The Chemistry of Climate Change

learning objectives

Students will:

- *Identify sources of air pollution.*
- *Identify solutions to air pollution.*
- *Distinguish between natural and human caused sources of air pollution.*
- *Define what makes pollution, pollution.*
- *Calculate the weight of various pollutants.*
- *Visualize the amount of air pollution emitted by a car each year.*

subjects

Environmental Education
Math
Science
Social Studies

WISCONSIN MODEL ACADEMIC STANDARDS

ENVIRONMENTAL EDUCATION
B.8.15, B.8.17, B.8.18, C.12.1, D.8.1, D.8.5

MATH
B.8.2, B.12.3, F.8.1, F.8.2, F.12.3

SCIENCE
F.8.10, G.8.3, G.12.3, G.12.5

SOCIAL STUDIES
D.8.11

materials

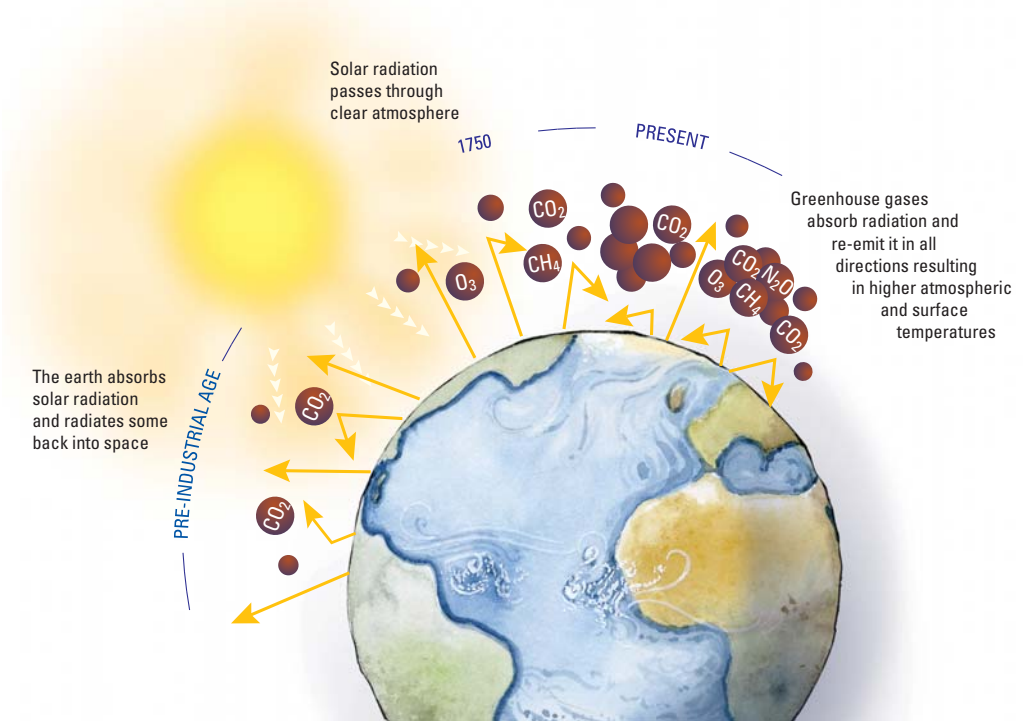
- ☐ Laminated Wisconsin DNR *Where's the Air?* poster
- ☐ Washable markers
- ☐ Many 2-liter soda bottles
- ☐ Periodic Table of Elements
- ☐ Worksheets included in this activity

Background

The thin layer of gases that surround Earth, otherwise known as the atmosphere, is changing. The current composition of Earth's atmosphere is mostly nitrogen and oxygen. It also contains water droplets, fine particles, argon, and very small amounts of carbon dioxide (CO_2), nitrogen oxides (NO_X), methane, and other gases. Most of these substances have been present in the atmosphere for millions of years and come from natural sources like volcanoes, forest fires, plants, animals, and decaying organic matter. But in today's atmosphere, the amount of some of these substances is much higher than it was hundreds of years ago due to pollution from our industrial revolution. We can see results of human sources of air pollution as smog over our cities, though many air pollutants are invisible.

One key component to our atmosphere that makes this planet livable is the greenhouse effect. This is a naturally-occurring phenomenon in which greenhouse gases—water vapor, carbon dioxide, methane, nitrogen oxides, and ozone—trap heat in Earth's atmosphere. The sun radiates heat toward Earth constantly. Earth absorbs some of that heat, but a large portion "bounces" off Earth's surface back towards space. The greenhouse gases present in the atmosphere trap some of this heat before it is radiated back into space. The greenhouse effect is responsible for maintaining Earth's temperature and is necessary for human survival.

The *Where's the Air?* poster lists natural and human sources of pollution. It is important to know the similarities and differences.



activity

CHEMISTRY OF CLIMATE CHANGE

Part A – What is Pollution?

Students will create a definition of pollution and determine the difference between naturally occurring and human-caused pollution using the Where's the Air? poster.

Procedure

What makes it "pollution?" . . . . . .

1) Working in groups, students will identify from the *Where's the Air?* poster, three sources of pollution.

2) With each source they should list the characteristics that make it "pollution." These could include:

- not biodegradable
- human-made
- negatively affects the quality of life (causes discomfort, ugly, smells bad, unhealthy, etc.)
- human beings have control over it
- contrasts with the natural landscape
- consumes an unreasonable amount of non-renewable energy
- occurs in quantities harmful to human health, i.e. damages respiratory system
- occurs in quantities harmful to animal and plant health
- occurs in quantities harmful to ecosystem health (may cause changes in climate or other natural phenomena or contribute to an unsustainable situation).

3) Have students refer to their lists and create a set of criteria that forms their definition of an "air pollutant."

Refining the criteria . . . . . .

1) Assign each group one of the human-produced sources of air pollution and one of the naturally-produced sources of air pollution from the poster. Have students apply their criteria to each. Would the item be a pollutant or source of pollution according to the students' criteria? Ask them to think about the part that human control plays in this question. Would they want to focus their pollution reduction on a natural source of pollution or a human source?

2) After they apply their criteria and decide whether the item is a pollutant or not, give them the option to revise their criteria. Students may feel that the biggest need is to defend their criteria. Impress on them that changing their minds after careful consideration is acceptable and to be expected in the process of critical thinking.

Reducing pollution . . . . . .

For the sources assigned above under *Refining the Criteria,* have the students answer these questions:

- Who is responsible for releasing this pollutant into the environment?
- Would it still be a pollution problem if released in smaller amounts?
- What is currently being done to control this pollutant? Who is doing it? What role does government play? Industry? You?
- How is this pollutant affecting global climate change?

activity

CHEMISTRY OF CLIMATE CHANGE

Part B – Sources and Solutions

Students will find the sources of air pollution, the solutions to air pollution, and how air pollution is transported.

Natural sources of air pollutants . . . . . .

EXAMPLES: volcanoes, geysers, plants, wetlands/swamps, animals

Volcanoes release tremendous amounts of gases and particles into the air. Decaying organic materials in oceans, swamps, and bogs release greenhouse gases like methane and carbon dioxide. Even cows belch methane. The easily recognized smell of a skunk and the scent from pine trees are caused from the release of volatile organic compounds (VOCs). Though we need photosynthesis to give us oxygen, all trees and plants release VOCs in varying amounts during the process. These sources are called "biogenic," and they release VOCs and other greenhouse gases that are part of the natural chemistry of Earth and its atmosphere.

Some biogenic pollution sources could have dramatically altered Earth's atmosphere at different times in the past. Volcanoes have been known to change weather patterns for years after erupting. Since little can be done to control natural pollution, and we need sources like plants for food, shelter, and oxygen production, our focus is on controlling human sources.

Human sources of air pollution . . . . . .

EXAMPLES: buses, tractors, gas stations, trash burning, sewage treatment plants, bakeries.

Air pollution from human sources tends to concentrate in urban areas where people live and work. Many of these pollutants come from the burning of coal, wood, oil and other fuels for electricity, transportation, and heat. Carbon dioxide, methane, and nitrous oxide are the three main pollutants causing climate change.

Carbon Dioxide (CO_2) enters the atmosphere through the burning of fossil fuels (oil, natural gas, and coal), solid waste, trees and wood products, and also as a result of other chemical reactions (e.g. manufacture of cement). Carbon dioxide is also removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle.

Methane (CH_4) is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills.

Nitrous Oxide (N_2O) is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.

For this information and more, see EPA's climate change web page, listed in the e-Appendix.

Due to easy transport, air pollution is more than just a local concern. Both natural and human sources of air pollution can be transported almost anywhere in the world on global winds. The regional air transport diagram on the back of the *Where's the Air?* poster shows the type of weather system associated with high levels of air pollution in Wisconsin.

Procedure

Sources of air pollution . . . . . .

1) Students working in small groups circle as many sources of air pollution as they can find pictured on the *Where's the Air?* poster.

2) Students will chart all of the sources of air pollution, the process that produces each, and the reason for the process.

SOURCE	PROCESS	REASON
car	*burning gasoline*	*transportation*

Some answers are listed on the back of the poster. These lists include both natural and human sources.

3) Students will then share their answers with the class. To motivate them, award 1 point for each pollution source found and 2 points for any original answer found by only one group. Recognize or award the group with the most points.

Solutions to air pollution . . . . . .

Students work in small groups and circle as many of the solutions to air pollution that they can find pictured on the *Where's the Air?* poster.

Groups create a chart of all of the solutions to pollution shown on the poster, and identify the action involved and who is doing the action.

SOLUTION	ACTION	WHO
biking	*reduced car use*	*commuters*

Again, some answers are listed on the back of the poster.

3) Students will then share their answers with the class. Again, award 1 point for each solution found and 2 points for any original answer found by only one group.

4) Students can expand their list of solutions to include any other solutions that are not on the poster. *Examples are:* education, working at home, landscaping, combining trips, reduced travel, cleaner fuels, etc.

Part C – Pounds of Pollution

Students will calculate the pounds of pollution emitted by vehicles and visually represent it with 2-liter soda bottles.

Air pollution is a difficult concept to grasp. We often cannot see it, yet it affects our daily lives and contributes to global climate change. Transportation is one of the most important sectors contributing to air pollution. According to the U.S. Environmental Protection Agency (EPA), transportation accounts for about 29% of all greenhouse gas emissions. Air pollution often is referred to in terms of pounds. Air has weight, but do you know what *volume* of gas equals a pound?

Cars emit many air pollutants, including greenhouse gases. A car making an 18-mi round trip commute, 5 days/wk, 48 wks/yr, spews 4,500 lbs of CO_2, 160 lb CO, 16 lbs of VOCs, 16 lbs of NO_x, and smaller amounts of benzene, formaldehyde, particle pollution, and other toxic chemicals into the air.

Procedure

1) Calculate the volume of 1 pound of the air pollutant you are interested in:

$$\frac{454\text{ g}}{1\text{ lb}} \times \frac{1\text{ mole}}{\text{“x” g}} \times \frac{22.4\text{ L}}{1\text{ mole}} = \text{liters of gas/lb}$$

Explanation: 454 grams = 1 pound. To find out how many grams of pollutant are in a mole, calculate using values from the Periodic Table of Elements. Add together the grams per mole for each element in the compound. For example, one atom of oxygen = 16 g/mole; carbon = 12 g/mole. This totals 44 g/mole for a carbon dioxide molecule (CO_2 is 2 oxygen atoms plus 1 carbon atom).

Car emissions that contribute to climate change (and their weights per mole) are carbon dioxide (CO_2 = 44g), carbon monoxide (CO = 28g) and nitrogen dioxide (NO_2 = 46g).

At 0°C and one atmosphere of pressure, the volume of a mole of gas is 22.4 liters. Multiplying by this value converts a pound of gas into an equivalent number of liters.

Calculate how many 2-liter bottles are needed for the display using this equation:

$$\frac{\text{liters of gas/lb}}{2\text{ liters}} = \text{total bottles/lb of gas}$$

For example when CO_2, calculated to be 221 liters per pound, is divided by 2, you find it takes 115.5 bottles to represent a pound of CO_2. *(See sidebar for other answers.)*

Discussion Questions

1) How many bottles would be needed to represent the hypothetical car's *(see emission estimates above)* yearly CO_2 and CO emissions? *Calculations at right.*

2) Calculate how many bottles would be needed to represent the amount of CO_2 and CO your class members contribute to the atmosphere during one school week. Use the hypothetical car amounts above.

3) On a hot summer day in southeastern Wisconsin 261.95 tons of NO_x is emitted. If this amount were made up entirely of NO_2, how many soda bottles would this be? *Calculations at right.*

Going Beyond

1) Discuss how much air pollution students can save from entering the atmosphere by driving one trip less per week or day.

2) Before doing the *Pounds of Pollution* activity, have students track the miles they drive, or are driven, in a week. Use this to calculate the volume of CO_2 emitted. After the activity, have them track it again, perhaps having a class contest to see who can reduce their miles and emissions the most. (To reward car pooling and mass transit, divide the miles traveled by the number of occupants in the vehicle—not counting the driver if the driver is only along to give them a lift). Keep a chart of class results over time.

3) What other ways can students reduce air pollution?

4) Have students discuss the future of the air if we all continue driving the way we currently do. Have students compare how different driving behaviors or vehicles would impact the environment. (To do this, request a copy of the *eXtraordinary Road Trip* computer game from *DNRAirEducation @wisconsin.gov*.) How will this affect climate change?

KEY TO NO. OF BOTTLES

CO_2 = 231 liters/lb = 115.5 bottles/lb
CO = 363 liters/lb = 181.5 bottles
NO_2 = 221 liters/lb = 110.5 bottles

ANSWERS TO QUESTION 1

115.5 bottles/lb of CO_2 x 4500 lbs emitted by the average car per yr = 519,750 bottles/year

181.5 bottles/lb of CO x 160 lbs emitted by the average car per yr = 29,040 bottles/year

ANSWERS TO QUESTION 3

Multiply the 261.95 tons of NO_x by 2000 lbs/ton to get 523,900 lbs of NO_x. Multiply this by 110.5 bottles/lb of NO_2 and you get 57,890,950 soda bottles worth emitted on one summer day.