information on the Scenario card. You will then help the patient answer questions from the class. If questions are asked which are not answered on the Scenario card, you will consult with the patient about how to best answer the questions (in a way that would not alter the conclusion reached by the class).

GROUP TASK CARD

CLASS MONITOR

It is your responsibility to maintain order and designate whose turn it is to ask a question. Call on those with their hand raised so that they can ask questions one at a time and everyone can hear the answers. You will want to pace the questions so that the Scribe has time to write the answers on the board.

GROUP TASK CARD

SCRIBE

You are responsible for writing information on the board as the patient and his or her family member answer questions from the class. Making a list of this information will make it easier for the class to focus on what they know so far, choose good questions to ask next, and determine the pollutant that is associated with or causing the patient's symptoms.

Student Worksheet #1:
What are the Health Impacts of Air Pollution?

Name: _____

Complete this worksheet after reviewing *Background Reading: What Are the Health Impacts of Air Pollution?* and the *Pollutants Chart: Sources and Effects of Air Pollutants.*

Use the back of this page if more space is needed.

1. How much air do we breathe every minute?

2. Which body system is most likely to be affected by air pollutants?

3. Who is affected by air pollution?

4. Why is it difficult to determine the health effects of different air pollutants?

5. Briefly explain how researchers study the health impacts of air pollution.

6. Which system, besides the respiratory system, can be affected by air pollution?

7. Describe the health effects of particle pollution.

8. Describe the health effects of ground-level ozone.

Student Worksheet #2: Which Pollutant?

Name: _____

Refer to the *Background Reading: What Are the Health Impacts of Air Pollution?* and the *Pollutants Chart: Sources and Effects of Air Pollutants* as needed as you try to determine the following information about the "patients" in each group. Enter your answers for each patient below during group presentations and afterwards during class question and answer sessions. You will be seeking information about:

- **Symptoms—**Note key symptoms or behaviors in the patient.
- **Pollutant most likely to be associated with or causing symptoms—** Note the pollutant most likely to be associated with or cause these symptoms.
- **Health Precautions—**Note precautions that could have been taken to prevent or decrease the likelihood of the problem arising.

1. Francisco (or Francesca) Grijalva (young adult runner)

Symptoms:

Pollutant most likely to be associated with or causing symptoms:

Health Precautions:

(continued) Student Worksheet #2: Which Pollutant?

2. Chris Chapman (crossing guard)

Symptoms:

Pollutant most likely to be associated with or causing symptoms:

Health Precautions:

3. Jerry and Dot Wolak (middle-aged walkers)

Symptoms:

Pollutant most likely to be associated with or causing symptoms:

Health Precautions:

Teacher Answer Sheet #1: What are the Health Impacts of Air Pollution?

[Instruct students to complete Worksheet #1 after reviewing the *Background Reading: What Are the Health Impacts of Air Pollution?* and the *Pollutants Chart: Sources and Effects of Air Pollutants*]

1. How much air do we breathe every minute? *Answer:* 6 to 10 liters of air.

2. Which body system is most likely to be affected by air pollutants?

   Answer: Since the respiratory system comes in direct contact with the air we breathe, it is the body system most likely to be affected by air pollutants.

3. Who is affected by air pollution?

   Answer: Air pollution can affect anyone. People with lung disease (and heart disease, for particle pollution), children, adults who are active outdoors, and older adults are at greater risk from air pollution. But even healthy teenagers, young adults, and strong athletes can experience negative health effects from high levels of air pollution, especially when exercising outdoors.

4. Why is it difficult to determine the health effects of different air pollutants?

   Answer: First, it would not be ethical for researchers to put people in a lab and expose them to high levels of a pollutant. Second, people who live in heavily polluted areas often are exposed to more than one pollutant. In addition, the concentration of each pollutant changes during the day. All of this makes it difficult to separate out the effects of each pollutant. Also, some people are more susceptible to the effects of air pollutants than other people.

5. Briefly explain how researchers study the health impacts of air pollution.

   Answer: One way to study the relationship between air pollution and health is to compare hospital records and death records to pollutant levels. Researchers have found that during extreme air pollution events, hospital admissions for respiratory problems increase. Death rates also increase, especially among the elderly and those who already have circulatory or respiratory problems.

6. Which system, besides the respiratory system, can be affected by air pollution?

   Answer: The circulatory system.

(continued) Teacher Answer Sheet #1: What are the Health Impacts of Air Pollution?

7. Describe the health effects of particle pollution and ground-level ozone.

   Answer:

   When we inhale particle pollution, tiny particles get deep into the lungs. Particle pollution can:

   - Irritate the eyes, nose, and throat
   - Produce coughing and phlegm
   - Result in chest tightness and breathing difficulties
   - Aggravate lung disease (including asthma) or heart disease
   - Reduce lung function in children (long-term exposure)
   - Cause chronic bronchitis (long-term exposure)
   - Result in premature death

   When we inhale ozone, we may experience:

   - Coughing, wheezing, shortness of breath
   - Throat irritation, chest tightness
   - Pain with deep breathing
   - Reduced lung function
   - Aggravated lung disease, including asthma
   - Structural changes of the lungs (long-term exposure)
   - Premature death

   Aggravation of heart or lung disease can lead to:

   From exposure to ozone–

   - Increased medication use
   - Increased school absences
   - More doctor visits

   From exposure to both particle pollution and ozone–

   - More symptoms of ill health
   - More emergency room visits
   - Increased hospital admissions
   - Increased number of deaths

Teacher Answer Sheet #2: Which Pollutant?

Note: Instructions to students on Student Worksheet #2 are: Refer to the *Background Reading: What Are the Health Impacts of Air Pollution?* and the *Pollutants Chart: Sources and Effects of Air Pollutants* as needed as you try to determine the following information about the "patients" for each group. Enter your answers for each patient below during group presentations and afterwards during class question and answer sessions. You will be seeking information about:

- **Symptoms—**Note key symptoms or behaviors in the patient
- **Pollutant most likely associated with or causing symptoms—**Note the pollutant this is most likely to be associated with or causing these symptoms
- **Health Precautions—**Note precautions that could have been taken to prevent or decrease the likelihood of the problem arising

1. Symptoms Scenario A: Francisco (or Francesca) Grijalva (young adult runner)

Symptoms: Feeling short of breath, coughing and spitting while running, symptoms occurring during outdoor exercise on summer afternoons

Pollutant most likely associated with or causing symptoms: Ground-level ozone

Health Precautions: Exercise outdoors in the early morning before ozone levels begin to rise

Teacher Notes for Discussion of Symptoms Scenario A: Exposure to high ground-level ozone concentrations can affect even healthy teens and active adults. In this scenario, the time of day and time of year during which the problem occurs provide clues that ground-level ozone, rather than another pollutant, is likely to be responsible.

2. Symptoms Scenario B: Chris Chapman (crossing guard)

Symptoms: Chest pain and chest tightness, previous heart attack, white shirt gets dirty after crossing guard work

Pollutant most likely associated with or causing symptoms: Long exposure to high levels of air pollutants, especially particle pollution, from work installing traffic lights, working as a crossing guard, and taking walks in the area

(continued) Teacher Answer Sheet #2: Which Pollutant?

Health Precautions: Check the AQI when particle pollution is "Unhealthy." Be sure to take walks on less busy roads with less traffic pollution. (And don't wear white shirts!)

Teacher Notes for Discussion of Symptoms Scenario B: The busy traffic intersection and the presence of several factories in the area are indications that high amounts of particle pollution may be present. Also, particle pollution can be high at any time of day or year, even early mornings, and in winter (while ozone is usually higher in the afternoons and evenings, in warmer weather.)

3. Symptoms Scenario C: Jerry and Dot Wolak (middle-aged walkers)

Symptoms: Wheezing and coughing, feeling queasy, asthma acting up

Pollutant most likely associated with causing symptoms: Ground-level ozone

Health Precautions: Avoid exercising along busy roads. Avoid exercising during the times of day when ozone levels are highest (which is late afternoon or early evening).

Teacher Notes for Discussion of Symptoms Scenario C: The time of day (mid-afternoon) and the fact that it's a warm, sunny day are clues that ozone is the problem, in addition to the actual physical symptoms. Even young, trained endurance athletes can suffer similar symptoms at unhealthy ozone levels.

Tracking Air Quality

Learning Objectives

Students will:

- **Observe air quality changes and the impact of weather on air quality.**
- **Demonstrate data gathering and analysis skills and graphing skills.**
- **Apply techniques of comparison and critical thinking.**

Grade Level: Grades 6-8

Estimated Time: 30 minutes - 1 hour per session (6 sessions, optional)

Background Summary

In this activity, students locate and study color-coded maps from the Internet showing air quality data for their area. By graphing the data from these maps and discussing the results, they learn how clean or polluted the air they breathe is, the extent of the ozone season in their area, and the relationship between weather and air pollution. While learning about air pollution, they build their research, graphing, and critical thinking skills.

Through this activity, they also become familiar with the Air Quality Index—a standard index for reporting daily air quality to the public. Students learn how the different colors of the AQI scale correspond to different levels of health concern. They also learn who may be affected at different levels of ozone pollution and particle pollution and what steps can be taken to protect health from air pollution.

Materials Needed

- Internet access
- Student Worksheets (included)
- Colored pencils/markers in black, green, yellow, orange, red, and purple

Key Questions

See questions posed in Activities 1 through 6.

Vocabulary

Ozone—A gas that occurs naturally in the Earth's upper atmosphere (stratosphere) and also at ground level. Ozone can be "good" or "bad" for people's health and the environment, depending on its location. High up in the atmosphere, ozone helps protect people from too much ultraviolet radiation from the sun. Near the Earth's surface, ozone is an air pollutant that can result in breathing difficulties.

React—When two or more chemicals interact and form a new chemical.

Elevated—Increased in amount or degree.

Episode—Exceeding usual conditions.

Forecast—Predict in advance.

Particle pollution—Tiny particles of dust, dirt, smoke, and liquid droplets in the air.

General Directions

This activity has a number of variations, all of which involve accessing, observing, and gathering data from AQI color-coded air quality maps on the Internet. Students can be assigned an activity on their own, if they have individual access to the Internet. Or, they can work in teams; each team will need Internet access. If teams are used, the work can be divided in a number of ways. For example, each team can graph data for a different year (in which case three teams can be used) and then the teams can compare their data. Or, each team can focus on air quality data for a particular month in each of the three years. The team then can summarize the data for that month and note any trends.

Accessing and Navigating Air Quality Maps

1. Explain that students will research and graph daily changes in ground-level ozone levels. Inform students that the effects of ground-level ozone are different than those of the ozone layer high up in the atmosphere (the stratosphere). The ozone layer helps protect us from too much ultraviolet

radiation from the sun. In contrast, ground-level ozone is a pollutant that can result in breathing difficulties.

2. Provide students with copies of the graph of "Air Quality Versus Time" (Student Worksheet #1). (This graph has an "x" axis labeled "date" with a scale of 31 days and a "y" axis labeled "Air Quality Index" with a scale of 0 to 300. Note: The AQI scale actually runs to 500, a hazardous level that would trigger health warnings of emergency conditions, but pollution levels in the U.S. virtually never rise above 300.)

3. Have each student/team access the following Internet data:

   Archived air quality maps at: www.airnow.gov -

a) Click on the "More Maps" tab.

b) Select "Archived Maps by Region." Here students can see all the maps for a whole month at a time.

c) For "Map Type," select "Ozone" (or "Particles" if you are doing Activity 6). Other options are for "Map Region," "Month," and "Year." You may want the students to choose the region they live in, or you may have them examine a region with more ozone (or particles) such as California or the South. You may want to choose areas in advance so that you know ahead of time that they will be good for teaching purposes.

4. Ask students to click on "Air Quality Index (AQI)" in the "Links A-Z" box to observe the color-coded AQI scale. Each color corresponds to a segment of the AQI scale. Ask students to use colored markers to mark these segments on the "y" axis of their Student Worksheet #1 graph as follows: green = 0 to 50; yellow = 51 to 100; orange = 101 to 150; red = 151 to 200; purple = 201 to 300. Have students label these segments as indicated in the key: good, moderate, unhealthy for sensitive groups, unhealthy, very unhealthy.

5. Ask students to click on "Publications" in the "Links A-Z" box on any page at www.airnow.gov. On the "Publications" page, find the "Air Quality Guide for Ozone." Ask them to look at this guide and notice that the right-hand column has specific messages about how people can protect their health at each different level of ozone pollution.

6. For Activity 4, students will need to access three ozone animation maps located here: www.epa.gov/airnow/teachers/toolkit/maps/. They may need to watch each animation several times to complete the task.

Activity 1: Graph Ozone Levels for the Warm Months of the Year

Estimated Time: 1 hour *(or more depending on the number of students and the number of questions you ask them)*

Summary: At ground level, ozone forms when the chemicals nitrogen oxides (NO_x) and volatile organic compounds (VOC) react in the presence of heat and sunlight. Therefore, ground-level ozone pollution tends to form in warm weather. Each area's ozone season will be as long or as short as the number of warmer months. For this activity, students observe how ozone levels change over several consecutive months and record their observations on the graph "Air Quality Versus Time" (Student Worksheet #1). Students should have a separate graph for each month. If possible, ask students to gather data for all warmer months (i.e., months when temperatures tend to be consistently in the 70s or higher), as well as the cooler month just before and after the warm months. They can gather each month's data fairly quickly by observing the AIRNow Web page that displays all maps for that month (see Step 3 above under "Accessing and Navigating Air Quality Maps"). Though the maps are small, the colors can be observed reasonably well. If there is any question about what the colors are on the map, students can click on the map to observe it in a larger size. For each day of each month, ask students to record on their "Air Quality Versus Time" graph for that month the highest AQI color they see. For example, if they see the colors green, yellow, and orange on a map, they should record that day as "orange" by marking the highest AQI level on the "orange" segment of the "y" axis (i.e., all orange days are marked as "150" which is the highest AQI level for orange; all green days are marked as "50" which is the highest AQI level for green, etc.).

Now ask students to fill out the table "Total Number of Days Each Month with Elevated Ozone Levels" (Student Worksheet #2) to record the total number of days in each month with ozone levels that were green, yellow, orange, and red.

After preparing the graphs and table, students can be asked any or all of the following questions:

1. What was the first day for that year when ozone levels were elevated (i.e., yellow or higher)?
2. What was the last day for that year when ozone levels were elevated?
3. Which month had the most green days?
4. Which month had the most yellow days?
5. Which month had the most orange days?

6. Which month had the most red days?
7. Which month had the most purple days?
8. What was the longest ozone "episode"? In other words, what was the most number of days in a row that ozone was elevated in any of these months?
9. Which month of the year was the worst month for ozone (i.e., had the most days when ozone was higher than green)? Which was the next worse ozone month?
10. Rank the months according to how bad they were for ozone, starting with the worst month at the top and the best month at the bottom. Now think about how hot these months are. What do you notice about ozone levels in hotter months?
11. How many total days over all these months were ozone levels elevated (i.e., higher than green)?
12. What percentage of days over these months were ozone levels elevated?
13. Who are the people that must be careful when ozone is at an orange level ("Unhealthy for Sensitive Groups") or above? (Refer students to "Links A-Z" at the bottom of any page on www.airnow.gov. Click on the "Air Quality Index (AQI)" page, or click on "Publications" and look in the Air Quality Guide for Ozone. Note—The answer is: People with lung disease [such as asthma], and children and adults who are active outdoors.)

Activity 2: Compare Ozone Levels Over Three Years

Estimated Time: 30 minutes *(to answer the questions below after students have prepared the graphs and table as described under Activity 1)*

Ask students to create the graphs and table described under Activity 1 for three archived years of ozone data. For each of the questions under Activity 1, have students compare the answers for the three years to answer these additional questions:

1. Which year had the longest ozone season (i.e., the time period from the first day ozone was observed to the last day)?
2. When you ranked the months from worst to best based on number of days of elevated ozone, were the results the same for each year or different? Does there seem to be any pattern to when ozone levels are elevated in this area? How would you describe that pattern?
3. Children can be sensitive to ozone when it reaches orange levels (see Activity 1, Step 13). During what time period of the year might it be a good idea to check the AQI forecast regularly?

Activity 3: Graph and Compare Ozone Levels in One Region of the U.S. versus Another

Estimated Time: 20 minutes *(after students have prepared the graphs and table as described under Activity 1 for both regions)*

Summary: Different areas of the U.S. have significantly different ozone seasons depending on a number of factors, including climate, pollution sources, and regional transport of pollution away from one area and into another. For this activity, students will create the graphs and table as described under Activity 1 for the same year for two very different areas of the United States. They will answer the questions listed under Activity 1 for each area, and then compare the two areas by answering these additional questions. This will be most interesting if you pick an area that contrasts with your region. For example, if you live in an area where ozone is less often a problem (for example, the Northwest or Hawaii), have students compare that to areas with more frequently elevated ozone levels (such as California, the South and Southwest, and the Mid-Atlantic and Northeast states)—or vice versa. Once the graphs and table have been prepared, ask students to use the data to answer the following questions:

1. Which region has the longest ozone season? By how much do the two seasons differ? Do you think this is related to temperature in these areas?
2. Compare the total number of days in each region that ozone was elevated. How much worse was ozone pollution in one region versus the other?
3. Compare the length of the longest ozone episode in the two regions. Was the longest ozone episode in the region during the longest ozone season?

Activity 4: Graph and Compare Ozone Levels Over the Course of the Day

Estimated Time: 45 minutes

Summary: Ozone levels tend to be lowest in the morning, rise during the afternoon, and then decline later in the evening. This is because (1) temperature and sunlight catalyze the formation of ozone, and (2) the pollutants from human activities (such as transportation) that react to form ozone tend to increase during the day and early evening.

For this activity, students will hypothesize what they expect to observe about ozone levels over the course of a day based on an understanding of how ozone is formed. They will then observe actual ozone levels over the course of three days to test whether their hypothesis is correct. They will record their observations on the table called "Daily Air Quality for _____" (Student Worksheet #3). The rows of the table are marked off in 1-hour increments. The columns correspond to the ozone level (as indicated by the AQI color) for each day.

Start the activity by explaining that ozone at ground level is not emitted directly. Rather, it is formed when two types of pollutants (nitrogen oxides and volatile organic compounds) react in the presence of heat and sunlight. Explain that sources of nitrogen oxides and volatile organic compounds include cars, power plants, and chemical plants. Ask students: If ozone needs heat and sunlight to form, when during the day do you think ozone levels will be highest? Then ask them to record data, as described below, to test their hypothesis.

For this exercise, students will use ozone "animation" maps from three areas of the U.S. that tend to have unhealthy ozone levels in warm months.

Ask students to go to www.epa.gov/airnow/teachers/toolkit/maps/

These maps loop through the ozone levels in 20-minute increments. The date and time are shown on the map. Have the students record the highest AQI color for each hour. The animation is rapid, but tell students they can watch the animation as many times as they need to be able to write down one color for each hour. After the students have filled out all the ozone levels for one day, they should do the same for the second map and then the third. At this point, they should have enough data to answer the following questions:

1. Of the three days, what was the earliest time that ozone was elevated (i.e., above green)?
2. Of the three days, what was the latest time that ozone was elevated?

3. For each day, what time of day was the ozone level the highest?
4. For each day, what time of day was ozone at the green level (i.e., not elevated)?
5. Based on these data, was your hypothesis about ozone correct?
6. When ozone levels are elevated, especially starting at an orange or red level, it's a good idea to take it easier when you're outside (so you don't breathe as much or as deeply). You can cut back on vigorous outdoor activities. If the air quality forecast predicts ozone pollution for a summer day, what time of day should you think about taking it easier?

Activity 5: Graph Real-Time Ozone Data for a Month During Ozone Season

Estimated Time: 20 minutes the first day, 5 minutes per day after that, and 20 minutes for discussion on the final day.

If school is in session in your area during the ozone season, students can track the actual ozone forecast and levels each school day for a month. They can compare the forecast data to the actual data to see how accurate the forecasts are. They can also track the peak temperature each day to see whether there is a correlation between ozone levels and temperature.

Each day, at the same time of day if possible, have students record the following data on the "Daily Ozone Forecast, Peak Ozone Level, and Daily Peak Temperature" table (Student Worksheet #4):

- Ozone forecast. Ask students to visit the AIRNow Web site at: www.airnow.gov. Ask them to record the day's ozone forecast for a city or area that you or they choose. To find an area, enter the zip code in the "Local Air Quality Conditions" box and click GO. Or, click on "U.S. Air Quality Summary" and then click on the area which will be listed under its state. This will bring them to a page that provides "Air Quality Forecast," "Current Conditions," and "Past Air Quality Maps and Data." Students should record both ozone forecasts (Today and Tomorrow), as available, on the Worksheet table. Note that the ozone-specific forecasts are found under "AQI – Pollutant Details" in the "Air Quality Forecast" box.
- Yesterday's peak ozone level. Then ask students to record the peak ozone level for that city for the prior day. Students can access yesterday's peak level data using the "Past Air Quality Maps and Data" box mentioned above. Click on "Yesterday's Maps and Data" to see yesterday's value for ozone.
- Yesterday's peak temperature. Ask students to record the peak temperature by going to www.wunderground.com then entering the city and state or zip code. This will take them to a page of data for that city. Ask them to scroll down the page to an area called "Weather History & Almanac." In this box, for most cities, they will find yesterday's maximum temperature, which they should record on their tables. For cities which yesterday's temperature is not provided, they can click on "Yesterday's Official Weather and Almanac" for nearby areas.

Once students have gathered a month's worth of data, they can answer the following questions:

1. For each day of the month, compare the forecast ozone level with the actual ozone AQI level. For how many days did the forecast accurately predict the day's ozone level? For how many days did the forecast predict that ozone levels would be higher than they were? For how many days did the forecast predict ozone levels would be lower than they were?
2. Calculate the average temperature for all days when the ozone level was green. Then calculate the average temperature for all days when the ozone level was yellow, for all days when the ozone level was orange, and for all days when the ozone level was red. What do you notice about temperature and ozone levels?
3. What ideas do you have for reducing ozone pollution during the day? (Possible answers include: drive less by walking, biking, carpooling, or using public transportation. Turn off lights and equipment when you aren't using them; conserving electricity means less pollution generated by power plants. Every little bit helps!)

Activity 6: Compare Ozone and Particle Pollution

Estimated Time: 30 to 60 minutes depending on how many months of data are gathered.

Summary: Particle pollution and ground-level ozone behave in very different ways. Ground-level ozone forms in warm weather and is generally highest in the afternoon and early evening. Particle pollution can be high at any time of year and any time of day. It can be particularly bad in winter during inversions, when warm air traps pollution in a location for a period of time. For this activity, students will gather data for levels of particle pollution throughout the year and compare these data with what they have observed for ozone in the earlier activities. Have students record their observations on the graph "Air Quality vs. Time" (Student Worksheet 1). Students should have a separate graph for each month.

They can gather each month's data fairly quickly by observing the AIRNow Web page that displays all maps for that month (see Step 3 above under "Accessing and Navigating Air Quality Maps"). Though the maps are small, the colors can be observed reasonably well. If there is any question about what the colors are on the map, students can click on the map to observe it in a larger size. For each day of each month, ask students to record on their "Air Quality Versus Time" graph for that month the highest AQI color they see. For example, if they see the colors green, yellow, and orange on a map, they should record that day as "orange" by marking the highest AQI level on the "orange" segment of the "y" axis (i.e., all orange days are marked as "150" which is the highest AQI level for orange; all green days are marked as "50" which is the highest AQI level for green, etc.).

Now ask students to fill out the table "Total Number of Days Each Month with Elevated Particle Levels" (Student Worksheet #5) to record the total number of days in each month with particle levels that were green, yellow, orange, red, and purple.

Then have students answer these questions:

1. Were there any months when particle pollution was never elevated above the green level?
2. Are there any times of year when particle pollution appears to be worse? How does this compare with ozone?

Explain that particle pollution affects health in a different way than ozone, so the advice given to protect your health when particle pollution is elevated is different than the advice given for ozone. Have students access the *Air Quality Guide for Particle Pollution* by clicking on the AQI colors to the right of the particle pollution maps. Ask:

1. Who is "sensitive" to particle pollution?
2. How does this differ from who is sensitive to ozone pollution?
3. If you have asthma, at what AQI level should you consider taking it easy when you are active outside? (Answer: Orange, unless you are unusually sensitive, in which case, yellow.)

For Further Exploration

If it is winter and you live in an area that tends to have inversions, students can track real-time air pollution data for particle pollution, as well as temperature and wind speed, as described for ozone under Activity 5. Also, have students track local weather reports for information on when temperature inversions are occurring and report back to the class.

- Ask students: What did you observe about particle pollution levels during the inversion? Is there a relationship between cold temperatures and inversions? Is there a relationship between wind speed and inversions?
- Have students write a report on what a temperature inversion is.

Also see the lesson plans on temperature inversions in this toolkit (Trapping Air Pollution: Temperature Inversions #1, for Grades 3-5; and Trapping Air Pollution: Temperature Inversions #2, for Grades 6-8).

Acknowledgments/Resources

Air Pollution: What's the Solution? See various URLs, including:

www.k12science.org/curriculum/airproj/

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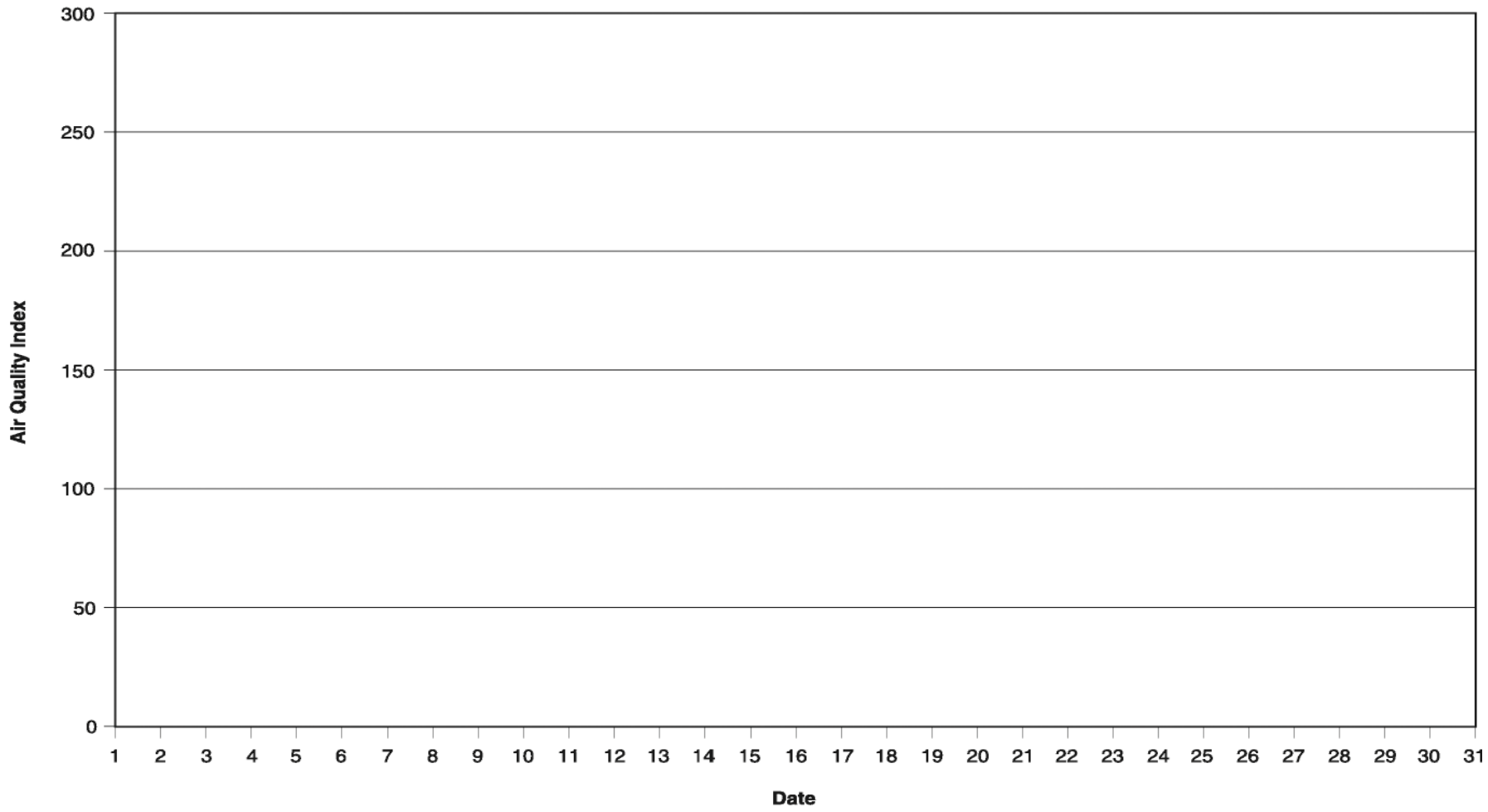
Next Generation Science Standards

Chemical Reactions
Human Impacts
Weather and Climate
Engineering Design

Student Worksheet #1: Activities 1, 2, 3 and 6

Air Quality vs. Time



Month: _____

Student Worksheet #2: Activities 1, 2, and 3

Total Number of Days Each Month with Elevated Ozone Levels

COLOR	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL DAYS of Each Color
Green													
Yellow													
Orange													
Red													
Purple													
TOTAL DAYS Ozone was Above Green													

Student Worksheet #3: Activity 4

Daily Air Quality for _____

Time of Day	Highest AQI Color Observed on_____(Date)	Highest AQI Color Observed on_____(Date)	Highest AQI Color Observed on_____(Date)
12 a.m.			
1 a.m.			
2 a.m.			
3 a.m.			
4 a.m.			
5 a.m.			
6 a.m.			
7 a.m.			
8 a.m.			
9 a.m.			
10 a.m.			
11 a.m.			
12 p.m.			
1 p.m.			
2 p.m.			
3 p.m.			
4 p.m.			
5 p.m.			
6 p.m.			
7 p.m.			
8 p.m.			
9 p.m.			
10 p.m.			
11 p.m.			

Student Worksheet #4: Activity 5

Daily Ozone Forecast, Peak Ozone Level, and Daily Peak Temperature

Day of the Month	Ozone Forecast Today _____Tomorrow:_____	Actual Peak Ozone Level	Actual Peak Temperature
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
31			

Student Worksheet #5: Activity 6

Total Number of Days Each Month with Elevated Particle Levels

COLOR	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL DAYS of Each Color
Green													
Yellow													
Orange													
Red													
Purple													
TOTAL DAYS Particles were Above Green													

Smog Alert

Learning Objectives

Students will:

- **Create artificial "smog" in a jar.**
- **Recognize that invisible air pollutants and weather conditions are involved in creating smog.**
- **Understand that not all air pollution is visible.**
- **Appreciate that human activities can cause air pollution.**

Grade Level: Grades 6-8

(Note: With careful supervision, this activity can also be done with Grades 3-5)

Estimated Time: 20 minutes

Background Summary

The expression "smog" was first used in "Turn-of-the-Century" London to describe a combination of "smoke" and "fog." Smog occurred when water vapor in the air condensed on small particles of soot in the air, forming small smog droplets. Thousands of Londoners died of pneumonia-like diseases due to the poisonous air.

Ozone is a primary ingredient of smog. Ozone is formed when pollutants in the air, called "precursors" (notably nitrogen oxides, or NO_x, and volatile organic compounds, or VOCs), are heated by the sun and react chemically. The pollutants that form ground-level ozone are produced by sources such as automobile exhaust, industry and power plant smokestacks, and fumes from chemical solvents such as paint thinner or pesticides.

Ground-level ozone pollution is harmful to our health and environment; in contrast, the ozone layer that is high up in the atmosphere (the stratosphere) helps protect us from the sun's harmful ultraviolet radiation. An easy way to remember this difference is "Ozone: good up high, bad nearby."

Weather conditions such as the lack of wind or a "thermal inversion" can cause ozone to be trapped over a particular area. (A thermal inversion occurs when a layer of warm air in the Earth's atmosphere traps cold air and pollution, including ground-level ozone, below it). (**Note**: Also see *Trapping Air Pollution: Temperature Inversions* #1 and #2 lessons in this toolkit.)

Ground-level ozone can cause health problems such as difficulty breathing, aggravated asthma, reduced resistance to lung infections, colds, and eye irritation.

Severe smog and ground-level ozone problems often occur in many major cities, although wind can also carry it to more rural areas.

Materials Needed

- Clean, dry, wide-mouth glass jar (e.g., mayonnaise jar)
- Heavy aluminum foil
- Two or three ice cubes
- Ruler
- Scissors
- Stop watch or watch with second hand
- Matches

Key Questions

- Do you think you've ever seen smog? What do you think it's made of? What about ground-level ozone?
- Do you think smog can affect people's health? If so, how?

Vocabulary

Precursor—A compound that reacts and produces another compound.

Ozone—A gas that occurs both in the Earth's upper atmosphere and at ground level. Ozone can be "good" or "bad" for people's health and the environment, depending on its location in the atmosphere. High up in the atmosphere, ozone helps protect people's health from too much ultraviolet radiation from the sun. Near the Earth's surface, ozone is an air pollutant that can result in breathing difficulties.

Model—A representation of a system that allows for investigation of the properties of the system.

Steps

> Check with the school principal or facilities manager to make sure this activity is allowed in the classroom. Be careful if you conduct this activity. The teacher may want to (or be required to) use matches instead of having the students do so. If students use the matches, they should do so only under teacher supervision.

1. Explain that the class will perform an experiment in which they will create artificial "smog" in a jar. Make sure that students understand that the jar is only a model, and models by nature are limited. For example, the purpose of this model is to illustrate the appearance and behavior of smog, not the composition or effects. It is important to understand that smog is not just a "smoky fog," but a specific phenomenon.
2. Select students to perform the experiment. Have a student cut a strip of paper about 6 inches by 2 inches. Fold the strip in half and twist it into a rope.
3. Have students make a snug lid for the jar out of a piece of aluminum foil. Shape a small depression in the foil lid to keep the ice cubes from sliding off. Carefully remove the foil and set it aside.
4. Have the students put some water in the jar and swish it around to wet all of the inside of the jar. Pour out the extra water.
5. The teacher (or possibly the students under teacher supervision, if school rules allow it) then lights the paper "rope" with a match and drops it and the match into the damp jar. Quickly put the foil lid back on the jar and seal it tightly. Put ice cubes on the lid to make it cold. (The ice cubes will make the water vapor in the jar condense.) Students must do this step very quickly, perhaps with some assistance.
6. Ask students to describe what they see in the jar. How is this like real smog? What conditions in the jar produced "smog"? (*Correct answer:* Moisture and soot particles from the burning matches, plus carbon dioxide and other solvent vapors.)
7. Ask the students if they have ever seen smog (not fog).

For Further Exploration

Have students put a glass (not plastic) thermometer into the jar before they do the experiment. Have them record the temperature before proceeding to step 4. Have them record the temperature again during step 5. Ask them to describe what the temperature did and why. Let them try it again without adding water.

Assign students to small groups to answer the following questions and report back to class in two weeks. One group will consider the physical and chemical sciences and the other group will consider the health and ecological sciences. Each group should consider referring to several sources of information to answer the questions. Students could possibly interview a weather reporter or meteorologist at the local television or radio station or airport, or a health scientist from the city or county health department or air quality agency.

(a) What conditions are necessary to produce smog in the air? Under what circumstances will these conditions exist in the city? How often are they likely? Can they be predicted in advance?

(b) What are the health effects of smog on people? Why doesn't everyone in the city get sick or have similar symptoms from smog? What types of people are most sensitive to ground-level ozone? What types of people are sensitive to particle pollution?

Acknowledgments/Resources

Project A.I.R.E. (Air Information Resources for Educators), EPA Region 1: New England Educational Resources Library, Activity 14. URL: www.epa.gov/ne/students/pdfs/activ14.pdf

Easterbrook, G. 1993. Winning the War on Smog. Newsweek 122 (23) (August).

Pasternak, J. 1991. Long-Term Lung Damage Linked to Air Pollution; Respiratory Deterioration Is Found in Areas Where Air Is Dirtiest. Los Angeles Times (29), p. A1 (March).

Smog Blamed for Increase in Asthma Cases. 1991. Los Angeles Times (2), p. A1 (December).

Scott, G. 1992. Two Faces of Ozone. Current Health 19 (2), p. 24 (September).

Next Generation Science Standards

Human Impacts
Earth's Systems
Weather and Climate
Engineering Design

Trapping Air Pollution: Temperature Inversions #2

Learning Objectives

Students will:

- **Determine whether a temperature inversion has occurred in a specific location.**
- **Explore the AIRNow Web site for air quality (particle pollution) information and changes, and the Weather Underground Web site for related weather data.**
- **Learn how temperature inversions and wind can trap air pollutants, affect air quality, and impact health.**

Grade Level: Grades 6–8

Estimated Time: 1.5 hours

Background Summary

See the *Temperature Inversions, Weather, and Air Quality: Background Information* handout.

Materials Needed

- Internet access
- Copies of T*emperature Inversions, Weather, and Air Quality: Background Information* handout (one per student)
- Copies of *Temperature Inversion* graphic handout (one per student)
- Student Worksheet
- Teacher Answer Sheet

Key Questions

- Normally, do you think air temperature is cooler or warmer the higher up you go in the atmosphere? (*Correct answer:* The air is usually cooler higher up in the atmosphere.)
- What weather conditions do you think might contribute to temperature inversions? (*Possible answers:* temperature, wind, sky cover, length of night time, high pressure systems.)
- How can temperature inversions affect air quality and people's health? (*Possible answer:* Temperature inversions can trap air pollutants and make air quality worse. If people breathe in more air pollution, they may have trouble breathing and may have more health problems.)

Vocabulary

Temperature inversion—A layer of warm air that prevents the rise of cooler air and pollutants beneath it.

Stagnant—Not circulating or flowing.

Steps

1. Distribute the *Temperature Inversions, Weather, and Air Quality: Background Information* handout and the *Temperature Inversion* graphic handout to the class and discuss the information. Tell students that they can refer to these materials as they conduct the activities in this lesson.

2. Have students access the Air Quality Index (AQI) chart at the bottom of the Air Quality Index page on the AirNow Web site (the last chart on the page): www.airnow.gov/index.cfm?action=aqibasics.aqi

   Discuss the AQI with the class: Tell students to think of the AQI as a yardstick that runs from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern. The AQI is divided into six categories, based on numerical values, as shown in the chart. Each category is assigned a specific color, indicating air quality levels ranging from good (green) to unhealthy (red) to hazardous (purple). The column on the right of the chart ("Meaning") explains the possible health effects associated with each AQI level. The AQI is reported daily for five major air pollutants. This lesson will explore the AQI for particles, one of these five pollutants.

3. Distribute the Student Worksheet. Have students examine the particles map included in the Student Worksheet for Salt Lake City, Utah on January 1, 2004. (Step 1 on the Student Worksheet.)

   Tell students that particle pollution is expressed as colored circles that correspond to the AQI colors.

   Ask the class: What Air Quality Index (AQI) level (color and corresponding meaning) was reached for particles on January 1, 2004, for Salt Lake City? Tell students to record the answer in Question #1 on their Student Worksheet. (See Teacher Answer Sheet for answers to all questions.)

4. Next have students access the Weather Underground Web site and tell them to obtain the following weather conditions: maximum and minimum actual temperatures (in Farenheight degrees) and maximum wind speed (in miles per hour) for Salt Lake City, Utah on January 1, 2004. (Students should ignore the other weather data.)

   (If anyone has trouble accessing this Web page, the URL is: www.wunderground.com/history/airport/KSLC/2004/1/1/DailyHistory.html)

   Tell the class to record the weather data (temperature and wind speed) for Salt Lake City on January 1, 2004 on their Student Worksheet in the blank chart, which is Question #2a of their Student Worksheet.

5. Ask the class if anyone skis or snowboards. Tell students to examine the weather conditions for Snowbird Ski Area on January 1, 2004 provided in the chart on their Worksheet Question #2b.

   Ask students to compare the weather conditions (temperature and wind) for January 1, 2004 in Salt Lake City (Chart 2a of their worksheets) to the same weather conditions at Snowbird Ski Area (Chart 2b), which is just outside of Salt Lake City, on the same day.

   Tell students to record their observations about the weather in the two locations (Salt Lake City and Snowbird) in Question #2c of their worksheets, as it relates to previous class readings and discussions about temperature inversions. Discuss students' answers for Student Worksheet Questions #2b and #2c and the correct answers.

6. Now have students graph the temperatures in Salt Lake City for January 1, 2004 as instructed on the blank graph in Question #3 of the Student Worksheet.

7. Next have students graph the temperatures at Snowbird for January 1, 2004 as instructed on the blank graph in Question #4 of the Student Worksheet.

   Review and discuss students' graphs in Worksheet Questions #3 and #4 and the correct graphs (see Teacher Answer Sheet).

8. Tell students to examine the particles map included in the Student Worksheet for Salt Lake City, Utah on January 9, 2004.

   Ask the class: What Air Quality Index (AQI) level (color and meaning) was reached for particles on January 9, 2004, in Salt Lake City? Tell students to record the answer in Question #5 on their Student Worksheet.

9. Have students access the Weather Underground Web site and obtain the weather conditions (temperature and wind speed) for Salt Lake City, Utah on January 9, 2004.

   (In case anyone has trouble accessing this Web page, the URL is: www.wunderground.com/history/airport/KSLC/2004/1/9/DailyHistory.html)

   Tell the class to record the weather data for Salt Lake City for January 9, 2004 on their Student Worksheet in the chart in Question #6a.

10. Tell students to examine the weather conditions at Snowbird Ski Area for January 9, 2004, which are provided in the chart in Question #6b on the Student Worksheet.

11. Have students compare the weather conditions (temperature and wind speed) for January 9, 2004 in Salt Lake City to the weather conditions at Snowbird Ski Area on the same day, and record their observations in Question #6c of the Student Worksheet, as it relates to previous class readings and discussions about temperature inversions. Discuss students' answers and the correct answer.

12. Have students graph the temperatures in Salt Lake City for January 9, 2004 on the blank graph in Question #7 as instructed on the Student Worksheet.

13. Have students graph the temperatures at Snowbird for January 9, 2004 on the blank graph in Question #8 as instructed on the Student worksheet.

    Review and discuss students' graphs for Questions #7 and #8 and the correct graphs (see Teacher Answer Sheet).

14. *Final lesson discussion*. Proceed to either the *For Further Exploration* section of this lesson plan to include additional weather conditions that can impact air quality, or to the *Evaluation* section questions for the final class discussion.

Adaptation

Students could work in small groups rather than individually.

For a simpler lesson on temperature inversions, see *Trapping Air Pollution: Temperature Inversions #1* (included for Grades 3-5) in this Toolkit. If time permits, the class could first conduct the Temperature Inversion #1 lesson, and in following sessions conduct the more advanced *Trapping Air Pollution: Temperature Inversions #2* lesson.

For Further Exploration

Expand the discussion to include other weather conditions in addition to temperature and wind speed that can contribute to temperature inversions, such as clear skies, long nights, and high pressure systems.

(*Background for this discussion:* Clear skies increase the rate of cooling at the Earth's surface, resulting in lower temperatures near the ground. Long nights allow for cooling of the ground to continue over a longer period of time, resulting in a greater temperature decrease at the surface. Since the nights are longer in winter, inversions are stronger and more common during winter months. In addition, strong high pressure systems can also increase the likelihood of temperature inversions because in a high pressure system the air is stagnant, which keeps the air—and pollutants in the air—where they are.)

Proceed to the *Evaluation* questions below for the final class discussion.

Evaluation

To assess students' grasp of the information in this lesson, ask and discuss the following:

A. From the graphs for Snowbird ski area that you created in Worksheet Questions #4 and #8), what do you observe about the temperatures at the base and peak of the mountain at Snowbird on the two days observed (January 1 and January 9, 2004)? Explain.

   Answer: On January 1, the temperature at the peak of the mountain was cooler than the temperature at the base of the mountain, which indicates normal temperature conditions. On January 9, the temperature at the peak of the mountain was warmer than the temperature at the base of the mountain, which indicates a temperature inversion. These conditions confirm the conditions the class discussed when comparing the Salt Lake City and Snowbird weather charts: that normal weather conditions existed on January 1, 2004, and that a temperature inversion occurred on January 9, 2004. The temperature inversion on January 9 helps explain why the AQI (Air Quality Index) for air quality was "red" or "unhealthy" for that day, since the cool air and any pollutants in it were trapped below the layer of warmer air above it, increasing air pollution. (Note that on January 1, 2004, the air quality was "green," or "good," under normal temperature conditions when a temperature inversion did not occur.)

B. What were the differences in wind speed on the two days? Explain.

   Answer: On January 1, 2004, there were strong winds, both in Salt Lake City and at Snowbird. These winds encouraged mixing and movement of air, and moving away of any air pollutants that might be present. On January 9, 2004, there was no wind (or only light winds) in both locations. So the trapped air from the temperature inversion would remain trapped and stagnant (would not be blown away by the wind), and any air pollutants present would remain in the air. This also helps explain why the AQI for January 1 was "green" or "good" and why the AQI for January 9 was "red" or "unhealthy."

C. List and explain some of the conditions that can contribute to the formation of a temperature inversion:

- A layer of warmer air above a layer of cooler air
- No or little wind
- Mountains nearby
- (If *For Further Exploration* was included in the lesson, also): clear skies, long nights, high pressure systems

Acknowledgments/Resources

Adapted from Air Pollution: What's the Solution?—Temperature Inversion at: www.k12science.org/curriculum/airproj/pm_inversion.html

Next Generation Science Standards

Human Impacts
Weather and Climate
Engineering Design

Temperature Inversions, Weather, and Air Quality: Background Information

What is a temperature inversion? Under normal weather conditions, air temperature is cooler as you go higher up in the atmosphere. This is because the sun's energy is converted to heat at the ground level, which in turn warms the air closer to the Earth's surface. The warm air cools as it rises in the atmosphere. When a temperature inversion occurs, the opposite is true: warmer air is above cooler air, and the cooler air is "trapped" below the warmer air.

How can temperature inversions affect air quality? Air temperature can have an important effect on air quality. During a temperature inversion, the warm air layer above the cooler air acts as a lid, trapping not only the cooler air below it, but also any pollutants that might be in the cooler air. Because the pollutants cannot rise and move away, they may build up, resulting in poor air quality, which may negatively affect people's health. These pollutants may come from vehicles, fireplaces and wood stoves, and industries that release pollutants into the air. In some locations, local governments ban the use of wood stoves and fireplaces under certain weather and pollution conditions.

How can wind and mountains influence temperature inversions and air quality? When there is no wind or only calm winds, air and any pollutants in it remain stagnant, which can contribute to maintaining temperature inversion conditions and to air pollution. On the other hand, a strong wind can move pollutants away from an area and clear the air. In addition, local topographical features, such as nearby mountains, can increase the formation of temperature inversions, especially in valleys. Cold air sinks to the valley floor or base of a mountain and becomes trapped there.

What is the Air Quality Index (AQI)? This lesson explores the Air Quality Index (AQI), which reports air quality levels every day for many locations in the U.S. Different AQI levels are color-coded and linked to different health concerns.

This lesson examines weather conditions to determine whether a temperature inversion exists and how weather and temperature inversions affect air quality.

Temperature Inversion

Source: U.S. EPA, Office of Air Quality Planning and Standards.

Student Worksheet:
Trapping Air Pollution: Temperature Inversions #2

Name: _____

1. Figure A is a partilcle pollution map for Salt Lake City on January 1, 2004.. What AQI level was reached?

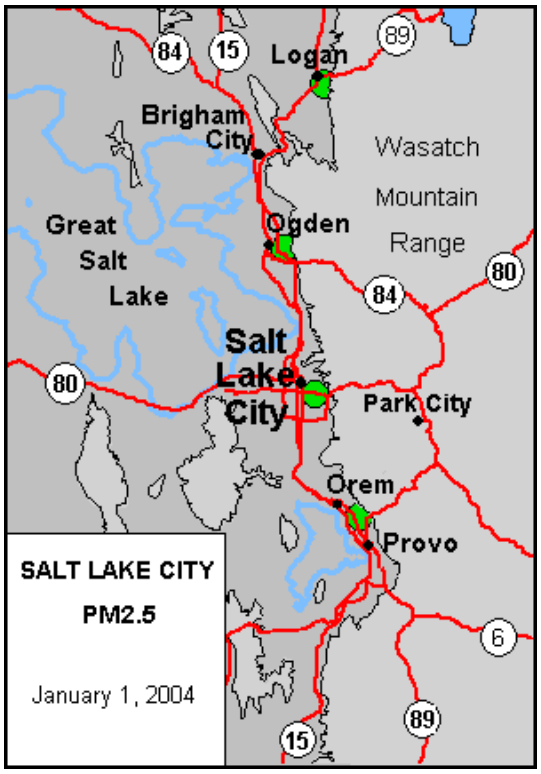


Figure A

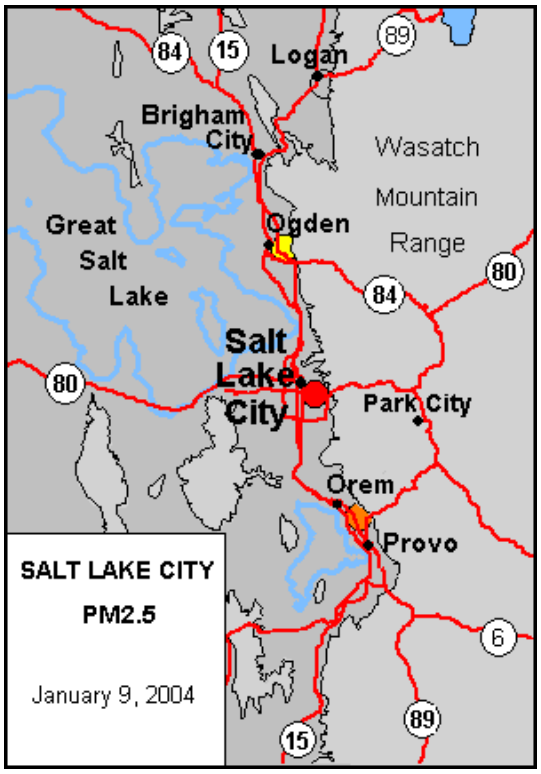


Figure B

2. Access the Weather Underground Web site and obtain the following weather conditions for Salt Lake City, Utah on January 1, 2004: minimum and maximum temperatures (in Farenheight) and maximum wind speed.

   Access at: Salt Lake City, Utah on January 1, 2004.

   (If you have trouble accessing this Web page, the URL is: www.wunderground.com/history/airport/KSLC/2004/1/1/DailyHistory.html)

2a. Record the weather data in the chart below for Salt Lake City on January 1, 2004.

Max. Actual Temp.	Min. Actual Temp.	Max. Wind Speed

(continued)

Student Worksheet: Trapping Air Pollution: Temperature Inversions #2

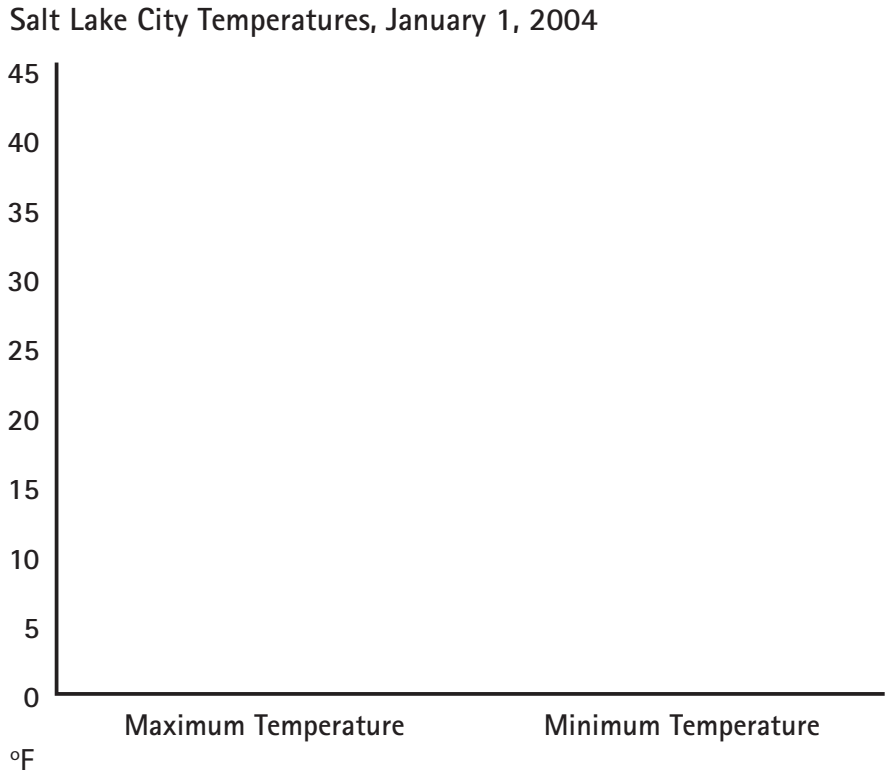
Name: _____

2b. Review the weather data in the table below for Snowbird Ski Area for January 1, 2004.

Snowbird Snow Report				January 1, 2004			
New Snow		Snow Depth Mid-Mtn.	Snow Fall Year to Date	Temperature			Wind Hidden Peak
24 hr	48 hr			Tram Base	Mid-Mtn.	Hidden Peak	
0"	0"	156"	412"	40F	32F	26F	51 mph
38 F		Hi: 40F Lo: 33F		**Today's Forecast:** Overcast, unseasonably warm, with strong winds.			

2c. How do the weather conditions (temperatures and wind speed) in Salt Lake City compare to the conditions at Snowbird on January 1, 2004?

3. Graph the maximum and minimum temperatures for Salt Lake City for January 1, 2004. Draw a line from the maximum to the minimum temperature.

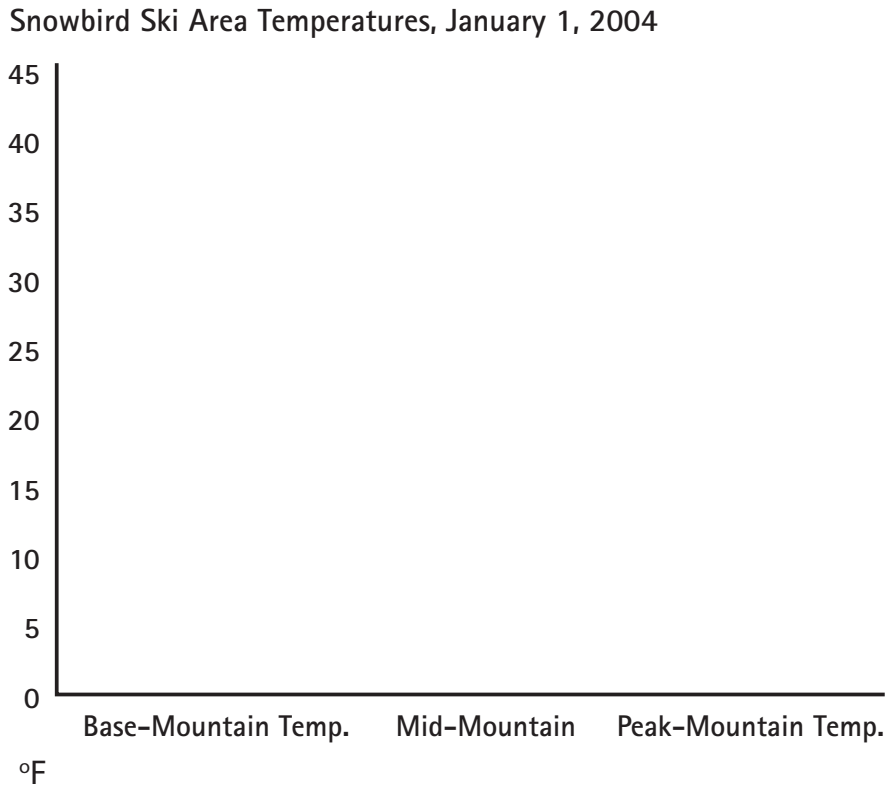


(continued)

Student Worksheet: Trapping Air Pollution: Temperature Inversions #2

Name: _____

4. For Snowbird Ski Area, for January 1, 2004, graph the peak-mountain, mid-mountain, and base-mountain temperatures. Draw a line to connect these points.



5. Figure B on page 131 is a particle pollution map for Salt Lake City, Utah on January 9, 2004. What AQI level was reached?

(continued)

Student Worksheet: Trapping Air Pollution: Temperature Inversions #2

Name: _____

6. Access the Weather Underground Web site and obtain the following weather conditions for Salt Lake City, Utah on January 9, 2004: maximum and minimum temperatures, and wind speed.

   Access at: Salt Lake City, Utah on January 9, 2004.

   (If you have trouble accessing this Web page, the URL is: www.wunderground.com/history/airport/KSLC/2004/1/9/DailyHistory.html)

6a. Record the weather data below for Salt Lake City on January 9, 2004.

Max. Actual Temp.	Min. Actual Temp.	Max. Wind Speed

6b. Review the weather data in the table below for Snowbird Ski Area for January 9, 2004.

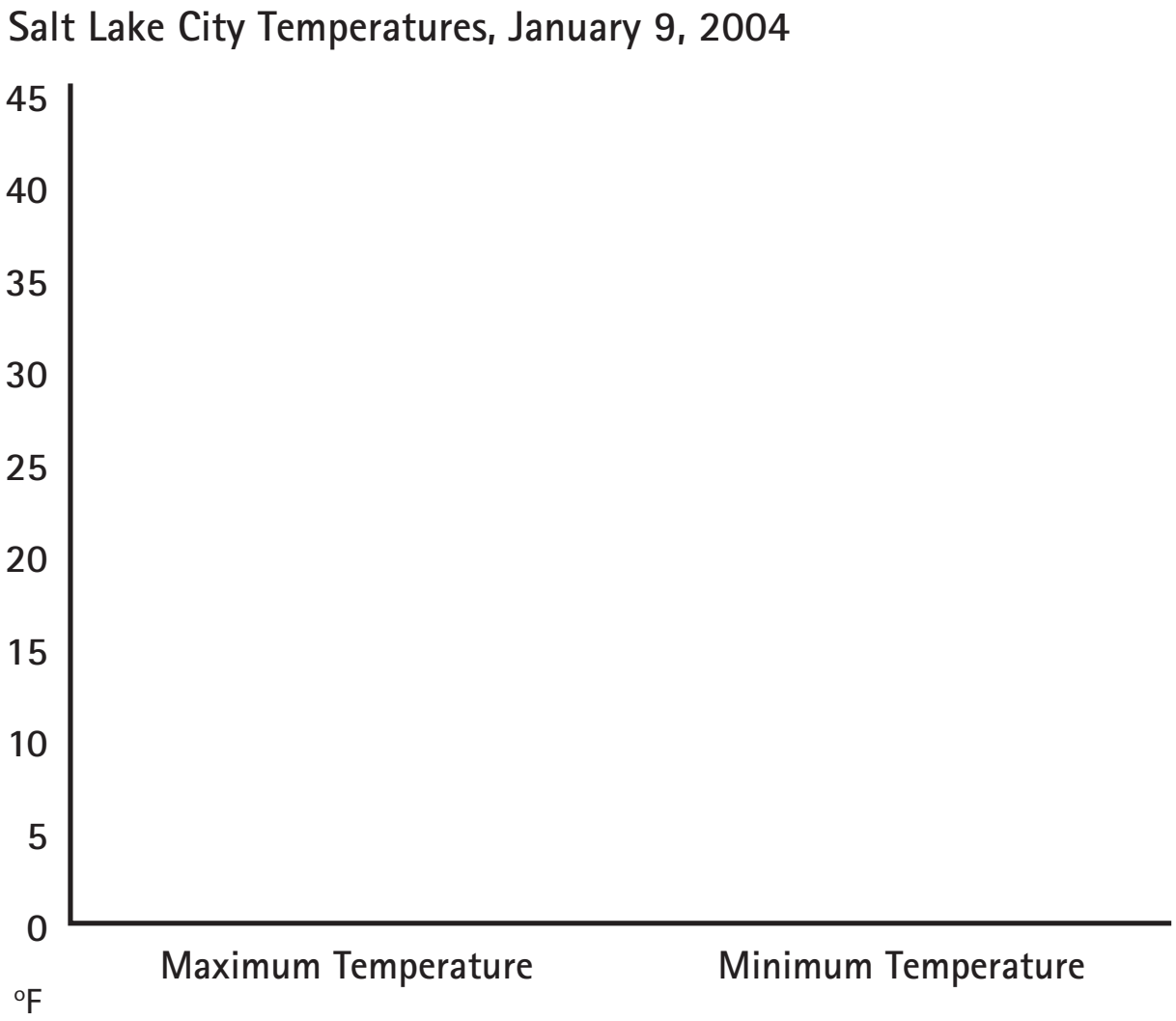
Snowbird Snow Report				January 9, 2004			
New Snow		Snow Depth Mid-Mtn.	Snow Fall Year to Date	Temperature			Wind Hidden Peak
24 hr	48 hr			Tram Base	Mid-Mtn.	Hidden Peak	
0.12"	0.3"	158"	414"	20F	24F	36F	9 mph
17 F		Hi: 40F Lo: 10F		**Today's Forecast:** Mostly Cloudy, 10% chance of snow, light to no wind.			

6c. How do the weather conditions in Salt Lake City compare to the conditions at Snowbird on January 9, 2004?

Student Worksheet: Trapping Air Pollution: Temperature Inversions #2

Name: _____

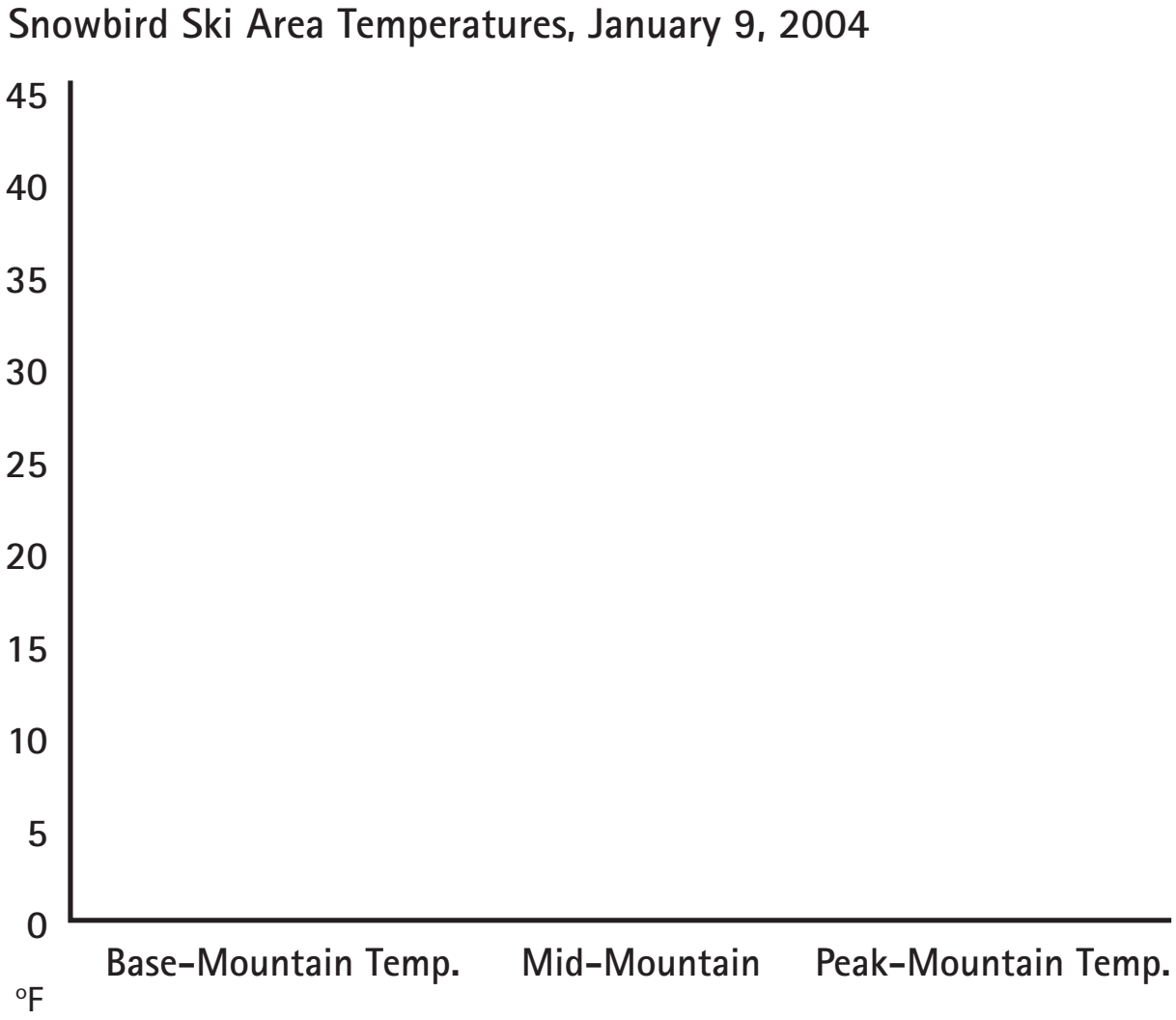
7. Graph the maximum and minimum temperatures for Salt Lake City for January 9, 2004. Draw a line from the maximum to the minimum temperature.



Student Worksheet: Trapping Air Pollution: Temperature Inversions #2

Name: _____

8. For Snowbird Ski Area, for January 9, 2004, graph the peak-mountain, mid-mountain, and base-mountain temperatures. Draw a line to connect these points.



Teacher Answer Sheet:
Trapping Air Pollution: Temperature Inversions #2

1. What AQI level was reached for particles on January 1, 2004 in Salt Lake City?

   Answer: Green, or Good

2a. Record the weather data below for Salt Lake City on January 1, 2004.

   [Answers:]

Max. Actual Temp.	Min. Actual Temp.	Max Wind Speed
42° F	35° F	43 mph

2b. Review the weather data in the table below for Snowbird Ski Area for January 1, 2004.

2c. How do the weather conditions (temperature and wind speed) in Salt Lake City compare to the conditions at Snowbird on January 1, 2004?

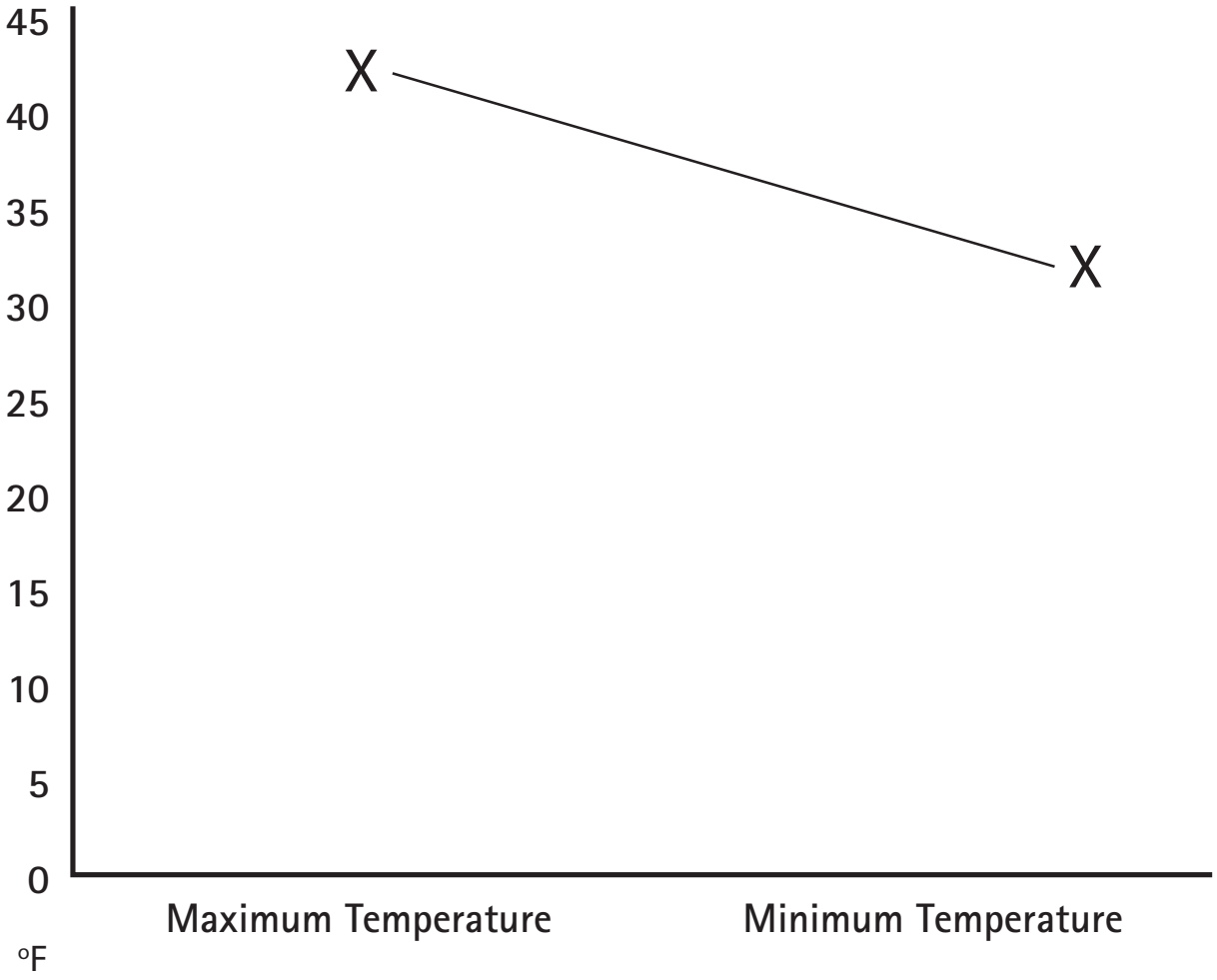
Snowbird Snow Report				**January 1, 2004**			
New Snow		**Snow Depth** Mid-Mtn.	**Snow Fall** Year to Date	**Temperature**			Wind Hidden Peak
24 hr	48 hr			Tram Base	Mid-Mtn.	Hidden Peak	
0"	0"	156"	412"	40F	32F	26F	51 mph
38 F		Hi: 40F Lo: 33F		**Today's Forecast:** Overcast, unseasonably warm, with strong winds.			

Answer: The temperatures in Salt Lake City were warmer, and the winds were calmer than at Snowbird. So cooler air and more wind in the mountains were above warmer and calmer air in the valley/city. These are normal weather conditions.

Teacher Answer Sheet: Trapping Air Pollution: Temperature Inversions #2

3. Graph the maximum and minimum temperatures for Salt Lake City for January 1, 2004. Draw a line from the maximum to the minimum temperature.

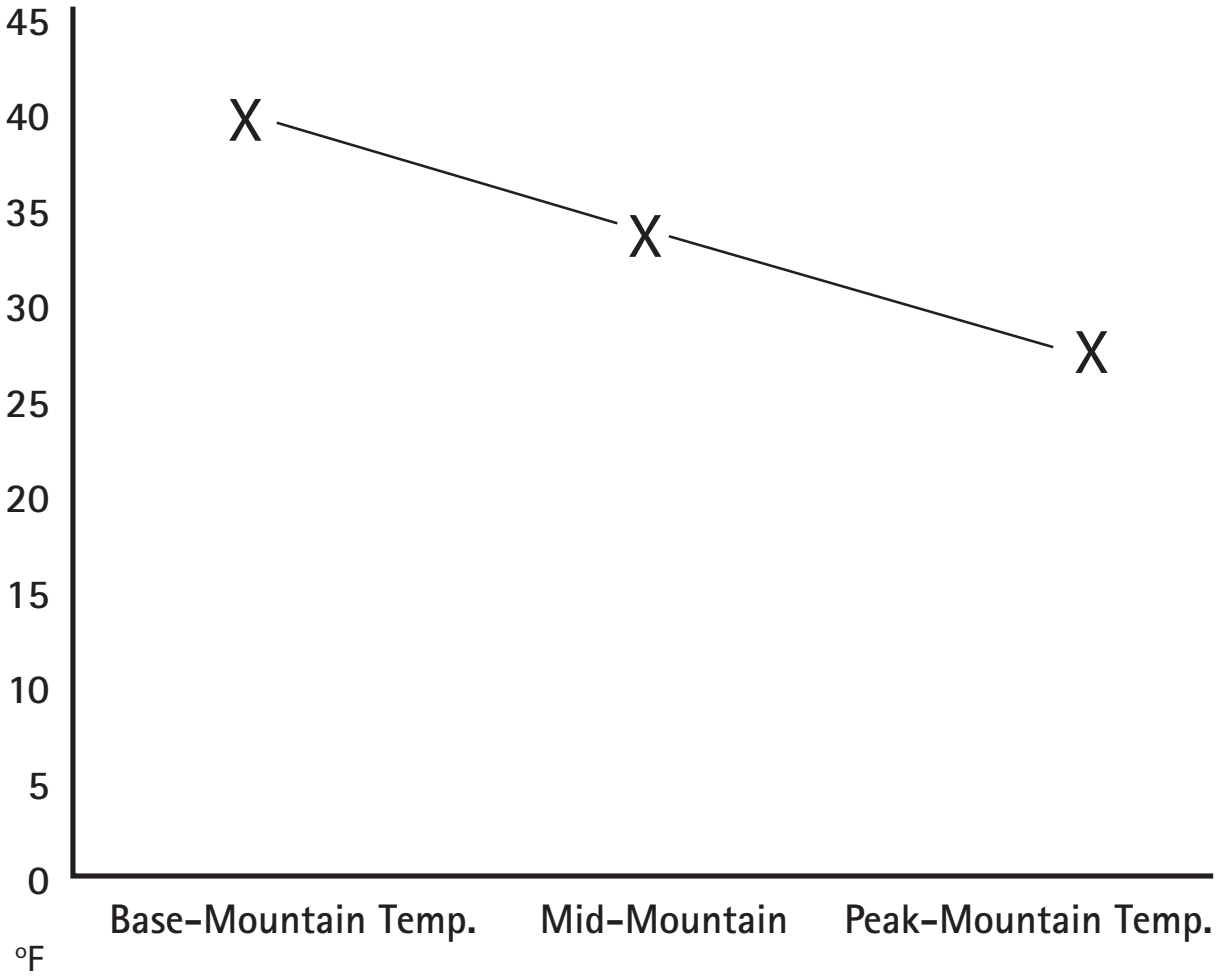
Salt Lake City Temperatures, January 1, 2004 *[Completed graph]:*



Teacher Answer Sheet: Trapping Air Pollution: Temperature Inversions #2

4. For Snowbird Ski Area, for January 1, 2004, graph the peak-mountain, mid-mountain, and base-mountain temperatures. Draw a line to connect these points.

Snowbird Ski Area Temperatures, January 1, 2004 *[Completed graph]:*



5. What AQI level was reached for particles on January 9, 2004 in Salt Lake City?

Answer: Red, or Unhealthy

(continued)

Teacher Answer Sheet: Trapping Air Pollution: Temperature Inversions #2

6a. Record the weather data below for Salt Lake City on January 9, 2004.

[Answers]:

Max. Actual Temp.	Min. Actual Temp.	Max Wind Speed
26° F	14° F	8 mph

6b. [Students review the chart below on weather conditions at Snowbird Ski Area for January 9, 2004]

Snowbird Snow Report				January 9, 2004			
New Snow		Snow Depth Mid-Mtn.	Snow Fall Year to Date	Temperature			Wind Hidden Peak
24 hr	48 hr			Tram Base	Mid-Mtn.	Hidden Peak	
0.12"	0.3"	158"	414"	20F	24F	36F	9 mph
17 F		Hi: 40F Lo: 10F		**Today's Forecast:** Mostly Cloudy, 10% chance of snow, light to no wind.			

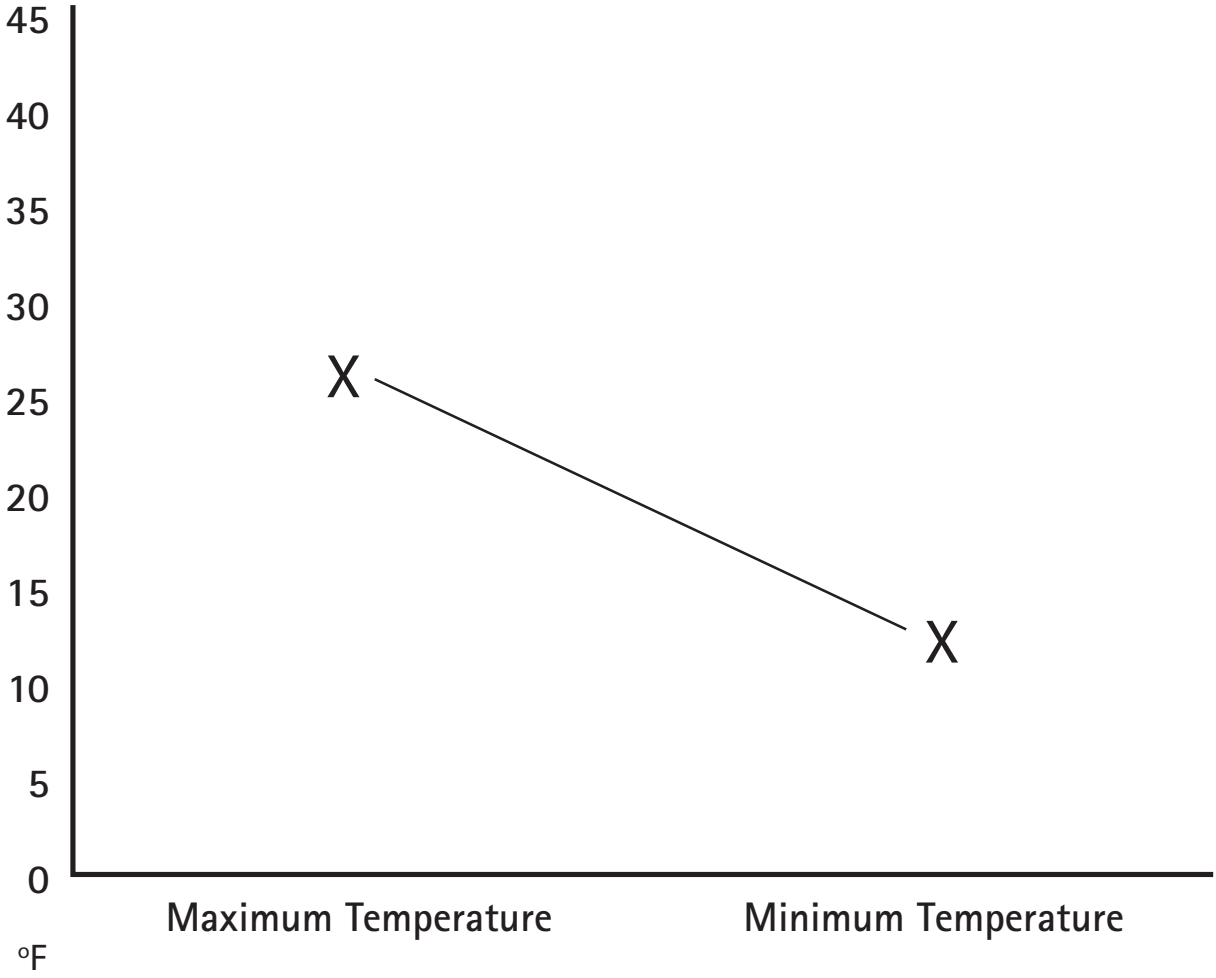
6c. How do the weather conditions in Salt Lake City compare to the conditions at Snowbird on January 9, 2004?

Answer: The maximum temperature on the mountain at Snowbird was warmer than the maximum temperature in Salt Lake City. So there was warmer air on the mountain than in the valley (city). This reflects the conditions of a temperature inversion, with warmer air above cooler air. The cooler air, and any pollutants in it, are trapped below the warmer air. Also, there was no wind (or only little wind) to move the air and any pollutants in it away from this area.

Teacher Answer Sheet: Trapping Air Pollution: Temperature Inversions #2

7. Graph the maximum and minimum temperatures for Salt Lake City for January 9, 2004. Draw a line from the maximum to the minimum temperature.

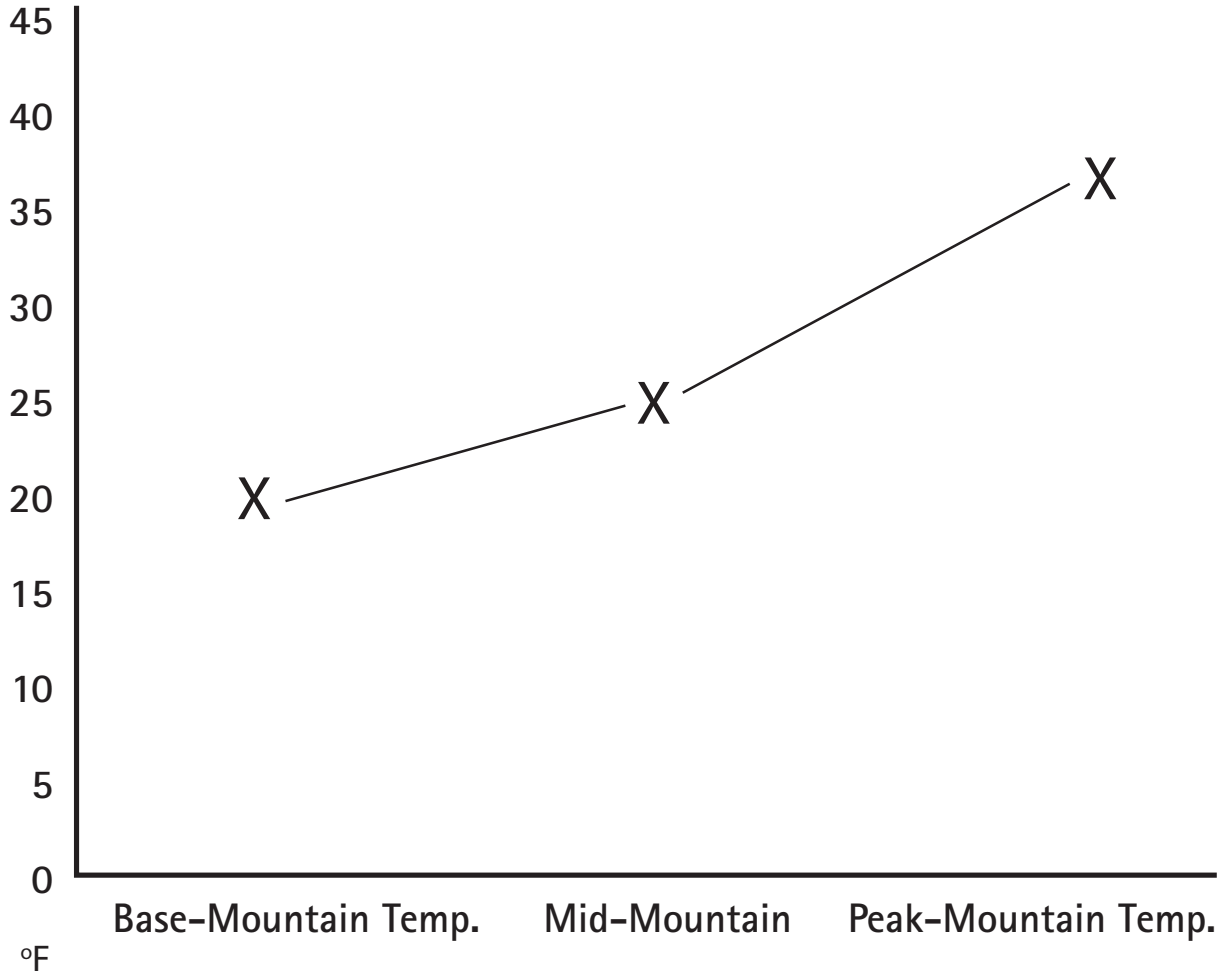
Salt Lake City Temperatures, January 9, 2004 *[Completed graph]:*



Teacher Answer Sheet: Trapping Air Pollution: Temperature Inversions #2

8. For Snowbird Ski Area, for January 9, 2004, graph the peak-mountain, mid-mountain, and base-mountain temperatures. Draw a line to connect these points.

Snowbird Ski Area Temperatures, January 9, 2004 *[Completed graph]:*



9. See lesson plan, Step #14 and *Evaluation*, for final class discussion.

What's "Riding the Wind" in Your Community?

Learning Objectives

Students will:

- **Identify particle pollution in the air that is carried and deposited by the wind.**
- **Determine the approximate direction from which particle pollution comes.**
- **Consider possible sources of particle pollution in the community and beyond.**
- **Understand the possible health effects of particle pollution.**
- **Learn how to check daily air quality.**

Grade Level: Grades 6-8

Estimated Time: 1.5 hours (over 2 to 3 sessions)

Background Summary

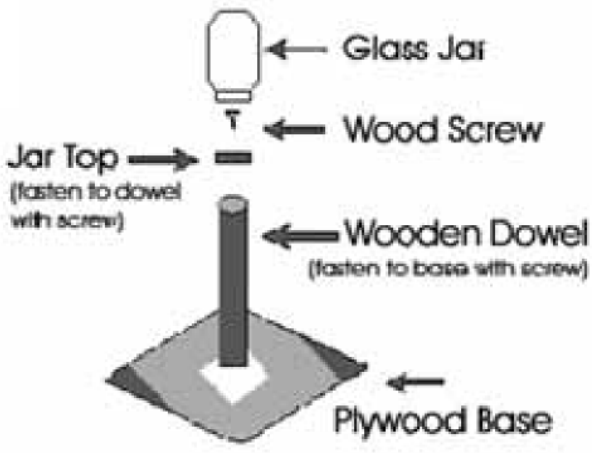
Ever wonder what's floating in the air? Sometimes the air contains particle pollution, which is made up of particles of dust, dirt, smoke, and liquid droplets. Wind can blow particle pollution in the air from nearby sources as well as from distant locations. The movement of wind-blown particles is more horizontal than vertical. Particle pollution that we can easily see ranges in size from approximately 20 to 100 microns. For comparison purposes, a human hair is approximately 70 microns in diameter. A good collecting surface is a vertical plane. Sticky paper wrapped around a jar can be used as a sample collector and will work well to capture the particles. By having students make and analyze their own sample collector, they will be able to see particle pollution in the air that may not generally be visible, learn which direction the particle pollution comes from, and determine what the sources of the particle pollution might be.

Materials Needed

- Small glass or plastic jar with a lid (several jars that fit the same lid will allow for the collection of several samples)
- Plywood base (approximately 24" x 24")
- Wooden dowel (approximately 3" diameter, 30" long)
- 2 Wood screws
- Compass
- Spray can of quick drying clear lacquer
- Double sided tape, or contact paper
- Blank directional graphic (included)
- Sample Data Table and Graph (included)

Key Questions

- Do you think you can always see air pollution? (*Answer:* No, sometimes particles are too small to see.)
- What do you think some sources of air pollution might be in your community? (*Possible answers:* Factory smokestacks, car/vehicle emissions, power plants, dust from construction sites, fireplaces and wood stoves, smoke from forest fires)
- Do you think air pollution can reach your community from far away? How? From what sources? (*Possible answers:* Yes. The most likely sources of this pollution might be power plants and factories.)
- Do you think the weather can affect air pollution levels? (*Answer:* Yes. Wind can blow air pollution from long distances away into a community. Also particle pollution is often greater in the winter time, and particularly when there is a temperature inversion.)



- Do you think there are health effects associated with particle pollution? What health effects? (Answer: Yes. Particle pollution can cause breathing difficulties and aggravate heart disease or lung disease (including asthma). For people with heart disease, particle pollution has been linked to heart attacks.)

Vocabulary

Particle pollution—Tiny particles of dust, dirt, smoke, and liquid droplets in the air.

Temperature inversion—When cold air in the atmosphere (and any air pollution in it) is trapped under warmer air above it; this is a reversal of normal conditions, in which temperature decreases as you go higher in the atmosphere.

Steps

1. Assemble the sample collector stand as indicated in the picture above under "Materials Needed."
2. Place the stand for holding the glass jar on a flat and safe area of the school grounds or roof. Try to keep the sampler as far away from obstructions as possible.
3. Wrap one strip of double-sided tape around the jar. If using contact paper be sure that the sticky side is facing away from the jar. Fasten one edge to the jar with tape and be sure that the edges overlap and stick together so that the paper will stay on the jar. Mark the exposed edge as North.
4. Screw the jar onto the cap on the stand and use a compass to be sure that the edge marked "North" is facing North.
5. Leave the jar exposed for seven days. Then spray the paper with the lacquer to fix the particles collected and to avoid having additional particles adhere to the paper.
6. After the lacquer dries, remove the tape or contact paper from the sampler and divide it into eight equal parts. One section of the strip will represent each direction, i.e., North, Northwest, West, Southwest, South, Southeast, East, Northeast. Label each section.
7. Lay the tape on a flat surface and estimate the percent of particle coverage for each section. Use the table below to record the class's estimates.
8. Hand out copies of the Sample Data Table and Graphic and review it with the class. Then distribute the Blank Directional Graphic for Entering Data (included) and have the students, either individually or in groups, draw in the data from the table. For this lesson, assume that 2 cm = 10% coverage. The sample site will be at the center of the graph. Tell students to use the Sample Data Table and Graphic as an example of how to enter and interpret their data on the blank graphic.
9. When students have completed their directional graphics, they should be able to look at them and start to form simplified ideas regarding what general direction particle pollution, and possibly other pollutants that affect your community, come from.
10. After finishing the graphs, discuss with the class:

- From what direction did most of the particle pollution appear to come?
- Knowing your community, what do you think some of the sources of the particle pollution might be? (*Possible answers:* Nearby dirt driveways, vehicle exhaust, factory emissions, power plants, dust from construction sites, fireplaces and wood stoves, smoke from fires.) Mention that the wind may also have blown the particle pollution from far away to your area from some of these types of pollution sources.
- How do you think that weather might affect particle pollution? (*Answer:* Particle pollution can occur at any time of year, but it can be especially bad during winter, when the weather is calm, and especially when a temperature inversion exists, allowing particle pollution to build up. A temperature inversion occurs when cold air, and any air pollution in it, is trapped under warmer air above it; this is a reversal of normal conditions, in which temperature decreases as you go higher in the atmosphere.)
- Do you think particle pollution can affect our health? How? *(Answer:* Yes. Particle pollution, especially smaller particles, can penetrate deep into the lungs and even get into our bloodstream. Particle pollution can cause a range of health effects, from coughing to aggravated asthma and heart disease. For people with heart disease,

Direction	N	NW	W	SW	S	SE	E	NE
Estimated Coverage								

particle pollution has been linked to heart attacks. Many studies link high particle pollution with increased emergency room visits and hospital admissions. People that are particularly sensitive to particle pollution include people with heart or lung disease, older adults, and children.)

- How might we and our community reduce air pollution? (*Possible answers:* People could drive less and walk, bicycle, or take public transportation (e.g., buses, trains, subways) more often. They could carpool more. People could use wood stoves and fireplaces less often. We can turn off lights, TVs, computers, and other equipment when we're not using them. Factories and power plants could use cleaner fuels and other substances that produce less air pollution.)
- Do you think there are ways to check what the air quality is? (Answer: Yes. You can check the air quality each day and for the next day on the Internet at: www.airnow.gov which provides an Air Quality Index, or AQI. The AQI is also often part of the weather report in newspapers and on TV and the radio. The AQI provides information on five air pollutants, including particle pollution.)

Adaptation

For lower grades, see the How Dirty is the Air We Breathe? lesson plan in this Toolkit for Grades K-2 on preparing a simpler air pollution tester.

For Further Exploration

See the Trapping Air Pollution: Temperature Inversions #1, Trapping Air Pollution: Temperature Inversions #2, and Save Smog City 2 from Particle Pollution lesson plans in this Toolkit.

Acknowledgments/Resources

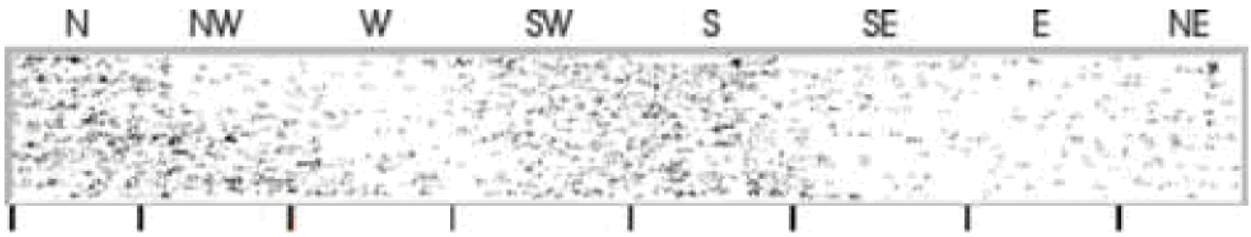
U.S. EPA and the Air and Waste Management Association. Adapted from the Air Pollution Control Association, Air Pollution Experiments for Junior and Senior High School Science Classes. Pittsburgh, PA.

Next Generation Science Standards

Human Impacts
Engineering Design

What's "Riding the Wind" in Your Community?

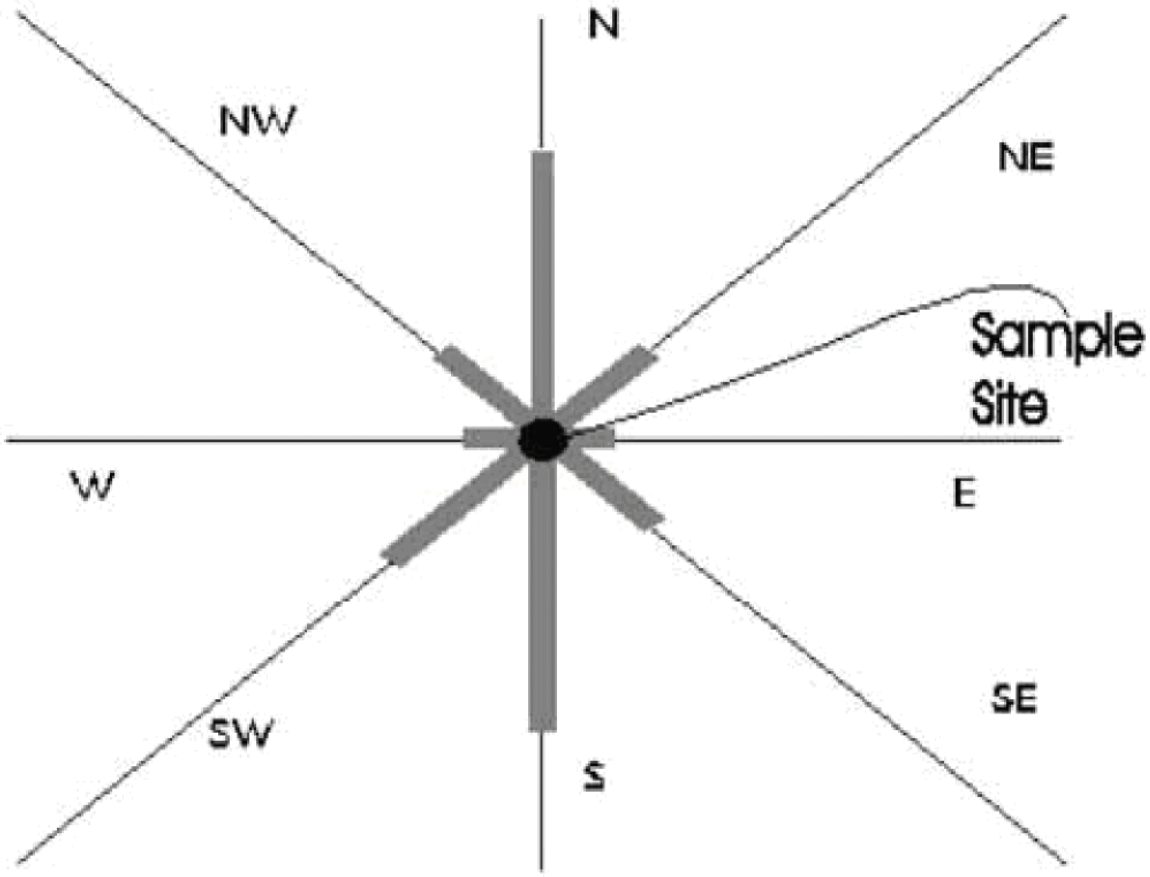
Sample Data Table and Graphic



Direction	N	NW	W	SW	S	SE	E	NE
Estimated Coverage	25%	10%	5%	15%	25%	10%	5%	5%

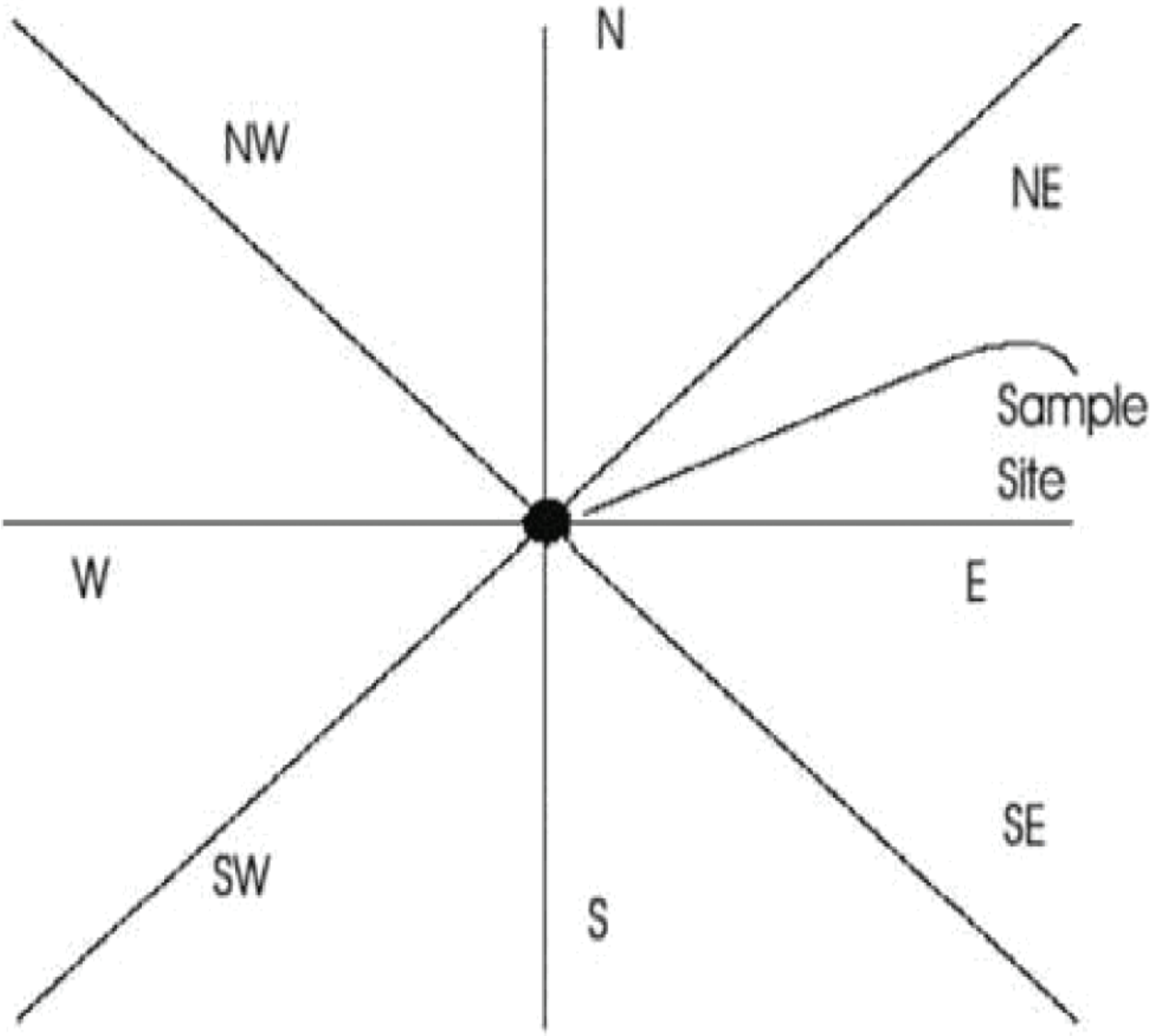
For example we estimate the strip above is covered as indicated in the table below.

Start with the estimated particle coverage that came from the north, 25%. Since 2 cm on the graph represents 10% coverage, a 5 cm line will represent 25%. Draw a bar north extending 5 cm from the center of your directional graphic. A 2 cm bar should extend towards the northwest, and so on.



What's "Riding the Wind" in Your Community?

Blank Directional Graphic for Entering Data



Data Collection Site _____

Data Collection Dates _____

Save Smog City 2 from Ozone

Learning Objectives

Students will:

- **Understand how weather and people's activities affect air pollution.**
- **Explore how changes in key variables can affect air pollution and health.**
- **Identify things people can do to reduce air pollution.**

Grade Level: Grades 6-8

Estimated Time: 1 hour

Background Summary

Ozone is made up of three oxygen atoms. Ozone in the air acts differently depending on where it is. The ozone layer high up in the atmosphere occurs naturally and helps protect us from receiving too much of the sun's harmful ultraviolet radiation. But when ozone is near the Earth's surface (at ground level), it is an air pollutant that can harm our health and our environment. You can remember this difference by thinking, "Good up high, bad nearby." Ground-level ozone pollution can irritate the throat and lungs, cause coughing, and make asthma worse.

Ground-level ozone forms when certain pollutants in the air are baked by the sun and undergo chemical reactions. These pollutants are volatile organic compounds (VOCs) and nitrogen oxides (NO_x). VOCs are emitted from gasoline, industrial chemicals, paints, household cleaners, and other products. NO_x is produced from burning certain fuels such as gasoline.

Many things can affect how much ground-level ozone pollution there is, including the weather, emissions released from cars and factories, and the population in a specific area. Ozone pollution is worse in the summer when there are high temperatures, calm winds, and lots of sunshine.

Make sure the class understands what emissions are, since this is an important concept of this lesson and the Smog City 2 Web site on which this lesson is based. ***Ask the class*** if they know what emissions are. Based on their responses, guide the class to understand that emissions are releases of pollutants, or other substances that can become pollutants, from vehicles, factories, power plants that make electricity, and even some products that we use at home, such as paints.

Tell the class *that the Air Quality Index, or AQI*, indicates how clean or polluted the air is in a specific location each day. Ozone is one of five major air pollutants that the AQI covers, and is one of the most common air pollutants in the U.S. The AQI has six levels for air quality: Good (green), Moderate (yellow), Unhealthy for Sensitive Groups (orange), Unhealthy (red), Very Unhealthy (Purple), and Hazardous (Maroon). Tell students that you will discuss the AQI more as the lesson continues.

Ozone is part of "smog"—a term that originally meant a combination of smoke and fog. These days, smog refers to a combination of particles, ozone, and other chemicals in the air. Tell students that they will be playing an online computer game called Smog City 2 about ozone that lets them change things like the weather, emissions from cars and power plants, and population to see how these changes affect ozone pollution.

Materials Needed

- Internet access
- Teacher Answer Sheet (included)
- Student Worksheet (included)

Key Questions

- What is smog? (*Answer:* Smog originally was a combination of smoke and fog. These days, smog refers to a combination of particles, ozone, and other chemicals in the air.)
- Is ozone good or bad? (*Answer:* Both. Good ozone is ozone up high in the atmosphere, where it helps protect us from too much of the sun's ultraviolet radiation, which can be harmful to our health. Bad

ozone is at ground-level, and is a pollutant that can cause breathing problems and lung irritation.)

- Can people's activities affect air pollution? How? (*Answer:* Yes. Vehicle emissions contribute to ozone pollution, as do power plant and factory emissions, and some household products, like paints.)
- Can the weather affect air pollution? How? (*Answer:* Yes. Ozone pollution is worse in hotter weather, when there is lots of sunlight and calm winds.)
- What can people do to protect their health from air pollution? (*Answer:* Take it easier outside when air is polluted. Tell an adult if it feels more difficult to breath.)
- What can people do to reduce air pollution? (*Possible Answers:* Drive less; take buses, trains, and subways instead of driving; share a ride with friends; walk and bicycle instead of driving; drive cars that make less emissions; use ATVs less or use bicycles instead.)

Vocabulary

Emissions—Substances discharged into the air. Releases of pollutants from a variety of sources and activities, including vehicles, factories, power plants that make electricity, and wood-burning stoves and fireplaces, among others.

Ozone—A gas that occurs both in the Earth's upper atmosphere and at ground level. Ozone can be "good" or "bad" for people's health and the environment, depending on its location in the atmosphere. High up in the atmosphere, ozone helps protect people from too much ultraviolet radiation from the sun. Near the Earth's surface, ozone is an air pollutant that can result in breathing difficulties.

Air Quality Index (AQI)—A color-coded scale that provides daily air quality and health information.

Steps

1. Tell students to access the Smog City 2 Web site at www.smogcity2.org and click on "Save Smog City 2 from Ozone." Then have the class minimize the instructions box at the top right corner of the screen (this lesson covers some of the information in the box). Also, have students ignore the "Information" box at the bottom of the screen; they will be exploring several of these concepts in this lesson.
2. Tell the class not to click on anything until you tell them to (it's tempting!). Point out the main categories on the left of the screen with the class, including Weather, Emissions, and Population (you will be discussing these throughout the lesson). Also tell them to notice how each of the settings under these categories are pre-set to a certain level. Tell them that they will explore what happens when some of these settings are changed.

   Mention to students that the "Total Emissions" graph towards the bottom of the page reflects all the Emissions categories at the levels you set when you play the game (including energy sources, cars and trucks, off road vehicles, consumer products, and industry).

   (If students ask, tell them that the "Random Events" box is for learning about a different pollutant, called particle pollution, which you may cover in other lessons. *Note:* Several lessons in this Toolkit cover particle pollution.)
3. Tell the class they are first going to explore how weather conditions can affect ground-level ozone pollution and health. Tell students that in the real world we can't control the weather, but in Smog City 2 you can experiment with how the weather affects pollution levels by adjusting the controls.
4. Tell students to look at the black sign in the main picture to find out what the current temperature and AQI are. Remind students that the AQI tells how much air pollution there is. Tell them to observe the AQI (Air Quality Index) box in the lower right corner of the screen. The default setting is "Red" (see the top of this box, "Ground Level AQI" and the color itself at the bottom) and the corresponding health level is "Unhealthy" (see just below the colored graph where it says "Health.") Under this health level is a corresponding health message.

   Review the health message in the box for a Red, Unhealthy AQI with the class: "Active children and adults, and people with lung disease, such as asthma, should avoid prolonged or heavy exertion outdoors. Everyone else, especially children, should reduce prolonged or heavy exertion outdoors."
5. Tell students to record the current temperature and AQI on Question #1 of their Student Worksheet.

6. Tell students to now increase the temperature to 110° F by moving the "Temperature" button as far to the right as it will go.

   Note: Tell students that settings can be changed by clicking on the new level they want. Remind them to wait until you tell them to change any of the settings.

7. Tell students to again check the black sign in the picture. Ask them if the temperature and the AQI changed. Ask students why they think this change in the AQI happened. Tell them to record this information in Question #2 of the Student Worksheet. Discuss the answers with the class.

   (*Correct answer:* The AQI increased from 175 to 202. Ground-level ozone increased because ozone levels are generally higher when temperatures are high.)

8. Have students click the "Reset" button on the bottom left of the screen so that everything returns to the original settings.

9. Tell students to observe the current "Clouds/Sky Cover" button setting (farthest to the left – the lowest setting), the main cityscape picture at this setting, and the AQI at this setting, and record these conditions in Question #3 on their Student Worksheet.

10. Tell students to move (increase) the "Clouds/Sky Cover" button to the far right setting (the highest setting), and to record the new "Clouds/Sky Cover" condition and the AQI on their worksheets, again in Question #3. Ask students whether changing the cloud conditions changed the AQI level, and to add why they think this happened to their Question #3 answers. Discuss the answers with the class.

    (*Answer:* The original Clouds/Sky Cover conditions at the lowest level were sunny—there was only one passing cloud in the sky in the picture—and the AQI was 175, Red, Unhealthy. When the Clouds/Sky Cover conditions were changed to the highest level, there were more clouds in the sky, and the AQI decreased to 119 and changed from Unhealthy to Unhealthy for Sensitive Groups. [Tell students that they will explore what "Unhealthy for Sensitive Groups" means later in the lesson.] Air pollution, and the AQI, decreased because ozone levels are highest when there is lots of sunshine, and adding clouds reduced the amount of sunshine, which reduced ozone formation.)

11. Have the class press the "Reset" button on the lower left side so that everything returns to the original settings.

12. Now explore changes in Emissions with the class. Tell students to observe the current emissions level for "Cars and Trucks" and record the current AQI on Question #4 of their Student Worksheet.

13. Tell students that the mayor of Smog City 2 has just purchased a whole new fleet of low-emission vehicles to replace all cars used by city government employees. So, the class needs to decrease the emissions level from Cars and Trucks to the second to lowest setting (from the current setting, which is the second to highest level) to reflect this change. Tell students to record the AQI level in Question #4 on their Student Worksheet, and if the AQI changed, why they think this occurred. Discuss the answers with the class.

14. Have the class press the "Reset" button on the lower left side so that everything returns to the original settings.

15. Tell students that a new, really awesome ATV (all-terrain vehicle) is now available in Smog City 2, and that lots of kids and their families are buying them. Under the Emissions category, have students increase emissions from "Off Road" vehicles to the highest setting (all the way to the right) and tell them to record what happens to the AQI in Question #5 of their Student Worksheet. Tell them to compare this AQI number to the Emissions number in Question #4, and if the AQI changed, why they think this happened. Discuss the answers with the class.

16. Have students press the "Reset" button.

17. Tell students that in Smog City 2, you can increase the population from near-zero to as high as about 2 million people. Tell students to observe the AQI under the current "Population" setting and record this information in Question #6 on their Student Worksheet.

18. Now tell students to change the "Population" control to the highest setting (farthest to the right). Ask students what happens to the AQI, and why they think this happened. Have students record this information in Question #6.

    After hearing some of the responses to Question #6, discuss with students that as population increases in an area, emissions and air pollution

usually also increase from the use of more energy, cars, consumer products, and industries.

19. Tell students that ozone can irritate the throat and lungs, cause coughing, and make asthma worse. Tell students to look at the top of the column on the left of the Save Smog City 2 from Ozone page and click on "Air Quality Index (AQI)" (the second heading).

    (*Note:* If the class is also studying particle pollution, you can mention that some of the health symptoms of ozone and particle pollution are similar, such as irritation of the throat, coughing, and aggravating asthma, but some health symptoms are different. For example, particle pollution can make heart disease worse.)

    Look at the color chart at the bottom of the AQI page with the class and review each different color's health message so that students understand how changes in air pollution, as reflected by changes in the AQI, can affect people's health.

20. Ask students what steps they think they or other people could take to reduce emissions and ozone pollution, and to record their answers in Question #7 on their Student Worksheet. Discuss the answers, as indicated below.

    (*Correct answers might include:* Drive less; take buses, trains, and subways instead of driving; walk and bicycle instead of driving; drive cars that produce less emissions; use ATVs less or use bicycles instead; use lawnmowers that don't use gasoline or electricity. Also, power plants could use wind power, solar power, or hydroelectric power instead of coal, oil, or natural gas. Factories can use cleaner technologies that produce fewer emissions. Companies can make and sell fuels for cars from waste products instead of gasoline.)

For Further Exploration

Change some of the other settings in Save Smog City 2 from Ozone, such as Wind, Consumer Products, and Industry, and discuss with the class how these changes can affect ozone pollution, the AQI, and health.

Conduct some of the activities on particle pollution in Save Smog City 2 from Particle Pollution.

Explore the "Create Your Own Smog City 2 Experience" on the Smog City 2 Web site (best to do this after you have introduced particle pollution to students).

Acknowledgments/Resources

Sacramento Regional Air Quality Management District and U.S. EPA.

Smog City 2 at: www.smogcity2.org.

Next Generation Science Standards

Human Impacts
Engineering Design

Student Worksheet: Save Smog City 2 from Ozone

Name: _____

1. Record the current temperature and AQI in "Save Smog City 2 from Ozone":

   Current temperature:

   Current AQI:

Number	Color	Health Level

2. Record the AQI when the temperature is changed to 110^0 F:

Number	Color	Health Level

   If the AQI changed when you increased the temperature, why do you think this occurred?

3. Record the current "Clouds/Sky Cover" conditions and the current AQI.

   Current Clouds/Sky Cover:

   Current AQI:

Number	Color	Health Level

(continued)

Student Worksheet: Save Smog City 2 from Ozone

Name: _____

After you've changed the settings, record the new cloud conditions and the AQI under the new cloud conditions.

Clouds/Sky Cover when changed to highest level:

AQI when changed Clouds/Sky Cover to highest level:

Number	Color	Health Level

If the AQI changed when you changed the Clouds/Sky Cover to the highest level, why do you think this change occurred?

4. Record the AQI associated with the current Emissions level for Cars and Trucks:

Number	Color	Health Level

Now record the AQI when the Emissions level for Cars and Trucks was changed to reflect government use of low-emission vehicles (to second to lowest setting):

Number	Color	Health Level

Name: _____

If the AQI changed when you changed the Emissions level for Cars and Trucks, why do you think this occurred?

5. Record the AQI when new ATVs are bought and used (increase Off Road vehicles to highest level—far right). Compare this number to the Emissions numbers in Question #4.

Number	Color	Health Level

If the AQI changed when you changed the Emissions level for Off Road vehicles, why do you think this occurred?

6. Observe and record the AQI level at the current Population setting.

Current AQI:

Number	Color	Health Level

Name: _____

Then record the AQI when the Population level is changed to the highest setting.

AQI at highest Population level:

Number	Color	Health Level

If the AQI changed when the population increased, why do you think this occurred?

7. What steps do you think you or other people could take to reduce emissions and ozone pollution?

Teacher Answer Sheet: Save Smog City 2 from Ozone

1. Record the current temperature and AQI in "Save Smog City 2 from Ozone":

   Current temperature: 90° F

   Current AQI:

Number	Color	Health Level
175	Red	Unhealthy

2. Record the AQI when the temperature is changed to 110° F:

Number	Color	Health Level
202	Red	Unhealthy

   Ask: If the AQI changed when you increased the temperature, why do you think this occurred?

   Answer: Ground-level ozone increased because ozone levels are generally higher when temperatures are higher.

3. Record the current "Clouds/Sky Cover" conditions and the current AQI.

   Current Clouds/Sky Cover: One cloud passing by

   Current AQI:

Number	Color	Health Level
175	Red	Unhealthy

   After you've changed the settings, record the new cloud conditions and the AQI under the new cloud conditions.

   Clouds/Sky Cover when changed to highest level: More clouds

   AQI when changed Clouds/Sky Cover to highest level:

Number	Color	Health Level
119	Orange	Unhealthy for Sensitive Groups

If the AQI changed when you changed the Clouds/Sky Cover to the highest level, why do you think this change occurred?

Answer: Air pollution, and the AQI, decreased because ozone levels are highest when there is lots of sunshine, and adding clouds reduced the amount of sunshine, which reduced ozone formation.

4. Record the AQI associated with the current Emissions level for Cars and Trucks:

Number	Color	Health Level
175	Red	Unhealthy

Now record the AQI when the Emissions level for Cars and Trucks was changed to reflect government use of low-emission cars (second to lowest setting):

Number	Color	Health Level
119	Orange	Unhealthy for Sensitive Groups

If the AQI changed when you changed the Emission level for Cars and Trucks, why do you think this occurred?

Answer: The AQI decreased from 175, Red, Unhealthy, to 119, Orange, Unhealthy for Sensitive Groups, because the lower emission vehicles released fewer NO_x and VOCs emissions, which decreased the formation of ozone pollution.

5. Record the AQI when new ATVs are bought and used (increase Off Road vehicles to highest level, far right). Compare this number to the Emissions numbers in Question #4.

Number	Color	Health Level
190	Red	Unhealthy

If the AQI changed when you changed the Emissions level for Off Road vehicles, compared to when you changed the Emissions level for Cars and Trucks for lower emission vehicles in Question #4, why do you think this occurred?

Answer: The AQI increased from 119, Orange, Unhealthy for Sensitive Groups in Question #4 (for lower emission vehicles) to 190, Red, Unhealthy, when the Emissions level for Off Road vehicles was increased for more ATV use. This occurred because the use of additional ATVs increased vehicle emissions, which contributed to increased ozone formation.

6. Observe and record the AQI level at the current Population setting.

   Current AQI:

Number	Color	Health Level
175	Red	Unhealthy

   Then record the AQI when the population level is changed to the highest setting.

   AQI at highest Population level:

Number	Color	Health Level
215	Purple	Very Unhealthy

   If the AQI changed when the population increased, why do you think this occurred?

   Answer: As population increases in an area, emissions usually also increase from the use of more energy, cars, consumer products, and industries.

7. What steps do you think you or other people could take to reduce emissions and ozone pollution?

   Answers: Drive less; take buses, trains, and subways instead of driving; walk and bicycle instead of driving; drive cars that make less emissions, such as hybrid vehicles and others that use less gasoline; use lawnmowers that don't use gasoline or electricity. Also, power plants could use wind power, solar power, or hydroelectric power instead of coal, oil, or natural gas. And, factories can use cleaner technologies that produce fewer emissions.

Student Handout

Breathe Smart! Four Things KIDS Can Do

1

Find out what AQI color for today is where you live.

- Visit the AIRNow Web site at www.airnow.gov.
- Tell your parents about the AQI so they can help you.

2

Protect your health when the air is dirty.

- Take it easier when you play outside.
- If it feels harder to breathe, tell an adult.

3

Help reduce pollution.

- Turn off lights, TVs, and computers when not using them.
- Walk, bike, or take a bus or train with an adult. But remember, your safety always comes first!

4

Visit the AQI kids' site at www.airnow.gov
(click on "Kids" in the "Learning Center")

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Additional Activities

Additional Activities

Introduction

Teachers can use these additional activities as supplements to the lesson plans in this toolkit, or as brief introductions to air quality issues if time is limited. Prior to conducting these activities, teachers may want to review the fact sheets, handouts, and *Background Summary* sections in applicable lesson plans for relevant information to share with students.

Grades K-2

Why Is Coco Orange?

- Read **"Why is Coco Orange?"** to your students. This picture book introduces the AQI colors to children in grades K-2, teaches them what the different colors mean, how to recognize health symptoms and what actions to take when air quality is bad (www.airnow.gov/picturebook).

- Check your local AQI forecast at www.airnow.gov. Make copies of the "coloring page" and have your students color the chameleons to match today's AQI color. (www.airnow.gov/picturebook).

- Have your students complete the activity sheets at www.airnow.gov/schoolflag.

Match Game

- Access the "clean air/dirty air" matching cards from "Connecting Activity #2 – Clean Up on Gloomy-Doomy" (see the last two pages) at: www.intheair.org/modules/K-3-ConnectingActivity2.pdf

- Make copies of the matched sets and cut the cards apart, providing enough cards so that each student will have one card of a pair. Place the cards in a bag or box, half of them "dirty" and half "clean" air cards. Have students pick one card out of the box or bag. Ask students whether they think they have a card with a picture of what makes the air dirty or what keeps it clean. Have those with the "dirty air" cards move to one side of the room, and those with "clean air" cards move to the other side of the room. Check the accuracy of students' choices.

- Explain that the purpose of the game is to match clean air cards with dirty air cards to show how dirty air can be made cleaner. Have students look at their cards to decide what kind of match they will be looking for. Then have the two groups mingle and make the matches. When two students believe they have a match, they come to the teacher to see if they are correct. If so, they sit down together; if not, they go back into the group and try again.

- When all the matches have been made correctly, each pair describes to the class what is on their and their partners' cards and how the two pictures connect in keeping the air clean. The teacher helps students with the answers as needed, for example: a fly swatter and a can of insect spray are a match because a fly swatter can kill a fly without putting something harmful in the air that will make it dirty, or polluted, like insect spray will; a bicycle and a car are a match because a bicycle gets you places without polluting the air, while a car gets you places by burning gas that puts pollution into the air.

(Source: Missouri Botanical Garden's Earthways Center and the U.S. EPA, In the Air curriculum, K-3 Education Module)

Visible and Invisible Air Pollution

- Gather together needed materials: yellow and blue powdered drink mixes, squeezable bottles, and several large sheets of scrap paper (newspaper is fine) for the demonstration or for each group. Either the teacher can demonstrate the experiment to the class, or divide the class into groups of approximately six students each.
- Fill one squeezable bottle with yellow drink mix and water. Fill the other bottle with blue drink mix and water. Put large sheets of paper on the floor or table where the students will be making "pollution." Position the papers at a full arm's length extended from the body.
- Tell students that we all need clean air to breathe and keep us healthy. But sometimes the air gets dirty, or polluted. Tell them that some air pollution can be seen, but other air pollution is invisible. Tell students that the squeezable bottles are like smokestacks from factories, which sometimes release pollution into the air. The different colors in the bottles are like air pollution coming out of the smokestacks. The blue color is like air pollution that you can see. The yellow color is like invisible air pollution.
- Let students take turns shaking the closed bottle of the yellow mix and water. Then open the spout and tell the students with the bottles to extend their arms away from their bodies and over the paper. Help them squirt the bottle hard straight into the air above the paper. Repeat the activity with the second squeezable bottle filled with the blue mix and water.
- Ask students which color was easier to see (*Answer:* blue). Tell students that the blue color, which was easy to see, is like air pollution you can see. The yellow, which was harder to see, is like some pollution that is invisible or not very easy to see. Both kinds of pollution exist in our air. Both visible and invisible pollution can affect people, like making it harder to breathe.

(*Source:* Indiana Department of Environmental Management, Activities, Lesson Plans, and Coloring Books, Environmental Education Plans, Air Quality, Clearing the Air lesson, Activity #2, www.in.gov/idem)

Milkweed Polka Dots

- In this Internet activity, students learn that plants can be damaged by air pollution (ground-level ozone pollution, in particular). Students examine photos of milkweed leaves, which typically display black dots on their top leaf surfaces when stressed by high amounts of ground-level ozone. Students compare ozone damage to other types of damage.

- Introduce students to both milkweeds and monarch butterflies on the following Web page: http://dnr.wi.gov/org/caer/ce/eek/veg/plants/milkweed.htm.

  (Since the URLs for this Web page and the next one are long, you may want to first save them to your "Favorites" list for easy access.) Let students know that monarch butterflies lay their eggs on milkweed plants and that monarch caterpillars eat the leaves. If you are able to find one, show students a healthy milkweed leaf.

- Go to the following Internet Web page to view milkweed damage from ozone pollution:

  http://dnr.wi.gov/org/caer/ce/eek/teacher/milkweed.htm. Have students study the photo of the ozone-damaged leaf. Discuss the symptoms of milkweed damage from ozone pollution with students: small black dots on the top (not bottom) of the leaves; damage to the leaf, not the veins; damage that won't rub off or wash off. On this same Web page, click on "See the list of slides." Either have students pick a few of these slides to compare with the ozone-damaged leaf photo, or allow them to view the entire slide show. Share with students the information provided on some slides regarding how the damage shown differs from ozone damage to milkweed leaves.

(*Source:* EEK! Teachers Pages – Milkweed Monitoring Project, http://dnr.wi.gov/org/caer/ce/eek/teacher/milkweed.htm)

More Activity Ideas

- Make a clean air kite.

- Draw a picture of your favorite clean air environment (e.g., a park, forest, lake).

Grades 3-5

Lung Capacity

- In this activity, the teacher demonstrates "lung capacity" to the class—the amount of air that you can hold in your lungs. Tell students that doctors and nurses sometimes measure lung capacity to see how well a person's lungs are working. Also tell students that air pollution can reduce a person's lung capacity. A person with reduced lung capacity breathes less air into his or her lungs. Reduced lung capacity can contribute to heart and lung diseases. Access this experiment at: www.tryscience.org/experiments/experiments_begin.html?lung.

(*Source:* Tryscience, IBM Corporation, New York Hall of Science, and the Association of Science-Technology Centers, Experiments, Lung Capacity)

Tomorrow's Air Quality Index (AQI)

- As homework, tell students to find your local Air Quality Index (AQI) forecast for the next day and report it to class tomorrow. Tell students to try to find the AQI forecast for tomorrow in local newspapers, which is often on the weather report page, and cut it out. Or, they can try to find the AQI on the Internet at www.airnow.gov, print it out, and bring it to class. If they hear the AQI forecast for tomorrow on the radio or TV, they can report what they heard to the class. The teacher should bring in his or her own AQI information to verify students' responses. In class the next day, discuss students' results and the AQI (e.g., colors, meanings, health effects, what students can do to protect their health on days with poor air quality).

Air Quality Crossword Puzzle

Directions

Fill in the crossword puzzle with your answers to the questions below.

Across

1A. What we call the air when it is dirty from things like dust, soot, or chemicals.

2A. In addition to power plants and factories, these moving things that take us places can pollute the air.

3A. Tell an adult if you find it harder to _____ on a day when the air is polluted.

4A. Forest _____ can pollute the air.

5A. The name of the Web site where the AQI can be found.

6A. We need to breathe _____ to live.

7A. The AQI color that means the air quality is "good."

Down

1D. "AQI" is an acronym for the Air _____ Index.

2D. You might hear about the AQI on the TV, or see it in the newspaper, as part of the weather _____.

3D. You might want to do this instead of run on days when the air is polluted.

4D. If possible, find out what _____ the AQI is for today and tomorrow.

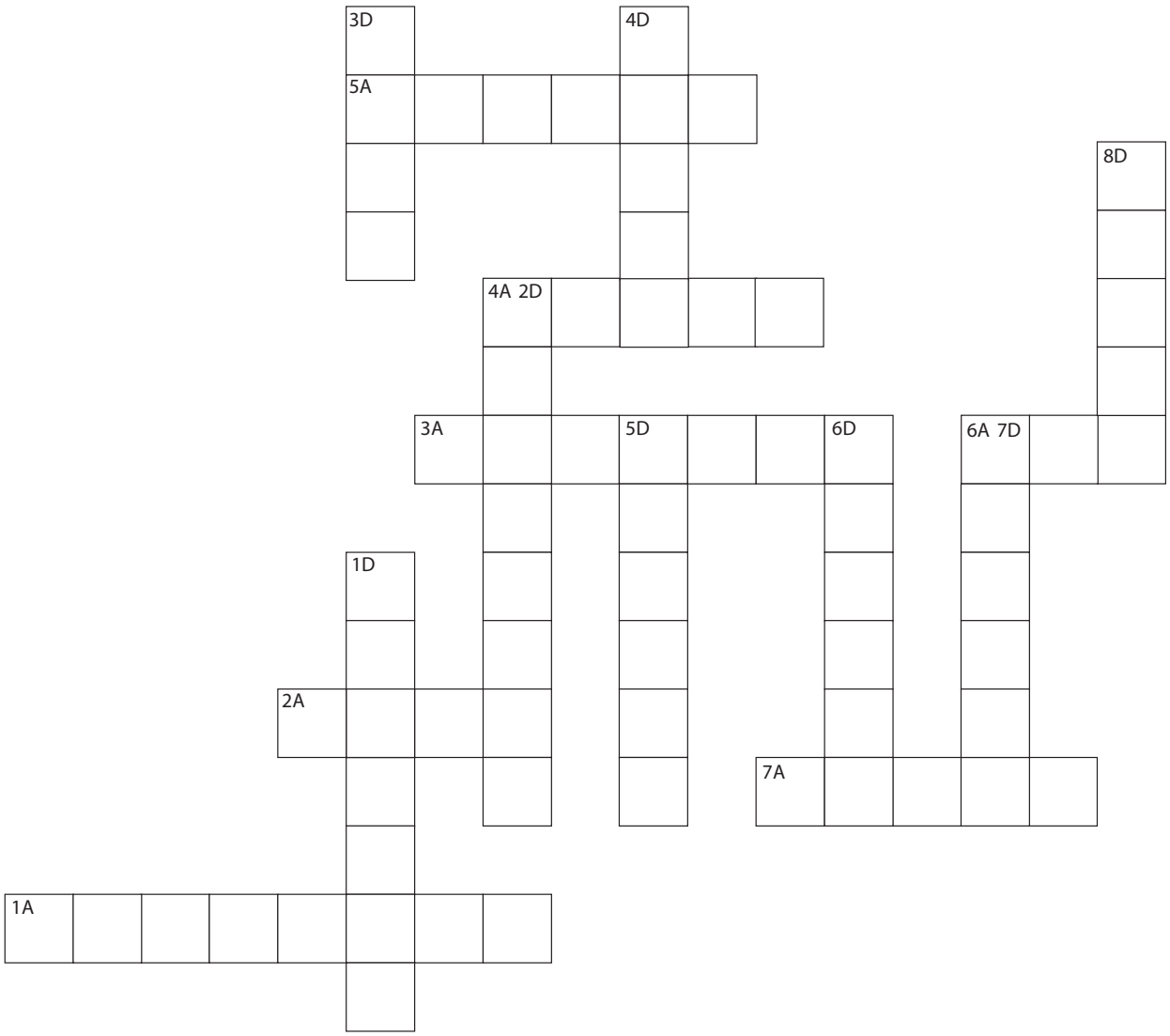
5D. Air pollution can make this breathing problem worse.

6D. Take it _____ when you're outside when the air is polluted.

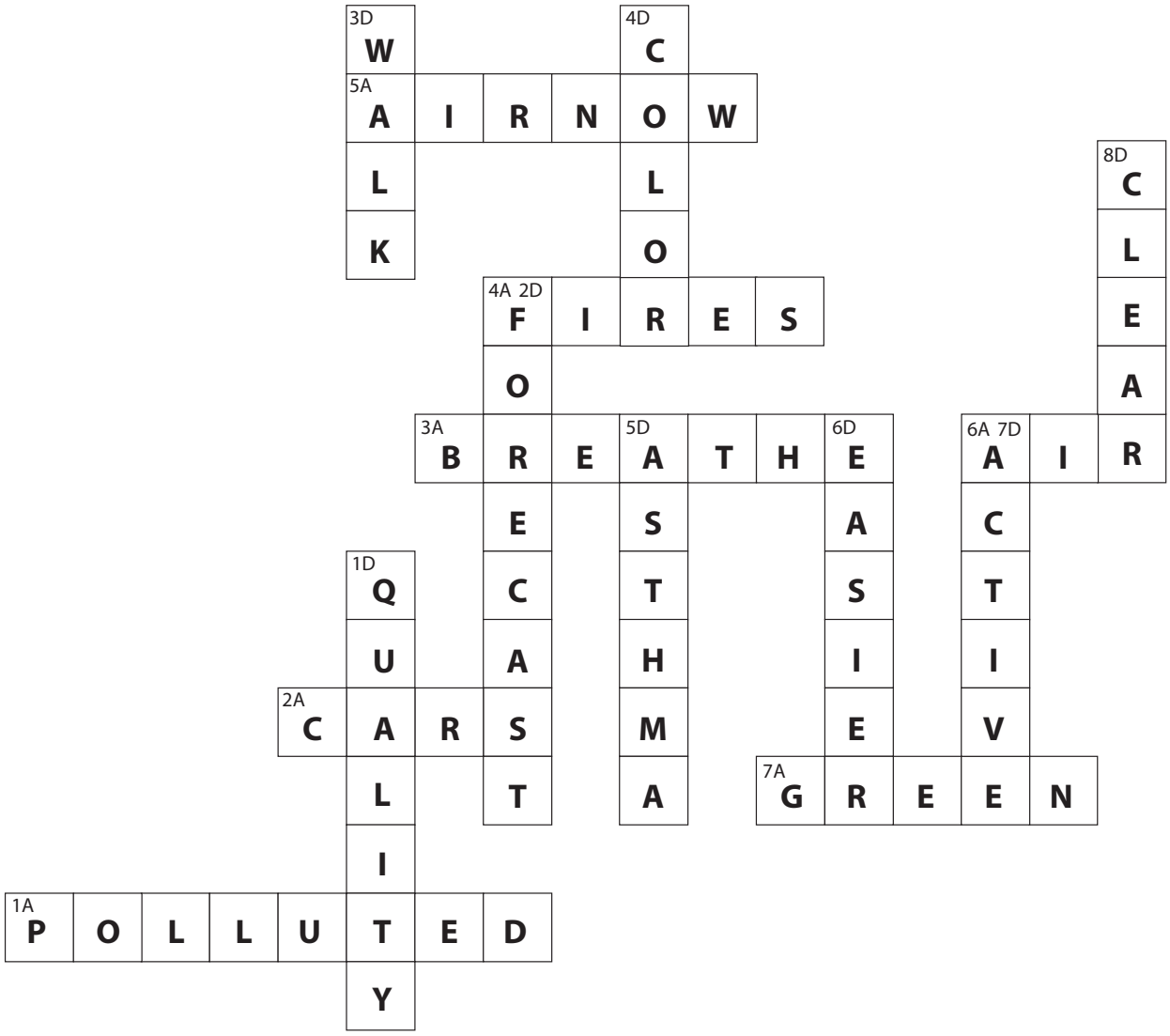
7D. We breathe faster and more deeply when we're _____ than when we're resting.

8D. Most of the time, when the air is not polluted, it is _____.

Air Quality Crossword Puzzle



Answers to Air Quality Crossword Puzzle



What's Your A.Q.I.Q.? (Air Quality Intelligence Quotient): True or False

Student Worksheet:

Circle "true" or "false" as the correct answers for the statements below.

1.	Air pollution is only a problem in big cities.	True	False
2.	Dirty air is costly to every American.	True	False
3.	When the air is polluted, you can always see and smell it.	True	False
4.	Clean air is the responsibility of industry alone.	True	False
5.	The only health effect of ozone pollution is coughing.	True	False
6.	Cars contribute a lot to air pollution problems.	True	False
7.	Air pollution is now under control and will not be a problem in the future.	True	False

What's Your A.Q.I.Q.? (Air Quality Intelligence Quotient): True or False

Teacher Answer Sheet:

1. **Air pollution is a problem only in big cities.** *False.* Everyone is affected by air pollution. The air we breathe does not usually stay in the same place, hovering over us. Oftentimes the air moves. Wind carries pollution to us from hundreds of miles away. Also, the pollution that we produce, no matter how small an amount it may seem, can be significant when combined with everyone else's "small amounts."

2. **Dirty air is costly to every American.** *True.* We pay in health problems caused by air pollution, and the cost of treating people with those health problems. Also, we pay hidden costs in the price of things we buy, for example, the cost of new technology to reduce air pollution. It is frequently less expensive to prevent pollution from occurring in the first place, rather than cleaning it up after it pollutes the air.

3. **When air is polluted, you can always see and smell it.** *False.* Some pollutants are odorless and colorless (such as ozone). That is why it is important to find the Air Quality Index (AQI) in the newspaper, on your favorite news station, or on the Internet (at: www.airnow.gov).

4. **Clean air is the responsibility of industry alone.** *False.* We all have an important role to play in improving our air quality. Choices you can make to improve air quality include turning off lights, TVs, and computers when not using them, and walking, bicycling, or taking a train, bus, or subway (with adult permission) instead of driving places in a car, when possible.

5. **The only health effect of ground-level ozone pollution is coughing.** *False.* Ozone pollution can cause people to cough, but it can also affect our lungs—it can make it harder to breathe, and make asthma worse.

6. **Cars contribute a lot to air pollution problems.** *True.* The automobile industry has made some improvements in equipment in cars that helps reduce pollution, and individual cars and buses release fewer pollutants into the air today than before. However, more people are driving today than ever, and that adds up to a lot of pollution.

7. **Air pollution is now under control and will not be a problem in the future.** *False.* Ozone and particle pollution are still serious problems in many locations in the United States. We all need to be aware of how our activities contribute to pollution and find ways to reduce air pollution and protect our health from the effects of air pollution.

(*Source:* Ozone Action! Let's Clear the Air. West Michigan Clean Air Coalition, Education, Educational Packet 6-8, www.wmcac.org)

Concept Map

- Have students develop their own concept maps on air quality. For information on concept maps, see: www.inspiration.com/visual-learning/concept-mapping
- Have the class make a list of key words relating to air quality, for example, some of the vocabulary words in the lesson plans and fact sheets in this toolkit. Examples of possible key words are: air pollution, emissions, ozone, particle pollution, AQI, smog, visible, invisible, health, breathing problems, cough, heart problems, temperature inversion, school bus, cars, factory smokestacks, asthma, car tailpipes, dirty windows.
- In class or as homework, have students begin by writing the words "air quality" in the middle of a blank page (preferably unlined paper). Tell them to add words that relate to air quality, and add lines to connect the related words. Have them add "connecting words" on the lines so that each statement makes sense (an example is "can cause" between "air quality" and "breathing problems" and between "air quality" and "air pollution"). Tell students that they can extend the branches out to three or four branches, and that they should try to include examples and words from their own personal experiences. Tell students they should also include pictures and colors in their concept maps. Have students share their maps with the class, and hold a class discussion.

More Activity Ideas

- Write a clean air poem.
- Make a poster showing what people can do to protect their health when air quality is not good (see *Breathe Smart! Four Things Kids Can Do* handout in this toolkit).
- Make a poster showing what people can do to improve air quality (see *Breathe Smart! Four Things Kids Can Do* handout in this toolkit).
- Make a poster showing poor air quality (e.g., pollution from vehicle tailpipes, particle pollution on windows, smokestacks) and good air quality. Remind students that air pollution can also be invisible.

- **Create a timeline** linking industrialization to air quality.
- **Write an essay.** Tell students: You live in a biosphere because there is no clean air left outside of it; write 10 of your thoughts/feelings about this. Have students read the essays in class and discuss.
- **Write a report.** Tell students: You are a local elected environmental official. What environmental regulations might you pass? Consider important issues in your community (e.g., air quality in the community), and what barriers you might encounter (e.g., industry doesn't want to spend more money on controlling air pollution; no public transportation exists in your community). Read and discuss the reports in class.
- **Write a jingle/song** encouraging people to improve air quality.
- **Take a series of photographs** on air quality and display them on poster board. Share students' photo displays with the class/school.

(*Source:* Flight for Life, www.nb.lung.ca/FFL/)

- **Research "green" vehicles**, as described in the following activity.

Green Vehicles

Through class discussion and online resources, students learn about "green" vehicles—those that are more fuel-efficient and/or produce less air pollution emissions—and "shop" for their first car.

Ask students what they think "green" vehicles are. Then tell them that "green" vehicles can refer to vehicles that are either energy-efficient, produce less air pollution, or both. Ask students why they think most vehicles on the road today are not "green." Most cars today burn gasoline made from oil to produce energy to move the vehicle forward. Burning gasoline releases emissions into the air that contain air pollutants or pollutant-forming substances. Because the number of vehicles on the road, and the miles they travel, have almost doubled since 1970, air pollution is still a serious problem. Decreasing amounts of oil available to produce gasoline is also a major concern.

Describe several types of green vehicles to the class, including:

- **Hybrid vehicles –** are more energy-efficient than conventional cars because hybrids use electricity part of the time instead of gasoline; at other times they use gasoline. Hybrid cars may or may not produce less air pollution emissions.
- **Low emission vehicles –** produce less air pollution than older gasoline-powered vehicles. There are also "ultra-low," "super-ultra low," "partial zero," and "zero" emission vehicles. Most newer vehicles now meet low emission or ultra-low emission requirements. Electric and fuel cell vehicles are examples of zero emission vehicles.

Green Vehicles (continued)

- **Alternative fuel vehicles –** use fuels other than gasoline, such as biofuels made from biomass (natural materials such as plants and biodegradable wastes), ethanol, and methanol. Propane or natural gas can also be used; these produce air emissions, but less than gasoline-powered vehicles.
- **Electric cars –** run completely on electricity instead of gasoline, and produce no air emissions.
- **Fuel cell vehicles –** use hydrogen instead of gasoline; other chemicals could also be used, but these would most likely produce some air emissions (while fuel cells do not), although less than using gasoline.

Hybrids are currently available to buy commercially. Vehicles powered by ethanol in combination with gasoline are also readily available. The other types of green vehicles or alternative fuels are generally not yet commercially available, but much research is being conducted on them.

Ask students: If you were going to buy your first car next week, what things would you look for? (Probable answers: color, speed, cost, special features.) Ask them if they would consider how much gasoline a vehicle uses (miles per gallon), and much fuel would cost to fill up the tank (how "fuel-efficient" the vehicle is). Ask them if they would consider how much air pollutant emissions a car produces.

- With students, visit EPA's Green Vehicle Guide Web site at www.epa.gov/greenvehicles/Howto.do and compare hybrids to other makes and models.
- Also visit the U.S. Department of Energy's and EPA's Fuel Economy Web site at www.fueleconomy.gov/feg/findacar.htm, which compares vehicles based on miles per gallon, annual fuel cost, and EPA pollution score.

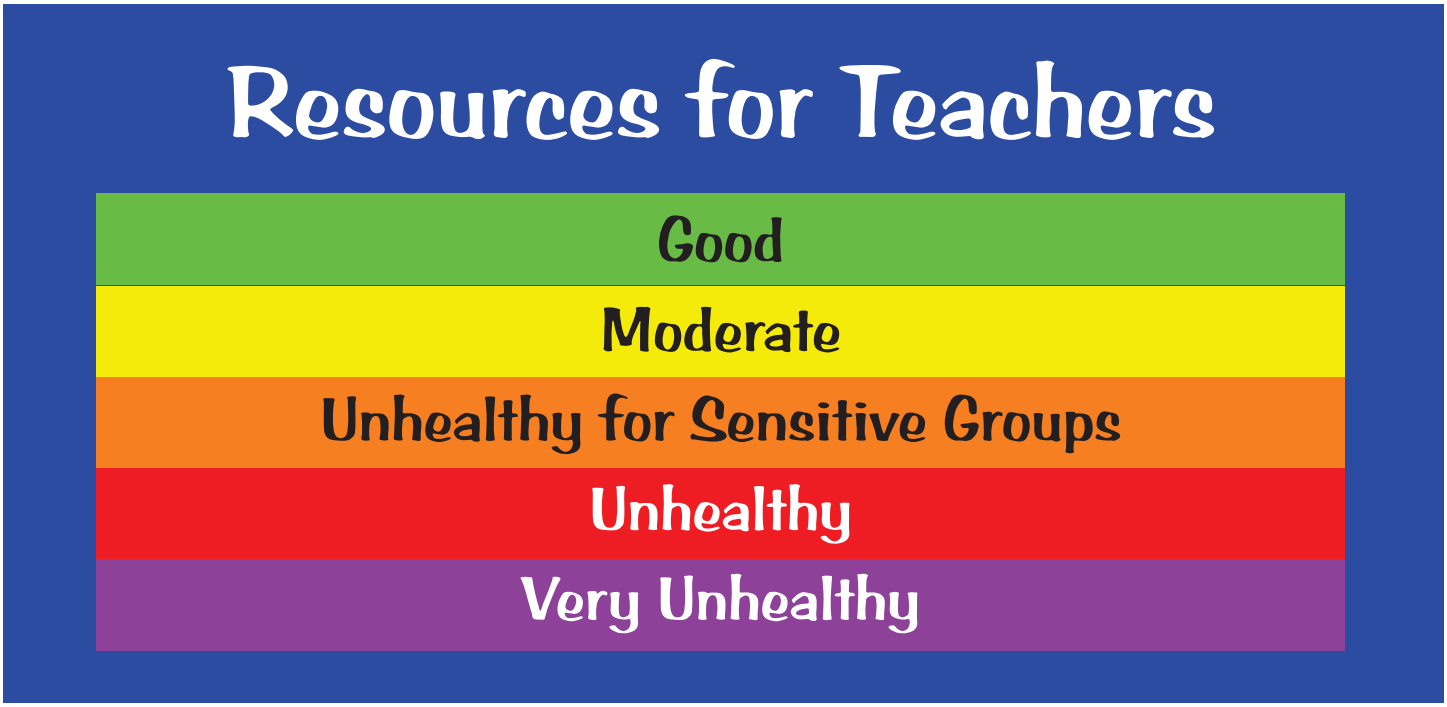
For more information on green vehicles, see the Web site: www.sdrafvc.org/PDFS/CarsCarsCars05.pdf.

Also let students know that properly maintained vehicles pollute much less and get better gas mileage. Tell them that they can encourage their family to keep vehicle engines properly tuned and tires properly inflated, and not to top off the gas tank when fueling – gas spills evaporate and contribute to smog. Also tell them that turning off a car when it's standing still (like when you're waiting for someone to come out of his or her house), rather than keeping it going at such times (known as "idling"), reduces air pollution and saves gasoline.

Summarize by telling students that one of the best ways to protect air quality is to reduce our use of gasoline–powered vehicles when possible and switch to cleaner fuels when available. Using buses, bicycles, subways, trains, and car pools, or walking places instead of using cars, helps keep the air clean.

(*Source:* American Lung Association of San Diego and Imperial Counties, CA, Education, Cars, Cars, Cars Lesson Plan & Teacher's Guide)

Resources for Teachers



Air Pollution and Health

Through regulation and voluntary change, levels of many air pollutants have decreased significantly in recent decades. Still, in many parts of the U.S. the air is often polluted at levels that can affect our health. Millions of people are exposed to unhealthful levels of ground-level ozone or particle pollution every year.

Ozone

What is ozone? Ozone is an odorless, colorless gas composed of three atoms of oxygen. Ozone occurs naturally in the Earth's upper atmosphere (the stratosphere) and as a pollutant at ground level. Stratospheric ozone protects us from the sun's harmful ultraviolet rays. This beneficial ozone is gradually being destroyed by manmade chemicals. At ground level, ozone is a harmful pollutant formed when emissions from vehicles, power plants, and industrial sources react in the presence of sunlight and heat.

When and where is ozone a concern? Because it needs heat to form, ozone pollution is a concern in warmer weather, particularly in the afternoon and early evening. Ozone can be transported by winds hundreds of miles from where it formed, so it can be found in both urban and rural environments.

Can we see ozone in the air? By itself, ozone in the air is invisible, so we can be breathing harmful ozone levels even when the air looks clear. When ozone mixes with particles (described below), it forms a brown summertime haze known as "smog."

Why is ozone pollution bad? Ozone can trigger a variety of health problems, even at relatively low levels. Health effects from ozone include aggravated asthma and increased susceptibility to respiratory illnesses like pneumonia and bronchitis. Symptoms to watch for when ozone is in the air include coughing, pain when taking a deep breath, and breathing difficulties, especially when you are active outdoors. But ozone damage can also occur without any noticeable signs. And, for some people, several months of repeated exposure to ozone can permanently damage the lungs. Ozone is also bad for our environment, damaging plants and trees and reducing crop and forest yields.

Who's at risk from ozone pollution? People with respiratory problems are most vulnerable, but even healthy people and children who are active outdoors can be affected when ozone levels are unhealthy. This is because during physical activity, ozone penetrates deeper into the parts of our lungs that are most vulnerable to ozone.

Particle Pollution

What is particle pollution? Particle pollution includes dust, soot, dirt, and liquid droplets. Some particles are large enough to be visible. Others can only be seen under a microscope. The smaller particles cause the greatest health concern because they penetrate deeper into the lungs and can even enter our bloodstream.

What causes particle pollution? Sources of particle pollution include vehicles, factories, and power plants, as well as natural sources such as forest fires and volcanoes.

When and where is particle pollution worst? Particle pollution can be high at any time of year. It can be especially bad during winter, when warm air above cold air causes "inversions"

that can trap pollutants in one area for a period of time. Particle pollution can be higher near busy roads and factories, and can reach very hazardous levels in areas downwind of forest fires. Particle pollution can be high indoors, especially when outdoor particle levels are high.

Why is particle pollution bad? Health effects from particles range from coughing and aggravated asthma to chronic bronchitis and even premature death. Many studies link particle pollution levels with increased hospital admissions and emergency room visits. If you have heart disease, particle exposure can cause serious problems in a short period of time—even heart attacks—with no warning signs. Particle pollution also has significant environmental effects. Particles are a major component of haze, which can reduce visibility, for example in national parks and other scenic vistas. Particles are a major contributor to "acid rain," which harms the environment in a number of ways, including making lakes and other water bodies more acidic, which can harm the health of aquatic life; damaging trees and soils; and deteriorating buildings and statues.

Who's at risk from particle pollution? People with heart or lung disease are at risk because particle pollution can aggravate these diseases. Many studies show that when particle levels are unhealthy, older adults are more likely to be hospitalized, and some may die of aggravated heart or lung disease, perhaps because these diseases were previously undiagnosed in these patients. Children are at risk because their lungs are still developing and they are usually very active.

Protect Your Health

Because ozone and particles remain a significant public health concern in many areas of the U.S., the U.S. EPA, in partnership with federal, state, and local agencies and tribes, have set up a nationwide network for reporting daily air quality information and forecasts for these two pollutants, as well as three others. This information is available on the Internet at: www.airnow.gov, in newspapers, via radio and television announcements, and in many areas via air quality notifications sent to your email or cell phone (www.airnow.gov/enviroflash). Daily air quality is reported using a standard, color-coded scale called the Air Quality Index, or AQI. The AQI makes air quality reports as easy to understand as weather reports.

The best way to protect your health is to check the air quality level and forecast daily for your area, and the related health messages provided by the AQI. By doing so, you can find out when ozone or particle levels are elevated. You can also take simple precautions to minimize exposure, even when you don't feel obvious symptoms. Precautions include:

- When possible, plan activities and exercise when pollution levels are lower (e.g., typically morning or evening for ozone).
- If pollution levels are unhealthy, take it easy when you are active outside. For example, reduce the intensity of your activity (e.g., go for a walk instead of a jog) or reduce the length of your activity. You can also choose to exercise at another time or on another day when the air quality is better. That way, you will reduce the amount of pollution you breathe.
- To reduce exposure to particle pollution, exercise away from busy roadways and other pollution sources.
- Check with your health care provider if you notice any symptoms (such as coughing, wheezing, difficulty breathing, or chest pain) when the air is polluted. This is especially im-

portant if you are a member of a sensitive group (i.e., for ozone—active children or adults, and people with lung disease; for particle pollution—people with heart or lung disease, older adults, and children).

What Is the Air Quality Index (AQI)?

The AQI is an index for reporting daily air quality. It uses a simple color-coded scale to tell you how clean or polluted your air is, and how you can protect your health at different levels of pollution. The AQI helps to make daily air quality information as easy to understand as weather forecasts.

How Does the AQI Work?

The AQI is essentially a yardstick that runs from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 represents good air quality with little potential to affect public health, while an AQI value over 300 represents hazardous air quality.

An AQI value of 100 generally corresponds to the national air quality standard for the pollutant, which is the level EPA has set to protect public health. When AQI values are above 100, air quality is considered to be unhealthy—at first for certain sensitive groups of people, then for everyone as AQI values get higher.

Understanding the AQI

To make it easier to understand, the AQI is divided into six categories:

Air Quality Index Values	Levels of Health Concern	Colors
When the AQI is in this range:	...air quality conditions are:	...as symbolized by this color:
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

Each category corresponds to a different level of health concern:

- **"Good"—**The AQI value for a particular community is between 0 and 50. Air quality is considered satisfactory, and air pollution poses little or no risk.
- **"Moderate"—**The AQI for a community is between 51 and 100. Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people. For example, people who are unusually sensitive to ozone may experience respiratory symptoms.
- **"Unhealthy for Sensitive Groups"—**When AQI values are between 101 and 150, members of sensitive groups may experience health effects. This means they are likely to be affected at lower levels than the general public. For example, people with lung disease are at greater risk from exposure to ozone, while people with either lung disease or heart disease are at greater risk from exposure to particle pollution. The general public is not likely to be affected when the AQI is in this range.

- **"Unhealthy"—**Everyone may begin to experience health effects when AQI values are between 151 and 200. Members of sensitive groups may experience more serious health effects.
- **"Very Unhealthy"—**AQI values between 201 and 300 trigger a health alert, meaning everyone may experience more serious health effects.
- **"Hazardous"—**AQI values over 300 trigger health warnings of emergency conditions. The entire population is more likely to be affected.

How Is a Community's AQI Calculated?

Air quality is measured by monitors that record the concentrations of the major pollutants each day at more than a thousand locations across the country. These raw measurements are then converted into AQI values using standard formulas developed by EPA. An AQI value is calculated for each pollutant in an area (ground-level ozone, particle pollution, carbon monoxide, sulfur dioxide, and nitrogen dioxide). The highest AQI value for the individual pollutants is the AQI value for that day. For example, if on July 12 a certain area had AQI values of 90 for ozone and 88 for sulfur dioxide, the AQI value would be 90 for the pollutant ozone on that day.

When and How Is the AQI Reported to the Public?

In large cities (more than 350,000 people), state and local agencies are required to report the AQI to the public daily. When the AQI is above 100, agencies must also report which groups, such as children or people with asthma or heart disease, may be sensitive to those pollutants. Many smaller communities also report the AQI as a public health service.

Many cities also provide forecasts for the next day's AQI. These forecasts help local residents protect their health by alerting them to plan their vigorous activities for a time when air quality is better.

The AQI is a national index, so the value and colors used to show local air quality and the levels of health concern will be the same everywhere in the U.S. You can always find AQI reports for areas across the U.S. on the Internet at EPA's AIRNow web site: www.airnow.gov . The AQI is also frequently reported in local newspapers, on local television and radio stations, and on many state and local telephone hotlines.

What Are Typical AQI Values in Most Communities?

In many U.S. communities, AQI values are usually below 100, with values greater than 100 occurring just several times a year. Typically, larger cities have more severe air pollution problems, and the AQI in these areas may exceed 100 more often than in smaller cities. AQI values higher than 200 are infrequent, and AQI values above 300 are extremely rare.

AQI values can vary from one season to another. In winter, for example, carbon monoxide may be high in some areas because the cold weather makes it difficult for car emission control systems to operate effectively. In summer, ozone may be a significant air pollutant because it forms in the presence of heat and sunlight. Particle pollution can be elevated at any time of the year.

AQI values also can vary depending on the time of day. For example, ozone levels often peak in the afternoon, while carbon monoxide is usually a problem during morning or evening rush hours. Particle pollution can be high at any time of day.

Additional Air Quality Resources

Curricula, Lesson Plans, and Activities

Air Pollution: What's the Solution?

This educational project uses online, real-time air quality and weather data to guide Grades 6-12 students in understanding the science behind the causes and effects of ground-level ozone pollution. Available at: www.k12science.org/curriculum/airproj/

Air Quality Education Program

The Delaware Department of Natural Resources and Environmental Control's Air Quality Education Program for Grades 6-12 includes detailed lesson plans. Available at: www.dnrec.state.de.us/DNREC2000/Divisions/AWM/aqm/education/Contnt.htm

AirNow Teacher's Air Quality Resources

This webpage provides curriculum resources, environmental education materials and classroom activities. www.airnow.gov/teachers

AQI Toolkit for Weathercasters

EPA's AQI Toolkit for Weathercasters is a companion to this AQI Toolkit for Teachers. The weathercasters toolkit includes presentations on air quality, weather, the AQI, ozone, particle pollution, and health for Grades 3-8 and adults, and earlier versions of the lesson plans in this toolkit. Available at: www.airnow.gov/index.cfm?action=aqifor.weathercast

Clean Air Campaign

The Clean Air Campaign and the Georgia Environmental Protection Division provide air quality lesson plans as well as school programs and children's activities. Available at: www.cleanaircampaign.org/Your-Schools

Eco Badge® Educational Products

Vistanomics' "eco store" sells air quality educational materials, including the Eco Badge® (a compact, easy-to-use device to measure ozone levels at home or in the work environment). The site also provides examples of successful teacher programs using the Eco Badge. Available at: www.ecobadge.com

EPA Teaching Resources—Air

This Web page provides links to curricula and activities on a variety of environmental topics, including ozone and the AQI. Available at: www.epa.gov/students/teachers.html

Flight for Life

The New Brunswick Lung Association provides educational resources on respiration, indoor and outdoor air quality, climate change, and health for elementary, middle school, and high school teachers and students. Available at: www.nb.lung.ca/FFL

In The Air

Provides environmental education materials for Grades K-12 and adults on airborne toxics. Developed by the Missouri Botanical Garden's Earthways Center and the EPA. Available at: www.intheair.org

Ozone Action

The West Michigan Clean Air Coalition offers educational packets with lesson plans and activities for Grades K-12. Available at: www.wmcac.org/resources/education.html

The KnowZone

Developed by the California Air Resources Board, The KnowZone offers a variety of teacher and student resources, including lesson plans, a video, a presentation, and Safe Routes to Schools information. Available at: http://www.arb.ca.gov/knowzone/knowzone.htm

SunWise School Program

An environmental and health education program designed to teach children and their caregivers how to protect themselves from overexposure to the sun. Available free of charge to schools, the SunWise Tool Kit contains classroom lessons and background information for Grades K-8. Available at: www.epa.gov/sunwise

Walking for Health and the Environment Curriculum

This curriculum for Grades K-5 helps students make connections between exercise, health, and the environment. Developed by Walk Boston and Eastern Research Group, Inc. (ERG). Available at: http://www.walkboston.org/what-we-do/initiatives/safe-routes-school

Selected Web Sites

AIRNow Web site

The AIRNow Web site provides the public with easy access to air quality information. The Web site provides real-time air quality conditions and daily air quality forecasts for over 300 cities across the U.S., teacher and student resources, links to more detailed state and local air quality Web sites, and real-time images of air quality and visibility via webcams. Available at: www.airnow.gov.

AIRNow's air quality resources for teachers can be found at:
www.airnow.gov/teachers

AIRNow's Air Quality Index Kids Page can be found at:
www.airnow.gov/kids

Smog City 2

The Smog City 2 Web site explores particle pollution and ozone pollution in a hypothetical city. Users can change variables such as weather conditions, emission levels, and population, and see how these changes affect air quality. Developed by the U.S. EPA and the Sacramento Air Quality Management District. Available at: www.smogcity2.org

Selected EPA Air Quality Publications

The following U.S. EPA publications are available online (print versions may be available free of charge) at: http://www.airnow.gov/index.cfm?action=pubs.index

- **Air Quality Index—A Guide to Air Quality and Your Health.** This booklet explains EPA's Air Quality Index (AQI) and the health effects of major air pollutants.
- **Air Quality Guide for Ozone.** This guide provides information about ways to protect your health when ozone levels reach the unhealthy range, and ways you can help reduce ozone air pollution.
- **Air Quality Guide for Particle Pollution.** This guide provides information about ways to protect your health when particle pollution levels reach the unhealthy range, and ways you can help reduce particle air pollution.
- **Particle Pollution and Your Health.** This short, colorful pamphlet describes who is at risk from exposure to particle pollution (also known as particulate matter), what health effects may be caused by particles, and simple measures that can be taken to reduce health risk.
- **Ozone and Your Health.** This short, colorful pamphlet describes who is at risk from exposure to ozone, what health effects are caused by ozone, and simple measures that can be taken to reduce health risk.
- **Ozone: Good Up High, Bad Nearby.** This publication provides information about ground-level and high-altitude ozone and their different effects.
- **Smog Who Does it Hurt?** This 8-page booklet provides more detailed information than "Ozone and Your Health" about ozone health effects and how to avoid them.
- **Summertime Safety: Keeping Safe from Sun Smog.** This document discusses summer health hazards that pertain particularly to children and includes information about EPA's Air Quality Index and UV Index tools.
- **"Why is Coco Orange?"** This picture book introduces the AQI colors to children in grades K-2, teaches them what the different colors mean, how to recognize health symptoms and what actions to take when air quality is bad (www.airnow.gov/picturebook).
- **School Flag Program.** A school based program that protects children's health. Schools fly a flag based on the color of the AQI to indicate the local air quality conditions. Information and resources are available on the flag program website at: www.airnow.gov/schoolflag
- **Effects of Common Air Pollutants Poster.** This 18"x 24" poster depicts and illustrates respiratory and cardiovascular effects of air pollution and symptoms. http://www.airnow.gov/index.cfm?action=health_providers.index