Lesson Three:
FIRE AND SMOKE

Lesson Overview

This lesson explores smoke as an outdoor air pollution problem that can trigger asthma episodes. Students explore several demonstrations that illustrate the link between particulate matter created by incomplete burning of fuel and how temperature inversions can worsen air pollution problems. Students also read about how wood smoke, agricultural field burning, and wildfires can worsen asthma symptoms. Extension activities are also included for additional classroom work or homework assignments.

Suggested Grade Levels: 7 & 8
Curriculum Connections: Outdoor air pollution, combustion, weather patterns, environmental science, asthma triggers, exploring models.

EALRs Addressed

This lesson addresses the following Washington State Essential Academic Learning Requirements (EALRs). The benchmarks listed are for grade 8 in science.

In this lesson, the student is asked to:

- Explain how human societies' use of natural resources affects quality of life and the health of ecosystems. (Science 1.3 Environmental and Resource Issues).
- Correlate models of the behavior of objects, events, or processes to the behavior of the actual things; test models by predicting and observing actual behaviors or processes. (Science 2.1 Modeling).

Teacher Background

For a more in-depth understanding of asthma, fire and smoke consult the following resources that were used to prepare this lesson:

- **Puget Sound Clean Air Agency's "Clean Air Express" Curriculum**
  http://www.pscleanair.org/news/cleanairexpress.html
- **Burning Issues—Wood Smoke Information**
  http://www.webcom.com/~bi/
- **Washington Department of Ecology Publications of the Health Effects of Wood Smoke**
  http://www.ecy.wa.gov/ (Search for "wood smoke health" for a variety of publications.)
- **Outdoor Burning Information**
  http://www.ecy.wa.gov/programs/air/outdoor_burning.htm
- **Washington Department of Ecology Agricultural Burning Information**
  http://www.ecy.wa.gov/programs/air/aginfo/agricultural_homepage.htm
- **Power Point Presentation on Agricultural Burning Study**
  "Pullman Ag Burning Health Effects Study"
  http://depts.washington.edu/pmcenter/res_reports.html
- **University of Washington's Fire, Smoke and Health Information**
  http://depts.washington.edu/wildfire/

Please be aware that **Activity #1** requires the use of matches, candles and Bunsen burners. Please be careful around open flames and take care not to set off the fire alarm. Keep a fire extinguisher nearby. This activity may be more appropriate as a teacher-led classroom demonstration.

Materials developed by the Integrated Environmental Health Middle School Project (NIEHS Grant #ES10738 and #ES07033).

Teacher Preparation

Materials:

Activity #1 — as a class demonstration:

- Candle; Bunsen burner; matches or lighter; two glass jars or heatproof plates

Activity #2 — as a class demonstration or in groups:

- Three identical glass containers, such as glass beakers or jars; water; salt; red, green and blue food coloring; pipette or eye dropper; cup or other container for mixing water; funnel; rubber tubing; stirring rod; hot plate, burner, or mug warmer.

- Make enough copies of the **Student Handout** for each student or group to have a set. Master copies of the handouts are included at the back of this book.

- If you are the first teacher in your team to use this FACT FILE, make copies of the student handout entitled, **Student Introduction: Environmental Health and Asthma**. Ensure that students have read the handout and mastered the content and vocabulary.

Procedure

- Have the students read **Student Handout #1** before beginning the following activities. The **Check Your Understanding** questions may be answered individually in writing or verbally in small groups.

- **Activity #1: Incomplete combustion**

  This activity might work best as a teacher-led demonstration to the class.

- Light the candle. Hold the glass jar or plate over the candle about 2 inches above the flame for about 30 seconds. If using a jar, hold the mouth of the jar over the flame at a 45 degree angle. Then, show the students how black soot has collected on the jar or plate. This soot is a result of incomplete burning of the candle wax. The soot is made up of tiny particles—or particulate matter—that combustion emits into the air. The flame also produces gases, which we cannot see.

- Now light a Bunsen burner. Repeat the above demonstration with the second jar or plate. Compare the jar or plate with one from the candle demonstration. Note that the Bunsen burner did not produce any soot, since the natural gas burns more completely and cleanly.

- Return to the candle. Hold the lit candle in one hand and a lit match in the other hand. Gently blow out the candle, then use the match to re-light the smoke chain (do not lit the wick). The smoke chain will light, causing the candle wick to re-light. Discuss how fuels that burn incompletely release harmful gases and particulate matter into the air.

- Discuss how wood smoke produces thick, dark smoke filled with harmful particulate matter, while natural gas burns more cleanly. However, the combustion of natural gas in stoves and fireplaces does cause an increase in nitrogen oxide, an indoor air pollutant. Other fuels, such as coal, oil and gasoline, also burn incompletely and produce smoke and soot.

- Refer to the circle graph in the **Student Handout #1** that shows air pollution sources in Washington State. Point out how much air pollution is attributed to indoor burning in wood stoves and fireplaces and to outdoor burning.

Materials developed by the Integrated Environmental Health Middle School Project (NIEHS Grant #ES10738 and #ES07033).

- **Activity #2: Temperature inversion**

  This demonstration illustrates how a temperature inversion works. Inversions can cause major air pollution episodes when a layer of pollution is trapped between layers of cold and warm air. In this activity, water represents different temperatures of air. This activity can be done as a teacher-led demonstration to the class or can be done by students working in small groups. Explain that air has some fluid-like properties and will form "layers" by temperature.

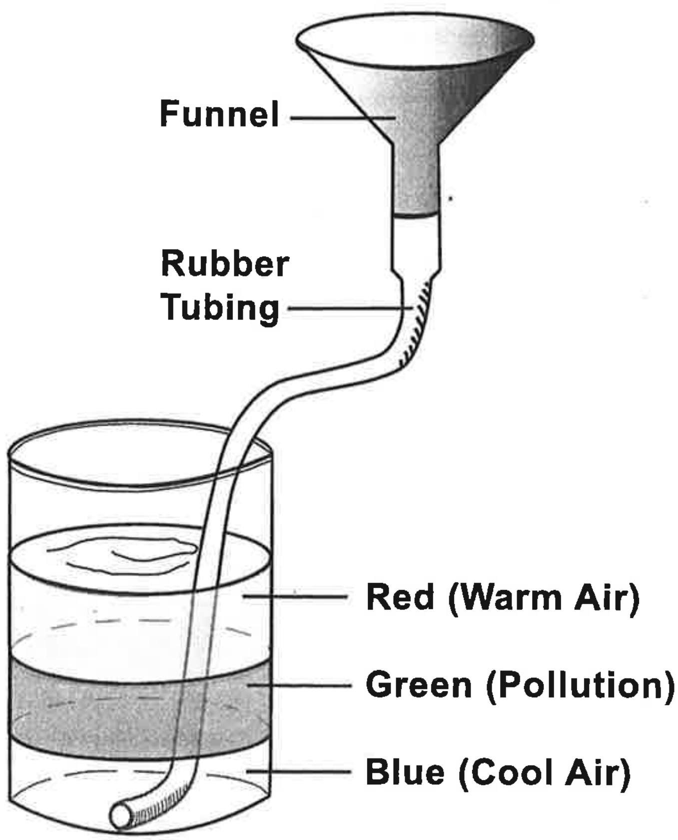
- Fill the three containers each a little less than half full with warm water. Put some red food coloring in the water in each container. Explain that the red water represents warm air and that it is less dense than cold air.

- Fill a cup or other mixing container with cold water and saturate it with salt (add salt until no more will dissolve). Dye this water blue. Explain that this represents cold air and that it is more dense than warm air.

- Fit the rubber tubing snugly over the end of the funnel. Pour the blue water slowly and carefully through the funnel into each container, making sure that the tubing is on the bottom of the container. This should result in two layers—blue on bottom and red on top.

- Fill a cup or other mixing container with lukewarm water. Add green food coloring and lightly salt the water. Explain that this represents air pollution.

- Show what happens when pollutants enter the air during an inversion. Use a pipette to slowly introduce the "pollution" to the other mix in each of the three containers. It will settle in a layer somewhere between the red and blue water.



- Explain that this is what happens when there is an inversion. The air is stagnant with little wind. This condition keeps the "cold" heavy air and "warm" light air from mixing, making it easier for pollution to become trapped above the cold layer of air. Instead of mixing in and blowing away, the cold air keeps the pollution trapped within our breathing space. Air pollution is generated daily by human activities such as indoor and outdoor burning, motor vehicles and industrial emissions. As the **Student Handout** explains, episodes of stagnant air and temperature inversions have been linked to increased cases of asthma episodes and other respiratory diseases. Set Container #1 aside.

- Demonstrate what happens when a windstorm comes into an area during an inversion. Use the stirring rod to stir up Container #2 so that the layers of mix.

- Demonstrate what happens when the ground begins to warm up. Place Container #3 on a mug warmer, burner or hot plate. Watch as the layer of cool, blue water warms up and begins to rise. You should see a mixing of the layers as the warm water rises and cool water sinks. (You can also see this kind of thermal mixing in a cup of hot coffee when cold cream is poured in). These density currents can also be likened to weather and ocean currents.

- Compare Container #1 with the stable inversion model to Containers #2 and #3 that show how the inversion has been dispersed.

Student Assessment:
Use these questions as discussion points.

Check your students' understanding by asking the following questions:

- How might agricultural burning, wood smoke and wildfires be related to temperature inversions?

- Why are temperature inversions more common in valleys and areas bordered by mountains?

- What can people do during an inversion to reduce air pollution?

- What kind of weather is needed to break up an inversion?

- Explain why the fluids form distinct layers?

- Compare observed liquid densities with gases. Would the gases behave the same? Why or why not?

- How does the temperature inversion model relate to weather patterns and ocean currents?

Activity #1 and #2 were adapted with permission from Puget Sound Clean Air Agency's "Clean Air Express" curriculum.

Materials developed by the Integrated Environmental Health Middle School Project (NIEHS Grant #ES10738 and #ES07033).

Student Assessment

Student work can be assessed in the following ways, for a total of 100%.

10%	Did students view the demonstrations **Activity #1: Incomplete Combustion** and **Activity #2:Temperature Inversion**?
70%	Did your students read **Student Handout #1** and complete the **Check Your Understanding Questions**?
20%	Did students participate in a **class discussion** about outdoor air pollution and human health?

Extension Activities

The extension activities provide for more in-depth assessment of student understanding.

Burning Fuel

- Students burn different types of combustible fuel materials and compare what kinds of materials are released into the air from each fuel type. A lesson plan for this activity can be downloaded from the Clean Air Express curriculum. Look for Lesson #2 in the "Supplemental Activities 6-8" section.
  http://www.pscleanair.org/news/cleanairexpress.shtml

Charting Weather Patterns

- Students collect different types of weather data over several weeks, examining links between air pollution and weather. A lesson plan for this activity can be downloaded from the Clean Air Express curriculum. Look for Lesson #3 in the "Supplemental Activities 6-8" section.
  http://www.pscleanair.org/news/cleanairexpress.shtml

Satellite Images

- You can access a NOAA website with recent satellite images of forest fires to show students the geographic impact of the smoke plume. NOAA Satellites and Information website.
  http://www.osei.noaa.gov/

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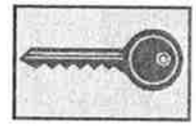
FIRE AND SMOKE
Student Handout #1



Smoke in Your Lungs

Every day, you breathe in tiny **particles** from smoke that can be harmful to your lungs. Just think about all the different sources of smoke that may surround you in your own home: wood smoke from fireplaces and wood stoves, cigarette smoke, smoke from burning candles and incense, and smoke from cooking foods, especially when frying or sautéing or when you accidentally burn your dinner. For people with asthma, the tiny particles in smoke can trigger asthma episodes and worsen their symptoms.

These different sources of indoor smoke can make the air within your home unsafe, especially for people with asthma. In addition, sometimes bigger events can cause serious outdoor air **pollution** problems that can affect a large number of people, such as wood fires in the winter time, field burning and wildfires.

Smoke is filled with tiny particles. These particles are less than 2.5 micrometers in diameter. A micrometer is one millionth of a meter, about the same as dividing one inch into 25,400 parts. These particles are so small that the diameter of a human hair is about 70 times bigger; a grain of salt is 100 times bigger. These particles are too small to be filtered by the nose and are inhaled deep into the lungs, where they can immediately cause inflammation or remain for months before causing trouble.

Killer Smog

Some of the worst cases of air pollution in history happened because of a weather pattern that trapped pollution close to the ground for days, creating a killer smog.

A **temperature inversion** is caused when a layer of warm air traps a layer of cool, heavy air close to the ground. Oftentimes, this happens on cold, clear, calm nights when the ground cools rapidly. The cold ground cools the air closest to it, but the air higher up is slower to cool. The upper warm layer of air acts like a lid, trapping the cool air—and any air pollution—close to the ground.

Air pollution, such as vehicle emissions or smoke from chimneys, can become trapped in the layer of cool air. If the air is **stagnant** for too long, it may allow high levels of pollution to accumulate and create **smog**. If pollutant levels become too high during a temperature inversion, people may be advised to stay indoors and avoid exercising. Sensitive people, such as infants, the elderly, or people with respiratory diseases like asthma may need to take extra precautions during a temperature inversion.

Temperature inversions can occur in almost any region, but they are most common in valleys or areas like the Puget Sound region that are bordered by mountains. Temperature inversions are common in winter time, when stagnant air and temperature inversions trap pollution in our breathing space. A temperature inversion will break up from a windstorm or when the ground heats up and the warm air rises, therefore mixing up the layers of the inversion.

In 1948, there were no air quality laws to limit how much pollution factories could put into the air. The small factory town of Donora, Pennsylvania is known for an air pollution tragedy that

Particles: Tiny pieces of a substance that are suspended in the air, such as dust or ash.

Pollution: The act of contaminating the air, water or soil with toxic substances.

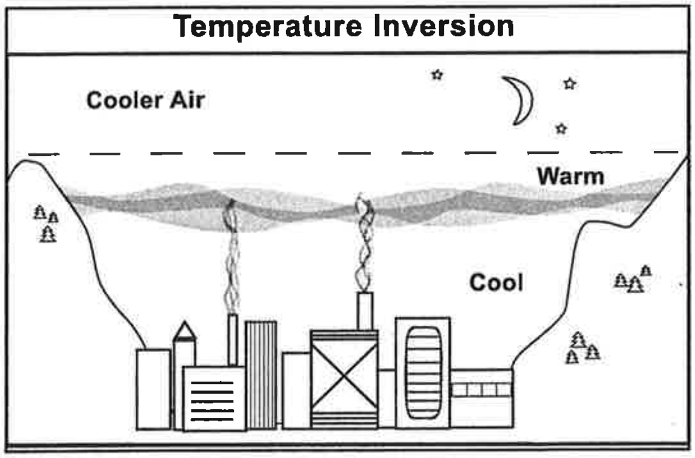
Temperature Inversion: An atmospheric condition in which a layer of warm air traps a layer of cold air close to the ground, causing the stagnant air to trap pollution near the ground.

Stagnant: Air that is motionless because there is no wind.

Smog: A term that was coined in London in 1911 to describe the thick smoke and fog that hangs in the air over industrialized areas. Now the term is incorrectly, but commonly used to describe low-lying air pollution often caused by motor vehicles.

Materials developed by the Integrated Environmental Health Middle School Project (NIEHS Grant #ES10738 and #ES07033).

helped emphasize the need for today's air quality laws. In October of 1948, the town of Donora experienced an unusually long temperature inversion. The inversion combined with toxic pollutants including flouride gas from a zinc and steel factory, trapping the pollutants in the stagnant air hanging over the town. The air was heavy with yellow-white smog that became so thick that the town's residents could not see well enough to drive; even walking outside became difficult. People did not understand that the smog was dangerous for their health. The thick smog contributed to the deaths of 21 people in two days. One-third of the town's population—about 6,000 people—became ill.



A similar disaster occurred in London in 1952. A week-long temperature inversion combined with heavy pollution from coal factories, diesel buses and coal burning stoves to create killer smog. In four days, the smog contributed to the deaths of about 4,000 people. The total number of people who died is closer to 12,000 people. This was not the first time London had experienced killer smog. In 1909, stagnant air and coal burning contributed to the deaths of 1,000 people in one winter. Later, in 1962, 750 people died from causes related to smog. Both the Pennsylvania and the London disasters caused the citizens of Donora and London to demand that their governments develop laws to protect clean air and help prevent further disasters caused by killer smog.

Check Your Understanding

1. How does a temperature inversion make pollution worse?
An inversion traps air pollution in a layer of cold air that is held close to the ground by an overlying layer of warm air. The pollution is trapped in people's breathing space.

2. What caused the smog in Pennsylvania and London?
The combination of a temperature inversion and industrial and residential emissions (factories, coal burning stoves and diesel buses) caused the killer smog.

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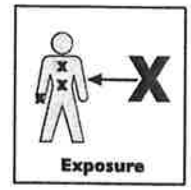
Wood Smoke



Most people enjoy the cozy smell of a crackling fire in the fireplace. Some people depend on wood-burning fireplaces and stoves for cooking and heating. Did you know that wood smoke is filled with substances that are potentially harmful to humans? Wood does not burn completely, so it may release harmful substances in its smoke. Wood smoke can irritate the eyes, cause headaches and trigger allergies and asthma episodes.

Wood smoke contains over 200 chemicals. The smoke includes a combination of substances that are dangerous for humans to inhale, including carbon monoxide, particulate matter including soot and ash, and some cancer-causing compounds. Also, other kinds of toxic substances in the air may attach to the particles in wood smoke, actually hitching a ride deep into your lungs where they can potentially cause serious health problems. Wood smoke can make many respiratory diseases worse, including asthma.

Half of the homes in Washington State have fireplaces. There are over a half million fireplaces and wood stoves in the Puget Sound area alone. In urban and suburban areas, wood smoke can become concentrated and cause a big outdoor pollution problem.

Pollution from wood-burning fireplaces and stoves makes up about 9% of all of the outdoor air pollution in Washington State each year. However, this pollution is concentrated in the winter months when the air is often stagnant and when temperature inversions occur. On a crisp winter day, about 80% of the air pollution in some neighborhoods is caused from smoke from fireplaces and wood stoves.

Tips for better burning:

- Outdoor burning of yard waste is banned in many urban growth areas, such as the Puget Sound region. In other areas, check to see if a burn ban is in effect.
- Burning garbage is illegal because materials like plastics can produce harmful smoke.
- If possible, use alternative heat sources, such as natural gas, electric furnaces or pellet stoves.
- If you must burn wood, choose compressed sawdust logs (Presto Logs), which burn more completely than stick wood does. If you must burn wood, only burn dry wood that has aged for at least six months.

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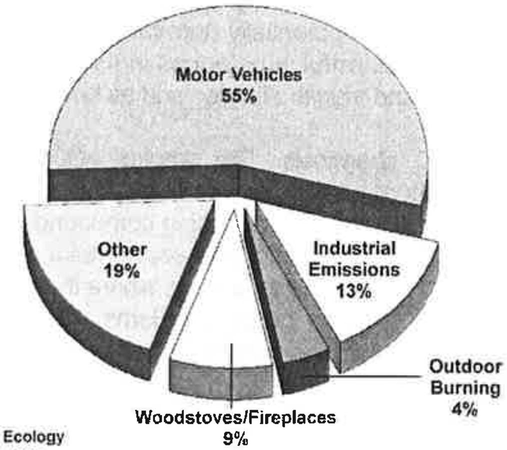
AIR POLLUTION SOURCES IN WASHINGTON

Statewide-Annual Average



Source:
Dept. of Ecology
April 18, 2002

Check Your Understanding

1. Why are wood smoke particles dangerous?
Wood smoke contains over 20 chemicals, some of which are dangerous to human health. Wood smoke may trigger asthma episodes.

2. Temperature inversions most often occur on cold, winter days. What happens to wood smoke during a temperature inversion?
The temperature inversion traps the wood smoke close to the ground. The smoke cannot disperse and hangs around in your breathing space.

Agricultural Field Burning

Field burning is a traditional method of getting rid of unwanted plant parts left over after harvest and preparing the fields for a new crop. Cereal (wheat, barley, corn and oats) and grass seed farmers have historically used field burning to get rid of stubble and straw and to take care of pest infestations and disease. However, setting fire to acres and acres of fields causes huge clouds of smoke. This smoke can cause health problems for people who inhale it, especially for people with asthma. Smoke from field burning has sometimes drifted over major highways and caused car accidents. The car accidents brought attention to the issue of field burning and caused changes to laws throughout the Pacific Northwest concerning field burning.

Many states now allow only a small number of acres to be burned each year on days where the weather makes it the safest. Other states continue to allow field burning, but provide information to the public on when and where field burning will take place. Many farmers depend on crop burning as an inexpensive, effective way of preparing a field for the next growing season.

Some farmers are exploring alternative ways to deal with unwanted plant parts instead of burning them. Stubble and straw can be raked, mowed, chopped and left to decompose in the soil. Leftover straw can be made into an interesting particleboard material that is used to build kitchen cabinets and countertops. Scientists are also researching the use of straw as a pulp to make paper.

Check Your Understanding

1. What are some pros and cons of field burning?

Pros:* *Field burning is a way to get rid of unwanted plant parts after harvest and to get rid of insect infestations and disease. It is inexpensive and effective.

Cons: Field burning causes clouds of smoke, which can cause health problems. Also, the smoke has caused car accidents in the past.

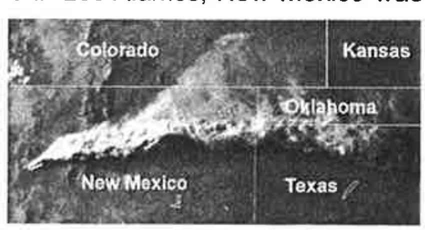
Just Say No to Wildfire Smoke

Wildfires can be sparked by lightening, started by an abandoned camp fire or purposefully lit as part of a **controlled burn** to remove dry brush, grass and diseased trees.

Controlled Burn:
A fire that is purposefully set and carefully monitored in order to burn dry brush, grass or diseased trees.

Smoke from wildfires has the same health impacts as wood smoke from fireplaces and wood stoves. However, the amount of smoke from a wildfire is much worse, often blanketing entire communities in thick, choking smoke. All people can be harmed by inhaling this smoke, but people with respiratory diseases like asthma have to be extra careful around a wildfire. Sometimes, people who are sensitive to wood smoke must stay indoors or may even need to evacuate to someplace less smoky.

Smoke from wildfires can travel long distances, so a fire in a different area can still have a big impact. For example, the Cerro Grande wildfire in Los Alamos, New Mexico was started as a controlled burn by the National Park Service in May 2000. After just one day, the fire quickly got out of hand and ended up burning more than 47,000 acres. Over 25,000 people in New Mexico were forced to evacuate their homes during the fire. Smoke from this fire traveled across New Mexico, Colorado, Oklahoma and Texas.



Satellite image of Cerro Grande Fire in New Mexico

Community Resources & Action

One California town has found a creative way to avoid doing controlled burns. The town of Mill Valley has employed 500 goats to gobble up dry brush and grass. The town hopes that their new four-legged employees will help reduce air pollution from the controlled burns they once used in the area.

Check Your Understanding

1. If smoke from a distant wildfire blanketed your community, what could you do to protect yourself from the smoke?

Answers will vary, but may include: avoid going outside; avoid exercising; keep windows closed; evacuate; etc.

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