

# Human Population Growth and the Environment

Human impacts on Earth can be seen from space.

## CAN YOU EXPLAIN IT?



### Gather Evidence

As you explore the lesson, gather evidence for how human activities affect the geosphere, atmosphere, hydrosphere, and biosphere.



**FIGURE 1:** This lake contains an orange-red substance.



Earth has existed for roughly 4.5 billion years. Our human species, *Homo sapiens*, evolved around 200,000 years ago. As the human population has grown, so has our dependence on Earth's resources. Human activities impact natural resources and Earth's cycles. Some activities are beneficial; however, many activities are harmful because they change the land, the air, and the waters of Earth.



**Predict** What do you think made the water in Figure 1 turn this color?

# Population Growth and Natural Resources

The human population has changed over time as a result of many factors. Increased use of natural resources, along with improvements in areas such as transportation, agriculture, health, and sanitation, have allowed the human population to grow.

## The Human Population

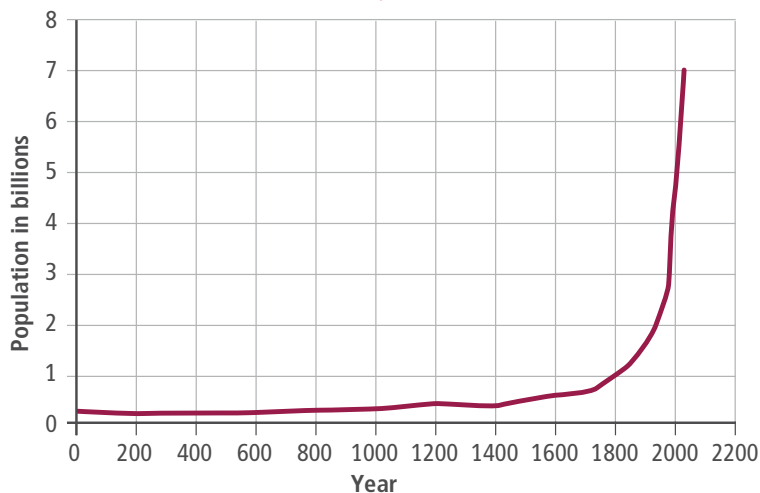
The graph in Figure 2 shows how the human population has changed over time. Although humans existed for hundreds of thousands of years before Year 0 on the graph, we will focus on more recent data for this analysis.



### Data Analysis

#### Human Population Growth

**FIGURE 2:** This graph shows how the human population has changed over time.



Source: U.S. Census Bureau; David Christian, *Maps of Time: An Introduction to Big History* (University of California Press, 2003), 209, 343

Use the graph of human population growth to answer the following questions:

1. What type of growth is the population experiencing? Explain your answer.
2. In what century did the population begin to increase rapidly? What factors do you think might have caused this change?
3. What are some other factors that might have allowed the population to continue to increase in more recent decades?
4. In what ways does the study of human population differ from the study of wildlife ecology?



**Predict** Make a list of the most important resources you use each day. Which of these come from natural resources?

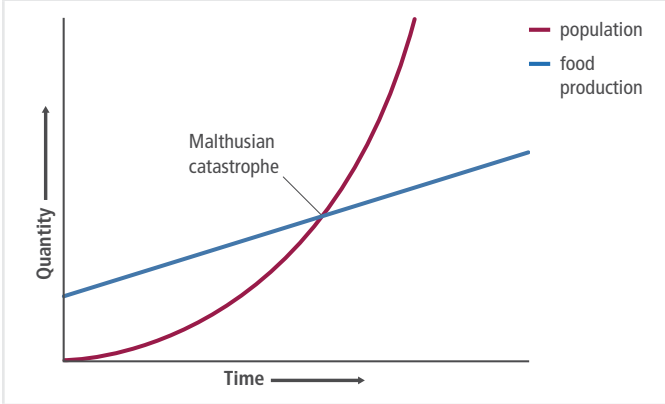


### Language Arts Connection

Populations can be analyzed in terms of the proportion of people in different age groups. Data can be used to make diagrams called population pyramids, which show the distribution of males and females in various age groups in a given population. Use Internet resources to find population pyramids for at least four different countries, and research some of the societal and environmental factors that account for the patterns in each pyramid. Make a poster or digital presentation to display your findings, and present the information to your peers.

## Malthus's Prediction

**FIGURE 3:** Malthus predicted human population growth would outpace food production.



## Carrying Capacity

Will the human population continue to grow? Will there ever be a time when Earth is not able to support human life? Humankind's quest to live by using Earth's resources has modified the planet's environment in many ways. Some of these changes have allowed Earth to support the growth of the human population. In other words, human activities overall have increased Earth's carrying capacity for humans.

What is Earth's carrying capacity, or maximum number, for humans? This value can only be predicted because human population growth is affected by so many factors. In the late 1700s, Thomas Malthus, an economist, wrote in a controversial essay that the human population was growing faster than Earth's resources could support. Furthermore, he said that if human population growth goes unchecked and

human population continues to increase, poverty and famine would result. These, according to him, are natural ways in which human population growth is checked.



**Predict** List some of the factors Malthus may not have accounted for when he wrote his essay about human population growth. What changes have occurred since the 1700s that have allowed the human population to avoid a "Malthusian catastrophe"?

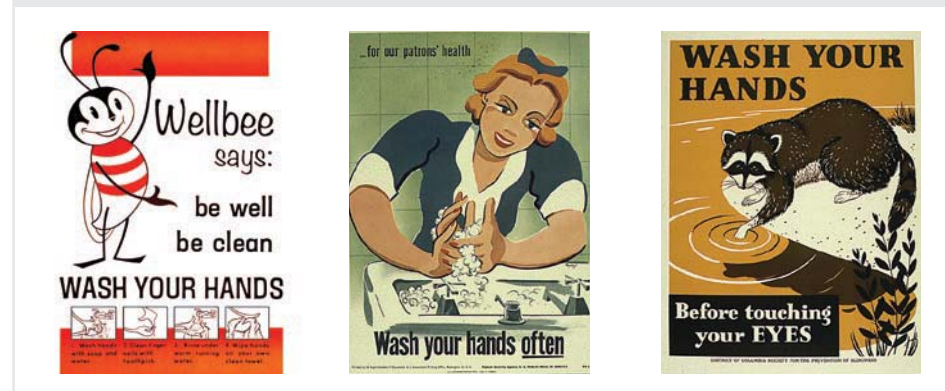
## Factors That Affect Population Growth

Malthus did not consider that the carrying capacity of an environment can change as the environment changes. In this case, the environment has changed due to technological advancements developed by humans. Industrial farming equipment has revolutionized the way we grow food, improvements in sanitation have reduced disease rates, and advances in medicine have greatly increased the human life span. These technologies have helped humans to live longer and have allowed the human population to grow exponentially. The world population was estimated to be over 7 billion in 2015. At the current rate of growth, scientists predict that the population will be around 9.5 billion in 2050.



**Collaborate** Write an answer to this question, and discuss it with a partner: How might societal, scientific, and economic factors changing over time influence the future growth rate of the human population?

**FIGURE 4:** In 1850, a physician named Ignaz Semmelweis, explained that doctors could reduce the spread of infectious disease by washing their hands before surgery. It was many years before this idea was full accepted, but it eventually revolutionized health and medicine.






# Natural Resources

Natural resources are any natural materials that are used by humans, such as water, petroleum, minerals, forests, and animals. Natural resources can be classified as renewable or nonrenewable.

## Renewable Resources

A **renewable resource** is a resource that can be replaced at the same rate that it is consumed. Wind energy is a renewable resource. The wind's kinetic energy, or energy of motion, turns the blades of a turbine that spin a generator and produce electricity for homes and commercial infrastructures. Other forms of renewable energy include biomass, geothermal, hydroelectric, and solar energy. Solar energy from the sun is captured by solar cells that are used to generate electricity in calculators, homes, and satellites. Some resources, like fresh water, are "potentially renewable," or renewable only if they are not used more quickly than they are replenished.

 **Explain** Why is lumber from trees considered a potentially renewable resource?

**FIGURE 5:** Some renewable natural resources are biomass, hydroelectricity, and geothermal energy.



**a Biomass** Biomass is material from plants and animals used as a source of energy. Ethanol, an alcohol that can be derived from organic sources such as corn, is a component of fuel.



**b Hydroelectric Energy** The kinetic energy of the falling water in dams is used to produce electricity.



**c Geothermal Energy** Geothermal plants use heat from within Earth to produce electricity.


Even though renewable resources can be replaced at the same rate they are consumed, using these resources can still have impacts on the environment and human health. For example, burning biomass releases carbon dioxide and can be dangerous for people who burn wood indoors for heating and cooking. The building of dams to tap the energy of falling water can change the temperature and composition of rivers. These changes affect the organisms that live in or near the rivers and may upset the stability of the ecosystem where the dam is built.



## Engineering

### Biomass and Human Health

It is estimated that about a third of the world's population burns wood or other biomass for heating and cooking. This produces carbon dioxide that pollutes indoor air, which can cause respiratory disease. But in many countries around the world, other sources of energy are not easily accessible. Cleaner, more efficient stoves are needed to reduce these impacts on the environment and human health.

 **Analyze** Research some of the current solutions being proposed to fix this problem. Make a list of the proposed solutions, and evaluate each based on how well it addresses the problem.

## Nonrenewable Resources

**Nonrenewable resources** are natural resources that are used faster than the rate at which they form. In other words, nonrenewable materials are typically extracted from Earth faster than they are replaced. Examples include minerals, nuclear materials, and fossil fuels such as coal, petroleum, and natural gas. Minerals are solid substances that are used in building materials, electronics, medical technologies, and even fireworks. Nuclear materials, such as uranium and plutonium, undergo reactions that produce a large amount of energy. This energy can be used to generate electricity.

Fossil fuels are extracted by various means, including mining, hydraulic fracturing, and drilling. Mining involves the extraction of coal from artificial tunnels or from Earth's surface. Hydraulic fracturing, also called fracking, is a process that injects a mixture of water, chemicals, and sand into impermeable rock to create cracks or fractures. This allows gases to be released and extracted as an energy source. Drilling involves boring holes into Earth to access and release oil and gas from the crust.

**Language Arts Connection** Most of the plastics we use are made from fossil fuels. Research some of the ways that plastics have impacted both human society and the environment, and make an infographic to display your findings.

**FIGURE 6:** Nonrenewable natural resources include fossil fuels, nuclear material, and minerals.



**a Fossil Fuels** Fossil fuels, like petroleum and natural gas, can be accessed through drilling.



**b Nuclear Energy** Nuclear reactions release heat, which can be converted into electrical energy.

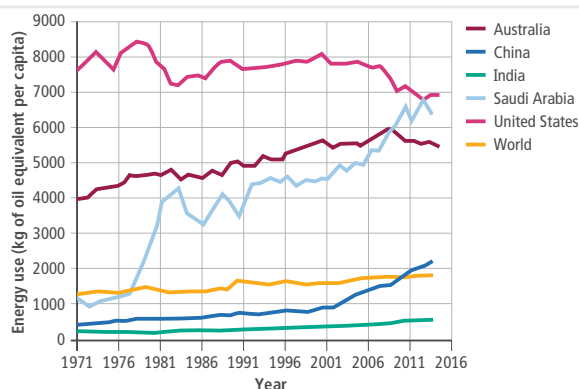


**c Minerals** Minerals like limestone, granite, and marble can be used as building materials.

Some methods used to extract natural resources can harm ecosystems and human health. Oil spills from drilling or transportation accidents damage aquatic ecosystems and pollute human drinking water. Coal miners who work below ground and inhale coal dust can develop black lung disease, which may lead to respiratory failure. The mixture injected to penetrate bedrock during hydraulic fracturing is also a health concern because it contains chemicals that could contaminate surface water or groundwater and may be toxic to humans.

### Per Capita Energy Consumption

**FIGURE 7:** Per capita energy consumption for selected countries



Source: Based on IEA data from Energy Use Data © OECD/IEA, [www.iea.org/statistics](http://www.iea.org/statistics), License: [www.iea.org/t&C](http://www.iea.org/t&C); as modified by HMH.

### Analyzing Per Capita Consumption

Alongside the increase in the human population over time is the increase of per capita consumption of resources. Per capita consumption of resources refers to the average amount of resources an individual within a population uses or consumes. The graph in Figure 7 shows per capita energy consumption for the world and for some countries.

**Analyze** What is the general trend in per capita energy use for the world? Do all countries show the same trend? What societal and economic factors might explain these differences?

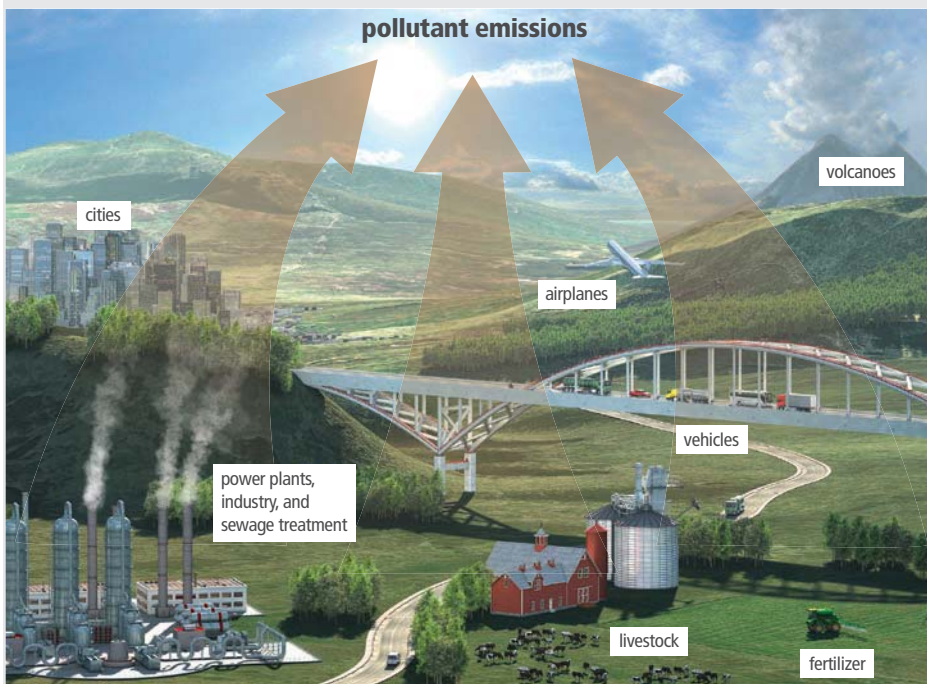
# Human Impacts on Air and Climate

What you see covering the city in Figure 8 is air pollution. This is one example of the negative impacts that can result from using natural resources. Air pollution can have adverse effects on human health and ecosystem function.

## Air Pollution

Anything added to the environment that has a negative effect on the environment or its organisms is called **pollution**. Pollutants, the substances that cause pollution, can take the form of chemicals, particulates, or microorganisms. The most common air pollutants are produced by fossil fuel emissions from driving cars and other vehicles. Waste products from power plants, refineries, and industrial and manufacturing plants contribute to air pollution because these facilities typically use fossil fuels.

**FIGURE 9:** Sources of air pollution include vehicles, agriculture, power plants, and cities.



The hazy material in Figure 8 is called smog. **Smog** is a type of air pollution caused by the interaction of sunlight with pollutants produced by fossil fuel emissions. Smog is composed of particulates and ground-level ozone. Particulates are microscopic bits of dust, metal, and unburned fuel. Some particulates may stay in the atmosphere for weeks before settling to the ground. When inhaled, they can cause health problems, such as asthma and other respiratory diseases.

In the presence of sunlight, some chemicals react to produce ground-level ozone ( $O_3$ ). When fossil fuels are burned, nitrogen oxides are produced. When these substances react with oxygen in the air in the presence of light, they produce  $O_3$  that tends to stay close to the ground. This is called ground-level ozone, which can be harmful to ecosystems and human health. However,  $O_3$  does play an important role in Earth's upper atmosphere by protecting the biosphere from harmful UV rays in sunlight.

**FIGURE 8:** This city is covered in a hazy material called smog.



**Gather Evidence** Have you seen any evidence of human impacts on the air in your town? What types of evidence would indicate air pollution?

**Explain** Some cities have “Ozone Action Days” when carpooling or taking public transportation is encouraged. These days tend to be scheduled when it is hot and sunny outside. Why is ground-level ozone worse on hot, sunny days?



### The Effects of Acid Rain

Design and carry out an experiment to determine the effects of acid rain on plant growth.

### Math Connection



Use the table in Figure 10 to answer these questions:

1. How many times greater is the GWP for nitrous oxide than for methane?
2. How much longer is the duration in the atmosphere for nitrous oxide than for methane?
3. Which of these two gases is most likely to have the greatest warming effect on Earth's climate? What other factors might need to be considered to form a valid conclusion?

## Acid Rain

When water falls to Earth, water molecules react with carbon dioxide to form carbonic acid. This weak acid breaks apart, leaving lone hydrogen ions. This gives rain a pH level of about 5.6. When air pollutants such as nitrogen oxides and sulfur oxides react with water, sulfuric and nitric acids are produced, making the pH of rain drop below 5.6. Thus, the rain becomes more acidic and is called **acid rain**.

Acid rain can have negative effects on soil. As pH decreases, reactions occur that cause metal ions to be released into the soil. These ions prevent plants from absorbing calcium, a nutrient that enhances plant growth and development. Aluminum can also be carried to bodies of water and can cause the deaths of fish and fish eggs. Humans are not affected directly by acid rain, but it can damage or destroy structures such as buildings, bridges, and statues.

## Climate Change

Earth is somewhat comparable to a greenhouse. Earth's atmosphere acts like the glass in a greenhouse. Solar radiation enters the atmosphere as high-energy wavelengths of light that warm Earth's surface. This energy is absorbed and reradiated as infrared radiation from Earth's surface. Some of the energy escapes into space. The rest is absorbed by gases and warms the air. This phenomenon, referred to as the **greenhouse effect**, keeps the temperature of Earth at a level that supports life.

When gases like carbon dioxide and methane are added to the atmosphere, they increase the amount of infrared energy that is trapped in the air. Figure 10 shows the properties of the main **greenhouse gases**, including their Global Warming Potentials (GWP). GWP is a comparative measure of how much heat a gas may absorb.

As more energy is stored in Earth's atmosphere and oceans, the cycling of matter and energy among ecosystems is altered. Studies suggest that hurricanes, for example, are becoming more intense on average. Scientists think this is because there is more energy stored as heat in Earth's oceans, and this energy provides the fuel for these destructive storms. As global temperatures rise, glaciers and ice caps have been observed decreasing in size, and the water contained in them is added to oceans. This causes average global sea level to rise, which affects ecosystems and human societies.

**FIGURE 10:** This table shows the Global Warming Potential of the main greenhouse gases. The concentration of each gas in the atmosphere is shown in parts per million.

Greenhouse gases	Concentration in 2016	Global Warming Potential (GWP) over 100 years	Duration in the atmosphere
<b>Water vapor</b>	variable	< 1	hours to days
<b>Carbon dioxide</b>	399.5 ppm	1	~100 to 300 years
<b>Methane</b>	1.8 ppm	28	12 years
<b>Nitrous oxide</b>	0.3 ppm	265	121 years
<b>Chlorofluorocarbons</b>	0.9 ppm	4,670 to 10,200	45 to 100 years

Source: Carbon Dioxide Information Analysis Center. Recent Greenhouse Gas Concentrations. [http://cdiac.ornl.gov/pns/current\\_ghg.html](http://cdiac.ornl.gov/pns/current_ghg.html). DOI: 10.3334/CDIAC/atg.032.



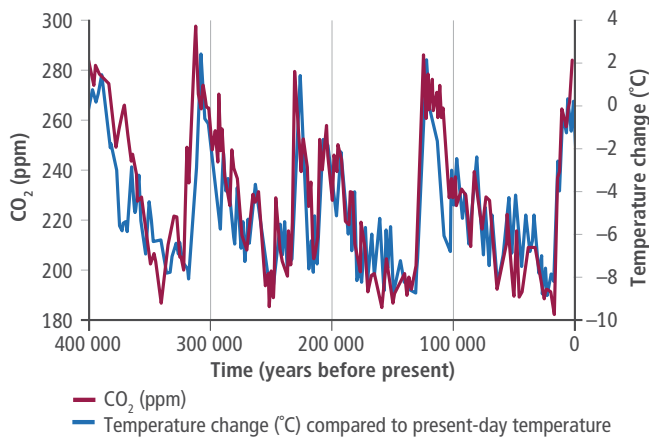


## Analyzing Climate Data

One method to detect and measure climate change is to compare the amount of atmospheric CO<sub>2</sub> present in the past to the amount in the atmosphere now. To infer CO<sub>2</sub> levels in the past, scientists use ice cores. Ice cores are long tubes of ice drilled from glaciers or ice sheets. As snow falls to Earth, the snow carries chemicals that are in the air at the time. The substances contained in snow are buried with the snow, one layer on top of another, over time. Air bubbles between snowflakes and grains become trapped when the snow is compacted. These air bubbles can provide information about the composition of the atmosphere. Scientists can also analyze ice cores to infer global temperature over time.

**FIGURE 11:** Ice cores provide information about past temperature and CO<sub>2</sub> levels.

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Source: Petit, J. R., et al., "Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica." *Nature* Vol 399 (1999) as quoted in NOAA, National Climatic Data Center, <http://www.ncdc.noaa.gov/paleo/globalwarming/temperature-change.html>



**a** Data from ice cores show fluctuations in CO<sub>2</sub> concentration and temperature variations dating back 400,000 years.

**b** An ice core is extracted in the Antarctic.



**Analyze** Answer these questions about the graph in Figure 11.

1. Describe patterns you see in the CO<sub>2</sub> and temperature data.
2. The CO<sub>2</sub> concentration in Earth's atmosphere has now reached 400 parts per million. How do you think this will affect average temperatures on Earth? Explain your answer.
3. What additional evidence would you need to support the claim that changes in CO<sub>2</sub> levels cause changes in average global temperatures?

Climate change poses many challenges for humans and ecosystems. If species cannot adapt quickly enough to changes in their habitat, they may face extinction. Humans are also experiencing the effects of climate change. As a result, many scientists, engineers, and governments have begun searching for solutions to this global issue.



**Model** Make a model illustrating how human activities change Earth's atmosphere and how these changes affect the hydrosphere and biosphere. Show how the flow of energy and matter is changed, and include feedback loops as necessary.



# Human Impacts on Water and Land

Human activities impact water and land. Humans convert rural areas to suburbs and natural areas to farmland, changing the layout and use of the land. To sustain these different communities, the flow of water is redirected to supply their needs. The impact of these activities can be reduced if water and land resources are properly managed.

## Impacts on Water

The availability of fresh water, population sizes, and economic conditions affect how people use water. Worldwide, agriculture accounts for about 67 percent of water usage, industry accounts for more than 19 percent, and household activities such as drinking and washing account for about 10 percent of water usage.

### Water Pollution

Nearly every way that humans use water contributes to water pollution, though the main causes are generally due to industry and human population growth. Humans rely on water to manufacture many different products, and human population growth is amplifying the problem.

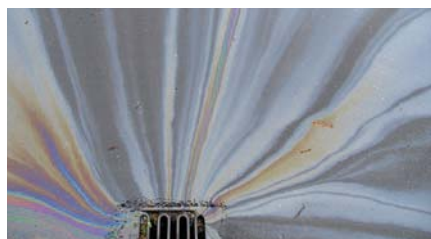
Water pollution comes from two types of sources. **Point source pollution** is pollution discharged from a single source. An example of point source pollution is a waste-release pipe from a factory manufacturing plastic products. **Nonpoint source pollution** comes from many different sources that are often difficult to identify. An example of this form of pollution is excess fertilizer that comes from farmlands and homes.

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### Hands-On Lab

**Modeling Groundwater Contamination** Use a model to determine how much land can be contaminated by a leaking underground storage tank (UST).

**FIGURE 12:** Pollution that comes from an identified single source is a form of point source pollution, while pollution that comes from many sources is a nonpoint source of pollution.



**a** Rain can wash oil, pesticides, and fertilizers into storm drains.



**b** Feedlots can discharge high volumes of animal waste, which can flow into bodies of water.



**c** Industries can discharge waste with heavy metals, pharmaceuticals, hormones, and other chemicals.



**Collaborate** Write an argument that answers the questions below. Then, explain your answers to a partner and note any differences in your arguments.

1. Which of the images in Figure 12 are point sources and which are nonpoint sources? Are any difficult to classify as one or the other? Explain your answers.
2. Which would be easier to prevent—point sources or nonpoint sources? Explain your answer.

## Managing Water

One of the biggest advances in improving human health has been the development of sanitation and wastewater management technologies. Wastewater is water that contains waste from homes or industry. A wastewater treatment process can filter and treat water to make the water clean enough to return to a river, lake, or ocean where it becomes part of the water cycle again.

Wastewater treatment can remove organic material, such as human body waste, as well as scum like oil and grease. Bacteria, which can be harmful to humans and other organisms, are killed in the process. However, some countries do not have wastewater management systems, making people more likely to be exposed to disease-causing agents. Obtaining safe drinking water is a problem for people in many areas of the world. Solutions aimed at treating these problems include building necessary infrastructures such as plumbing, educating the public about sanitary practices, and increasing access to fresh drinking water.

**FIGURE 13:** Wastewater treatment plants pool and process wastewater so that it can be released to the environment.



Another way humans manage water is by building structures such as dams that change the natural flow of water. Dams are built for a variety of reasons, including electricity generation. During dry seasons, water from dams may be released to irrigate agricultural lands for crop production. Some dams are used as a means to control flooding by holding water during heavy precipitation periods, so rivers do not overflow and cause flooding. Water in dams can also be redirected to homes to be used as drinking water or to industrial areas for industrial purposes.

Dams benefit humans, but they can negatively affect ecosystems. Dams can increase the risk of flooding in some cases. Releasing excess water from dams can cause flooding downstream, and intense storms can cause water to flow over a dam. Also, the water that dams hold contains silt that otherwise would be deposited along beaches or riverbanks, so dams may change the formation of natural landscapes. Silt deposition can increase soil fertility, and lack of silt may deprive plants of important nutrients. The quality of the water held in the reservoir can also change. For example, changes in the amount of oxygen and water temperature may impact the populations of organisms that live in a local ecosystem.



**Analyze** Study Figure 14. How did building the dam affect the river and the surrounding land? How might this affect ecosystems in this area?

### Technology and Society

Advanced wastewater treatments can turn wastewater into drinking water. Even though this technology is available, it is still not widely used in the United States. What societal factors might be hindering the use of this technology, and how could these be addressed?

**FIGURE 14:** At the top, there is a view of a region before a dam was built. At the bottom, there is the same region after a dam was constructed.



## Impacts on Land

As the human population grows, more land is needed for homes, agriculture, and the extraction of natural materials. For example, aluminum is a metal used in products like bakeware, cans, and airplane parts. This natural resource must be mined from Earth. Building, agriculture, and mining activities often impact organisms by disrupting local ecosystems and causing pollution.

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### Hands-On Lab



#### Modeling Soil Erosion

Develop a model to measure the effectiveness of different kinds of ground cover in controlling soil erosion.

### Soil Erosion

Human activities such as clear-cutting forests, building structures, raising livestock, and growing crops can damage land. These activities often involve the removal of plants from their natural habitat, which leaves the soil exposed. Additionally, loss of plant cover can lead to less absorption of rainwater. With sufficient plant loss, soil may be transported away by moving water, wind, and other agents. This is called **soil erosion**. Soil may be washed away, sometimes into nearby bodies of water. Soil erosion can reduce the fertility of land, thereby reducing crop production. It can also damage infrastructure and change the quality of water in rivers and streams. Soil can carry with it disease-causing organisms called pathogens. These pathogens may be transported into bodies of water, negatively affecting the health of humans and other species.



## Engineering

**FIGURE 15:** Terracing prevents soil erosion and water loss by using ridges to capture rainwater that would otherwise flow down the slope.



## Soil and Water Engineering

The field of soil and water engineering applies science and technology to design solutions that conserve water and soil resources. Engineers can help farmers and agricultural operations conserve valuable topsoil and more precisely apply water to crops. One technique that has been used for centuries to reduce soil erosion caused by rainfall is soil terracing, shown in Figure 15.

Farmers can also prevent soil erosion by leaving field residues on the ground after a crop has been harvested. Field residues are the stems, leaves, and other plant parts that are not harvested. Leaving these materials on the soil surface reduces soil and water loss. It also helps the soil retain important nutrients.

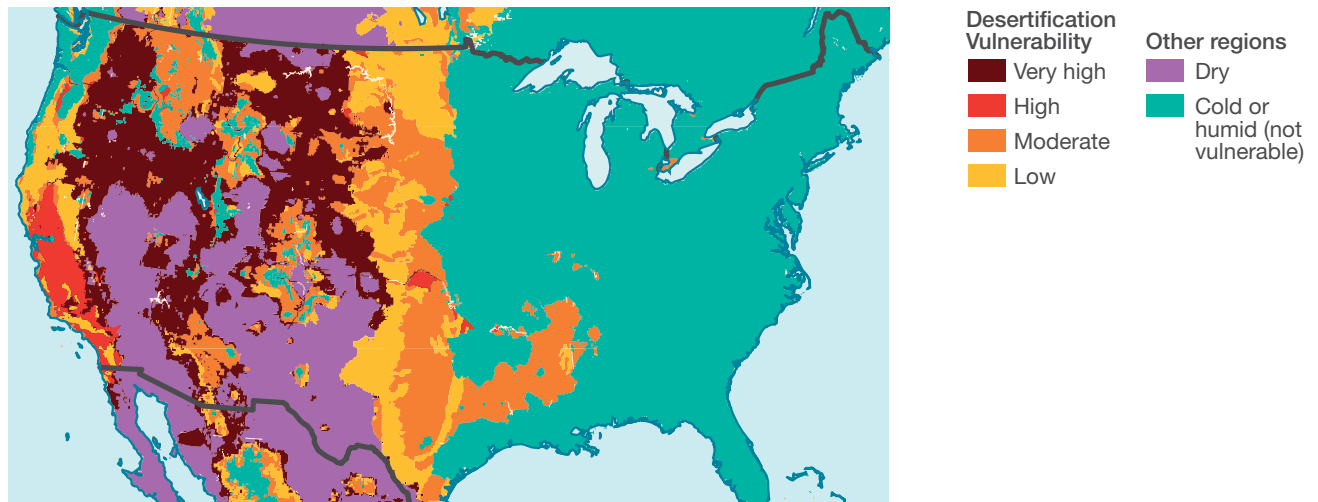


**Explain** Imagine you are a soil engineer called upon to help a farmer prevent soil erosion caused by the wind. Write a list of questions you would ask to define and delimit the problem.

Continuously growing the same crops on the same land is another way that nutrients are removed from soil. The use of fertilizers to replace these nutrients can lead to other negative outcomes. Artificial eutrophication, or the buildup of nutrients, can occur in water bodies that receive runoff from overfertilized soil. Soil can also be compacted, or pressed together, by heavy farm equipment or during construction. When soil is compacted, it does not absorb water as readily, and plant roots cannot grow normally. If soil is damaged enough, a process called **desertification** can occur. This makes land in dry areas become more desert-like over time. Many factors, including drought, deforestation, and poor farming techniques, increase the likelihood of desertification.



**FIGURE 16:** This map shows the vulnerability of different areas to desertification.



## Mining

When fossil fuels and minerals are mined, parts of the ecosystem, including rocks, soil, plants, and animals, are removed. There are two main types of mining. Subsurface mining is the extraction of materials from below Earth's surface. Drilling for oil and gas is an example of subsurface mining. Surface mining involves the removal of rocks and soil from Earth's surface to expose and extract minerals. Mining can damage land, air, and water. For example, when water runs through mines, it can become acidic, causing metals to be released from the surrounding rock. This mixture of acidic water and metals is called acid mine drainage and is very harmful to living things. It can also contaminate drinking water and corrode metal structures such as bridges. Mining may also release harmful chemicals into the atmosphere. Additionally, mining disturbs soil, and therefore can cause erosion and land damage.

**Analyze** Where are the areas at most risk located? What factors might make these areas more vulnerable to desertification?

**FIGURE 17:** There are two main types of mining—subsurface mining and surface mining.



**a** Subsurface mining involves the extraction of minerals and fossil fuels from below Earth's surface.



**b** Surface mining operations remove rocks and soil on the surface, exposing minerals to be extracted.

**Language Arts Connection** Develop an argument based on evidence for which type of mining (surface or subsurface) has fewer environmental impacts.

**Explain** Make a claim based on evidence for how human impacts on land and water could change Earth's carrying capacity for humans. How would it change, and why?

# Hands-On Lab

## MATERIALS

- beaker, 250 mL
- marker
- pencil
- ruler, metric
- seedling, potted radish (4)
- water, pH 3, 100 mL
- water, pH 4, 100 mL
- water, pH 5, 100 mL
- water, pH 6, 100 mL

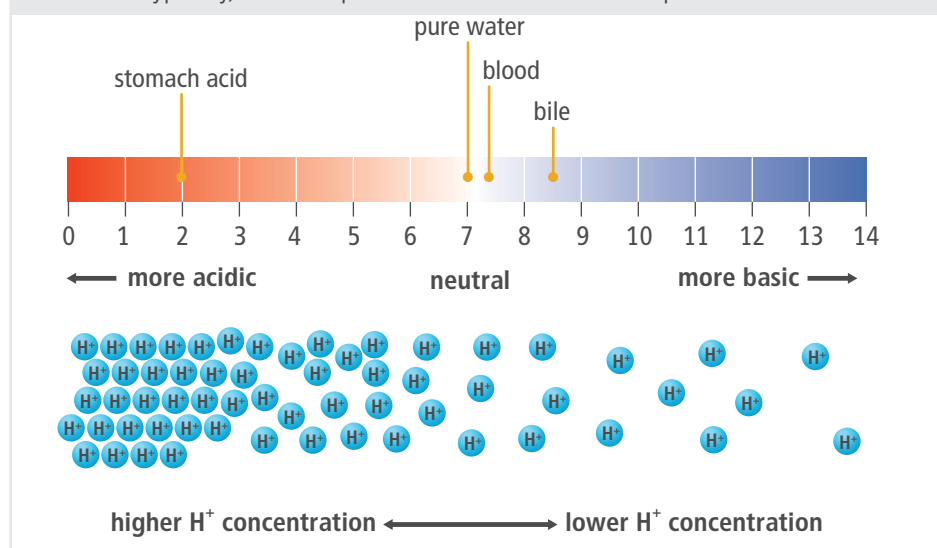


## The Effects of Acid Rain

Recall that rain typically has a pH of about 5.6. Human activities that involve burning fossil fuels release oxides, specifically sulfur and nitrogen oxides, into the air. When these oxides react with water, acids are produced. These substances lower the pH and make rain more acidic. Acid rain can affect both plant and animal life.

In this lab, you will design an experiment to determine the effects of acid rain on plant growth. You will then perform your experiment, record and analyze your data, and explain the relationship between the pH of water and plant growth based on patterns observed in the experiment.

**FIGURE 18:** Typically, rain has a pH of about 5.6. Acid rain has a pH lower than 5.6.



**Predict** How does acid rain affect plant growth? Make a prediction about the relationship between the pH of water and plant growth.

## PROCEDURE

Follow these steps to complete this part of the activity.

1. Write a procedure explaining how you will set up and conduct an experiment to test how acid rain affects plant growth. Identify the independent and dependent variables and the constants you will maintain. Use the questions below to help you write your procedure.
  - What amount of water will you use to water the plants?
  - How often will you water the plants?
  - How will you measure the effects of acid rain on plant growth, both quantitatively and qualitatively?
  - How often will you collect data?

2. Have your teacher approve your procedure before you perform your experiment.
3. Design a data table to organize your results.
4. Gather your materials.
5. Set up and conduct your experiment.

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## ANALYZE

Follow these steps to complete this part of the activity.

1. Graph your data. Determine whether a line graph or bar graph is appropriate, and construct that type of graph.
2. Describe patterns you see in the data. How did each pH affect plant growth?

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## EXPLAIN

Write an explanation that includes the following sections.

**Claim** What is the relationship between the pH of water and plant growth? Was your prediction correct?

**Evidence** Give specific examples from your data to support your claim.

**Reasoning** Explain how the evidence you gave supports your claim. How does it back up what you are saying?

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## REFINE

**Address Error** Identify possible sources of experimental error in your design. List possible reasons for inconsistent results you may have observed.

**Propose Changes** What changes would you make to this procedure if you were to do it again? Why would you make these changes?

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## EXTEND YOUR INVESTIGATION

Measure the pH of rain in your area. Based on the results of your experiment, what could you conclude about how the pH of rain might affect the growth of plants?

What other types of evidence would you need to form a valid conclusion?

CALCULATING YOUR  
CARBON FOOTPRINT

POLLUTION AND  
HUMAN HEALTH



CLEANING UP  
OIL SPILLS

Go online to choose one of  
these other paths.



# Lesson Self-Check

## CAN YOU EXPLAIN IT?

**FIGURE 19:** This lake has turned red as a result of acid mine drainage.



When fossil fuels and minerals are mined, rocks are exposed. These rocks contain substances that can react with air and water. The red-orange material in the river in Figure 19 is the result of acid mine drainage. Water passing through abandoned mines reacts with iron sulfide in the mines. This reaction produces sulfuric acid and iron, which is dissolved in the water. When iron precipitates out of the water, it forms a solid with the observed red-orange color.

Acid mine drainage can contaminate drinking water and make people sick. It can contaminate aquatic habitats and affect organisms that live there. The acid in the water can also deteriorate metal structures.



**Explain** Refer to the notes in your Evidence Notebook to construct an explanation for how human activities could lead to the changes in this lake.

1. Explain how human needs and lifestyles contribute to the activities that cause acid mine drainage.
2. Make a model to illustrate how human activities led to the changes observed in this lake and how these changes will in turn affect Earth's geosphere, hydrosphere, biosphere, and atmosphere.
3. Use your model to brainstorm a possible solution to this problem. Explain how this solution would decrease negative impacts on Earth's natural resources.

## CHECKPOINTS

## Check Your Understanding

- Which of these have contributed to the increase of human population growth? Select all correct answers.
  - discovery of penicillin
  - increase in antibiotic-resistant bacteria
  - transportation that allows food distribution
  - administration of vaccinations
  - availability of all types of fast food
- Wheatgrass is the young grass of the wheat plant, and it is used to feed livestock. What kind of resource is wheatgrass?
  - renewable and biomass
  - nonrenewable and biomass
  - renewable and fossil fuel
  - nonrenewable and fossil fuel
- Which of these activities would be the best way to reduce fossil fuel use?
  - riding a bike to school
  - eating processed foods
  - watching TV
  - buying books
- A drought leads to loss of much of the local vegetation. Which measures would be best for preventing soil erosion?
  - plant more bushes and trees
  - water remaining plants daily
  - cover soil with stones or rocks
  - add more soil to the ground
- How does deforestation affect climate change?
- If the human population were to exceed Earth's carrying capacity, how would human population growth change?
- Consider the group of words *groundwater, trees, solar energy, and steel*. Which does not belong to the group and why?
- Suppose you are an environmental engineer, a scientist who helps develop solutions to environmental problems. You have been hired by a manufacturing plant to help conserve natural resources and save money. What suggestions would you give to achieve these goals?
- Which of the following is *not* an example of a point-source pollution?
  - oil that is escaping from a damaged tanker
  - heavy metals that are leaching out of an underground mine
  - water runoff from residential lawns
  - untreated sewage that is accidentally released from a wastewater treatment plant
- Over a long period of time, how might living things adapt to increased carbon dioxide levels and climate change? Do you think most species will adapt, or are many species likely to go extinct?

## MAKE YOUR OWN STUDY GUIDE



In your Evidence Notebook, design a study guide that supports the main ideas from this lesson:

**The human population has increased over time because of advances that support and prolong human life.**

**Human activities can impact air, land, and water quality. However, actions can be taken to reduce negative impacts on the environment.**

Remember to include the following information in your study guide:

- Use examples that model main ideas.
- Record explanations for the phenomena you investigated.
- Use evidence to support your explanations. Your support can include drawings, data, graphs, laboratory conclusions, and other evidence recorded throughout the lesson.

Consider how human activities can affect the environment, life on Earth, and Earth's climate.