

The Urban Heat Island Effect and Air Quality

Concept:

Increases in urban temperature directly contribute to ozone levels and indirectly to other greenhouse gases. These gases, in turn, contribute to higher temperatures. This "spiraling" effect, accordingly, affects human health and our environment.

Lesson Three Goal:

Students will learn about greenhouse pollutants. Also, they will learn about how these pollutants either intensify or are intensified by the urban heat islands effects.

Utah State Science Core Objectives:

- 5th grade: 3050-02

- 6th grade: 3060-0101

Intended Learning Outcomes:

1. Students will learn about primary greenhouse gases that occur naturally and unnaturally.
2. Students will learn about gases that indirectly contribute to the greenhouse effect by reacting with other chemicals in the air to produce ozone, which is a powerful greenhouse gas.
3. Students will learn that increases in temperature, such as those characteristics of urban heat islands, increase the reaction rates that form ozone.
4. Students will learn the major sources of certain air pollutants along the Wasatch Front. Furthermore, that the elements and sources of pollution in the summer are not the same as they are in the winter.

Materials/Preparation:

1. Overheads of pie-charts showing sources of air pollutants along the Wasatch Front
2. Overhead of an air pollution flow chart
3. Air filters, coffee filters, or paper towels
4. Vocabulary sheet
5. *What Affects Air Quality* word puzzle
6. Optional: *Outline of Pollutants and Their Affects on Air Quality* worksheet for class discussion

Vocabulary Words:

Pollution, greenhouse effect, carbon dioxide (CO₂), carbon monoxide (CO), methane (CH₄), nitrous oxide (N₂O), nitrogen oxides (NO_x), volatile organic compounds (VOCs), particulate matter (PM₁₀ & PM_{2.5}), ground-layer ozone, smog, wintertime inversion

Background Information:

1. About the Greenhouse Effect:
 - a. Greenhouse Effect refers to a term that describes the role of man-made and natural greenhouse gases in increasing the Earth's temperature higher than "normal."
 - b. Greenhouse gases absorb heat energy that is given off by the Earth, which prevents the Earth's heat from escaping into space.
 - c. The Greenhouse Effect and Urban Heat Island Effect are related (details below).
2. Primary Greenhouse Gases—Information and Sources:
 - a. Primary greenhouse gases include water (H₂O), carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and ozone (O₃).
 - b. H₂O vapor is the most prevalent, yet least problematic of the greenhouse gases.
 - c. CO₂ emissions (man-made) come from the burning of fossil fuels (burning of coal, natural gas, and petroleum) primarily from transportation and electricity generation.

- d. CH₄ emissions (man-made) come from production and burning of fuels, decomposition of waste in landfills, and certain processes common to agriculture (e.g., "burping cows").
 - e. N₂O emissions (man-made) are a byproduct of fuel burning from transportation and electricity generation. N₂O emissions also come from certain soil practices and the application of fertilizers in agriculture.
3. About Ozone:
- a. There are two "types" of O₃
 - i. Stratospheric O₃ (sometimes called the "good ozone") occurs naturally in the highest level of the Earth's atmosphere. This O₃ prevents much of the harmful UV radiation from reaching the Earth's surface.
 - ii. Tropospheric O₃ (ground-layer O₃) occurs in the lowest level of the Earth's atmosphere. This O₃ acts as a powerful greenhouse gas.
 - b. Ground-layer O₃ is the major component of smog.
 - c. Ground-layer O₃ is one of the products formed primarily during the burning of fuels.
 - d. The formation of ground-layer O₃ is dependent on local weather conditions.
 - e. Warmer temperatures increase the rate of ground-layer O₃ formation. Case in point: In Los Angeles, for every degree increase in temperature above 70° F, the incidence of smog increases by 3% (DOE 1996).
 - f. Problems of ground-layer O₃ (summertime smog)
 - i. O₃ is not filtered by the lungs
 - ii. O₃ competes with oxygen for space in our blood system.
 - iii. O₃ potentially damages trees and other plants.
4. Sources of Tropospheric O₃ Forming Gases:
- a. NO_x emissions (man-made) are formed during the burning of fuels. They are formed in the presence of nitrogen (from the air), oxygen (from the fuels), and extreme heat (from the engines).
 - b. VOC emissions are "engineered" compounds that are released into the air by industry and transportation uses.
 - c. CO emissions (man-made) are colorless, odorless gases produced primarily during the burning of gasoline.
5. Urban Heat Island and the Greenhouse Effect and Ozone:
- a. A community experiencing an urban heat island during the summer requires more air conditioning to maintain comfortable indoor conditions than if they were not experiencing an urban heat island.
 - b. Increases in air conditioner use directly increases the need for energy production, which increases CO₂ emissions.
 - c. Higher amounts of CO₂ increase the amount of heat held in the lower atmosphere of the Earth.
 - d. Increase in air temperatures increases the production of ground-layer ozone. Ground-layer ozone
 - i. Adds to greenhouse gas levels that increase the amount of heat retained, which adds to the urban heat island phenomenon.
 - ii. Increases the health problems associated with ozone.
6. Major sources of greenhouse gases along the Wasatch Front:
- a. Summertime
 - i. Ozone: Ozone is the primary summertime pollutant. The reason why ozone is a problem in the summer and not in the winter is because of the extremely high temperatures experienced along the Wasatch Front during the summer. The major source of ozone is from the burning of fuels for transportation; however, another source might be summertime forest fires.
 - ii. PM_{2.5} & PM₁₀: These pollutants are very small particulates of 0-2.5 or 0-10 microns. These particulates might be a problem during the summertime because of forest fires.
 - b. Wintertime
 - i. CO: CO is the primary wintertime pollutant. The reason why CO is a problem in the winter and not in the summer is because of wintertime inversions (cold air

- trapped near the ground by warmer air above). The problem with inversions is they prevent the natural mixing of the upper and lower atmospheres. Pollutants, therefore, get concentrated in the lower atmosphere. The major source of CO is from the burning of fuels for transportation.
- ii. $PM_{2.5}$ & PM_{10} : These particulates become a problem during the winter when inversions trap tail pipe and wood-burning emissions in the lower atmosphere. Along the Wasatch Front, we have a mandatory wood-burning program. On no wood burning days, the amount of particulates in the air can be reduced by about 10-15%.

Instructional Procedures:

1. Discuss the information provided in the "background information" section. For clarity and review, have students complete the *Outline of Pollutants and Their Affects on Air Quality* worksheet during the class discussion. Place students in groups to list possible solutions to combat the problems of pollution. Discuss as a class each group's list of solutions.
2. Demonstrate that small particles of dust exist in the air we breath.
3. For a short-term experiment, cover the end of a vacuum nozzle with an air or coffee filter. Vacuum the air, and then observe the dust and other small particles collected on the filter. Discuss the possibility of bacteria or other germs (that are not visible) "catching a ride" on these larger dust particles. Discuss where these particles end up e.g., our noses, eyes, ears, mouth, skin, hair, etc.
4. For a longer-term experiment, partially cover a heat intake duct with a tissue or coffee filter. Monitor the filter daily for at least a week. Do this same procedure, however cover a heat register output. Discuss what is released into the environment from the classroom (intake duct) and what is released into the classroom (output register). Note: particulate matter will be particularly high and colorful near the white board.
5. Handout and review the vocabulary list provided. Students may want to use the table on the sheet or something similar to review the vocabulary words.
6. Complete the puzzle provided.

Lesson Three Vocabulary:

1. Particulate Matter (PM_{10}) – small particles of polluting compounds. Fine particulate matter may be visible or unseen. Smoke is one of the most easily recognized forms of particulate. Particulates come from forest fires, industrial sources, wood burning fireplaces, vehicles, construction, and gravel pits. Particulates affect wintertime inversions.
2. Carbon monoxide (CO) – colorless, odorless gas. Produced by burning of fuel in vehicles. Major contributor to wintertime smog. Carbon monoxide binds with the hemoglobin in our blood making it hard for our bodies to use oxygen.
3. Nitrogen oxides (NO_x) — major contributor to ground layer ozone and cause of the "brown haze" in smog. NO_x come from mixing vehicle fuel burned at a high temperature with nitrogen in the air.
4. Carbon dioxide (CO_2) – colorless, odorless gas; emitted by power plants in large amounts; also exhaled as waste by plants and animals. CO_2 contributes to the greenhouse effect, which may cause a gradual warming of the earth. This warming would eventually impact plant growth and the melting of the polar ice caps.
5. Volatile organic compounds (VOCs) –compounds that are released into the air by industry and transportation uses.
6. Ground layer ozone (summertime smog) – formed when sunlight acts on chemicals given off during the burning of fuels. Smog can make it hard to breathe, make your eyes look red, and cause a stuffy nose.
7. Wintertime inversion – occurs when warmer air temperatures above trap colder air temperatures near the ground. This inversion does not allow a natural mixing of lower and upper atmospheric air, so pollutants are trapped and collect near the ground surface.

Pollutant/Inversion	Characteristics	Sources	Effects

What Affects Air Quality

Fill in the puzzle with the terms that best match the descriptions. If each row is filled in correctly, the word that best describes the general category of this lesson will be spelled out down a column.

0	X	X	X	X	X	X	X	X	X	P	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	X	X	X	X	X														X	X	X	X	X	X
2	X	X	X																	X	X	X	X	X
3	X	X	X																					
4	X	X	X	X	X	X	X	X	X											X	X	X	X	X
5	X	X	X	X	X	X	X						X	X	X	X	X	X	X	X	X	X	X	X
6	X	X																		X	X	X	X	X
7	X	X	X	X																X	X	X	X	X
8	X	X	X	X	X																	X	X	X
9	X	X	X														X	X	X	X	X	X	X	X

1. First letter of the word that best describes the general category of this lesson.
2. Transportation and generation of electricity are the primary source of this carbon compound.
3. Primary element of summertime smog.
4. Many of these are considered "engineered" compounds that are released into the air by industry and transportation uses.
5. Primary source of pollution during the winter and summer along the Wasatch Front.
6. Very small particles that contributes significantly to wintertime pollution.
7. The result of this situation increases the temperature in communities, which increases the primary summertime pollutant.
8. Primary element of wintertime pollution; vehicles are the primary source.
9. This environmental condition increases the formation of ozone.
10. This nitrogen-containing compound is a byproduct of fuel burning by transportation and electricity uses.

Answers

0								P											
1					C	A	R	B	O	N	D	I	O	X	I	D	E		
2				G	R	O	U	N	D	L	A	Y	E	R	O	Z	O	N	E
3				V	O	L	A	T	I	L	E	O	R	G	A	N	I	C	C
4								A	U	T	O	M	O	B	I	L	E	S	
5								P	M	T	E	N							
6				U	R	B	A	N	H	E	A	T	I	S	L	A	N	D	
7					C	A	R	B	O	N	M	O	N	O	X	I	D	E	
8					H	I	G	H	T	E	M	P	E	R	A	T	U	R	E
9					N	I	T	R	O	U	S	O	X	I	D	E			

Outline of Pollutants and Their Effects on Air Quality

1. Greenhouse Effect

Term describing what happens when greenhouse gases add to an increase in the Earth's temperature.

- Greenhouse gases absorb heat energy from the _____, which prevents this heat from escaping into _____.
- Many of the greenhouse gases occur _____ in the environment. They create a problem when they are at unnaturally _____ concentrations.
- The _____ Effect and Urban Heat Island _____ are related.

2. Primary Greenhouse Gases

- Water (H₂O) vapor: This is the most common, yet causes the least amount of _____.
- Carbon dioxide (CO₂)
 - Unnatural CO₂ emissions come from the burning of _____ (coal, natural gas, petroleum).
 - This happens mostly because of transportation and _____ generation.
- Methane (CH₄): Unnatural CH₄ emissions come from the burning of _____, break down of _____ in landfills, and certain processes common to agriculture (e.g., "burping cows").
- Nitrous Oxide (N₂O)
 - Unnatural N₂O emissions are a result of the _____ of fuel for transportation and electricity generation.
 - N₂O emissions also come from applying _____ in agriculture.

3. Ozone (O₃)

- Two types:
 - Stratospheric O₃ (good ozone), which is found in the _____ level of the Earth's atmosphere. This ozone prevents much of the harmful _____ radiation from reaching the Earth's surface.
 - Ground-layer O₃ occurs in the _____ level of the Earth's atmosphere and acts as a powerful _____ gas. Major component of _____. The

formation of ground-layer ozone depends on local _____ conditions.
Warmer temperatures cause more ground-layer _____ to form.

- b. Problems with ground-layer ozone (summertime smog)
 - i. O_3 is not filtered by the _____
 - ii. O_3 competes with oxygen in our _____ system.
 - iii. O_3 can damage _____ and other _____.
- 4. Urban Heat Islands and Ozone
 - a. An urban heat island requires more _____ to maintain comfortable indoor temperatures.
 - b. Increases in air _____ use directly increases the need to _____ more electricity, which increases CO_2 emissions.
 - c. Higher concentrations of CO_2 increase the amount of _____ retained near the Earth's surface, which increases how fast ground-layer _____ is formed.
 - d. Increased ozone adds to the greenhouse gas levels that increase the amount of _____ retained, which adds to an urban heat island phenomenon.
- 5. Major Sources of Greenhouse Gases Along the Wasatch Front
 - a. Summertime:
 - i. High summer temperatures
 - ii. Burning of fuels for _____
 - iii. Forest Fires
 - b. Wintertime:
 - i. Inversions which trap CO from the burning of fuels for _____
 - ii. Particulates trapped by inversions come from tail pipes of vehicles and the burning of _____