Pollutants Making More Pollutants

How do pollutants interact with the environment to create more pollution, and what effects do secondary pollutants have on the environment and human health?

Overview

Students use models to explore how primary pollutant emissions interact with environmental components to form secondary pollutants. Students also examine how secondary pollutants impact the environment and human health.

For the complete activity with media resources, visit:
http://education.nationalgeographic.org/activity/pollutants-making-more-pollutants/

Directions

1. Activate students' prior knowledge about secondary pollutants.

Review with students the terms pollutants, particulate pollutants, and gaseous pollutants. Tell students that primary gaseous pollutants can interact with environmental components to make secondary pollutants. Tell students that two common secondary pollutants are ozone, a component of smog, and acid precipitation. Ask students to think about where and when smog and acid rain form. Ask:

- *What do you think is happening in the environment (wind, precipitation, temperature) when there are smog events?* (Students may mention that smog events are most common in cities in the summer months. Students should state that smog events are rare when the wind is blowing [barring geographic barriers] or when there is regular precipitation.)
- *How do you think acid precipitation forms in the atmosphere?* (Students may mention that pollutants combine with water in the clouds to make the precipitation acidic.)

Tell students that science is a process of learning how the world works and that scientists do not know the “right” answers when they start to investigate a question. Let students know that they can see examples of scientists' uncertainty in forecasting air quality. Tell students that air quality is measured by the Air Quality Index. Show students the **Air Quality Index**, which includes explanations of the ranges used in the air quality index. Then project the **Forecast of Air Quality on December 10, 2013** image and **Air Quality on December 10, 2013** image. (Click on the link in the media carousel above and download using the arrow in the lower right corner of the window.) Tell students that these are snapshots of the air quality forecast and the real-time air quality in the United States on December 10, 2013. Ask:

- *Did the forecast accurately predict which areas would have poor quality air?* (The forecast air quality overlaps with many of the poor air quality areas, but it does not cover all of them. The air quality in some areas [Northern California] is much worse than the forecast predicted.)

- *Why do you think scientists did not accurately predict the air quality for more of the United States?* (Student answers will vary. The air quality forecast is affected by human activities that may not be easily predicted.)

Tell students they will be asked questions about the certainty of their predictions. Let students know they should think about what scientific data is available as they assess their certainty with their answers, and encourage them to discuss the scientific evidence with each other to better assess their level of certainty with their predictions

2. Discuss the role of uncertainty in the scientific process.

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3. Introduce the concept of stocks and flows in a system.

Tell students that materials flow into and out of systems. The flow of the materials over time can change and can be influenced by many different factors and interacting parts. Scientists think about how one part of the system can affect other parts of the system. Give students a simple example of a stock and flow in a system, as described in the scenario below.

There is a bathtub with water flowing in from the faucet and water leaving through the drain. Ask:

- *When the drain is plugged, what happens to the level of water in the bathtub?* (The water level will increase because the outflow of water is stopped, but water keeps coming in from the faucet.)

- *When the faucet is turned off, what happens to the level of water in the bathtub?* (The water level will decrease because the inflow of water is stopped, but the water keeps leaving through the drain.)

- *How can the level of water in the bathtub be kept at the same level?* (The water in the bathtub can be kept at the same level by making the inflow equal to the outflow. Then, the water that comes in through the faucet will be offset by the water that leaves through the drain.)

Tell students they will be following the flow of materials, in this case the amount of air pollution, in the system. Let students know they will be exploring some environmental and human factors that contribute to changes in the amount of pollution being added to and removed from the modeled system.

4. Introduce and discuss the use of computational models.

Introduce the concept of computational models, and give students an example of a computational model that they may have seen, such as forecasting the weather. Project the **NOAA Weather Forecast Model**, which provides a good example of a computational model. Tell students that scientists use models to predict future conditions based on current information about the energy and moisture in the atmosphere. Scientists use atmospheric models, such as these, to forecast where and when air quality may be bad.

5. Have students launch the Pollutants Making More Pollutants interactive.

Provide students with the link to the Pollutants Making More Pollutants interactive. Divide students into groups of two or three, with two being the ideal grouping to allow groups to share a computer workstation. Tell students they will be working through a series of pages of data with questions related to the data. Ask students to work through the interactive in their groups, discussing and responding to questions as they go.

Tell students that this is Activity 4 of the **Will the Air Be Clean Enough to Breathe?** lesson.

6. Discuss the issues.

After students have completed the activity, bring the groups back together and lead a discussion focusing on these questions:

- Show the **Air Pollution Model 2**. *What environmental conditions led to a high concentration of secondary pollutants in the model?* (Wind blowing from the water blows pollutants against the mountain so they are trapped over the city. Little rain means that the pollutants are not washed out of the air. Intense sunlight helps primary pollutants create secondary pollutants.)
- *What conditions are best for forming a smog event?* (Low winds, or wind blowing towards a geographic barrier, low precipitation, and high sunlight will help the formation of smog.)
- *If there are more people in a city, will there be more smog?* (That depends on what the people are doing in the city. If they are not creating a lot of NO_x or VOCs, there will be little ozone formed. When there is less ozone, there is less of a chance of smog.)
- *Would requiring everyone in cities to use electric cars prevent poor air quality events?* (It might prevent smog events if the electricity is generated far outside the city or if electricity comes only from solar, wind, nuclear, or hydroelectric plants. If the power plants are located in the city [or the wind blows towards the city], pollutants from burning coal, natural gas, or biomass could blow into the city. With electric cars, the pollution is just pushed to another region.)
- *Is there a way to stop all acid rain events?* (No, but acid rain events can be limited by limiting the amounts of SO_2 emitted by power plants. Some SO_2 is emitted naturally, so there will always be some acid rain, particularly downwind from volcanoes.)

TipTeacher Tip

If you want to save students' data for grading online, register your class for free at the High-Adventure Science portal page.

TipTeacher Tip

This activity is part of a sequence of activities in the **Will the Air Be Clean Enough to Breathe?** lesson. The activities work best if used in sequence.

Modification

This activity may be used individually or in groups of two or three students, or as a whole class activity. If using as a whole class activity, use an LCD projector or interactive whiteboard to project the activity.

Informal Assessment
1. Check students' comprehension by asking students the following questions:

- What environmental component affects the formation of smog?
- In what season is smog most likely to form? Why?
- How can acid rain form thousands of miles from a pollution source?

2. Use the answer key to check students' answers on embedded assessments.

Objectives
Subjects & Disciplines
Science
- Earth science
- General science

Learning Objectives
Students will:

- describe why intense sunlight can decrease air quality in a pollution event
- describe the effect of solar intensity on the formation of ozone
- explain the effect of precipitation on the concentration of pollutants in the atmosphere
- explain how acid rain is formed from primary pollutants

Teaching Approach
- Learning-for-use

Teaching Methods
- Discussions
- Multimedia instruction
- Self-paced learning
- Visual instruction
- Writing

Skills Summary
This activity targets the following skills:

- 21st Century Student Outcomes
  - Information, Media, and Technology Skills
    - Information, Communications, and Technology Literacy
  - Learning and Innovation Skills
    - Critical Thinking and Problem Solving
- 21st Century Themes
  - Global Awareness

- Critical Thinking Skills
    - Analyzing
    - Evaluating
    - Understanding

National Standards, Principles, and Practices

National Science Education Standards

• **(5-8) Standard A-1:**
Abilities necessary to do scientific inquiry
• **(5-8) Standard D-1:**
Structure of the earth system
• **(5-8) Standard F-1:**
Personal health
• **(5-8) Standard F-4:**
Risks and benefits
• **(9-12) Standard A-1:**
Abilities necessary to do scientific inquiry
• **(9-12) Standard A-2:**
Understandings about scientific inquiry
• **(9-12) Standard C-5:**
Matter, energy, and organization in living systems
• **(9-12) Standard F-1:**
Personal and community health
• **(9-12) Standard F-2:**
Population growth
• **(9-12) Standard F-4:**
Environmental quality
• **(9-12) Standard F-5:**
Natural and human-induced hazards

Common Core State Standards for English Language Arts & Literacy

• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Key Ideas and Details, RST.11-12.1
• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Key Ideas and Details, RST.9-10.3
• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Craft and Structure, RST.9-10.4
• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Key Ideas and Details, RST.6-8.1
• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
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• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Key Ideas and Details, RST.11-12.3

ISTE Standards for Students (ISTE Standards*S)

• **Standard 3:**
Research and Information Fluency
• **Standard 4:**
Critical Thinking, Problem Solving, and Decision Making

Next Generation Science Standards

• **Crosscutting Concept 1:**
Patterns
• **Crosscutting Concept 2:**
Cause and effect: Mechanism and prediction
• **Crosscutting Concept 3:**
Scale, proportion, and quantity
• **Crosscutting Concept 4:**
Systems and system models
• **Crosscutting Concept 5:**
Energy and matter: Flows, cycles, and conservation
• **Crosscutting Concept 7:**
Stability and change
• **Science and Engineering Practice 1:**
Asking questions and defining problems
• **Science and Engineering Practice 2:**
Developing and using models
• **Science and Engineering Practice 3:**
Planning and carrying out investigations
• **Science and Engineering Practice 4:**
Analyzing and interpreting data
• **Science and Engineering Practice 6:**
Constructing explanations and designing solutions
• **Science and Engineering Practice 7:**
Engaging in argument from evidence
• **Science and Engineering Practice 8:**
Obtaining, evaluating, and communicating information

Preparation
What You'll Need
Required Technology
- Internet Access: Required
- Tech Setup: 1 computer per learner, 1 computer per small group, Interactive whiteboard, Projector

Physical Space
- Classroom
- Computer lab
- Media Center/Library

Grouping
- Heterogeneous grouping
- Homogeneous grouping
- Large-group instruction
- Small-group instruction

Resources Provided: Websites
- Air Quality Index (AQI) Basics

Resources Provided: Handouts & Worksheets
- Answer Key - Pollutants Making More Pollutants

Resources Provided: Interactives
- Pollutants Making More Pollutants interactive

Resources Provided: Images
- Forecast of Air Quality, December 10, 2013
- Air Quality on December 10, 2013

Background & Vocabulary
Background Information
Primary air pollutants can be converted into secondary pollutants, such as ozone and acid rain, by interacting with environmental components. When nitrogen oxides and sulfur dioxide combine with water in clouds, they form acid precipitation. The acidic precipitation can cause plant damage and destruction of aquatic habitats as the waters become more acidic.

When nitrogen oxides and volatile organic compounds mix in the presence of sunlight, a secondary pollutant–ozone–can be produced. Ozone is a powerful irritant to the human respiratory system and plants' leaves alike. Because ozone is created as a result of the chemical reactions between nitrogen oxides and volatile organic compounds in the presence of sunlight, it is called a photochemical pollutant. Smog that results from such ozone is called photochemical smog.

Prior Knowledge

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Recommended Prior Activities

- Measuring Air Quality
- Movement of Pollutants
- Visible and Invisible Pollutants

Vocabulary

Term	Part of Speech	Definition
acid	*noun*	chemical compound that reacts with a base to form a salt. Acids can corrode some natural materials. Acids have pH levels lower than 7.
air quality	*noun*	measurement of pollutants and other harmful materials in the air.
atmosphere	*noun*	layers of gases surrounding a planet or other celestial body.
carbon monoxide	*noun*	Carbon monoxide is a colorless, odorless, and tasteless gas that is slightly less dense than air. It can be toxic to humans.
intensity	*noun*	measure of magnitude.
model, computational	*noun*	a mathematical model that requires extensive computational resources to study the behavior of a complex system by computer simulation.
nitrogen oxide	*noun*	one of many chemical compounds made of different combinations of nitrogen and oxygen.
ozone	*noun*	form of oxygen that absorbs ultraviolet radiation.
particulate	*adjective, noun*	microscopic solid or liquid particle, often suspended in the atmosphere as pollution.
pollutant	*noun*	chemical or other substance that harms a natural resource.
precipitation	*noun*	all forms in which water falls to Earth from the atmosphere.
smog	*noun*	type of air pollution common in manufacturing areas or areas with high traffic.
solar radiation	*noun*	light and heat from the sun.
sulfur dioxide	*noun*	greenhouse gas that can cause acid rain.
system	*noun*	collection of items or organisms that are linked and related, functioning as a whole.

Term	Part of Speech	Definition
volatile organic compound (VOC)	*noun*	gas released from some solids or liquids that may cause harm to people and the atmosphere.

For Further Exploration

Websites

- National Geographic Encyclopedic Entry: air pollution
- National Geographic Encyclopedic Entry: smog
- National Geographic Environment: Air Pollution

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This material is based upon work supported by the National Science Foundation under Grant No. DRL-1220756. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.