NATIONAL GEOGRAPHIC

lesson

Will the Air Be Clean Enough To Breathe?

What are the interactions of factors that affect a region's air quality?

Content Created by

The Concord Consortium

Activity 1: Measuring Air Quality | 45 mins

Directions

1. Activate students' prior knowledge about air quality.

Show the **Highland Park Optimist Club banquet in 1954** 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 bad air quality has a negative effect on human health. Air quality was poor in the United States before Clean Air Act regulations went into effect in 1970. Many areas around the world still experience very poor air quality. Ask:

- *Why do you think air quality is better in the United States today than it was before 1970?* (Air quality is better because the Clean Air Act set air quality standards that states and localities had to meet. They reduced their emissions to meet the standards, and the air quality improved.)
- *What causes poor air quality events?* (There are many causes of poor air quality events. Human actions [burning fuels and using volatile organic compounds] put pollutants into the air. Natural events [forest fires and volcanic eruptions] can also affect air quality.)
- *Are human processes the only causes of air pollution?* (Humans are not the only causes of air pollution. Forest fires and volcanic eruptions are two natural causes of poor air quality.)

Tell students that air quality is measured by the air quality index. Show students the **Air Quality Index,** and then access the **Air Now: Today's AQI Forecast** website and show the air quality forecast map for the United States. Ask:

- *Where is the air quality forecast to be the worst in the United States today?* (Answers will vary depending on the day.)
- *What do you think is the cause for the poor air quality in the United States today?* (Depending on the area of the country, the poor air quality could be due to fires, emissions from power plants

and factories, and/or emissions from vehicles. Stagnant weather patterns can contribute to poor air quality events.)

- *How do you think scientists forecast air quality?* (Scientists use data from real-time monitoring stations to measure the level of pollutants in particular areas and weather forecasts to predict where wind will blow pollutants (or leave pollutants over a particular location).)

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

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. Show 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.

3. Have students launch the Measuring Air Quality interactive.

Provide students with the link to the Measuring Air Quality 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 that they will be working through a series of pages of data with questions related to the data. Ask students to work through the activity in their groups, discussing and responding to questions as they go.

Tell students that this is Activity 1 of the **Will the Air Be Clean Enough to Breathe?** lesson.

4. Discuss the issues.

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

- *What groups of people are most at risk from poor air quality?* People who work outdoors are most at risk, followed by those with breathing problems, such as asthma, emphysema, and COPD (chronic obstructive pulmonary disease).

- *What do officials suggest people do when bad air quality is forecast?* (When bad air quality is forecast, officials suggest limiting outdoor activities.)

- *What might happen to air quality if the population continues to grow?* (If the population continues to grow, air quality might decrease, especially in areas of the world where air quality is already bad a lot of the time.)

- *How might humans mitigate bad air quality events in the future?* (Humans might be able to mitigate bad air quality events through technology. Technology could be developed that removes more emissions from cars, factories, and power plants. Technology could also change so that manufacturing and transportation methods don't require burning of fuels that release pollutants into the air.)

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. It may also be modified for a whole-class format. If using as a whole-class activity, use an LCD projector or interactive whiteboard to project the activity. Turn embedded questions into class discussions. Uncertainty items allow for classroom debates over the evidence.

Informal Assessment

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

- What factors contribute to poor air quality events?
- What effects can air pollution regulations have on air quality?

- What can be done to reduce or manage pollutant emissions?

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

Objectives

Subjects & Disciplines

Science

- Earth science
- General science

Learning Objectives

Students will:

- explain the link between human and ecosystem health and air pollution
- describe natural and anthropogenic sources of air pollution

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 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:**
Craft and Structure, RST.9-10.4
• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Key Ideas and Details, RST.6-8.3
• **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:**
Craft and Structure, RST.6-8.4
• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Craft and Structure, RST.11-12.4
• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Key Ideas and Details, RST.11-12.3
• **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.9-10.1
• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Key Ideas and Details, RST.9-10.3

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 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 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

Background & Vocabulary

Background Information

Poor air quality can negatively affect human and environmental health. Air quality can suffer due to both natural and anthropogenic (human-caused) events. Anthropogenic emissions can be controlled. Air quality has improved in the United States since the passage of the first Clean Air Act in 1970.

The Clean Air Act set national ambient air quality standards for six common pollutants: particulates, ozone, sulfur dioxide, nitrogen oxides, carbon monoxide, and lead. States were required to develop plans to achieve good air standards and to control emissions drifting across state lines. Pollution control devices were developed for stationary (power plant, factory) and mobile (vehicle) pollution sources. The Clean Air Act has been updated several times since the initial law was passed in 1970.

As a result, air quality in the United States is better today than it has been in the past 50 years. Poor air quality events are still common in many other countries around the world. Global air movements can bring pollutants from other countries to the United States. A system of local air measurement stations provides a real-time look at air quality around the United States. Based on these measurements and on weather forecasts, scientists can provide air quality forecasts. You can see the current and forecast air quality at AirNow.gov. Air quality is defined into six categories: Good, Moderate, Unhealthy for Sensitive Groups (USG), Unhealthy, Very Unhealthy, and Hazardous. (See the Air Quality Index (AQI) chart from the Environmental Protection Agency (EPA) in the resource carousel.)

Prior Knowledge

[]

Recommended Prior Activities

- None

Vocabulary

Term	Part of Speech	Definition
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.
model, computational	*noun*	a mathematical model that requires extensive computational resources to study the behavior of a complex system by computer simulation.
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.
smog	*noun*	type of air pollution common in manufacturing areas or areas with high traffic.
system	*noun*	collection of items or organisms that are linked and related, functioning as a whole.

Partner

The Concord Consortium

Funder

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.

Partner

Activity 2: Movement of Pollutants | 45 mins

Directions

1. Activate students' prior knowledge about air movements in the atmosphere.

Show the **Air Pollution From a Power Plant** photograph. Tell students that pollutants emitted into the atmosphere do not stay in the atmosphere or even directly above the polluting source forever. They move throughout the atmosphere and are moved and removed by natural processes. Ask:

- *What natural process causes pollutants to move away from the pollution source?* (Wind will cause pollutants to move away from the source.)
- *What natural process would remove pollutants from the atmosphere?* (Precipitation would remove pollutants from the atmosphere.)

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

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 that 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.

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 Movement of Pollutants interactive.

Provide students with the link to the Movement of 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 models with questions related to the models. Ask students to work through the interactive in their groups, discussing and responding to questions as they go.

Tell students that this is Activity 2 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:

- *What conditions allow for the best air quality over the city in the model* (**Model 2: Cross-Section of a City: With Graph**)*?* (In the city in the model, the best air quality is achieved when the wind is blowing toward the water or when it rains frequently.)
- *How did you get poor air quality over the city in the model* (**Model 2: Cross-Section of a City: With Graph**)*?* (Poor air quality can result when the wind is blowing towards the mountains, when there is infrequent rain, and when there is infrequent rain and intense sunlight.)
- *Where did you put factories in Model 3 so that all the cities had good air quality* (**Model 3: Satellite View of a City**)*?* (Factories should be placed south of the northeastern-most mountains so that the wind won't blow the pollutants to City A. The wind from the northeast or east will not blow pollutants into any city when the factories are located directly south of the northeastern-most mountains.)
- *How can pollution from Asia affect North America?* (The wind blows primarily from the West. Polluted air over Asia can be blown across the ocean to affect cities in North America.)
- *How could tall buildings affect a city's air quality?* (Tall buildings could form a barrier to pollutants' escape from the area. This is dependent on the wind direction.)
- *Mexico City, Mexico is surrounded by mountains on all sides. How does this affect the region's air quality?* (The air quality could be affected by the mountains because the pollution might not be able to rise up over the mountains and blow away. This could make the air quality in the city quite poor.)

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. It may also be modified for a whole-class format. If using as a whole-class activity, use an LCD projector or interactive whiteboard to project the activity. Turn embedded questions into class discussions. Uncertainty items allow for classroom debates over the evidence.

Informal Assessment

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

- What natural process removes pollutants from the atmosphere?
- How can air quality over an area be poor even if there are no local emissions?
- How do geographical barriers affect the pollution level in cities?

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

Objectives

Subjects & Disciplines

Science

- Earth science
- General science

Learning Objectives

Students will:

- identify factors that affect air quality over a given area
- describe how pollutants move through the atmosphere
- explain how air movements affect the air quality over a given area
- explain how precipitation can improve air quality over an area

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**:
Craft and Structure, RST.6-8.4
• **Reading Standards for Literacy in Science and Technical Subjects 6-12**:
Key Ideas and Details, RST.6-8.3
• **Reading Standards for Literacy in Science and Technical Subjects 6-12**:
Key Ideas and Details, RST.9-10.1
• **Reading Standards for Literacy in Science and Technical Subjects 6-12**:
Craft and Structure, RST.11-12.4
• **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

Background & Vocabulary

Background Information

Air quality is affected by natural processes. Wind can move pollutants from their source to far-away locations. Precipitation can remove pollutants from the atmosphere.

Scientists use computational models to predict the movement of pollutants from their sources and the formation of secondary pollutants. Satellites can monitor the movements of visible pollutants across long distances. A network of air quality monitors on the ground measures local concentrations of pollutants to provide more detailed forecasts of air quality.

Prior Knowledge

[]

Recommended Prior Activities

- Measuring Air Quality

Vocabulary

Term	Part of Speech	Definition
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.
intensity	*noun*	measure of magnitude.

Term	Part of Speech	Definition
model, computational	*noun*	a mathematical model that requires extensive computational resources to study the behavior of a complex system by computer simulation.
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.
system	*noun*	collection of items or organisms that are linked and related, functioning as a whole.

Partner

Funder

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.

Partner

Activity 3: Visible and Invisible Pollutants | 45 mins

Directions

1. Activate students' prior knowledge about types of pollutants.

Show the **1980 Mount St. Helens Eruption** photograph. Tell students that there are two types of pollutants: visible pollutants and invisible pollutants. Ask:

- *What kind of pollutants can you see in this picture?* (You can see ash emitted, rock fragments, and gas clouds.)

Tell students that there are many different types of invisible, or gaseous, pollutants. Let students know that they will be exploring the sources of visible and invisible pollutants and their effects on human and environmental health in this activity.

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

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 that 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.

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. Have students launch the Visible and Invisible Pollutants interactive.

Provide students with the link to the Visible and Invisible 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 that 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 3 of the **Will the Air Be Clean Enough to Breathe?** lesson.

5. Discuss the issues.

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

- *What types of particulate pollutants are produced naturally, and what types are produced through human actions?* (Some natural particulates include sand and salt particles, as well as ash and soot from forest fires. Ash and soot are also produced through human actions as materials are burned for fuel in transportation, heating, and electricity production. Humans cause some forest fires, making those “natural” sources really anthropogenic sources.)
- *How do invisible (gaseous) pollutants affect the environment?* (Invisible pollutants such as SO_2

and NO_x can combine with water to form acidic precipitation. The acidic precipitation can harm plants and animals. VOCs and CO are harmful to animals' health as well as human health.)

- *Why are particulate pollutants hazardous to human health?* (Particulates can be inhaled deep into the lungs and cross over into the bloodstream. Then they can travel around the body, causing effects to many organ systems.)

- *Show* the **NO_x Emissions, 2008** pie chart (page 6 of the interactive*). How many of the NO_x emissions are from human sources?* (Almost all of the NO_x emissions are anthropogenic. Up to 1% [miscellaneous and fires] could be from natural sources.)

- *What types of materials can cause indoor air pollution?* (Carpets, perfumes, hairsprays, furniture, and poorly ventilated heating/cooking devices can cause indoor air pollution.)

- *Why is indoor pollution more hazardous to human health than most outdoor pollution?* (Indoor pollution cannot be blown away by the wind or precipitated out of the air by rain or snow. It can be more concentrated because there is less dilution with clean air than is possible outdoors.)

- *How can increasing fuel efficiency reduce the emissions of gaseous pollutants (SO_2, NO_x, CO)?* (Increasing fuel efficiency can reduce the emissions of gaseous pollutants because less fuel needs to be burned to go the same distance [in a vehicle] or produce electricity [in a power plant]. If less fuel is used, there will be fewer emissions.)

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. It may also be modified for a whole-class format. If using as a whole-class activity, use an LCD projector or interactive whiteboard to project the activity. Turn embedded questions into class discussions. Uncertainty items allow for classroom debates over the evidence.

Informal Assessment

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

- What are some common visible and invisible pollutants?
- What is the effect of particulate emissions on human health?
- How do invisible (gaseous) pollutants affect the environment?

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

Objectives

Subjects & Disciplines

Science

- Earth science
- General science

Learning Objectives

Students will:

- identify common sources of particulate and gaseous pollutants
- explain how particulate emissions affect human health
- explain how gaseous emissions can result in acid rain
- explain how human health is affected by gaseous pollutants such as VOCs and carbon monoxide

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
- 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:**
Craft and Structure, RST.6-8.4
• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Key Ideas and Details, RST.9-10.1
• **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:**
Key Ideas and Details, RST.11-12.1
• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Key Ideas and Details, RST.11-12.3
• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Craft and Structure, RST.11-12.4

• **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Key Ideas and Details, RST.6-8.3

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 7:**
Stability and change
• **Science and Engineering Practice 1:**
Asking questions and defining problems
• **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

Background & Vocabulary

Background Information

Air pollutant emissions have an effect on human and environmental health. Particulate emissions (the visible pollutants) can be inhaled into the nose and lungs. The smallest particles can cross the alveolus-capillary barrier and make their way into the bloodstream.

Invisible pollutants (nitrogen oxides, sulfur dioxide, volatile organic compounds, carbon monoxide) also pose a threat to health. Carbon monoxide displaces oxygen in red blood cells, leading quickly to death if the carbon monoxide concentration is high. Nitrogen oxides, sulfur dioxide, and volatile organic compounds irritate the sensitive tissues of the airway; they are particularly irritating to people with pre-existing lung conditions such as asthma or emphysema.

In addition to posing a threat to human health, nitrogen oxides and sulfur dioxide are irritating to plants. Plants' leaves can be burned by dry deposits of nitrogen oxides and sulfur dioxide. When these pollutants 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.

Prior Knowledge

[]

Recommended Prior Activities

- Measuring Air Quality
- Movement of Pollutants

Vocabulary

Term	Part of Speech	Definition
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.
emission	*noun*	discharge or release.
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.
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.

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

Partner

Funder

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.

Activity 4: Pollutants Making More Pollutants | 45 mins

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.

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

that 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.

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:**
Craft and Structure, RST.6-8.4
- **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Key Ideas and Details, RST.6-8.3
- **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Key Ideas and Details, RST.9-10.1
- **Reading Standards for Literacy in Science and Technical Subjects 6-12:**
Craft and Structure, RST.11-12.4
- **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

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

[]

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.

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

Partner

The Concord Consortium

Funder

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.

Activity 5: Preventing Bad Air Days | 45 mins

Directions

1. Introduce students to the environmental factors that affect air quality.

Let students know that environmental factors affect the severity and duration of pollution events. Show the **New Bridge in Bratislava on Clear Day** photograph and the **New Bridge in Bratislava with Temperature Inversion** photograph. (Download the image by clicking on the down arrow in the lower right corner of the media carousel window.) Tell students that the temperature of the atmosphere affects the movement of pollutants. Ask:

- *What happened to the temperature of the air between the first picture and the second picture?* (There is a temperature inversion in the second picture. The air is cooler at the surface than it is above the surface. Normally, the air cools with increasing elevation.)
- *What happened to change the temperature of the atmosphere?* (A temperature inversion can be caused by cool air at the surface because of snow/ice on the surface or by cooler air blowing in off a colder body of water.)

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

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 that 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.

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 Preventing Bad Air Days interactive.

Provide students with the link to the Preventing Bad Air Days interactive. Divide students into groups of two or three, with two being the ideal grouping to allow groups to be able to share a computer work station. Tell students they will be working through a series of pages of questions related to the models in the activity. Ask students to work through the activity in their groups, discussing and responding to questions as they go.

Tell students this is Activity 5 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 the questions below.

NOTE: The answers provided are the correct answers; however, students should be encouraged to find these answers by using the models in the activity.

- *What conditions created a thermal inversion in Model 4 (***Model 4: Cross-Section of a City: With Thermal Inversion***)?* (The wind has to be coming from the water. The water is cooler than the land. The breeze coming off the water cools the surface of the land so it is colder than the layer of air directly above it.)
- *Why are smog events longer-lasting when there is a temperature inversion?* (Smog events are longer lasting when there is a temperature inversion because the temperature inversion prevents the air from rising through the atmosphere and dissipating over a larger area.)
- *Can thermal inversions be prevented?* (No, thermal inversions cannot be easily prevented. Thermal inversions are natural events. They are created when the surface is cooler than the air above. This can happen when there is snow on the ground, cooling the ground, while the Sun warms the air above it. They can also happen when cooler air blows off a large body of water onto the warmer land. The sea breeze [or lake breeze] cools the lower layer of air below the temperature of the air above.
- *Is it more important to limit the pollution from cars or from power plants and factories (***Model 5: Cross-Section of a City: With Pollution Control***)?* (The data from this model indicate that limiting vehicle pollution is more important to air quality than limiting power plant/factory pollution. This may or may not apply in the real world; the model's predictive power is limited because all car emissions are treated as the same, just as all power plant/factory emissions are treated as the same. The different types of pollutants emitted by the different pollution sources are not modeled with this model. The effect of weather is not modeled well enough to make long-term predictions about which pollution type has the biggest effect on the overall city pollution level.

Pollutants from other power plants/factories could blow in to this area; only a small portion of the Earth is modeled in this model.)

- *How can technology make a difference in air quality?* (Technology can be developed that can lower the emissions of cars, power plants, and factories. Technology can also increase the efficiency of the polluting sources, meaning that there would be less pollution per mile traveled/unit of electricity generated/product manufactured. Technology can also create more pollution as a side effect of more manufacturing and more demand for products that pollute.)

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. It may also be modified for a whole-class format. If using as a whole-class activity, use an LCD projector or interactive whiteboard to project the activity. Turn embedded questions into class discussions. Uncertainty items allow for classroom debates over the evidence.

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

- What is a thermal inversion?
- What conditions lead to a thermal inversion?
- How do pollution control devices work?

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 how a thermal inversion occurs and is dissipated
- explain how pollution control devices reduce emissions of pollutants from vehicles and smokestacks
- compare methods of transportation for their ability to prevent/reduce the number of bad air quality days

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

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.6-8.1
• **Reading Standards for Literacy in Science and Technical Subjects 6-12**:
Key Ideas and Details, RST.9-10.1
• **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**:
Craft and Structure, RST.6-8.4
• **Reading Standards for Literacy in Science and Technical Subjects 6-12**:
Craft and Structure, RST.11-12.4
• **Reading Standards for Literacy in Science and Technical Subjects 6-12**:
Key Ideas and Details, RST.6-8.3
• **Reading Standards for Literacy in Science and Technical Subjects 6-12**:
Key Ideas and Details, RST.11-12.3
• **Reading Standards for Literacy in Science and Technical Subjects 6-12**:
Key Ideas and Details, RST.11-12.1

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
• **HS. Earth's Systems:**
HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
• **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 5:**
Using mathematics and computational thinking
• **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

Background & Vocabulary

Background Information

The temperature profile of the atmosphere plays an important role in the level of pollutants in the air above a given location. Thermal inversions can trap pollutants in an area for a long period of time, leading to bad air quality. These events can be forecast and people can change their actions to prevent or reduce the number of bad air quality days. With these forecasts, people can plan their activities to minimize their exposure to poor quality air.

Prior Knowledge

[]

Recommended Prior Activities

- Measuring Air Quality
- Movement of Pollutants
- Pollutants Making More 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.
inversion	*noun*	act or circumstance of being upside-down.
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.
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.
scrubber	*noun*	device or method used to remove air pollutants from industrial exhaust.
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.

Term	Part of Speech	Definition
system	*noun*	collection of items or organisms that are linked and related, functioning as a whole.
volatile organic compound (VOC)	*noun*	gas released from some solids or liquids that may cause harm to people and the atmosphere.

Partner

Funder

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.

Funder

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.

Partner