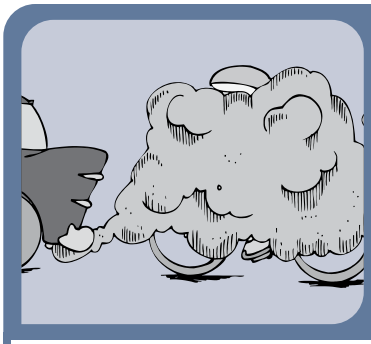


The Dirty Half Dozen

Through a card game, students match criteria pollutants generated through the use of energy to their effects, and identify ways these pollution problems can be solved or prevented.

Grade Level: 5–8

Subject Areas: English Language Arts, Health, Mathematics, Science, Technology Education

Setting: Classroom

Time:
Preparation: 90 minutes
Activity: Two 50-minute periods

Vocabulary: Carbon monoxide, Combustion, Criteria pollutant, Lead, Nitrogen oxides, Ozone, Sulfur dioxide, Suspended particulate matter

Major Concept Area:
The quality of the environment

Getting Ready: Create one set of each type of card from ***Cards For Dirty Half Dozen*** for each group of students. Cards may be enlarged. You may want to print these pages on cardstock and/or laminate them for longer use.

Objectives

Students will be able to

- list six major air pollutants and their sources and effects;
- explain how combustion of fuels contributes to the production of these pollutants; and
- identify what can be done to address air pollution problems.

Rationale

Understanding that fuel combustion is a major source of air pollution helps students appreciate the importance of managing energy resource use.

Materials

- Copies of following pages:
  - ***Criteria Pollutants, Their Sources and Effects***
  - ***Rules for Playing Dirty Half Dozen***
  - ***Cards for Dirty Half Dozen*** (each group will need a set, see **Getting Ready**)
  - ***Correct Sequence for Dirty Half Dozen Piles***
- Find additional resources related to this activity on keepprogram.org > Curriculum & Resources

Background

It's a typical day. You drive to and from work; live and work in heated buildings; cook food; mow your lawn; add carbon monoxide, nitrogen oxides, and ozone to the atmosphere; read the newspaper; and go to bed. Wait a minute! What's that about carbon monoxide, nitrous oxides, and ozone? Yes, each of us through our daily activities, especially those that involve fuel combustion, contribute to air pollution.

Air consists mainly of nitrogen, oxygen, water vapor, and other trace gases. Any other particulate matter or gas not normally found in air, whether it is visible or invisible, is considered pollution. Air pollution can range from dust to more noxious chemicals such as carbon monoxide. While there are some natural events that cause air pollution, such as volcanic eruptions and forest fires, the more serious cases of pollution are traced to human activities that involve the combustion of coal, oil, natural gas, and wood. We burn these fuels to heat our homes, run our cars, and generate electricity. Industries use these fuels to manufacture

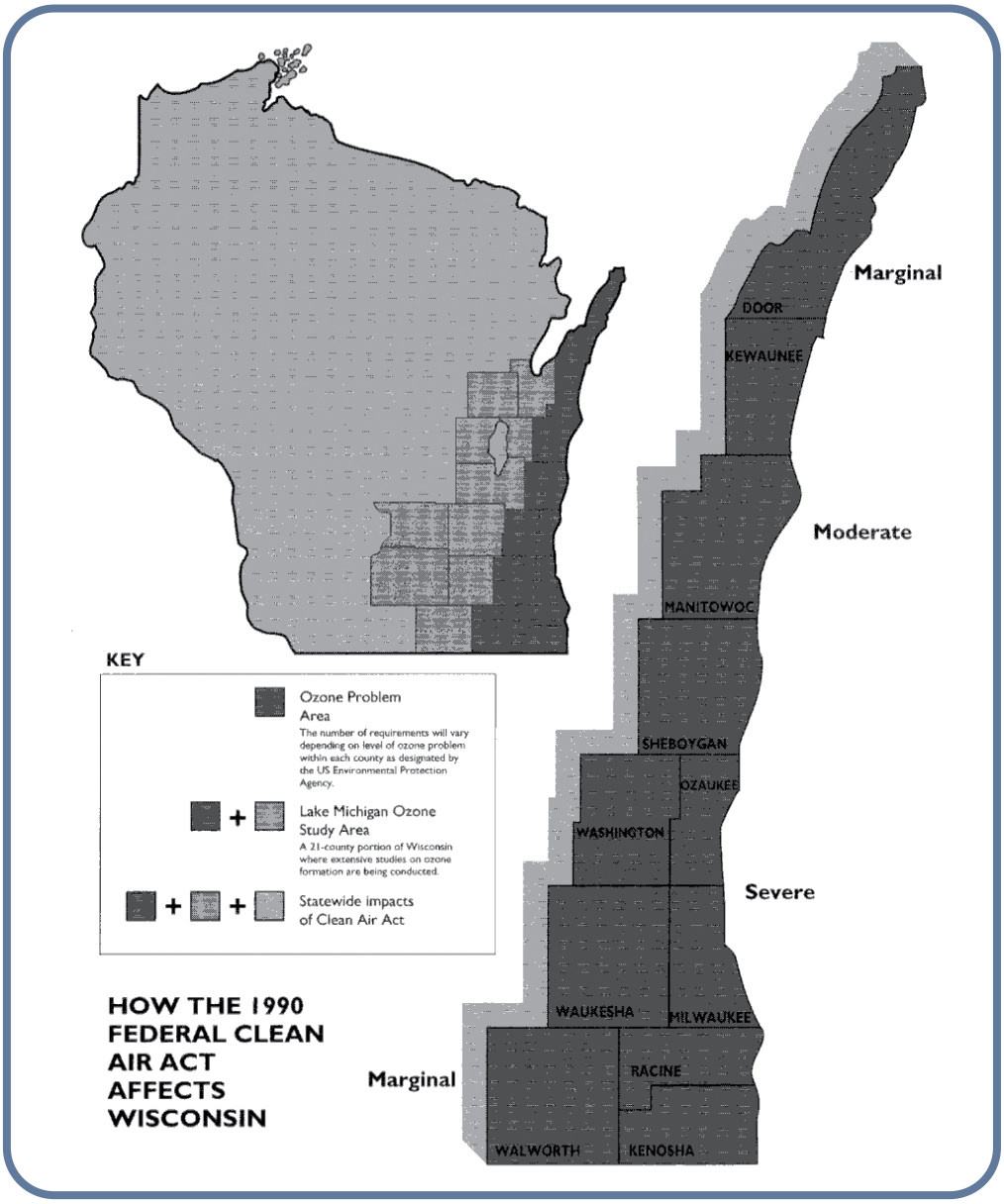
things we use, such as hair dryers and pencils. When the gas and particulate wastes from fuel combustion are disposed of into the air, they pollute it.

Earth's atmosphere seems so expansive; you might think it is impossible to add enough pollutants to damage it. However, it is possible to see and feel the effects of air pollution, especially in urban areas. These effects include smoggy skies, irritated eyes, respiratory illnesses, and damaged plants. Society's increased awareness of these effects motivated the support and passage of the Clean Air Act in 1970 and the reauthorization of the Act in 1990.

The Clean Air Act established National Ambient Air Quality Standards, which identify and set standards for criteria pollutants. Criteria pollutants are gases and particulate matter that have negative health and environmental effects. Specifically, they include carbon monoxide, lead, nitrogen oxides, ozone, suspended particulate matter (including particles less than 10 microns [PM10]), and sulfur dioxide. The standards are set to indicate how much of these pollutants can be present in the ambient air (the air that surrounds us) and still be considered safe. (See ***Criteria Pollutants, Their Sources and Effects***). The 1990 Clean Air Act Amendments added further criteria pollutant restrictions, identified 189 substances as hazardous air pollutants, and established actions that various areas of every state must take to protect/enhance air quality. The goal of the 1990 Amendments is to reduce emissions of hazardous air pollutants by more than 75 percent within ten years.

Wisconsin has extensive and detailed systems to monitor all criteria pollutants. The most prevalent criteria pollutant problem in Wisconsin is ozone. Much of the ozone enters Wisconsin from south and southeast of the state, and blankets the Lake Michigan area. NOTE: This ozone is different from the stratospheric ozone layer, which shields Earth from ultraviolet rays.

In an effort to reduce ozone, Wisconsin has implemented several programs. These include Ozone Action! Days



that are declared when weather conditions are likely to promote the buildup of unhealthy levels of ozone. On these days individuals, businesses, and municipalities are encouraged to curtail activities that may lead to ozone production. Other programs such as the Employee Trip Reduction Program, Clean School Bus USA and SmartWay Transport Partnership. aim to reduce the occurrence of ozone emission and other pollutants caused by automobiles.

Efforts continue to be made in Wisconsin and across the country to reduce other air pollutants as well. Air pollution control devices can be installed on factory and power plant smokestacks, automobile exhaust systems, and even woodstoves to trap pollutants before they get into the air. Cleaner-burning fuels and ways to burn fuels more efficiently have been and continue to be developed. Increased use of noncombustible renewable energy resources, such as hydropower, solar energy, and wind can contribute to cleaner air. As individuals, we can play a significant role in reducing air pollution. We can reduce the amount of fuel we burn by carpooling or using mass transit, by conserving electricity, and by reducing the number of times we mow our lawns.

There is evidence that some of these efforts have been successful. The Wisconsin Department of Natural Resources reports an apparent decreasing trend in the number of times ozone levels have exceeded federal health standards. Sulfur dioxide emissions in Wisconsin declined by 59 percent between 1980 and 1994, mostly because electric utilities switched to burning low sulfur coal in their power plants. Lead emissions from automobiles are virtually nonexistent due to the use of catalytic converters and unleaded gasoline. Although air pollution in Wisconsin continues to be a concern, the reduction of these three criteria pollutants is encouraging. With more successes like these, we may all breathe a little easier in the future.

Procedure

Orientation

Have students outline what they do on a typical day. Activities can include showering, making breakfast, driving to school, watching television, playing computer games, and so forth. Tell them to identify the items in the outline that require the burning of fuels. Remind students that every time they use electricity, chances are they are burning fuel (unless they get their energy from a nuclear power plant or from noncombustible renewables, such as hydropower, wind, or solar energy).

Steps

1. Show students a piece of wood. Ask the following questions.
   - Why is wood considered an energy source? Remind students that energy is stored in the chemical bonds of the molecules that make up the wood.
   - How do we get energy from wood? One way is to burn it (another way is to eat it, but this works better for termites than for humans).
2. Burn the wood, or show students a burned piece of wood. Discuss what happened to the stored energy. Much of the stored energy was converted to light and heat energy, but some still remains in the charred wood.
3. Ask students what happened to the material that made up the wood. Students should point out that some of the wood went, "up in smoke." What does this expression really mean? Where did it really go?
4. Inform students that smoke is a form of air pollution, because it is not a natural component of air. Tell students that with the burning of any fuel, such as coal or oil, energy is released and waste materials are left behind. Some of these waste materials are released into the atmosphere as emissions. When excessive amounts of these materials are released into the atmosphere, the environment and human health can be affected.
5. Identify the six major criteria pollutants, explain why

they are called criteria pollutants (see **Background**), and share the information sheets ***Criteria Pollutants, Their Sources and Effects***.

6. Ask students to consider the sources of these pollutants and to suggest ways to reduce or prevent their emission. Supplement their responses with information from the **Background** and other resources.

7. Tell students they will be playing a card game to help them summarize the sources and effects of the criteria pollutants. Divide the class into groups of three or four.

8. Hand out and discuss ***Rules for Playing Dirty Half Dozen*** and a set of ***Cards for Dirty Half Dozen***. Make sure students are familiar with the terms on all the cards. Group members can have specific responsibilities; for example, one student in the group should be the monitor and is responsible for making sure the rules of the game are followed. Other students can be responsible for gathering and keeping track of the cards, making sure the group plays cooperatively, and presenting their results to the class.

9. Have the class play the game. Refer to ***Correct Sequences for Dirty Half Dozen Piles*** for guidance. Allow the groups to play until they finish their games or until a certain time has passed (such as 15 minutes).

   Note: To make the game easier, have the students start with just two criteria and their sequential cards and work up to all six. Another simpler alternative game is the "Dangerous Duo." The only cards used are the Pollution Source Cards and the Type of Pollution Cards. Dangerous Duo is a memory game where the cards shuffled are placed face down. Students select two cards at a time. If they match (source to the type of pollution), the student keeps the cards. If they do not match, they are left in place but turned back over. Subsequent players select pairs of cards trying to remember where and what the cards were so they can make correct matches. The winner is the one with the most pairs.

Closure

Have each group work together to summarize and present their results. Challenge students to use the cards to develop a concept map for each fuel source that identifies the various pollutants, their effects, and solutions to prevent pollution. Encourage students to develop creative ways to inform others about how burning fuels contributes to air pollution and what individuals, industries, and governments can do to reduce air pollution and its effects (see **Assessment**).

Assessment

Formative

- Do students relate their own energy use (burning of fuels in electricity generation, running an automobile, and heating processes) to production of criteria pollutants?
- Did students sequence the cards correctly, identifying six major air pollutants, their sources, and their effects?
- Were students able to generate ways to reduce air pollution? Was this knowledge reflected in the game?
- Did students follow the rules of the game and play cooperatively?

Summative

The concept map is an excellent way for students to summarize their understanding of the activity. Consider the following to evaluate their understanding:

- How thoroughly was the concept map developed?
- Were there multiple connections and were they correct?
- What kinds of linking verbs did they use?

Extension

To have students educate others about fuel combustion and air pollution, suggest that students design posters that illustrate the pollutants and their sources and effects, including information about how people can manage energy use to reduce their contribution to air pollution.

Related KEEP Activities

Precede this activity with "Fuel That Power Plant" and an overview of the different combustible energy resources (adapt "Fueling Around" for older students). "Driving Reasons" and "At Watt Rate" help students appreciate how their personal energy use contributes to air pollution emissions. Other environmental topics are addressed in activities such as "Dealing with Nuclear Waste" and "Don't Throw Energy Away." Students will find pollution topics to research in the Energy Sparks section

Investigation Ideas: “Energy and the Environment.” Help students understand that by conserving energy they can help reduce air pollution. See Action Ideas: “Energy Efficiency Measures” in the Energy Sparks section.

Credits

Activity based on *Environmental Resource Guide Air Quality Grades 6-8*. “The Dirty Half Dozen” pp. 5–15, 1991, with permission from the Air & Waste Management Association, Pittsburgh, PA 15222. Used with permission. All rights reserved.

“Criteria Pollutants, Their Sources and Effects” material adapted from Wisconsin Department of Natural Resources, Bureau of Air Management. Wisconsin 1995 Air Quality Report. Madison, Wisc.: Wisconsin Department of Natural Resources, n.d. AM-207-96. Used by permission. All rights reserved.

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Criteria Pollutants, Their Sources and Effects

Sulfur Dioxide

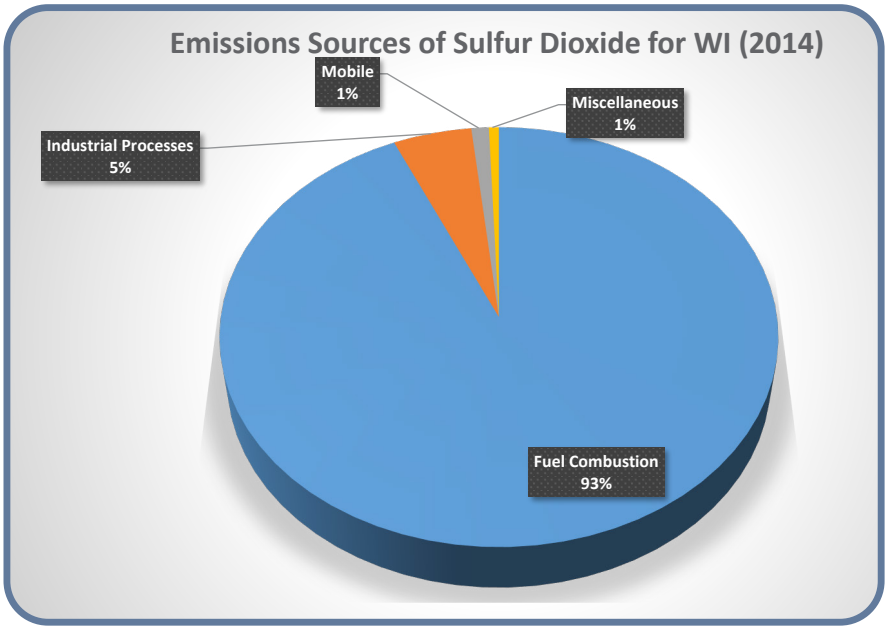
Sources

Ninety-five percent of pollution-related sulfur oxide emissions are in the form of sulfur dioxide (SO_2), a heavy, colorless gas with an odor like a struck match. This gas combines easily with water vapor and then with oxygen in the air, forming the irritating and corrosive sulfuric acid (H_2SO_4).

Emission sources of SO_2 in Wisconsin include the following:

- 93% from Fuel Combustion
- 5% from Industrial Processes
- 1% Mobile
- >1% from Fire and Solvent

NOTE: The amount of SO_2 released depends on the sulfur content of coal, normally 0.7 to 2% by weight. High sulfur coal sometimes contains as much as 6% sulfur by weight.



Health Effects

Sulfur dioxide not only has a bad odor, it can irritate the respiratory system. Exposure to concentrations greater than 6 parts per million (ppm) make breathing difficult. Prolonged exposure to concentrations less than 6 ppm can also impair respiratory functions. Children, the elderly, those with chronic lung disease, and asthmatics are especially susceptible to these effects.

Effects on Plants

Sulfur dioxide easily injures many plant species. Some of the most sensitive plants include various commercially valuable pines, legumes, red and black oaks, white ash, alfalfa, and blackberry.

Other Effects

Increases in sulfur dioxide concentrations accelerate the corrosion of metals, probably through the formation of acids. (SO_2 is a precursor to acidic deposition.) Sulfur oxides may also damage stone and masonry, paint, various fibers, paper, leather, and electrical components.

Criteria Pollutants, Their Sources and Effects

Suspended Particulate Matter

Sources

Tiny airborne particles or aerosols ranging in size from less than 1 micrometer to more than 100 micrometers are collectively referred to as total suspended particulate matter (TSP). These particles constantly enter the atmosphere from many sources. (For reference, the diameter of a typical human hair is 50 micrometers.)

Natural sources include the following:

- Soil
- Bacteria and viruses
- Fungi, molds, and yeast
- Pollen
- Salt particles from evaporating seawater

Human sources include the following:

- Combustion products from space heating
- Industrial processes
- Power generation
- Motor vehicle use
- Construction projects
- Agricultural development

Health Effects

More than 99 percent of inhaled particulate matter is either exhaled, trapped in the mucus lining of the windpipe and lungs, or expelled through coughing. Some of the smallest particles, however, lodge in the lung capillaries and alveoli, causing the following effects:

- Slowing down the exchange of oxygen and carbon dioxide in the blood, causing shortness of breath
- Straining the heart, because it must work harder to compensate for oxygen loss

The people most sensitive to these conditions include those with heart problems or respiratory diseases like emphysema, bronchitis, and asthma. The elderly and children are also very sensitive.

Materials/Vegetative Damage and Other Effects

Particulate matter is what most people see and feel when they experience “dirty air.” Particulate matter can

- corrode metals and masonry;
- dust the leaf surfaces of crops, trees, and shrubs, which may injure or inhibit the growth of these valuable plants; and
- impair visibility and reduce solar insulation.

Criteria Pollutants, Their Sources and Effects

Carbon Monoxide

Sources

Carbon monoxide (CO) is a colorless, odorless, and tasteless gas. It may temporarily accumulate at harmful levels, especially in calm winter and early spring weather when fuel combustion reaches a peak and during low temperatures when carbon monoxide is chemically most stable.

Sources of CO include the following:

- Automobile emissions
- Home/building heating (gas-fired furnaces)
- Volcanoes, thunderstorms, and forest fires.
- Vegetation during various growth stages
- The chemical transformation of methane (CH_4), a gas emitted from decaying plants in swamps and marshlands

Carbon monoxide from natural sources usually dissipates quickly over a large area, posing no threat to human health.

Health Effects and Other Effects

Carbon monoxide enters the bloodstream by combining with hemoglobin, the substance that carries oxygen to the cells. This combination occurs 200 times more readily with carbon monoxide than with oxygen, reducing the amount of oxygen distributed throughout the body by the bloodstream. Carbon monoxide adversely impacts health in many ways:

- Affects the central nervous system at relatively low concentrations
- Weakens heart contractions, lowering the volume of blood distributed to various parts of the body
- Causes healthy people to feel tired and drowsy from short-term exposure to concentrations greater than 30 ppm (parts per million)
- Causes shortness of breath and chest pain in people with heart disease at exposure levels as low as 10 ppm
- Promotes irritability, headaches, rapid breathing, blurred vision, lack of coordination, nausea, dizziness, confusion, and impaired judgment in healthy people exposed to levels greater than 35 ppm

Even three or four hours after exposure, half the excess carbon monoxide may remain in the bloodstream.

People especially susceptible to CO include the following:

- Children (and the human fetus)
- The elderly
- Those with respiratory or heart illnesses
- Those with anemia
- Those exposed for long periods of time, such as traffic officers and people sitting in parked or idling cars over sustained periods
- Cigarette smokers

Carbon monoxide does not appear to have adverse effects on plants, wildlife, or materials at concentrations commonly monitored in the ambient air.

Criteria Pollutants, Their Sources and Effects

Ozone

Ozone (O_3) is a very "active" form of oxygen that reacts rapidly and strongly with living tissues, plant-derived fabrics, dyes, rubber, and many other human-made materials. It is a colorless, odorless gas.

Sources

Ozone forms as a secondary pollutant, which means it is not directly emitted but is produced by a reaction involving other substances in the air. Hydrocarbons and nitrogen oxides (NOx) are ozone precursors. This means that they give rise to or are forerunners of ozone. They chemically react in sunlight to form ozone.

Sources of hydrocarbons include the following:

- Automobile exhaust
- Gasoline and oil storage and transfer
- Industrial use of paint solvents, degreasing agents, cleaning fluids, and ink solvents
- Incompletely burned coal or wood

Ozone derived from these sources and present near the earth's surface should not be confused with the stratospheric ozone layer located about 15 miles above the earth. This ozone layer helps shield the earth from cancer-causing ultraviolet rays.

Ozone is a major component of smog. The highest ozone levels in Wisconsin occur from mid-May to mid-September, especially in hot, hazy weather with southerly winds. Depending on the weather, ozone can remain in an area several days, with the highest levels building up in the afternoon and continuing into the evening. High ozone concentrations are more common in southern Wisconsin than in the north.

It was once believed that unhealthy levels of ozone (and its precursors) were confined to urban areas. However, in recent years the Wisconsin Department of Natural Resources has measured ozone levels exceeding national health standards in some of our rural areas as well. These rural concentrations may result from the transport of ozone and its precursors over long distances, indicating the regional nature of this air pollution problem.

Health Effects and Other Effects

Ozone, a highly reactive gas, affects the respiratory system by severely irritating the mucous membranes of the nose and throat. Since 90 percent of the ozone breathed into the lungs is never exhaled, ozone molecules react with sensitive lung tissue to cause several health consequences. Its effects are more severe in individuals with preexisting respiratory disease. Effects of ozone can be seen during short-term exposures to concentrations over 0.3 parts per million (ppm) or during more prolonged exposures to concentrations greater than 0.12 ppm.

Ozone can also damage leaves of sensitive plants and weaken materials such as rubber and fabrics.

Criteria Pollutants, Their Sources and Effects

Oxides of Nitrogen

Nitrogen gas (N_2), normally relatively inert (unreactive), comprises about 80 percent of the air we breathe. At high temperatures and under certain other conditions, it can combine with oxygen in the air to form several different gaseous compounds collectively called oxides of nitrogen (NOx). Nitric oxide (NO) and nitrogen dioxide (NO_2) are the two most important.

Sources

Major sources include the following:

- Fuel combustion in power plants and automobiles
- Processes used in chemical plants

Health Effects and Other Effects

Certain members of this group of pollutants, especially nitrogen dioxide (NO_2), are known to be highly toxic to various animals as well as to humans. High levels may be fatal, while lower levels affect the delicate structure of lung tissue. Short-term exposure of concentrations greater than 3 ppm can decrease lung functions and concentrations less than 3 ppm can irritate lungs. Children may also be especially sensitive to the effects of nitrogen oxides.

Oxides of nitrogen also can

- seriously injure vegetation at certain concentrations by
  - bleaching or killing plant tissue
  - causing leaves to fall
  - reducing growth rate
- deteriorate fabrics and fade dyes
- corrode metals (due to nitrate salts formed from nitrogen oxides)
- reduce visibility

Oxides of nitrogen in the presence of sunlight can also react with hydrocarbons to form ozone. Also, NOx is a precursor to acidic deposition, which may affect both terrestrial and aquatic ecosystems.

Criteria Pollutants, Their Sources and Effects

Lead

Sources

Lead is the most abundant toxic heavy metal; world production exceeds 3.5 million tons per year. Major lead emission stationary sources include the following:

- Waste oil and solid waste incineration
- Iron and steel production
- Lead smelting
- Battery and lead alkyl manufacturing

Motor vehicle emissions, at one time the major source of lead, have dropped by 89 percent since 1983, primarily because of reductions from automobile emissions. This reduction was caused by increased use of unleaded gasoline and the decreased use of leaded gasoline. In 1993 the production of vehicles requiring leaded gasoline became illegal, and in 1996 leaded gasoline was banned for motor vehicle use.

Health Effects

Lead is present in air, food, water, soil, dust fall, paint, and other materials. Lead is readily absorbed by the body via the primary routes of entry: inhalation and ingestion. Studies indicate that 10 to 20 percent of inhaled lead enters the bloodstream. In children, approximately 50 percent of ingested lead is absorbed compared to 8 to 10 percent in adults. This absorption rate is especially significant since much of children's lead exposure is caused by their normal habits of mouthing dirty hands, objects, and materials. There is no known safe blood lead concentration. But it is known that, as lead exposure increases, the range and severity of symptoms and effects also increases.

Known health effects of lead poisoning include the following:

- Anemia
- Brain and nervous system damage
- Severe kidney injury or failure
- Injury to the gastrointestinal system and the heart
- Damage to the reproductive system

Effects on Plants and Animals

At normal levels, lead does not usually pose a threat to plants and animals. However, exposure to high concentrations has adversely affected domestic animals, wildlife, and aquatic life. Areas near major sources, such as lead smelters, are most susceptible. (In past years, small animals trapped near highways showed high lead levels.)

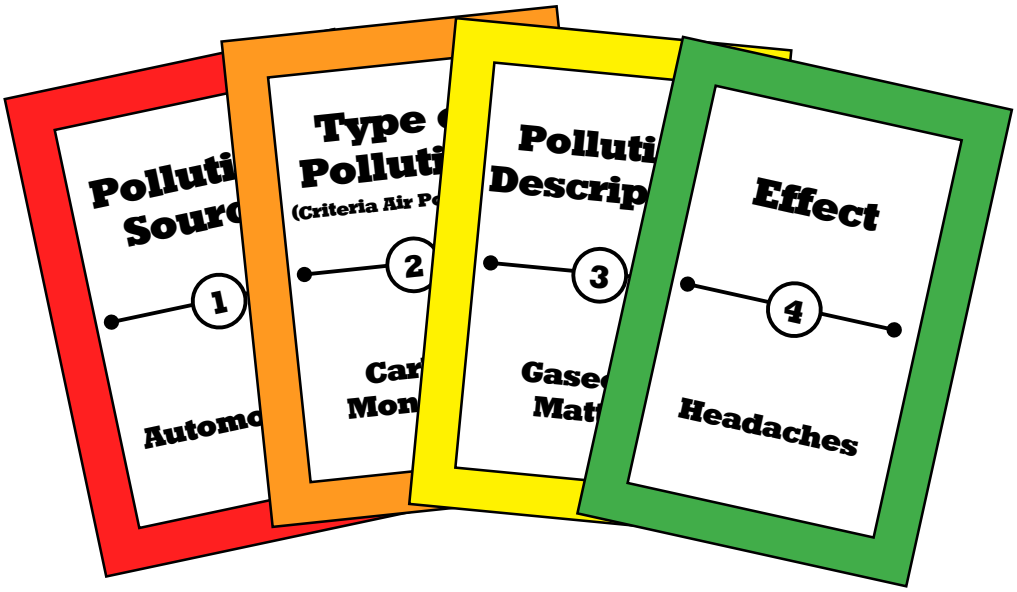
Rules for Playing Dirty Half Dozen

1. There are five sets of cards:
   - Pollution Source Cards – tells where pollution may come from
   - Type of Pollution Cards – names one of the criteria pollutants
   - Pollution Description Cards – describes characteristics of the pollutant
   - Effect Cards – tells what can happen to your health if you come in contact with pollutant
   - Prevention and Solution Cards – tells what can be done to prevent or reduce pollution or its effects

2. Shuffle the cards and deal each player seven cards. The remaining cards are put in a draw pile in the middle.

3. The goal of the game is to get rid of all the cards in your hand. You get rid of a card by starting or adding to piles in the center of the table.

4. The cards must be placed on a pile in the order listed above (Pollution Source Card, Type of Pollution Card, etc.). Each card that is played must correctly relate to the previous card (see examples below). Refer to notes you have taken about criteria air pollutants and to the information sheets ***Criteria Pollutants, Their Sources and Effects***. You may also want to have a copy of the sheet ***Correct Sequences for Dirty Half Dozen Piles*** for each group to use as reference.



5. Starting the Game: The person to the left of the dealer is the first to play. If the player has a Pollution Source Card, it is played. If not, one card is taken from the draw pile. If this card is a Pollution Source Card, it can be laid down; otherwise, the card is added to the player's hand and it becomes the next player's turn.

6. Playing the Game: The next player (to the left of the previous player) can either begin a new pile (with a Pollution Source Card) or add a correct card to an existing pile. Again, if the player does not have a correct card, one is drawn from the draw pile and either played (if correct) or added to the player's hand. It is then

Rules for Playing Dirty Half Dozen

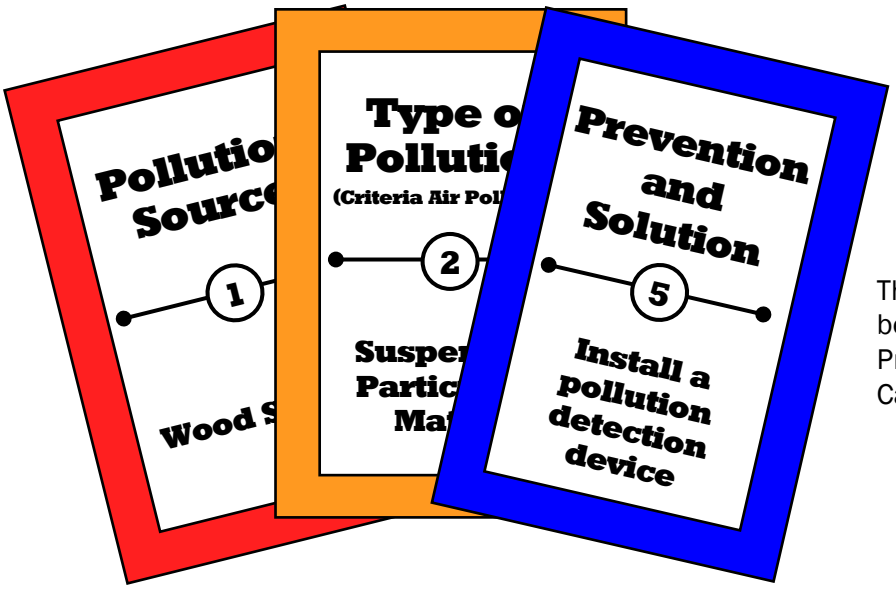
the next player's turn. This procedure continues until one player runs out of cards (or the teacher calls time).

7. The pile becomes the property of the person who played the last correct card in the sequence (always a Prevention and Solution card). Prevention and Solution cards are wild cards. A correct Prevention and Solution Card may be added to a pile at any time. Prevention and Solution cards are wild cards. A correct Prevention and Solution Card may be added to a pile at any time.

8. Ending the Game: You can win the game if you are the first person to put all your cards into correct sequences; or you have the most piles.

Examples:

- If the pile already has a Pollution Source Card, the next card must be a Type of Pollution Card. Correct pairs include: (1) Automobiles and Carbon monoxide, (2) Industries and refineries and Suspended particulate matter, and (3) Electric power plants and Oxides of nitrogen.
- If the pile already has a Pollution Source Card, a Type of Pollution Card, and a Pollution Description Card, the next card must be an Effect Card. A correct sequence would be, for example, Automobile, Carbon monoxide, Gaseous matter, Headaches.



This pile is closed because a correct Prevention and Solution Card has been placed.

Cards for Dirty Half Dozen

Pollution Source

1

Gas Burning Stoves and Water Heaters

Pollution Source

1

Industries and Refineries

Pollution Source

1

Small Gasoline Engines (lawn mowers, etc.)

Pollution Source

1

Automobiles

Pollution Source

1

Wood Stoves

Pollution Source

1

Electric Power Plants

Type of Pollution
(Criteria Air Pollutant)

2

Ozone

Type of Pollution
(Criteria Air Pollutant)

2

Suspended Particulate Matter

Type of Pollution
(Criteria Air Pollutant)

2

Sulfur Dioxide

Type of Pollution
(Criteria Air Pollutant)

2

Carbon Monoxide

Type of Pollution
(Criteria Air Pollutant)

2

Lead

Type of Pollution
(Criteria Air Pollutant)

2

Oxides of Nitrogen

Cards for Dirty Half Dozen

Pollution Description 3 Gaseous Matter	**Pollution Description** 3 Gaseous Matter	**Pollution Description** 3 Gaseous Matter	**Pollution Description** 3 Very small particles of soot, dust, liquid and other matter
Pollution Description 3 Metallic element found in particulate matter	**Effect** 4 Headaches	**Effect** 4 Lethargy and Sleepiness	**Effect** 4 Heart Damage
Effect 4 Brain Damage	**Effect** 4 Plant Damage	**Effect** 4 Irritates Respiratory System	**Effect** 4 Corrodes Metal

Cards for Dirty Half Dozen

Effect 4 **Smog**	**Effect** 4 **Reduces Visibility**	**Effect** 4 **Reduces Coordination**	**Effect** 4 **Harms Wildlife**
Prevention and Solution 5 **Set and enforce air quality standards**	**Prevention and Solution** 5 **Ensure combustion is clean and efficient**	**Prevention and Solution** 5 **Conserve electricity**	**Prevention and Solution** 5 **Reduce, reuse and recycle**
Prevention and Solution 5 **Use alternative energy source**	**Prevention and Solution** 5 **Install a pollution detection device**	**Prevention and Solution** 5 **Use a cleaner burning fuel**	**Prevention and Solution** 5 **Carpool, use mass transit, bike and walk**

Correct Sequences for Dirty Half Dozen Piles

NOTE: Students may find alternate sequences. If, after hearing the rationale for their sequence, you believe it is correct, add it to the list of these sequences.

Source	Criteria Pollutant	Description	Effect (each bullet indicates a separate card that matches the pollutant)	Prevention and Solution (each bullet indicates a separate card that matches the source, pollutant, description or effect)
Automobiles	Carbon monoxide	Gaseous matter	• Brain Damage • Reduces coordination • Headaches • Lethargy and sleepiness	• Car pool, use mass transit, bike, or walk • Set and enforce air quality standards • Ensure combustion is clean and efficient • Use alternative energy source
	Ozone	Gaseous matter	• Irritates respiratory system • Smog • Plant damage	
	Oxides of nitrogen	Gaseous matter	• Irritates respiratory system • Plant damage • Reduces visibility • Corrodes metals	
Woodstoves	Suspended particulate matter	Very small particles	• Heart damage • Corrodes metals • Reduces visibility	• Install a pollution detection device • Ensure combustion is clean and efficient • Set and enforce air quality standards
	Carbon monoxide	Gaseous matter	• Brain Damage • Reduces coordination • Headaches • Lethargy and sleepiness	
Electric power plants	Oxides of nitrogen	Gaseous matter	• Irritates respiratory system • Plant damage • Corrodes metals • Reduces visibility	• Install a pollution detection device • Set and enforce air quality standards • Conserve electricity • Use a cleaner burning fuel • Ensure combustion is clean and efficient
	Suspended particulate matter	Very small particles	• Heart damage • Corrodes metals • Reduces visibility	
	Sulfur dioxide	Gaseous matter	• Irritates respiratory system • Plant damage • Corrodes metals	

Correct Sequences for Dirty Half Dozen Piles

Source	Criteria Pollutant	Description	Effect (each bullet indicates a separate card that matches the pollutant)	Prevention and Solution (each bullet indicates a separate card that matches the source, pollutant, description or effect)
Gas-burning stoves and water heaters	Carbon monoxide	Gaseous matter	• Brain Damage • Reduces coordination • Headaches • Lethargy and sleepiness	• Install a pollution detection device • Ensure combustion is clean and efficient • Set and enforce air quality standards
Industries and refineries	Lead	Metallic element	• Brain damage • Harms wildlife	• Reduce, reuse,and recycle • Install a pollution detection device • Set and enforce air quality standards • Conserve electricity
	Suspended particulate matter	Very small particles	• Irritates respiratory system • Corrodes metals • Reduces visibility	
Small gasoline engines	Carbon monoxide	Gaseous matter	• Brain damage • Reduces coordination • Headaches • Lethargy and sleepiness	• Set and enforce air quality standards • Ensure combustion is clean and efficient • Use alternative energy source
	Ozone	Gaseous matter	• Irritates respiratory system • Smog • Plant damage	
	Oxides of nitrogen	Gaseous matter	• Irritates respiratory system • Plant damage • Reduces visibility • Corrodes metal	