Human Impacts on the Earth Environment

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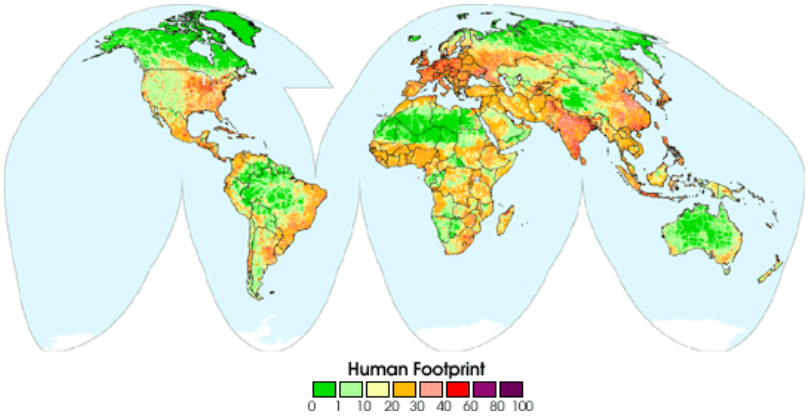
CHAPTER 1

Human Impacts on the Earth Environment

CHAPTER OUTLINE

Introduction



Surely Earth is too big for humans to impact it too much...

Many people think that Earth is so large that human activities couldn't possibly be making much of an impact on the planet. But human populations have expanded at a more than exponential rate and it is human ingenuity from advances in farming that has kept so many people alive. The map above depicts a quantitative analysis of human influence around the world. Low scores are the least human influence; higher scores are greater impact. Taken into account were population density, land transformation, human access, and power infrastructure. Human access and land transformation alter ecosystems and bring in pollution and invasive species, which decrease biodiversity. This chapter explores some of the impacts that humans have had on Earth's systems.

1.1 Growth of Human Populations

- Describe the rate of current human population growth.

What will stop population growth?

It took all of human history until 1802 for the human population to reach its first billion. It took just 12 years for it to acquire its most recent billion. Although the growth rate is predicted to slow later this century, there's no end to population growth in sight. Yet, the population can't continue to grow forever. How will it stop?

Human Population Numbers

Human population growth over the past 10,000 years has been tremendous (**Figure** 1.1). The entire human population was estimated to be

- 5 million in 8000 B.C.
- 300 million in A.D. 1
- 1 billion in 1802
- 3 billion in 1961
- 7 billion in 2011

As the human population continues to grow, different factors limit population in different parts of the world. What might be a limiting factor for human population in a particular location? Space, clean air, clean water, and food to feed everyone are limiting in some locations.

An interactive map of where human population growth has been over time: http://www.pbs.org/wgbh/nova/worldbalance/numbers.html .

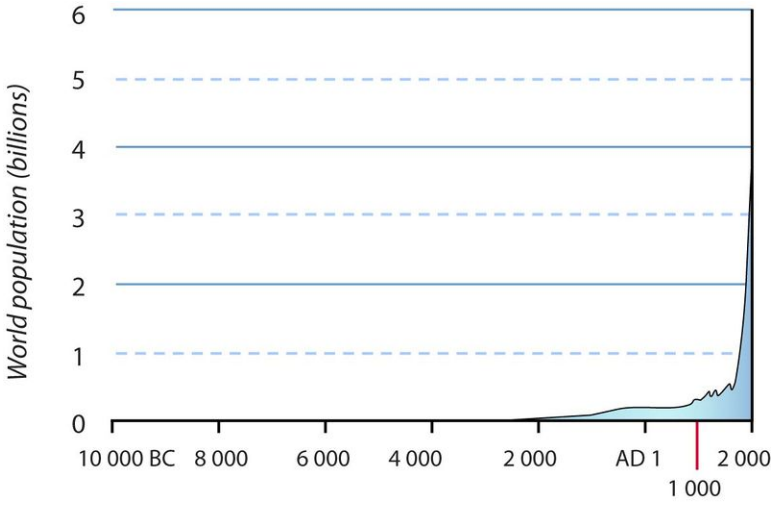


FIGURE 1.1

Human population from 10,000 BC through 2000 AD, showing the exponential increase in human population that has occurred in the last few centuries.

The Rate of Growth

Not only has the population increased, but the rate of population growth has increased (**Figure** 1.2). The population was estimated to reach 7 billion in 2012, but it did so in 2011, just 12 years after reaching 6 billion.

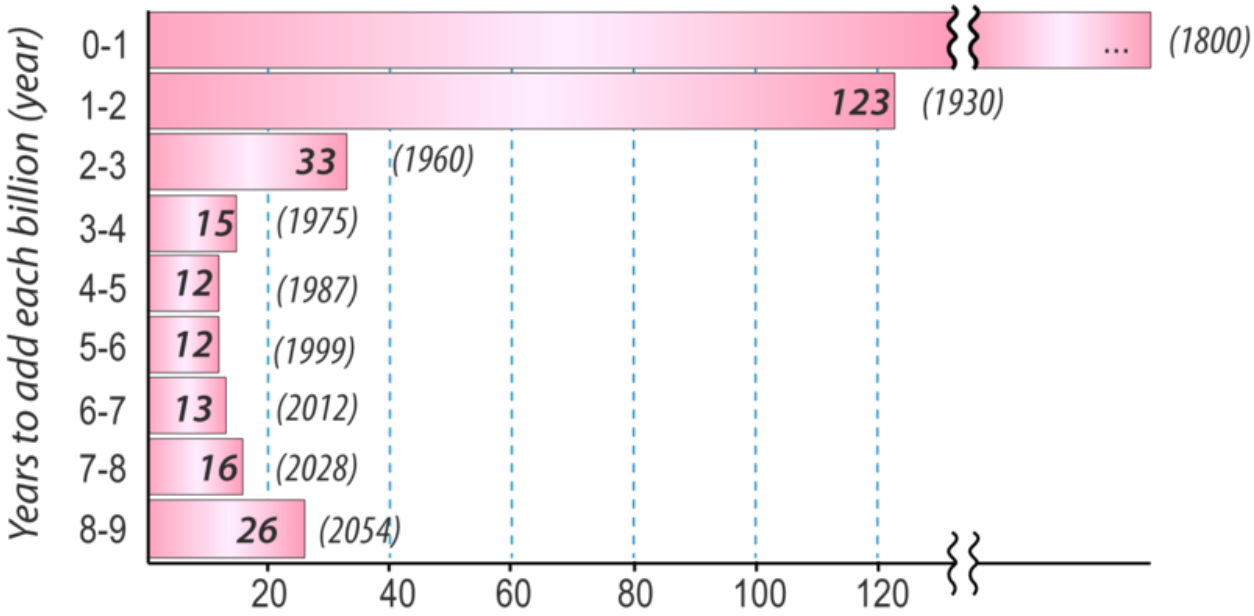


FIGURE 1.2

The amount of time between the addition of each one billion people to the planet's population, including speculation about the future.

Although population continues to grow rapidly, the rate that the growth rate is increasing has declined. Still, a recent estimate by the United Nations estimates that 10.1 billion people will be sharing this planet by the end of the century.

The total added will be about 3 billion people, which is more than were even in existence as recently as 1960.

Summary

- The human population is growing more than exponentially.
- The human population is increasing, the rate of human population growth is increasing, but the rate at which the rate of growth is increasing has declined.
- The United Nations estimates a population of 10.1 billion by the end of the century yet that is much less than the number we would expect if 1 billion people were being added every 12 years.

Practice

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=E8dkWQVFAoA

1. What is exponential growth in a population?
2. What happened in 1650?
3. What was the population in 1650? 1850? 1930? 1975? What is the population now?
4. What has the human population of the planet done in the past 80 years?
5. What does R versus K selection theory compare? What does that have to do with reproduction?
6. Which organisms tend to be R and which K? What population size do K organisms tend to have?
7. Why are humans considered to be K animals?
8. How have humans managed to go 350 years with a population growth curve that looks more like an R animal? Describe the reasons.
9. What is the estimated carrying capacity of humans on Earth?
10. How do ecologists now try to determine what the carrying capacity is? Why is this not the same for everyone on Earth?
11. What happens as we take up more space and resources?
12. What does it mean that the rate of human population growth peaked in 1962? Is population still growing?
13. Why is the rate of population growth decreasing and how can we make the rate decrease further?

Practice Answers

1. When the population grows proportional to the size of the population even as the size of the population is increasing.
2. Human populations began probably the longest period of exponential growth of any population ever.
3. 1650: 500 million; 1850: 1 billion; 1930: 2 billion; 1975: 4 billion; current: over 7 billion
4. It has tripled.
5. Quantity (R) versus quantity (k). Some organisms have huge numbers of offspring in the hopes that some survive and others have the number of offspring that the habitat can support (the carrying capacity).
6. Smaller ones are R and larger ones are K. K organisms have a population size close to the carrying capacity.
7. We only have a few kids and we put a ton of resources into them so we expect most of them to survive.
8. We raised the carrying capacity so far indefinitely by eliminating limiting factors: we've upped our ability to feed ourselves (mechanized ag), medical advances thwarted disease to reduce our numbers, sewage systems kept us healthier, we take our comfortable environments with us so we can live all over the planet.
9. No one knows; the averages are 10 to 15 billion.
10. They use an ecological footprint, which is how much land and how may resources a person needs to live. People have different footprints depending on what they eat and what they use.
11. We make it more difficult for other species to live. We compete with other humans as well.

12. The increase in population growth as been going down. but population is still growing exponentially; from 2.2 to 1.1%.
13. As women are educated they have fewer babies so we could give more opportunities to women to reduce population growth more. Kids are not needed as much so we can have smaller families.

Review

1. What does it mean that the human population growth rate is increasing?
2. What does it mean that the rate that the growth rate is increasing has declined?
3. What factors may someday limit human population growth?

Review Answers

1. The population is growing more rapidly all the time.
2. The amount that the population growth rate is increasing is shrinking.
3. Population may someday be limited by food, clean water, pollutants, disease, war.

1.2 Agriculture and Human Population Growth

- Explain how advances in agriculture have led to leaps in population numbers.

What's your vision of a chicken farm?

In many nations, farming today is industrial, growing the maximum amount of food for the minimum price, often without much thought as to the long-term social or environmental consequences. These industrial food production plants are a long way from the farms of the past.

Advances in Agriculture and Population

Every major advance in agriculture has allowed global population to increase. Early farmers could settle down to a steady food supply. Irrigation, the ability to clear large swaths of land for farming efficiently, and the development of farm machines powered by fossil fuels allowed people to grow more food and transport it to where it was needed.

Hunters and Gatherers

What is Earth's carrying capacity for humans? Are humans now exceeding Earth's carrying capacity for our species? Many anthropologists say that the carrying capacity of humans on the planet without agriculture is about 10 million (**Figure** 1.3). This population was reached about 10,000 years ago. At the time, people lived together in small bands of hunters and gatherers. Typically men hunted and fished; women gathered nuts and vegetables.

Obviously, human populations have blown past this hypothetical carrying capacity. By using our brains, our erect posture, and our hands, we have been able to manipulate our environment in ways that no other species has ever done. What have been the important developments that have allowed population to grow?

FIGURE 1.3

In a hunter-gatherer society, people relied on the resources they could find where they lived.

Farming

About 10,000 years ago, we developed the ability to grow our own food. Farming increased the yield of food plants and allowed people to have food available year round. Animals were domesticated to provide meat. With agriculture, people could settle down, so that they no longer needed to carry all their possessions (**Figure** 1.4). They could develop better farming practices and store food for when it was difficult to grow. Agriculture allowed people to settle in towns and cities.

FIGURE 1.4

More advanced farming practices allowed a single farmer to grow food for many more people.

When advanced farming practices allowed farmers to grow more food than they needed for their families (**Figure** 1.5), some people were then able to do other types of work, such as crafts or shop keeping.

FIGURE 1.5

Farming has increasingly depended on machines. Such advanced farming practices allow one farmer to feed many more people than in the past.

The Industrial Revolution

The next major stage in the growth of the human population was the **Industrial Revolution**, which started in the late 1700s (**Figure** 1.6). This major historical event marks when products were first mass-produced and when fossil fuels were first widely used for power.

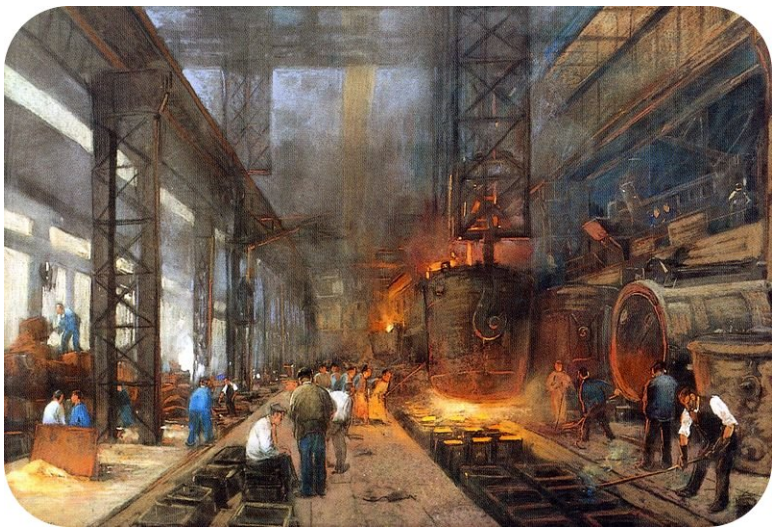


FIGURE 1.6

Early in the Industrial Revolution, large numbers of people who had been freed from food production were available to work in factories.

The Green Revolution

The **Green Revolution** has allowed the addition of billions of people to the population in the past few decades. The Green Revolution has improved agricultural productivity by:

- Improving crops by selecting for traits that promote productivity; recently, genetically engineered crops have been introduced.

- Increasing the use of artificial fertilizers and chemical **pesticides**. About 23 times more fertilizer and 50 times more pesticides are used around the world than were used just 50 years ago (**Figure** 1.7).
- Agricultural machinery: plowing, tilling, fertilizing, picking, and transporting are all done by machines. About 17% of the energy used each year in the United States is for agriculture.
- Increasing access to water. Many farming regions depend on groundwater, which is not a renewable resource. Some regions will eventually run out of this water source. Currently about 70% of the world's fresh water is used for agriculture.

FIGURE 1.7

Rows of a single crop and heavy machinery are normal sights for modern day farms.

The Green Revolution has increased the productivity of farms immensely. A century ago, a single farmer produced enough food for 2.5 people, but now a farmer can feed more than 130 people. The Green Revolution is credited for feeding 1 billion people that would not otherwise have been able to live.

The Future

The flip side to this is that for the population to continue to grow, more advances in agriculture and an ever increasing supply of water will be needed. We've increased the carrying capacity for humans by our genius: growing crops, trading for needed materials, and designing ways to exploit resources that are difficult to get at, such as groundwater. And most of these resources are limited.

The question is, even though we have increased the carrying capacity of the planet, have we now exceeded it (**Figure** 1.8)? Are humans on Earth experiencing **overpopulation**?

There is not yet an answer to that question, but there are many different opinions. In the eighteenth century, Thomas Malthus predicted that human population would continue to grow until we had exhausted our resources. At that point, humans would become victims of famine, disease, or war. This has not happened, at least not yet. Some scientists think that the carrying capacity of the planet is about 1 billion people, not the 7 billion people we have today. The limiting factors have changed as our intelligence has allowed us to expand our population. Can we continue to do this indefinitely into the future?

Summary

- Hunters and gatherers lived off the land, with no agriculture, and reached a total population of no more than around 10 million.
- Farming allowed people to settle down and allowed populations to grow.

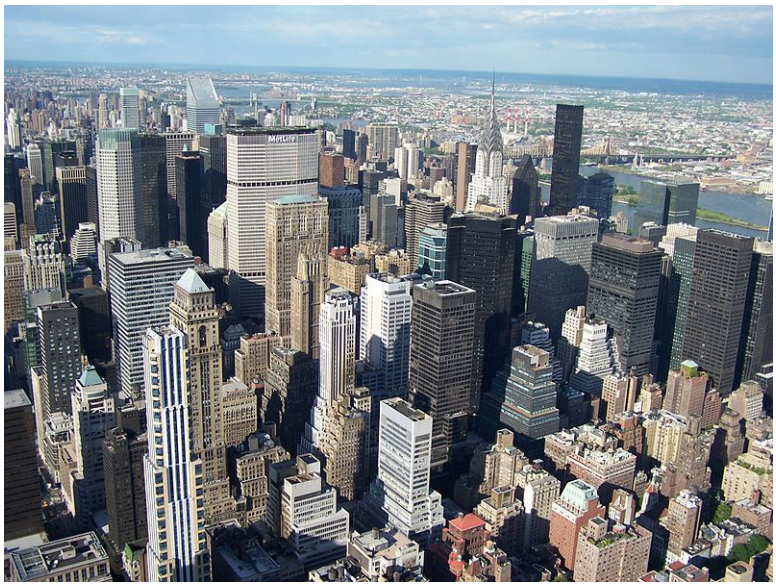


FIGURE 1.8

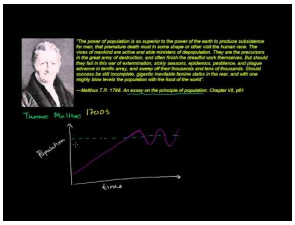
Manhattan is one of the most heavily populated regions in the world.

- The Green Revolution and the Industrial Revolution are heavily dependent on fossil fuels.

Practice

Use this resource to answer the questions that follow.

http://www.youtube.com/watch?v=r1ywppAJ1xs



MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/1554

1. Who was Thomas Malthus?
2. What did Malthus think would happen as population increased?
3. What did Malthus think would limit population?
4. What is the Malthusian limit?
5. What is happening to population growth in some developed countries today?
6. Malthus didn't account for what in his theory?
7. What country is close to the Malthusian limit today?

Practice Answers

1. Thomas Malthus was a famous pessimist at a time of great optimism about progress. He said there would be no way to stop population growth as long as food and other things weren't a problem.
2. Malthus thought that population would continue to increase until it reached some limit.
3. There would be a natural upper boundary in food production. Epidemics, pestilence, plague and famine would do the population in.

4. This limit is the top that the population can sustain itself. The limit could be moved up but eventually the Malthusian downers would happen.
5. We now see that people will restrict their reproduction if they have the opportunity. In some developed countries, like Japan, the population is decreasing.
6. When a society becomes rich enough they might do other things besides have kids with their time.
7. Bangladesh is the most population dense country in the world; 30-times more dense than the U.S. The land is very fertile so they can grow food but there are famines and also flooding.

Review

1. Link major advances in agriculture and industry with changes in the human population.
2. What is carrying capacity? Has the human population exceeded Earth's carrying capacity for humans? If so, how could this have happened?
3. What is the Green Revolution? How has it affected human population?
4. What do you think of Thomas Malthus' prediction? Have we proven Malthus wrong or have we just not gotten to that point yet?

Review Answers

1. When people began to farm they could settle into town and cities so population could grow. The Industrial Revolution allowed mass production of food and goods so population could grow. The Green Revolution introduced more efficient ways to grow crops, which meant a farm could support many more people and so population could grow.
2. Carrying capacity is the number of an organism that can live in a region without more deaths than births. Humans have raised the carrying capacity of Earth for humans so we haven't reached it yet, although it may lower as resources become scarce.
3. The Green Revolution was when agricultural productivity improved by the use of selected crops, artificial fertilizers and chemical pesticides, fossil fuels, plus reliance on water being brought into the area. This has allowed human population to skyrocket.
4. Malthus' prediction was not wrong. The limit has just been raised. Eventually we will reach the limit and population will stabilize or shrink.

1.3 Overpopulation and Over-Consumption

- Describe the consequences of the Green Revolution on Earth's systems.
- Define over-consumption and explain its impact on Earth's systems.

How many people could live in this house?

The amount of space and resources used by each resident of this house far exceeds the average for a single human resident of planet Earth and even more for a single person in a poor country in sub-Saharan Africa.

Consequences of the Green Revolution

The Green Revolution has brought enormous impacts to the planet.

Land Loss

Natural landscapes have been altered to create farmland and cities. Already, half of the ice-free lands have been converted to human uses. Estimates are that by 2030, that number will be more than 70%. Forests and other landscapes have been cleared for farming or urban areas. Rivers have been dammed and the water is transported by canals for irrigation and domestic uses. Ecologically sensitive areas have been altered: wetlands are now drained and coastlines are developed.

Pollution

Modern agricultural practices produce a lot of pollution (**Figure** 1.9). Some pesticides are toxic. Dead zones grow as fertilizers drain off farmland and introduce nutrients into lakes and coastal areas. Farm machines and vehicles used to transport crops produce air pollutants. Pollutants enter the air, water, or are spilled onto the land. Moreover,

many types of pollution easily move between air, water, and land. As a result, no location or organism —not even polar bears in the remote Arctic —is free from pollution.

FIGURE 1.9

Pesticides are hazardous in large quantities and some are toxic in small quantities.

Consequences for Other Resources

The increased numbers of people have other impacts on the planet. Humans do not just need food. They also need clean water, secure shelter, and a safe place for their wastes. These needs are met to different degrees in different nations and among different socioeconomic classes of people. For example, about 1.2 billion of the world's people do not have enough clean water for drinking and washing each day (**Figure** 1.10).

Over-Consumption

The addition of more people has not just resulted in more poor people. A large percentage of people expect much more than to have their basic needs met. For about one-quarter of people there is an abundance of food, plenty of water, and a secure home. Comfortable temperatures are made possible by heating and cooling systems, rapid transportation is available by motor vehicles or a well-developed public transportation system, instant communication takes place by phones and email, and many other luxuries are available that were not even dreamed of only a few

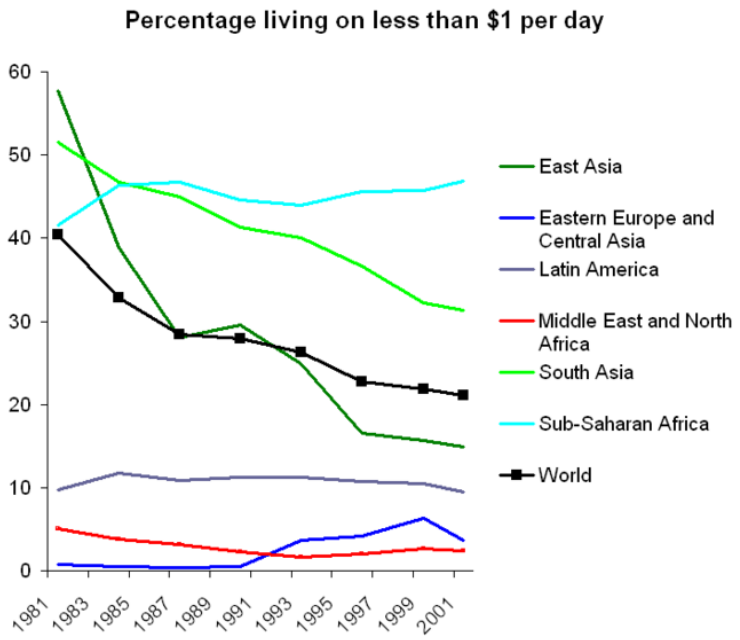


FIGURE 1.10

The percentage of people in the world that live in abject poverty is decreasing somewhat globally, but increasing in some regions, such as Sub-Saharan Africa.

decades ago. All of these require resources in order to be produced, and fossil fuels in order to be powered (**Figure** 1.11). Their production, use, and disposal all produce wastes.

Many people refer to the abundance of luxury items in these people's lives as **over-consumption**. People in developed nations use 32 times more resources than people in the developing countries of the world.

Summary

- The Green Revolution has allowed more people to be fed and the human population to increase. The consequences are land loss, pollution, and a tremendous use of fossil fuels.
- By keeping more people alive, the Green Revolution has put a strain on other needed resources like water and materials.
- Overpopulation is a big problem, but over-consumption is also depleting Earth's resources as some people in the world use far more materials than others.

Practice

Use these resources to answer the questions that follow.

https://www.youtube.com/watch?v=wji2uQUEVu0

1. What is the bank the announcer is referring to?
2. What are the two factors that our impact on this bank depend on?
3. Earth is now home to 7 billion people yet there is the statement that if everyone lived like an average European Earth could only support 2 billion in the long term, so what does that mean about the present?
4. What are ecosystem services? What are some examples?
5. What is overconsumpulation?
6. What does the speaker say will happen if we don't get population down to 2 billion?

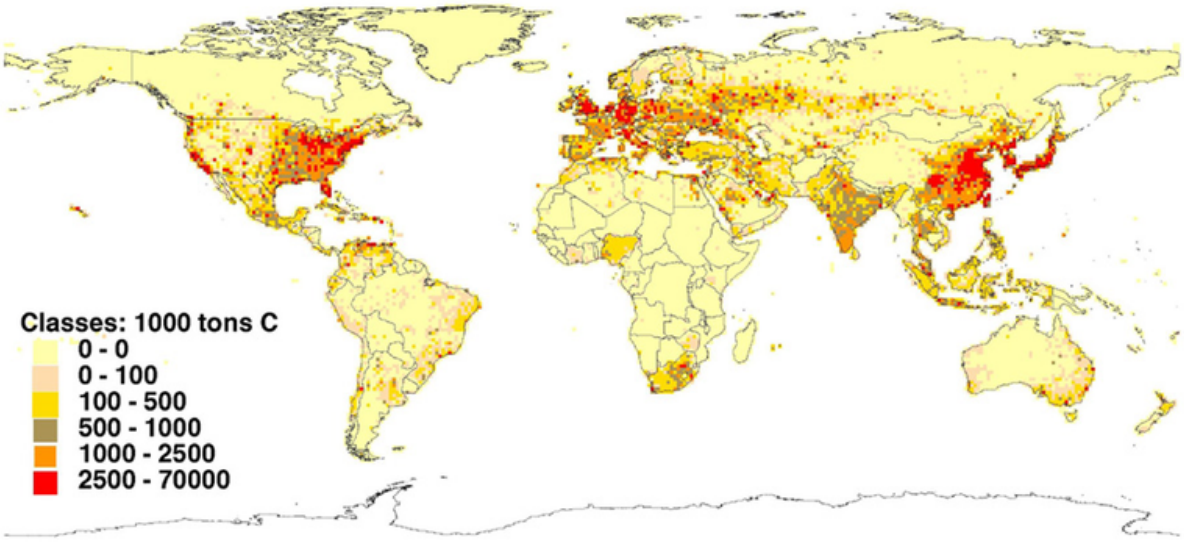


FIGURE 1.11

Since CO_2 is a waste product from fossil fuel burning, CO_2 emissions tell which countries are using the most fossil fuels, which means that the population has a high standard of living.

7. What are the two options?
8. What will happen if population continue to grow or doesn't shrink?

Practice Answers

1. Earth
2. How much individuals consume and how many consumers there are.
3. It means that many people are not living as well as the average European or the standard of living that people can have cannot be sustained in the long term or both.
4. Benefits the Earth provides us for free: bees as pollinators, groundwater, metals.
5. It is a cross between overconsumption and overpopulation?
6. The poor can never live well and ecosystem services will not be used sustainably.
7. Support the use of contraception globally or do nothing.
8. The world will experience pollution and waste, climate change, biodiversity loss, habitat degradation and soil erosion; more poverty; conflicts over basic resources.

Review

1. Why has so much natural land been converted to human uses? What happens to the ecosystems that are affected?
2. What causes pollution and why is it so widespread?
3. What do you use in your daily life that would be inconceivable for a poor teenager in sub-Saharan Africa? What about contrasting yourself with a poor teen living in an urban ghetto in the U.S.?

Review Answers

1. People need land for urban areas and for producing more food. Water has also been altered. Ecosystems are damaged or destroyed.
2. Pollution is a byproduct of modern life. Agricultural pollution is due to pesticides and artificial fertilizers.
3. Answer will vary but may include cell phones or smart phones, laptop computers or tablets, HD televisions, a blender, a car, probably even a bicycle would be unattainable for teenagers in Africa. In the U.S. the electronics, a bedroom of his/her own, the equipment needed for organized sports, etc.

1.4 Sustainable Development

- Define sustainable development.
- Describe forms of sustainable development and explain how they conserve energy and natural resources.

Is there another way?

Visibility in Beijing is sometimes so bad that the airport must be closed due to smog. In their rush to develop, many nations are making the same mistakes that the developed nations have already made. Can everyone find a more sustainable path?

Sustainable Development

FIGURE 1.12
Can society change and get on a sustainable path?

A topic generating a great deal of discussion these days is **sustainable development**. The goals of sustainable development are to:

- help people out of poverty.
- protect the environment.
- use resources no faster than the rate at which they are regenerated.

One of the most important steps to achieving a more sustainable future is to reduce human population growth. This has been happening in recent years. Studies have shown that the birth rate decreases as women become educated, because educated women tend to have fewer, and healthier, children.

Science can be an important part of sustainable development. When scientists understand how Earth's natural systems work, they can recognize how people are impacting them. Scientists can work to develop technologies that can be used to solve problems wisely. An example of a practice that can aid sustainable development is fish farming, as long as it is done in environmentally sound ways. Engineers can develop cleaner energy sources to reduce pollution and greenhouse gas emissions.

Citizens can change their behavior to reduce the impact they have on the planet by demanding products that are produced sustainably. When forests are logged, new trees should be planted. Mining should be done so that the landscape is not destroyed. People can consume less and think more about the impacts of what they do consume.

And what of the waste products of society? Will producing all that we need to keep the population growing result in a planet so polluted that the quality of life will be greatly diminished? Will warming temperatures cause problems for human populations? The only answer to all of these questions is, time will tell.

Summary

- Sustainable development tries to bring people up to certain minimum living conditions without doing further damage to the environment.
- To develop sustainably, the human population must stabilize.
- Resources must be developed and used consciously and in environmentally sound ways.

Practice

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=OXs8N0ccW_o

1. End at 10:38.

1. What is sustainable development?
2. What are some of the conflicts?
3. Can sustainable development be done?
4. What are the challenges?
5. What is human impact on the environment the product of? In which direction are those factors going (growing or shrinking)?
6. What will happen as resources become more limited?
7. What is the effect of bio-fuels on food prices?
8. What is the effect of affluence on pollution?
9. How is sustainable development an ethical issue?
10. At what level can this be addressed? What possible instruments are there to do this?
11. What is the problem with obtaining political leadership?
12. Why are we further from achieving sustainable development now htan we were 20 years ago?

Practice Answers

1. Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.
2. Environment vs development; north vs south

3. It's an aspiration, but we don't yet know if it's achievable.
4. ethics, politics, economic, law
5. Human Impact (K) = Population (P) x Affluence (A) x Technology (T); P is growing; A is growing and T is growing, but it can't compensate for the growth in P A so HI must be growing.
6. No, price will rise and fewer people will be able to afford them.
7. The price goes up so poor people can't afford food.
8. We export it to poor countries and regions; we also can't change climate change.
9. It pits the rights of relative rich people alive today against poor people alive today and future generations. Also, there are the rights of nature versus humans.
10. It must be addressed at the global, national and local levels. The instruments are economic with taxes and subsidies; laws and conventions; and information and persuasion.
11. Governments do not want to incur the political cost of doing any of these things because they will lose the next election.

Review

1. Why does the status of women help decrease population growth?
2. What is sustainable development? Do you think that it be achieved in your lifetime?
3. How can environmental protections be enacted and people be helped out of poverty at the same time? Are those goals conflicting?

Review Answers

1. Women who are educated tend to have fewer, healthier children so the population growth rate tends to go down.
2. Sustainable development tries to bring people out of poverty and keep the environment and resource use such that the future is protected for future generations.
3. People who are able to meet their needs can entertain ideas about environmental protection. People who are just trying to feed their family are less concerned about the environment.

1.5 Soil Erosion

- Explain how human activities cause soil erosion.

What would cause such a tremendous dust storm?

Farmers were forced off their lands during the Dust Bowl in the 1930s when the rains stopped and the topsoil blew off these former grasslands. A wind storm blew huge amounts of soil into the air in Texas on April 14, 1935. This scene was repeated throughout the central United States.

Causes of Soil Erosion

The agents of soil erosion are the same as the agents of all types of erosion: water, wind, ice, or gravity. Running water is the leading cause of soil erosion, because water is abundant and has a lot of power. Wind is also a leading cause of soil erosion because wind can pick up soil and blow it far away.

Activities that remove vegetation, disturb the ground, or allow the ground to dry are activities that increase erosion. What are some human activities that increase the likelihood that soil will be eroded?

Farming

Agriculture is probably the most significant activity that accelerates soil erosion because of the amount of land that is farmed and how much farming practices disturb the ground (**Figure** 1.13). Farmers remove native vegetation and then plow the land to plant new seeds. Because most crops grow only in spring and summer, the land lies fallow during the winter. Of course, winter is also the stormy season in many locations, so wind and rain are available to wash soil away. Tractor tires make deep grooves, which are natural pathways for water. Fine soil is blown away by wind.

The soil that is most likely to erode is the nutrient-rich topsoil, which degrades the farmland.

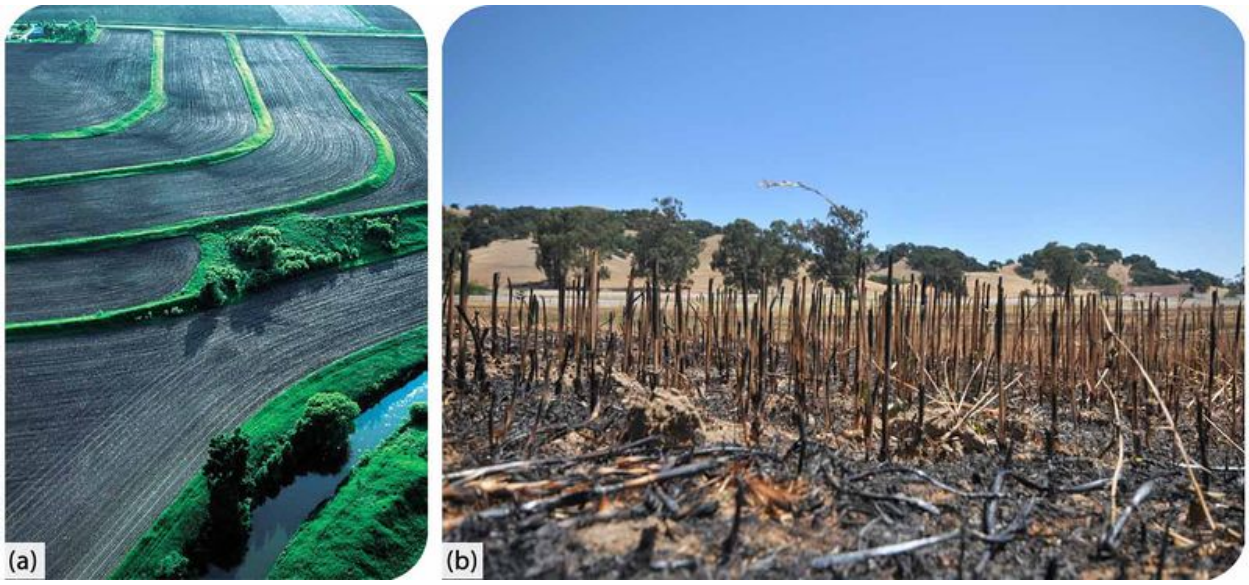


FIGURE 1.13

(a) The bare areas of farmland are especially vulnerable to erosion. (b) Slash-and-burn agriculture leaves land open for soil erosion and is one of the leading causes of soil erosion in the world.

Grazing

Grazing animals (**Figure** 1.14) wander over large areas of pasture or natural grasslands eating grasses and shrubs. Grazers expose soil by removing the plant cover for an area. They also churn up the ground with their hooves. If too many animals graze the same land area, the animals' hooves pull plants out by their roots. A land is overgrazed if too many animals are living there.

FIGURE 1.14

Grazing animals can cause erosion if they are allowed to overgraze and remove too much or all of the vegetation in a pasture.

Logging and Mining

Logging removes trees that protect the ground from soil erosion. The tree roots hold the soil together and the tree canopy protects the soil from hard falling rain. Logging results in the loss of **leaf litter**, or dead leaves, bark, and branches on the forest floor. Leaf litter plays an important role in protecting forest soils from erosion (**Figure** 1.15).

FIGURE 1.15

Logging exposes large areas of land to erosion.

Much of the world's original forests have been logged. Many of the tropical forests that remain are currently the site of logging because North America and Europe have already harvested many of their trees (**Figure** 1.16). Soils eroded from logged forests clog rivers and lakes, fill estuaries, and bury coral reefs.

Surface mining disturbs the land (**Figure** 1.17) and leaves the soil vulnerable to erosion.

Construction

Constructing buildings and roads churns up the ground and exposes soil to erosion. In some locations, native landscapes, such as forest and grassland, are cleared, exposing the surface to erosion (in some locations the land that will be built on is farmland). Near construction sites, dirt, picked up by the wind, is often in the air. Completed construction can also contribute to erosion (**Figure** 1.18).

Recreational Activities

Recreational activities may accelerate soil erosion. Off-road vehicles disturb the landscape and the area eventually develops bare spots where no plants can grow. In some delicate habitats, even hikers' boots can disturb the ground, so it's important to stay on the trail (**Figure** 1.19).

Soil erosion is as natural as any other type of erosion, but human activities have greatly accelerated soil erosion. In some locations soil erosion may occur about 10 times faster than its natural rate. Since Europeans settled in North America, about one-third of the topsoil in the area that is now the United States has eroded away.

FIGURE 1.16

Deforested swatches in Brazil show up as gray amid the bright red tropical rainforest.

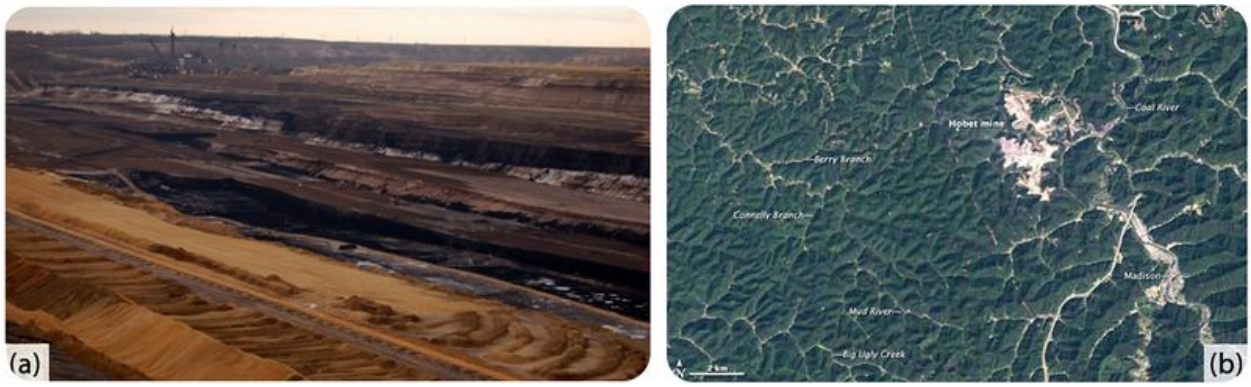


FIGURE 1.17

(a) Disturbed land at a coal mine pit in Germany. (b) This coal mine in West Virginia covers more than 10,000 acres (15.6 square miles). Some of the exposed ground is being reclaimed by planting trees.

Summary

- Although soil erosion is a natural process, human activities have greatly accelerated it.
- The agents of soil erosion are the same as of other types of erosion: water, ice, wind, and gravity.
- Soil erosion is more likely where the ground has been disturbed by agriculture, grazing animals, logging, mining, construction, and recreational activities.

FIGURE 1.18

Urban areas and parking lots result in less water entering the ground. Water runs off the parking lot onto nearby lands and speeds up erosion in those areas.

FIGURE 1.19

(a) ATV'S churn up the soil, accelerating erosion. (b) Hiking trails may become eroded.

Practice

1. Why do farmers till the soil?
2. What is the major problem with tilling?
3. What were other costs from soil erosion in the 20th century (note that the video incorrectly says 19th century)?
4. How does climate change affect soil degradation?
5. What is the solution? How does it work?
6. What is the benefit of this strategy?
7. What is the benefit from better farming practices?

Practice Answers

1. Tilling prepares the seed bed, releases nutrients to crops and controls weeds.
2. Tilling leaves the soil exposed and vulnerable to erosion, which degrades the farmland and pollutes off the farm.
3. The Dust Bowl blew topsoil into the air.
4. Extreme weather events like storms and floods impact already degraded soil. Degraded soil releases greenhouse gases, which makes climate change worse.
5. Conservation agriculture. Farmers do not till the soil and disturb it as little as possible. Leave crop residue in the fields to reduce soil erosion and evaporation and control weeds. Diversity the species and rotation of crops to increase soils resistance to pests and diseases.
6. It reduces the number of pre-seeding operations and saves money on fuel and allowing more efficient farm management.
7. Reduces erosion makes soil more fertile, holds water better.

Review

1. What is soil erosion? Why did soil erosion accelerate so greatly during the Dust Bowl?
2. How do human activities accelerate soil erosion? Since soil erosion is a natural process, is this bad?
3. What is the consequence of the acceleration of soil erosion?

Review Answers

1. Soil erosion is the removal of soil by erosional processes including water and wind. During the Dust Bowl the rains topped and the crops were not as good at holding the soil down as the native grasses had been.
2. Human activities that disturb the soil accelerate erosion. Nature keeps the soil down with grasses or other plants, but agriculture, logging, mining and other activities expose the soil to erosion. Soil erosion is natural but it is bad when it is in excess.
3. Loss of topsoil makes the soil less productive and can reduce productivity almost entirely.

1.6 Avoiding Soil Loss

- Describe steps that can be taken to minimize soil loss.

How does the terracing shown in this photo prevent soil erosion?

Terracing keeps the soil from moving very far downhill since it will only get as far as the next terrace downhill. Water will also be slowed by the terraces and so will be less able to carry tremendous amounts of soil downhill. Terracing is a great way to preserve soil when farming is being done on hillsides.

Soil Erosion

Bad farming practices and a return to normal rainfall levels after an unusually wet period led to the Dust Bowl. In some regions more than 75% of the topsoil blew away. This is the most extreme example of soil erosion the United States has ever seen.

Still, in many areas of the world, the rate of soil erosion is many times greater than the rate at which it is forming. Drought, insect plagues, or outbreaks of disease are natural cycles of events that can negatively impact ecosystems and the soil, but there are also many ways in which humans neglect or abuse this important resource. Soils can also be contaminated if too much salt accumulates in the soil or where pollutants sink into the ground.

One harmful practice is removing the vegetation that helps to hold soil in place. Sometimes just walking or riding your bike over the same place will kill the grass that normally grows there. Land is also deliberately cleared or deforested for wood. The loose soils then may be carried away by wind or running water.

Soil Conservation

Soil is only a renewable resource if it is carefully managed. There are many practices that can protect and preserve soil resources.

FIGURE 1.20

A farmer and his sons walk through a dust storm in Cimarron County, Oklahoma in 1936.

Organic Material

Adding organic material to the soil in the form of plant or animal waste, such as compost or manure, increases the fertility of the soil and improves its ability to hold on to water and nutrients (**Figure** 1.21). Inorganic fertilizer can also temporarily increase the fertility of a soil and may be less expensive or time consuming, but it does not provide the same long-term improvements as organic materials.

FIGURE 1.21

Organic material can be added to soil to help increase its fertility.

Preventing Soil Erosion

Soil is a natural resource that is vitally important for sustaining natural habitats and for growing food. Although soil is a renewable resource, it is renewed slowly, taking hundreds or thousands of years for a good fertile soil to develop.

Most of the best land for farming is already being cultivated. With human populations continuing to grow, it is extremely important to protect our soil resources. Agricultural practices such as rotating crops, alternating the types of crops planted in each row, and planting nutrient-rich cover crops all help to keep soil more fertile as it is used season after season. Planting trees as windbreaks, plowing along contours of the field, or building terraces into steeper slopes will all help to hold soil in place (**Figure** 1.22). No-till or low-tillage farming helps to keep soil in place by disturbing the ground as little as possible when planting.

FIGURE 1.22

Steep slopes can be terraced to make level planting areas and decrease surface water runoff and erosion.

The rate of topsoil loss in the United States and other developed countries has decreased recently as better farming practices have been adopted. Unfortunately, in developing nations, soil is often not protected.

Table 1.1 shows some steps that we can take to prevent erosion. Some are things that can be done by farmers or developers. Others are things that individual homeowners or community members can implement locally.

TABLE 1.1: Erosion

Source of Erosion	Strategies for Prevention
Agriculture	• Leave leaf litter on the ground in the winter. • Grow cover crops, special crops grown in the winter to cover the soil. • Plant tall trees around fields to buffer the effects of wind. • Drive tractors as little as possible. • Use drip irrigation that puts small amounts of water in the ground frequently. • Avoid watering crops with sprinklers that make big water drops on the ground. • Keep fields as flat as possible to avoid soil eroding down hill.

TABLE 1.1: (continued)

Source of Erosion	Strategies for Prevention
Grazing Animals	• Move animals throughout the year, so they don't consume all the vegetation in one spot. • Keep animals away from stream banks, where hills are especially prone to erosion.
Logging and Mining	• Reduce the amount of land that is logged and mined. • Reduce the number of roads that are built to access logging areas. • Avoid logging and mining on steep lands. • Cut only small areas at one time and quickly replant logged areas with new seedlings.
Development	• Reduce the amount of land area that is developed into urban areas, parking lots, etc. • Keep as much "green space" in cities as possible, such as parks or strips where plants can grow. • Invest in and use new technologies for parking lots that make them permeable to water in order to reduce runoff of water.
Recreational Activities	• Avoid using off-road vehicles on hilly lands. • Stay on designated trails.
Building Construction	• Avoid building on steep hills. • Grade surrounding land to distribute water rather than collecting it in one place. • Where water collects, drain to creeks and rivers. • Landscape with plants that minimize erosion.

Summary

- Soil is a renewable resource, but sometimes it is lost faster than it can be replaced.
- Soil resources must be preserved because there are many more people on Earth who need to eat and a great deal of topsoil has already been lost in many regions.
- There are many techniques available for preventing soil loss in agriculture, grazing, logging, mining, and recreation.
- Soil conservation is extremely important. Some helpful practices include adding organic material, terracing,

and no-till farming.

Practice

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=D-tLNesDYXA End at 7:25

1. What is soil erosion?
2. What increases soil erosion?
3. What are the negative effects of soil erosion?
4. What caused the Dust Bowl?
5. Is soil a renewable or nonrenewable resource on US cropland? Is that changing?
6. What did the 1985 Food Security Act do to protect sol?
7. What is conservation tillage?
8. What can be done on steep slopes to reduce erosion and why?
9. What is contour farming?
10. What is strip cropping?
11. What is alley-cropping or agroforestry?
12. How should water be added?
13. What is desertification?
14. How can desertification be slowed?

Practice Answers

1. The movement of soil components, especially surface litter and topsoil, by wind or water.
2. Activities such as farming, logging, construction, overgrazing and off-road vehicles.
3. It lowers soil fertility and can overload nearby bodies of water with sediment.
4. Grasses with deep roots were replaced with crops with shallow roots, and over-cultivation of land, disrupted topsoil and allowed soil to blow away.
5. On most US cropland, soil erodes faster than it forms, but that erosion has been cut by 65% since 1985.
6. Farmers were given a subsidy for taking highly erodible land out of production and replanting it with soil saving plants for 10 to 15 years.
7. Special machines that disturb the soil only where the planting is being done.
8. Terracing makes slop flat with steps to reduce flow of water.
9. Plowing and planting crops in rows across the slope of land rather than up and down.
10. Alternating strips of row crops are placed with cover crops to maintain topsoil.
11. Crops are planted in strips between trees and shrubs, which slow movement of water and wind, plus they provide shade.
12. Use only as much as is needed and use drip irrigation to put it right where it's needed.
13. Arid or semi-arid land is reduced in productivity by 10% or more due to natural drought and human activities.
14. Reduce overgrazing, deforestation, overplanting, irrigation, and mining.

Review

1. Why is it so important for strategies that prevent soil erosion to be understood and used?
2. Which agricultural techniques are better that preserving soils?
3. How do recreational activities exacerbate soil erosion and how can this be lessened?
4. Why does the addition of organic material to soil help with its conservation?
5. What are a few agricultural practices that make conserving soil a priority?

Review Answers

1. Healthy soil is needed to protect ecosystems and to maximize the health and productivity of farm land.
2. Adding organic material; rotating crops; alternating crops by row and season; planting nutrient-rich cover crops so the soil is never left exposed; planting trees as windbreaks; plowing along contours; building terraces; no til forming.
3. Hiking or off-road bikes or vehicles can destroy the plant-life and pack own the soil so other plants can't grow.
4. Organic material makes the soil more fertile and it also holds water better. Plants grow and the soil is held down.
5. Do not leave the soil exposed; surround the field with trees to buffer the wind; avoid using heavy equipment; use drip irrigation; keep fields flat.

1.7 Hazardous Waste

- Define hazardous waste.
- Explain how hazardous wastes negatively affect humans and the environment.

Are these hazardous wastes safely stored?

Hazardous wastes must be stored, used and disposed of properly. Some wastes are extremely corrosive and can get through steel drums over time. How can we be sure that hazardous wastes are actually stored safely for the time necessary?

What is Hazardous Waste?

Hazardous waste is any waste material that is dangerous to human health or that degrades the environment. Hazardous waste includes substances that are:

1. Toxic: causes serious harm or death, or is poisonous.
2. Chemically active: causes dangerous or unwanted chemical reactions, such as explosions.
3. Corrosive: destroys other things by chemical reactions.
4. Flammable: easily catches fire and may send dangerous smoke into the air.

All sorts of materials are hazardous wastes and there are many sources. Many people have substances that could become hazardous wastes in their homes. Several cleaning and gardening chemicals are hazardous if not used properly. These include chemicals like drain cleaners and pesticides that are toxic to humans and many other creatures. While these chemicals are fine if they are stored and used properly, if they are used or disposed of improperly, they may become hazardous wastes. Others sources of hazardous waste are shown in **Table** 1.2.

TABLE 1.2: Hazardous Waste

Type of Hazardous Waste	Example	Why it is Hazardous
Chemicals from the automobile industry	Gasoline, used motor oil, battery acid, brake fluid	Toxic to humans and other organisms; often chemically active; often flammable.
Batteries	Car batteries, household batteries	Contain toxic chemicals; are often corrosive.
Medical wastes	Surgical gloves, wastes contaminated with body fluids such as blood, x-ray equipment	Toxic to humans and other organisms; may be chemically active.
Paints	Paints, paint thinners, paint strippers, wood stains	Toxic; flammable.
Dry cleaning chemicals	Many various chemicals	Toxic; many cause cancer in humans.
Agricultural chemicals	Pesticides, herbicides, fertilizers	Toxic to humans; can harm other organism; pollute soils and water.

Summary

- Hazardous waste is material that is toxic, chemically active, corrosive, or flammable.
- Hazardous wastes are damaging to the environment or human health.
- Hazardous materials are found in a variety of settings, including industry, agriculture, and people's homes.

Practice

Use the resource below to answer the questions that follow.

- **Hazardous Waste** at http://www.learner.org/interactives/garbage/hazardous.html

1. What is hazardous waste?
2. How many hazardous wastes does the EPA recognize?
3. What household products can be recycled?
4. What household items should be disposed of as hazardous waste?
5. What criteria must be met for a hazardous substance to be washed down the drain? Give an example.
6. What is the best solution to minimize the need to deal with hazardous waste?

Practice Answers

1. Hazardous waste is waste that poses immediate or long-term risks to humans, animals, plants or the environment. It requires special handling for detoxification or safe disposal.
2. more than 500
3. oil
4. Any that indicate they are hazardous and can't be reused.
5. Only if it is safely disposed in the sewer system; e.g. antifreeze.
6. Reduce the need for hazardous waste. Find alternatives that are not hazardous.

Review

1. If pesticides are toxic, why do we spray them on food crops?
2. Why are some medical wastes hazardous?
3. What is hazardous waste? Is it always clear whether something is hazardous or not?

Review Answers

1. Good question.
2. They may have human blood or chemicals that are biologically dangerous. They may have radiation or other materials that are harmful.
3. Hazardous waste is any waste that is hazardous to human health or degrades the environment. It is not clear if some things are hazardous or not.

1.8 Impacts of Hazardous Waste

- Describe the impacts of hazardous waste on humans and the environment.
- Trace how these impacts led to the Superfund Act.

What role do citizens play in protecting their environment?

Sometimes it's up to the residents in an area to recognize the effects of hazardous waste and to get the government to find the responsible party and initiate cleanup. Here, a resident of Love Canal protests the hazardous waste contamination in her neighborhood.

Love Canal

The story of Love Canal, New York, begins in the 1950s, when a local chemical company placed hazardous wastes in 55-gallon steel drums and buried them. Love Canal was an abandoned waterway near Niagara Falls and was thought to be a safe site for hazardous waste disposal because the ground was fairly impermeable (**Figure** 1.23). After burial, the company covered the containers with soil and sold the land to the local school system for $1. The company warned the school district that the site had been used for toxic waste disposal.

FIGURE 1.23

Steel drums were used to contain 21,000 tons of hazardous chemicals at Love Canal.

Soon a school, a playground, and 100 homes were built on the site. The impermeable ground was breached when sewer systems were dug into the rock layer. Over time, the steel drums rusted and the chemicals were released into the ground. In the 1960s people began to notice bad odors. Children developed burns after playing in the soil, and they were often sick. In 1977 a swamp created by heavy rains was found to contain 82 toxic chemicals, including 11 suspected cancer-causing chemicals.

A Love Canal resident, Lois Gibbs, organized a group of citizens called the Love Canal Homeowners Association to try to find out what was causing the problems (See opening image). When they discovered that toxic chemicals were buried beneath their homes and school, they demanded that the government take action to clean up the area and remove the chemicals.

A video of Lois Gibbs describing the origin of the Love Canal problem: http://www.youtube.com/watch?v=PrzqFPego4A .

Superfund Act

In 1978, people were relocated to safe areas. The problem of Love Canal was instrumental in the passage of the the **Superfund Act** in 1980. This law requires companies to be responsible for hazardous chemicals that they put into the environment and to pay to clean up polluted sites, which can often cost hundreds of millions of dollars. Love Canal became a **Superfund site** in 1983 and as a result, several measures were taken to secure the toxic wastes. The land was capped so that water could not reach the waste, debris was cleaned from the nearby area, and contaminated soils were removed.

Impacts of Hazardous Waste

The pollution at Love Canal was not initially visible, but it became visible. The health effects from the waste were also not initially visible, but they became clearly visible. The effects of the contamination that were seen in human health included sickness in children and a higher than normal number of miscarriages in pregnant women. Toxic chemicals may cause cancer and birth defects. Why do you think children and fetuses are more susceptible? Because young organisms grow more rapidly, they take in more of the toxic chemicals and are more affected.

Cancer Clusters

Sometimes the chemicals are not so easily seen as they were at Love Canal. But the impacts can be seen statistically. For example, contaminated drinking water may cause an increase in some types of cancer in a community.

Why is one person with cancer not enough to suspect contamination by toxic waste? One is not a statistically valid number. A certain number of people get cancer all the time. To identify contamination, a number of cancers above the normal rate, called a cancer cluster, must be discovered. A case that was made into a book and movie called *A Civil Action* involved the community of Woburn, Massachusetts. Groundwater contamination was initially suspected because of an increase in childhood leukemia and other illnesses. As a result of concern by parents, the well water was analyzed and shown to have high levels of TCE (trichloroethylene).

Toxic Metals

Lead and mercury are two chemicals that are especially toxic to humans. Lead was once a common ingredient in gasoline and paint, but it was shown to damage human brains and nervous systems. Since young children are growing rapidly, lead is especially harmful in children under the age of six (**Figure** 1.24). In the 1970s and 1980s, the United States government passed laws completely banning lead in gasoline and paint. Homes built before the 1970s may contain lead paint. Paint so old is likely to be peeling and poses a great threat to human health. About 200 children die every year from lead poisoning.

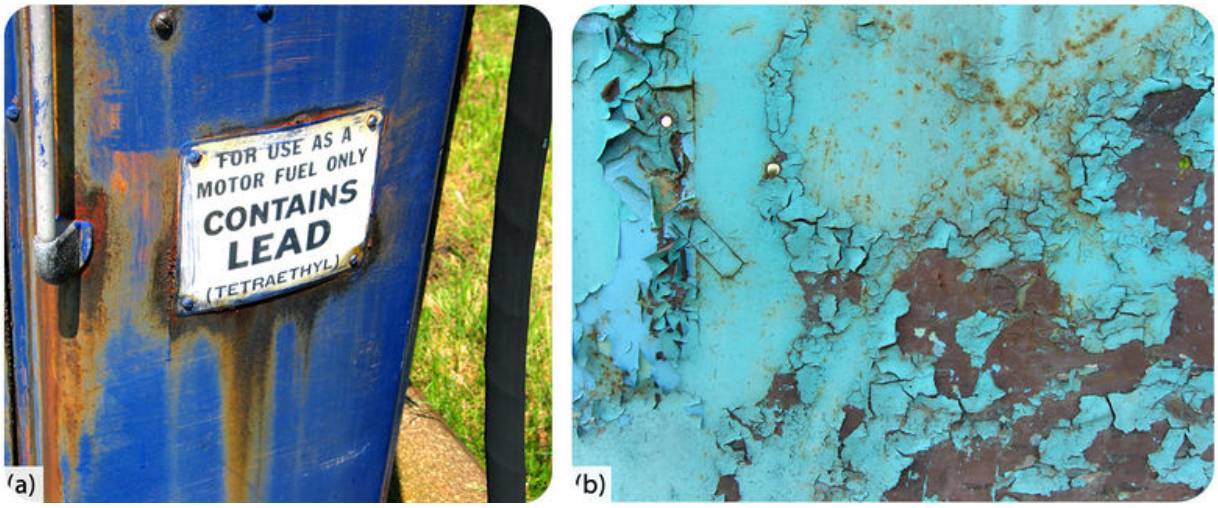


FIGURE 1.24

(a) Leaded gasoline. (b) Leaded paint.

Mercury is a pollutant that can easily spread around the world. Sources of mercury include volcanic eruptions, coal burning, and wastes such as batteries, electronic switches, and electronic appliances such as television sets. Like lead, mercury damages the brain and impairs nervous system function. More about the hazards of mercury pollution can be found later in this concept.

Summary

- The Superfund Act of 1980 requires that companies safely dispose of hazardous chemicals they generate and clean up sites they pollute.
- The effects of hazardous wastes on human populations include miscarriages, birth defects, brain damage, and cancer, particularly in children.
- An individual may develop a disease, like cancer, but when the number of cases of the disease exceeds what is found in other areas, it is cause for concern.

Practice

Use the resource below to answer the questions that follow.

1. What event spurred on the Superfund Act? What happened there?
2. What happened years later?
3. Why was Love Canal special and not special?
4. How did the federal government respond to the problem at Love Canal?
5. What does Superfund do?
6. Where does the money for Superfund come from?
7. How many Superfund sides are there?
8. What is the first step after the site has been identified?
9. What happens if that first step fails?
10. Why is cleanup expensive?
11. How does decontamination occur?
12. How long did it take to clean up Love Canal?
13. How will it be possible for there to be no more Superfund sites after the ones already identified have been cleaned up?

Practice Answers

1. At Love Canal, drums were filled with toxic wastes that were buried in the ground, covered with dirt and then covered with a subdivision.
2. The drums rusted and the toxic material leaked out. Birth defects started.
3. Love Canal was the first to make headlines but it was just one of hundreds of sites that were capable of doing the same thing.
4. They passed the Comprehensive Environmental Response Compensation and Liability Act of 1980.
5. It helps provide the money needed to find and clean up hazardous waste sites.
6. Taxes on gasoline and chemical companies.
7. There are more than 1,000 Superfund sites.
8. The EPA tries to find the responsible party to clean up the mess.
9. The EPA funds the cleanup.
10. Millions of tons of dirt have to be moved and decontaminated.
11. By incineration.
12. 20 years
13. Tougher environmental regulations keep the sites from being contaminated in the first place.

Review

1. If waste is to remain hazardous for a long period of time, how can society protect itself from problems as occurred at Love Canal?
2. What is the Superfund Act and how did Love Canal lead to it?
3. What is a cancer cluster? What should be done if one is found?

Review Answers

1. The sites have to be identified and cleaned up. New sites should not be created.
2. The Superfund Act requires companies to be responsible for hazardous chemicals they put into the environment and pay cleanup.
3. A cancer cluster is when a larger number of people get cancer than is the normal rate. This may indicate that there is toxic waste. If a cluster is found, the area needs to be searched for toxic waste and then cleaned up.

1.9 Preventing Hazardous Waste Problems

- Explain how to prevent pollution by hazardous wastes.

What should be done about hazardous waste sites?

Cleaning up toxic wastes has incredible costs in time and money. Laws now protect lands from contamination, but many sites were damaged before those laws were passed. No other organization is big enough, so it is the government's job to clean up a toxic site if the company that caused the damage no longer exists or cannot afford cleanup.

Preventing Hazardous Waste Pollution

Nations that have more industry produce more hazardous waste. Currently, the United States is the world's largest producer of hazardous wastes, but China, which produces so many products for the developed world, may soon take over the number-one spot.

Countries with more industry produce more hazardous wastes than those with little industry. Problems with hazardous wastes and their disposal became obvious sooner in the developed world than in the developing world. As a result, many developed nations, including the United States, have laws to help control hazardous waste disposal and to clean toxic sites.

As mentioned in the "Impacts of Hazardous Waste" concept, the Superfund Act requires companies to clean up contaminated sites that are designated as Superfund sites (**Figure** 1.25). If a responsible party cannot be identified, because the company has gone out of business or its culpability cannot be proven, the federal government pays for the cleanup out of a trust fund with money put aside by the petroleum and chemical industries. As a result of the Superfund Act, companies today are more careful about how they deal with hazardous substances.

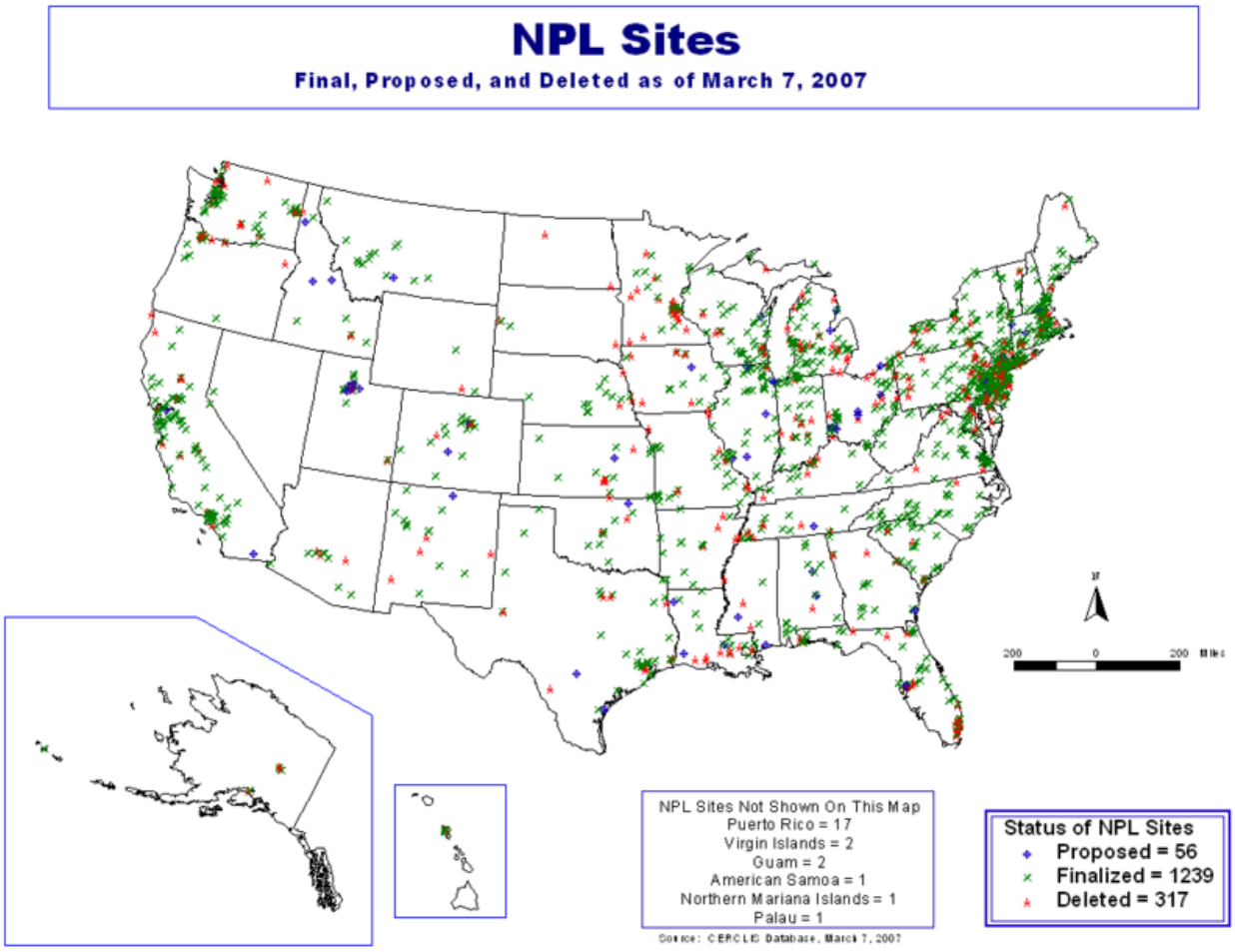


FIGURE 1.25

Superfund sites are located all over the nation and many are waiting to be cleaned up.

The Resource Conservation and Recovery Act of 1976 requires that companies keep track of any hazardous materials they produce. These materials must be disposed of using government guidelines and records must be kept to show the government that the wastes were disposed of safely. Workers must be protected from the hazardous materials.

To some extent, individuals can control the production and disposal of hazardous wastes. We can choose to use materials that are not hazardous, such as using vinegar as a cleanser. At home, people can control the amount of pesticides that they use (or they can use organic methods of pest control). It is also necessary to dispose of hazardous materials properly by not pouring them over the land, down the drain or toilet, or into a sewer or trashcan.

Summary

- Government regulations, like the Superfund Act, hold companies accountable for the hazardous materials they produce.
- Developed nations have seen the consequences of hazardous waste and are more likely to have protections in place than developing countries.
- People can lessen the hazardous waste problem by using materials that are not hazardous or by disposing of

wastes properly.

Practice

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=rCc3SRraeFg

1. Why can't hazardous wastes be thrown in the trash?
2. What does proper disposal of hazardous waste prevent?
3. Although this video is made for a specific location, how can you use the information to dispose of hazardous waste in your own region?
4. What typical household wastes are hazardous?
5. What should you do with the hazardous wastes?
6. What should you do with leftover pharmaceuticals?
7. How does the hazardous waste facility in Contra Costa County meet the motto reduce, reuse, recycle?
8. How can you find a hazardous waste facility in your area? Does your facility take all toxic waste items? How about pharmaceuticals?

Practice Answers

1. In some regions it's against the law. Some materials can be hazardous to human health and to the environment.
2. It keeps bad chemicals out of the water to protect marine life and our drinking water.
3. You can do the same things, you just need to find the locations where drop off facilities are.
4. Lighter fluid, aerosols, old batteries, electronic waste, toxic waste, poisons.
5. Pack them up safely and take them to a drop off facility.
6. Take them to a safe drop off.
7. They leave out the toxic materials for people to come get for free.
8. Do a web search for something like your town and hazardous waste facility.
9. Answers will vary.

Review

1. How do the Superfund Act and other government regulations prevent lands from being contaminated?
2. What can you do to prevent or lessen the generation of hazardous wastes?
3. Why does the United States have so many Superfund sites compared with other nations?

Review Answers

1. The Act requires companies to clean up contaminated sites and creates a fund to pay for cleanup if the company no longer exists.
2. Use less hazardous material or find non-toxic alternatives. Dispose of hazardous materials properly.
3. We have a lot because we have a lot of industry and mining; we also look for them and seek to try to clean them up.

1.10 Environmental Impacts of Mining

- Describe the environmental costs of mining.

How much does your mp3 player really cost?

Many of the things we want come partly from minerals. But making minerals useful often causes environmental damage.

Mining and the Environment

Although mining provides people with many needed resources, the environmental costs can be high. Surface mining clears the landscape of trees and soil, and nearby streams and lakes are inundated with sediment. Pollutants from the mined rock, such as heavy metals, enter the sediment and water system. Acids flow from some mine sites, changing the composition of nearby waterways (**Figure** 1.26).

FIGURE 1.26

Acid drainage from a surface coal mine in Missouri.

U.S. law has changed in recent decades so that a mine region must be restored to its natural state, a process called **reclamation**. This is not true of older mines. Pits may be refilled or reshaped and vegetation planted. Pits may be allowed to fill with water and become lakes or may be turned into landfills. Underground mines may be sealed off or left open as homes for bats.

Summary

- Surface mining clears the land, completely destroying the ecosystems that were found there.
- Mining releases pollutants, which affect the immediate area and may travel downstream or downwind to cause problems elsewhere.
- Reclamation occurs when people attempt to return the mined land to its original state.

Explore More

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=p5RcbPZXUZo

1. How was coal traditional mined in West Virginia?
2. What is mountaintop removal mining?
3. What is the first step after the site has been identified?
4. What role do geologists play?
5. How does the rock get broken?
6. What is done with the broken rock?
7. What is the ratio of coal to rock removed?
8. What is the advantage of mountaintop removal for miners?
9. What is the environmental cost?

Practice Answers

1. Men working deep underground.
2. Companies carve off the tops of mountains to get to the coal.
3. The trees are clear cut.
4. After the clear cutting the geologists locate where the deposits are.
5. The company drills holes that are loaded with powerful explosives and then blown up.
6. It is scooped up into mining trucks.
7. 1 ton of coal to 16 tons of earth.
8. It is safer because they don't have to work underground.
9. The mountains disappear along with the habitats for hundreds of species. People get the spare rock dumped into nearby valleys and local streams are destroyed. Communities have to relocate when coal companies buy up the land.

Review

1. What damage may be caused by mining?
2. Why is sediment considered a problem in mined areas?
3. If lands altered by mining in recent decades must be reclaimed, what happens to lands that were mined prior to that law?

Review Answers

1. Landscapes are cleared of trees and soil and the sediment is dumped into nearby stream valleys. Pollutants from the mined rock enter the ecosystem.
2. Sediment chokes rivers, kills organisms, buries the region under dirt.
3. They are just left.

1.11 Uses of Water

- Describe how humans use water in a variety of ways.

What do you use water for?

Drinking, of course. Bathing, naturally. But what else? Growing food, producing goods, recreation, maintaining healthy ecosystems: all require lots and lots of water.

Water Consumption

Humans use six times as much water today as they did 100 years ago. People living in developed countries use a far greater proportion of the world's water than people in less developed countries. What do people use all of that water for?

Human Uses of Water

Besides drinking and washing, people need water for agriculture, industry, household uses, and recreation (**Figure** 1.27). Recreational use and environmental use average 1% each.

Water use can be consumptive or non-consumptive, depending on whether the water is lost to the ecosystem.

- **Non-consumptive** water use includes water that can be recycled and reused. For example, the water that goes down the drain and enters the sewer system is purified and then redistributed for reuse. By recycling water, the overall water consumption is reduced.
- **Consumptive** water use takes the water out of the ecosystem. Can you name some examples of consumptive water use?

Agriculture

Some of the world's farmers still farm without irrigation by choosing crops that match the amount of rain that falls in their area. But some years are wet and others are dry. For farmers to avoid years in which they produce little or

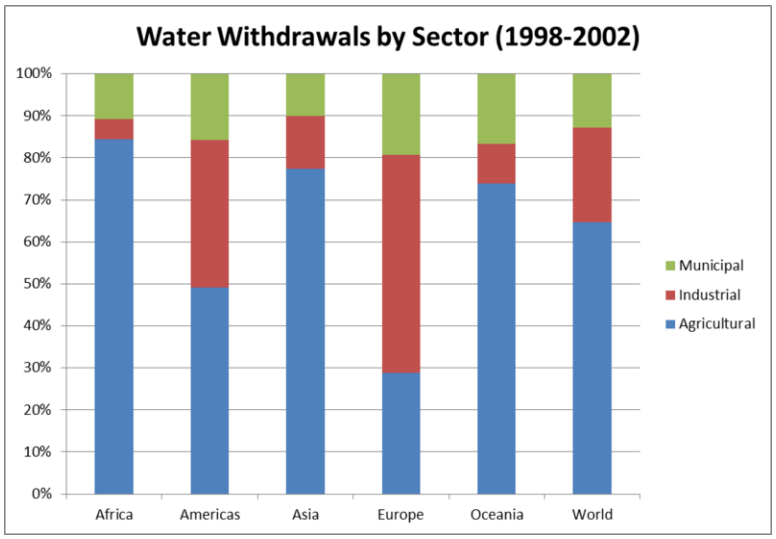


FIGURE 1.27

Water used for home, industrial, and agricultural purposes in different regions. Globally more than two-thirds of water is for agriculture.

no food, many of the world's crops are produced using irrigation.

Wasteful Methods

Three popular irrigation methods are:

- Overhead sprinklers.
- Trench irrigation: canals carry water from a water source to the fields.
- Flood irrigation: fields are flooded with water.

All of these methods waste water. Between 15% and 36% percent of the water never reaches the crops because it evaporates or leaves the fields as runoff. Water that runs off a field often takes valuable soil with it.

Non-wasteful Methods

A much more efficient way to water crops is **drip irrigation** (**Figure** 1.28). With drip irrigation, pipes and tubes deliver small amounts of water directly to the soil at the roots of each plant or tree. The water is not sprayed into the air or over the ground, so nearly all of it goes directly into the soil and plant roots.

Why Not Change?

Why do farmers use wasteful irrigation methods when water-efficient methods are available? Many farmers and farming corporations have not switched to more efficient irrigation methods for two reasons:

1. Drip irrigation and other more efficient irrigation methods are more expensive than sprinklers, trenches, and flooding.

2. In the United States and some other countries, the government pays for much of the cost of the water that is used for agriculture. Because farmers do not pay the full cost of their water use, they do not have any financial incentive to use less water.

What ideas can you come up with to encourage farmers to use more efficient irrigation systems?

FIGURE 1.28
Drip irrigation delivers water to the base of each plant so little is lost to evaporation and runoff.

Aquaculture

Aquaculture is a different type of agriculture. Aquaculture is farming to raise fish, shellfish, algae, or aquatic plants (**Figure** 1.29). As the supplies of fish from lakes, rivers, and the oceans dwindle, people are getting more fish from aquaculture. Raising fish increases our food resources and is especially valuable where protein sources are limited. Farmed fish are becoming increasingly common in grocery stores all over the world.

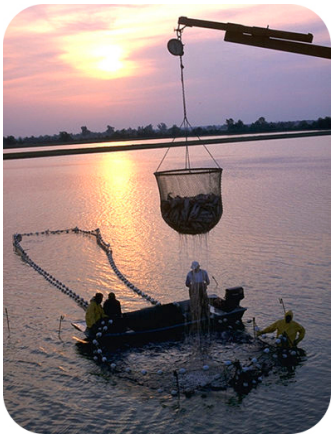


FIGURE 1.29
Workers at a fish farm harvest fish they will sell to stores.

Growing fish in a large scale requires that the fish stocks are healthy and protected from predators. The species raised must be hearty, inexpensive to feed, and able to reproduce in captivity. Wastes must be flushed out to keep animals healthy. Raising shellfish at farms can also be successful.

Aquaculture Problems

For some species, aquaculture is very successful and environmental harm is minimal. But for other species, aquaculture can cause problems. Natural landscapes, such as mangroves, which are rich ecosystems and also protect coastlines from storm damage, may be lost to fish farms (**Figure** 1.30). For fish farmers, keeping costs down may be a problem since coastal land may be expensive and labor costs may be high. Large predatory fish at the 4th or 5th

trophic level must eat a lot, so feeding large numbers of these fish is expensive and environmentally costly. Farmed fish are genetically different from wild stocks, and if they escape into the wild they may cause problems for native fish. Because the organisms live so close together, parasites are common and may also escape into the wild.

March 6, 2006 (Terra ASTER)

FIGURE 1.30

Shrimp farms on the coast of Ecuador are shown as blue rectangles. Mangrove forests, salt flats, and salt marshes have been converted to shrimp farms.

Industrial Water Use

Industrial water use accounts for an estimated 15% of worldwide water use, with a much greater percentage in developed nations. Industrial uses of water include power plants that use water to cool their equipment and oil refineries that use water for chemical processes. Manufacturing is also water intensive.

Household Use

Think about all the ways you use water in a day. You need to count the water you drink, cook with, bathe in, garden with, let run down the drain, or flush down the toilet. In developed countries, people use a lot of water, while in less developed countries people use much less. Globally, household or personal water use is estimated to account for 15% of world-wide water use.

Some household water uses are non-consumptive, because water is recaptured in sewer systems, treated, and returned to surface water supplies for reuse. Many things can be done to lower water consumption at home.

- Convert lawns and gardens to drip-irrigation systems.
- Install low-flow shower heads and low-flow toilets.

In what other ways can you use less water at home?

Recreational Use

People love water for swimming, fishing, boating, river rafting, and other activates. Even activities such as golf, where there may not be any standing water, require plenty of water to make the grass on the course green. Despite its value, the amount of water that most recreational activities use is low: less than 1% of all the water we use.

Many recreational water uses are non-consumptive including swimming, fishing, and boating. Golf courses are the biggest recreational water consumer since they require large amounts for irrigation, especially because many courses are located in warm, sunny, desert regions where water is scarce and evaporation is high.

This National Geographic video chronicles the conflict between conserving the Yangtze River for recreational uses versus damming it for the clean energy China needs so badly: http://video.nationalgeographic.com/video/player/environment/energy-environment/energy-conservation.html .

Environmental Use

Environmental use of water includes creating wildlife habitat. Lakes are built to create places for fish and water birds (**Figure** 1.31). Most environmental uses are non-consumptive and account for an even smaller percentage of water use than recreational uses. A shortage of this water is a leading cause of global biodiversity loss.

FIGURE 1.31
Wetlands and other environments depend on clean water to survive.

Summary

- Consumptive water use takes water out of the ecosystem; non-consumptive water use includes water that can be recycled and reused.
- People can use less water by having efficient systems for water use and by reusing and recycling water where possible.
- Some water must remain in the environment for recreational use for humans and to support ecosystems.

Practice

Use these resources to answer the questions that follow.

https://www.youtube.com/watch?v=HW5eBfZhE4M

1. Since so little water is drinkable, what could be done to make undrinkable water drinkable?
2. How much of the world's population doesn't have safe water?
3. Do people around the world die from water-related diseases?
4. How much water does the average person in North America use per day?
5. How much water does the average person in Europe use per day? What percentage of North America's use is that roughly?
6. How much water does the average person in Mozambique and other developing countries use per day? About what percentage of North America's water use is that roughly?

7. What happens to water availability as population grows?

Practice Answers

1. We could desalinate seawater to make fresh water.
2. 1/6
3. Yes, one per minute dies in India and four per minute around the world.
4. 105.7 gallons
5. 52.8 gallons, about half as uch
6. 1.3 gallons, about 1%
7. It decreases.

Review

1. Why do people in developed countries use so much more water than they used to?
2. Why don't localities and people use water in the most efficient way, rather than sometimes in wasteful ways?
3. What is aquaculture and why is it going to be increasingly important in the future?

Review Answers

1. Everyone has indoor plumbing and crops are mostly grown with irrigation. People have more stuff, which takes water to produce. Energy production often uses water.
2. So far water has been cheap to consumers so there is little incentive to change.
3. Aquaculture is farming, but for fish and seafood rather than land crops. The oceans are being tapped out so fish farming will become a more important source of protein for people around the world.

1.12 Water Distribution

- Describe how water is distributed across the globe.
- Explain the causes and consequences of water scarcity.

Will water cause the next war?

Wars have been fought over oil, but many people predict that the next war will be fought over water. Certainly, water is becoming scarcer.

Water Distribution

Water is unevenly distributed around the world. Large portions of the world, such as much of northern Africa, receive very little water relative to their population (**Figure** 1.32). The map shows the number of months in which there is little rainfall in each region. In developed nations, water is stored, but in underdeveloped nations, water storage may be minimal.

Over time, as population grows, rainfall totals will change, resulting in less water per person in some regions. In 2025, many nations, even developed nations, are projected to have less water per person than now

Water Shortages

Water scarcity is a problem now and will become an even larger problem in the future as water sources are reduced or polluted and population grows. In 1995, about 40% of the world's population faced water scarcity. Scientists estimate that by the year 2025, nearly half of the world's people won't have enough water to meet their daily needs. Nearly one-quarter of the world's people will have less than 500 m^3 of water to use in an entire year. That amount is less water in a year than some people in the United States use in one day.

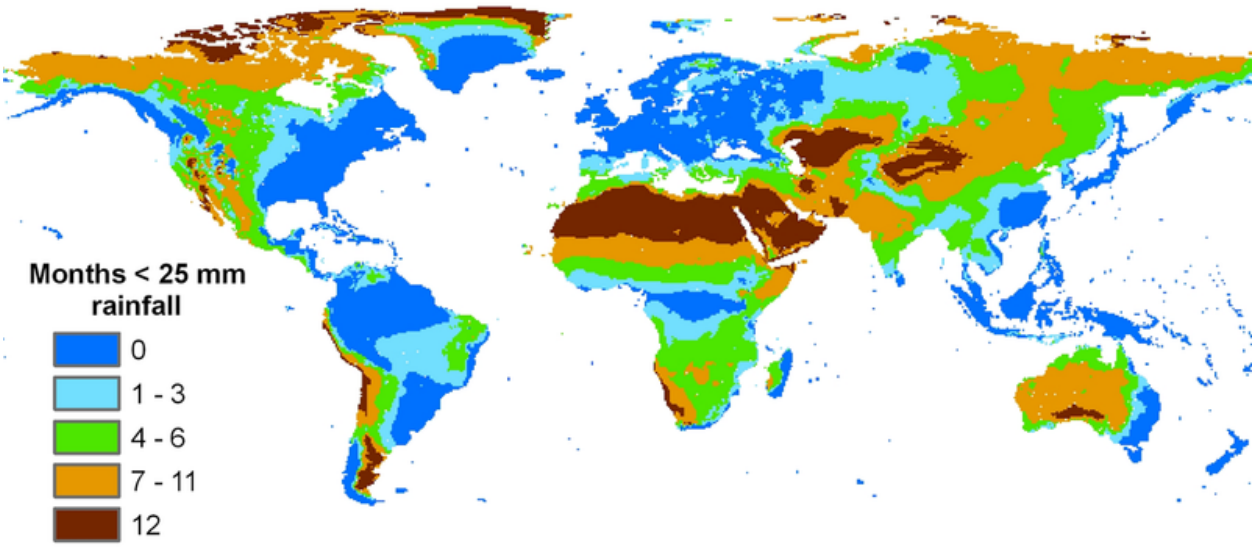


FIGURE 1.32
Some regions have very little rainfall per month.

Droughts

Droughts occur when a region experiences unusually low precipitation for months or years (**Figure** 1.33). Periods of drought may create or worsen water shortages.

Human activities can contribute to the frequency and duration of droughts. For example, deforestation keeps trees from returning water to the atmosphere by transpiration; part of the water cycle becomes broken. Because it is difficult to predict when droughts will happen, it is difficult for countries to predict how serious water shortages will be each year.

FIGURE 1.33
Extended periods with lower than normal rainfall cause droughts.

Effect of Changing Climate

Global warming will change patterns of rainfall and water distribution. As the Earth warms, regions that currently receive an adequate supply of rain may shift. Regions that rely on snowmelt may find that there is less snow and the melt comes earlier and faster in the spring, causing the water to run off and not be available through the dry summers. A change in temperature and precipitation would completely change the types of plants and animals that can live successfully in that region.

Water Scarcity

Water scarcity can have dire consequences for the people, the economy, and the environment. Without adequate water, crops and livestock dwindle and people go hungry. Industry, construction, and economic development is halted, causing a nation to sink further into poverty. The risk of regional conflicts over scarce water resources rises. People die from diseases, thirst, or even in war over scarce resources.

California's population is growing by hundreds of thousands of people a year, but much of the state receives as much annual rainfall as Morocco. With fish populations crashing, global warming, and the demands of the country's largest agricultural industry, the pressures on our water supply are increasing.

Find out more at http://science.kqed.org/quest/video/state-of-thirst-californias-water-future/ .

MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/447

Conflicts Over Water

As water supplies become scarce, conflicts will arise between the individuals or nations that have enough clean water and those that do not (**Figure** 1.34). Some of today's greatest tensions are happening in places where water is scarce. Water disputes may add to tensions between countries where differing national interests and withdrawal rights have been in conflict. Just as with energy resources today, wars may erupt over water.

Water disputes are happening along 260 different river systems that cross national boundaries. Some of these disputes are potentially very serious. International water laws, such as the Helsinki Rules, help interpret water rights among countries.

Summary

- A lot of the problem with water is that it is not evenly distributed across the planet.
- Many of the world's people live with water scarcity, and that percentage will increase as populations increase and climate changes.
- Some people predict that, just as wars are fought over energy now, future wars will be fought over water.

Practice

Use these resources to answer the questions that follow.

https://www.youtube.com/watch?v=6XvBxC9XMpE

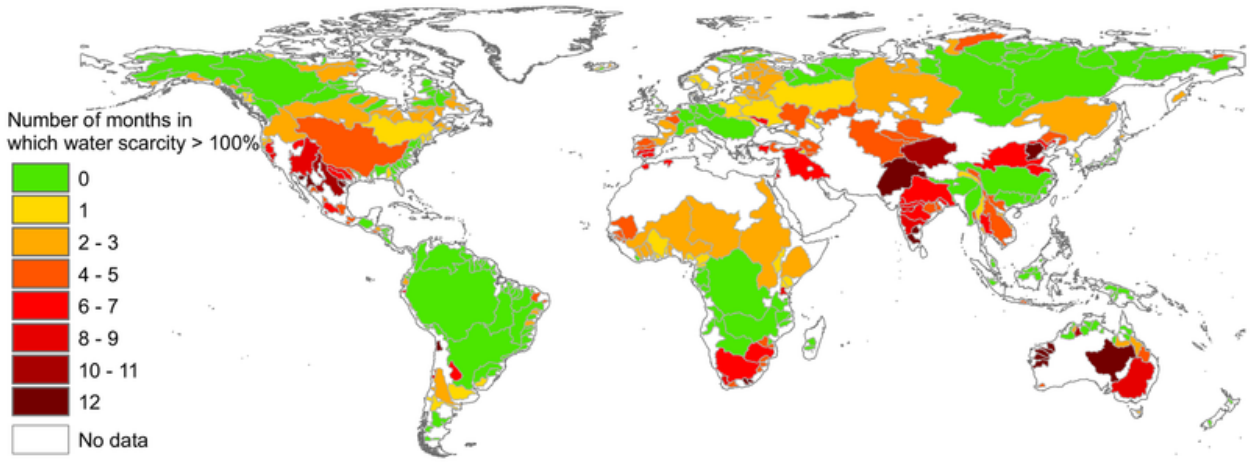


FIGURE 1.34

Many regions already experience water scarcity. This map shows the number of months in which the amount of water that is used exceeds the availability of water that can be used sustainably. This is projected to get worse as demand increases.

1. What does the water footprint of a product refer to?
2. What is the water footprint of developed nations, like the United States and southern Europe, per capita compared with developing nations? How about compared with the global average?
3. What is the water footprint of the United Kingdom and other northern European countries compared with the global average? How about with the developing nations?
4. What is used as the water footprint cap? Is that sustainable?
5. Besides living within the water footprint cap, what should governments do?
6. How can the issue of water equity be addressed?

Practice Answers

1. The amount of water that is used in the country per capita including the products that are made and the pollution generated to make them.
2. Much higher and also about two to three times the global average.
3. About the same as the global average but higher than the developing nations.
4. The amount of rain that falls into a drainage basin. Yes it is sustainable.
5. They should promote water use efficiency.
6. We need a treaty so that water footprint is more equal.

Review

1. How will changing climate affect the availability and distribution of water?
2. How do human activities affect the occurrence of droughts?
3. How do so many people live with so little water?

Review Answers

1. Rainfall patters may shift so some people may get more rain and some less. Droughts will increase. Snow may not come or may melt earlier in the spring so that snow and ice melt will not be an available water source in the summer in some regions.
2. Deforestation removes the evapotranspiration part of the water cycle; changing temperatures can change rainfall patterns.
3. Some people don't; they die of water related problems. Water scarcity contributes to hunger and the spread of disease. Wars can erupt over limited resources.

1.13 Safety of Water

- Describe the causes and consequences of unsafe water.

What do you see in this photo?

The Ganges River is sacred to the people of India. It is also a major source of water for drinking and bathing for millions of people. An estimated 400 million people are affected by pollution in the Ganges. What can be done to protect a water body that has so much pressure placed on it?

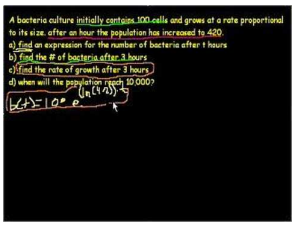
Scarcity of Safe Drinking Water

The water that comes out of our faucets is safe because it has gone through a series of treatment and purification processes to remove contaminants. Those of us who are fortunate enough to always be able to get clean water from a tap in our home may have trouble imagining life in a country that cannot afford the technology to treat and purify water.

Pollution

Many people in the world have no choice but to drink from the same polluted river where sewage is dumped. One-fifth of all people in the world, more than 1.1 billion people, do not have access to safe water for drinking, personal cleanliness, and domestic use. Unsafe drinking water carries many **pathogens**, or disease-causing biological agents such as infectious bacteria and parasites. Toxic chemicals and radiological hazards in water can also cause diseases.

Exponential growth of bacteria is explained in this video giving the viewer a good idea of how a small number of bacteria can cause a major toxic problem: http://www.youtube.com/watch?v=JWfTckls59k (16:00).



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Waterborne Disease

Waterborne disease caused by unsafe drinking water is the leading cause of death for children under the age of five in many nations and a cause of death and illness for many adults. About 88% of all diseases are caused by drinking unsafe water (**Figure** 1.35). Throughout the world, more than 14,000 people die every day from waterborne diseases, such as cholera, and many of the world's hospital beds are occupied by patients suffering from a waterborne disease.

FIGURE 1.35

Dracunculiasis, commonly known as Guinea Worm, is contracted when a person drinks the guinea worm larvae.

Guinea worm is a serious problem in parts of Africa that is being eradicated. Learn what is being done to decrease the number of people suffering from this parasite at the video below.

http://www.youtube.com/watch?v=u4kQWvUv_Ns

MEDIA

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URL: http://gamma.ck12.org/flx/render/embeddedobject/114938

Summary

- More than 1 billion people do not have access to water that is safe for drinking and washing.
- Waterborne diseases cause death and illness to people in many parts of the world.
- Government programs and international aid help to provide safe drinking water for some people.

Practice

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=nqvXjod_19A

1. How many children are killed by waterborne diseases every year?
2. What did one school in rural Kenya do to tackle its water problem?
3. What problems did the school have before the tank was built?
4. What has happened since the construction of the tank?
5. What burden do the students no longer have?
6. What is the source of water in the tank?

Practice Answers

1. about 760,000
2. It built a water tank.
3. They didn't have enough clean water for drinking, there wre waterborne disease outbreaks.
4. There are more students in the school.
5. They no longer have to haul water from home to school.
6. rainwater

Review

1. Would you go thirsty or would you drink from a water source that was visibly polluted?
2. Why do nations fail to provide safe drinking water for their people?
3. Why do waterborne diseases rarely strike in the developed world?

Review Answers

1. Answers will vary but most people would drink from a polluted water source if they got thirsty enough.
2. Usually it has to do with money. Creating infrastructure to treat used water and to deliver clean water to people is expensive.
3. We have water treatment plants that eliminate the pathogens.

1.14 Water Pollution

- Describe the sources of water pollution.

Is polluted water like this only seen in developing nations?

There is certainly polluted water in developed nations, but that water is cleaned and purified before it is put in taps and sent to people's homes. Pollutants come from a variety of sources.

Introduction

Freshwater and ocean pollution are serious global problems that affect the availability of safe drinking water, human health, and the environment. Waterborne diseases from water pollution kill millions of people in underdeveloped countries every year.

Sources of Water Pollution

Water pollution contributes to water shortages by making some water sources unavailable for use. In underdeveloped countries, raw sewage is dumped into the same water that people drink and bathe in. Even in developed countries, water pollution affects human and environmental health.

Water pollution includes any contaminant that gets into lakes, streams, and oceans. The most widespread source of water contamination in developing countries is raw sewage. In developed countries, the three main sources of water pollution are described below.

Municipal Pollution

Wastewater from cities and towns contains many different contaminants from many different homes, businesses, and industries (**Figure** 1.36). Contaminants come from:

- Sewage disposal (some sewage is inadequately treated or untreated).
- Storm drains.
- Septic tanks (sewage from homes).
- Boats that dump sewage.
- Yard runoff (fertilizer and herbicide waste).

FIGURE 1.36
Municipal and agricultural pollution.

Large numbers of sewage spills into San Francisco Bay are forcing cities, water agencies and the public to take a closer look at wastewater and its impacts on the health of the bay. QUEST investigates the causes of the spills and what's being done to prevent them.

Watch the investigation at http://science.kqed.org/quest/video/wastewater-woes-sewage-spills-in-sf-bay/ .

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Industrial Pollution

Factories and hospitals spew pollutants into the air and waterways (**Figure** 1.37). Some of the most hazardous industrial pollutants include:

- Radioactive substances from nuclear power plants and medical and scientific sources.
- Heavy metals, organic toxins, oils, and solids in industrial waste.
- Chemicals, such as sulfur, from burning fossil fuels.
- Oil and other petroleum products from supertanker spills and offshore drilling accidents.
- Heated water from industrial processes, such as power stations.

Agricultural Pollution

Runoff from crops, livestock, and poultry farming carries contaminants such as fertilizers, pesticides, and animal waste into nearby waterways (**Figure** 1.38). Soil and silt also run off farms. Animal wastes may carry harmful

FIGURE 1.37

Industrial Waste Water: Polluted water coming from a factory in Mexico. The different colors of foam indicate various chemicals in the water and industrial pollution.

diseases, particularly in the developing world.

FIGURE 1.38

The high density of animals in a factory farm means that runoff from the area is full of pollutants.

Fertilizers that run off of lawns and farm fields are extremely harmful to the environment. Nutrients, such as nitrates, in the fertilizer promote algae growth in the water they flow into. With the excess nutrients, lakes, rivers, and bays become clogged with algae and aquatic plants. Eventually these organisms die and decompose. Decomposition uses up all the dissolved oxygen in the water. Without oxygen, large numbers of plants, fish, and bottom-dwelling animals die.

Summary

- Municipal pollution comes from sewage, storm drains, septic tanks, boats, and runoff from yards.
- Industrial pollution, from factories and hospitals, includes radioactive substances; heavy metals and other pollutants in industrial waste; by-products of fossil fuel burning; oil and other petroleum products; and heat

from factories and power plants.
- Agricultural pollutants include wastes from animals, pesticides, herbicides, fertilizers, and soil.

Practice

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=phmN-IpR3xw

1. What is an example of point source pollution?
2. What is our biggest threat to clean water, at least in Indiana?
3. What are the common pollutants carried in non-source pollution?
4. Why does non-point source pollution have the greatest impact on water quality?
5. How does non-point source pollution end up in our water sources?
6. What are some of the common causes of non-point source pollution?

Practice Answers

1. Large pipes coming from industries and cities and releasing polluted water into water bodies.
2. Non-point source pollution, which comes from water that flows over fields, laws, parking lots and yards.
3. They are oils, chemicals, animal waste and soil.
4. It comes from everywhere and can be caused by daily activities magnified over the number of people.
5. Rainfall moves over and through the land and picks up and carries away natural and human made pollutants. It flows through storm drains and into lakes and streams. It can even filter underground.
6. Sources include over-applying fertilizer, herbicides and pesticides on plants; leaving oils and other chemicals on parking lots, roads, sidewalks and other hard surfaces; allowing soil erosion; leaving pet waste on the ground and not maintaining septic systems.

Review

1. How can fertilizers, which help things grow, be pollutants?
2. Why is raw sewage a major pollutant in some countries but not in developed countries?
3. How could heat be a pollutant? What damage could it cause?

Review Answers

1. Nutrients also promote algae growth in the water they flow into and then the waterways become clogged. These organisms die and decomposition uses up all the oxygen so there is no oxygen for other organisms and they die.
2. In developed countries sewage is treated before it is returned to the water system. Developing countries may not have enough money for this to happen.
3. Heated water can be harmful to an ecosystem that depends on water being a certain temperature. Organisms can die out and other organisms can take over.

1.15 Protecting Water From Pollution

- Explain how to reduce water pollution and clean up polluted water.

How do municipalities clean water?

We take clean water for granted because we have advanced wastewater treatment facilities that remove impurities with settling containers, filters, chemicals, and biological agents.

Reducing Water Pollution

Water pollution can be reduced in two ways:

- Keep the water from becoming polluted.
- Clean water that is already polluted.

Clean Water Act

Keeping water from becoming polluted often requires laws to be sure that people and companies behave responsibly. In the United States, the Clean Water Act gives the Environmental Protection Agency (EPA) the authority to set standards for water quality for industry, agriculture, and domestic uses. The law gives the EPA the authority to reduce the discharge of pollution into waterways, finance wastewater treatment plants, and manage runoff. Since its passage in 1972, more wastewater treatment plants have been constructed and the release of industrial waste into the water supply is better controlled.

The United Nations and other international groups are working to improve global water quality standards by providing the technology for treating water. These organizations also educate people in how to protect and improve the quality of the water they use (**Figure** 1.39).

FIGURE 1.39

Scientists control water pollution by sampling the water and studying the pollutants that are in the water.

Water Treatment

The goal of water treatment is to make water suitable for such uses as drinking, medicine, agriculture, and industrial processes.

People living in developed countries suffer from few waterborne diseases and illness, because they have extensive water treatment systems to collect, treat, and redeliver clean water. Many underdeveloped nations have few or no water treatment facilities.

Wastewater contains hundreds of contaminants, such as suspended solids, oxygen-demanding materials, dissolved inorganic compounds, and harmful bacteria. In a wastewater treatment plant, multiple processes must be used to produce usable water:

- **Sewage treatment** removes contaminants, such as solids and particles, from sewage.
- **Water purification** produces drinking water by removing bacteria, algae, viruses, fungi, unpleasant elements such as iron and sulfur, and man-made chemical pollutants.

The treatment method used depends on the kind of wastewater being treated and the desired end result. Wastewater is treated using a series of steps, each of which produces water with fewer contaminants.

What Can You Do?

What can individuals do to protect water quality?

- Find approved recycling or disposal facilities for motor oil and household chemicals.
- Use lawn, garden, and farm chemicals sparingly and wisely.
- Repair automobile or boat engine leaks immediately.
- Keep litter, pet waste, leaves, and grass clippings out of street gutters and storm drains.

Summary

- Keeping water from becoming polluted is easier, less expensive, and safer than cleaning it once it is polluted.
- Since the passage of the Clean Water Act, many wastewater treatment plants have been constructed and utilized.

- There are multiple levels of water treatment: some water is cleaned enough for use on lawns, while other water is cleaned enough to be safe for drinking.

Practice

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=ow-n8zZuDYc

1. What has the Clean Water Act been doing for the past four decades?
2. What has changed in the past 15 years?
3. What is keeping water clean about, according to the EPA Administrator?
4. Who depends on clean water?
5. Who had input into the new rules governing the Clean Water Act?
6. Does the proposal protect waters that were previously unprotected? What does it do?

Practice Answers

1. It has protected rivers, lakes, wetlands and coastal waters.
2. Two court decisions made it difficult to determine what is and is not protected, putting water bodies at risk.
3. It is about clean drinking water but also about keeping water clean in nature for people to enjoy.
4. Every sector of our economy: farms, manufacturers, and energy industry.
5. Input was taken from the Army Corps of Engineers, industry, and scientists.
6. No, it clarified which are protected and which are not. It cuts red tape to make protecting waters easier.

Review

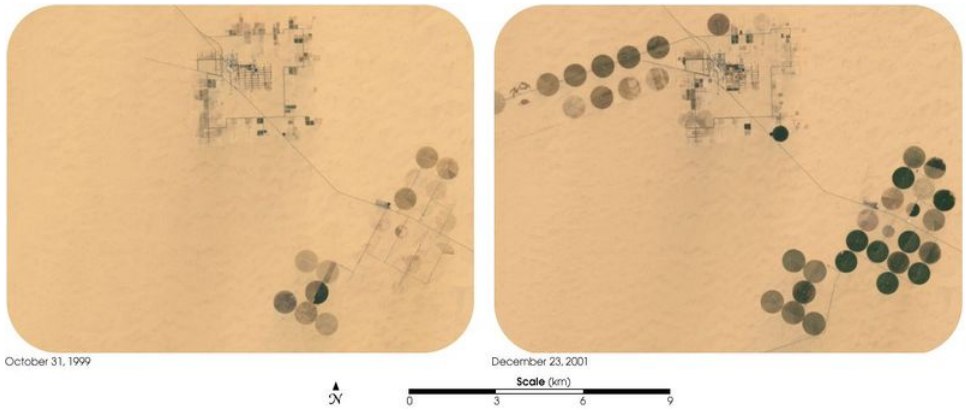
1. What is the purpose of the Clean Water Act?
2. How is wastewater treated?
3. What can the members of your household do to protect water quality?

Review Answers

1. It gives the EPA the authority to set water quality standards, to reduce pollution, to finance wastewater treatment plants and manage runoff.
2. Sewage is treated to remove contaminants and water that will be used for drinking is purified by removing micro-organisms and unpleasant elements and chemicals.
3. Individuals and households can dispose of hazardous wastes properly. use chemical sparingly or not at all. Repair leaks. Keep litter and wastes out of storm drains.

1.16 Groundwater Depletion

- Explain the causes and consequences of groundwater depletion.



Is it good to make the desert bloom?

Many sunny, arid regions are good for growing crops as long as water can be added. Some of the increase in productivity is due to farming in regions that are technically too dry. Groundwater can be used to make the desert bloom, but at what cost? And for how long? Eventually the wells will run dry.

Groundwater Overuse

Some aquifers are overused; people pump out more water than is replaced. As the water is pumped out, the water table slowly falls, requiring wells to be dug deeper, which takes more money and energy. Wells may go completely dry if they are not deep enough to reach into the lowered water table.

Other problems may stem from groundwater overuse. Subsidence and saltwater intrusion are two of them.

Ogallala Aquifer

The Ogallala Aquifer supplies about one-third of the irrigation water in the United States. The Ogallala Aquifer is widely used by people for municipal and agricultural needs. (**Figure** 1.41). The aquifer is found from 30 to 100 meters deep over an area of about 440,000 square kilometers!

The water in the aquifer is mostly from the last ice age. About eight times more water is taken from the Ogallala Aquifer each year than is replenished. Much of the water is used for irrigation (**Figure** 1.42).

Subsidence

Lowering the water table may cause the ground surface to sink. **Subsidence** may occur beneath houses and other structures (**Figure** 1.43).

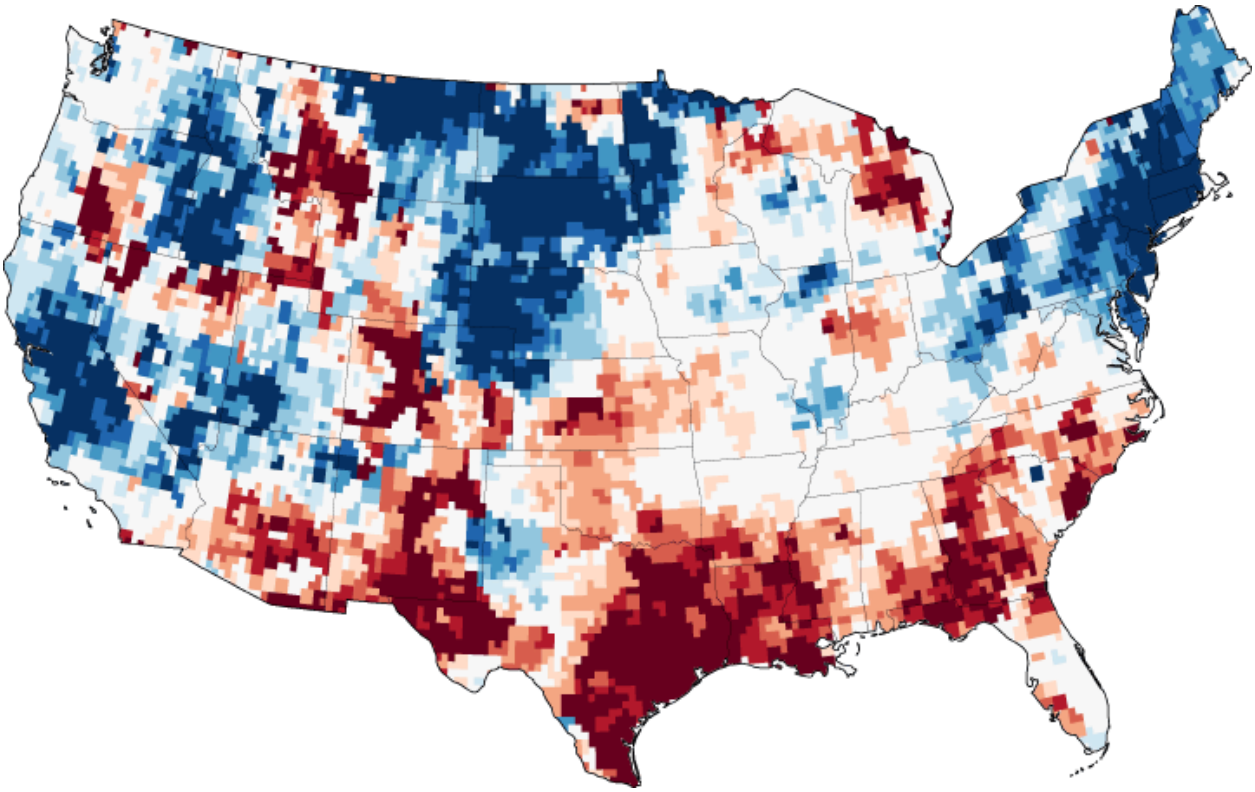


FIGURE 1.40

Intense drought has reduced groundwater levels in the southern U.S., particularly in Texas and New Mexico.

Salt Water Intrusion

When coastal aquifers are overused, salt water from the ocean may enter the aquifer, contaminating the aquifer and making it less useful for drinking and irrigation. Salt water incursion is a problem in developed coastal regions, such as on Hawaii.

Summary

- When water is pumped from an aquifer, the water table declines and wells must be drilled deeper.
- The Ogallala Aquifer was filled in the ice age but is being used to irrigate the farms of the Midwestern U.S. at a rate far greater than it is being replenished.
- Ground subsidence and saltwater intrusion are two possible consequences of groundwater overuse.

Practice

Use this resource to answer the questions that follow.

http://www.youtube.com/watch?v=o1QsCa7RmmU

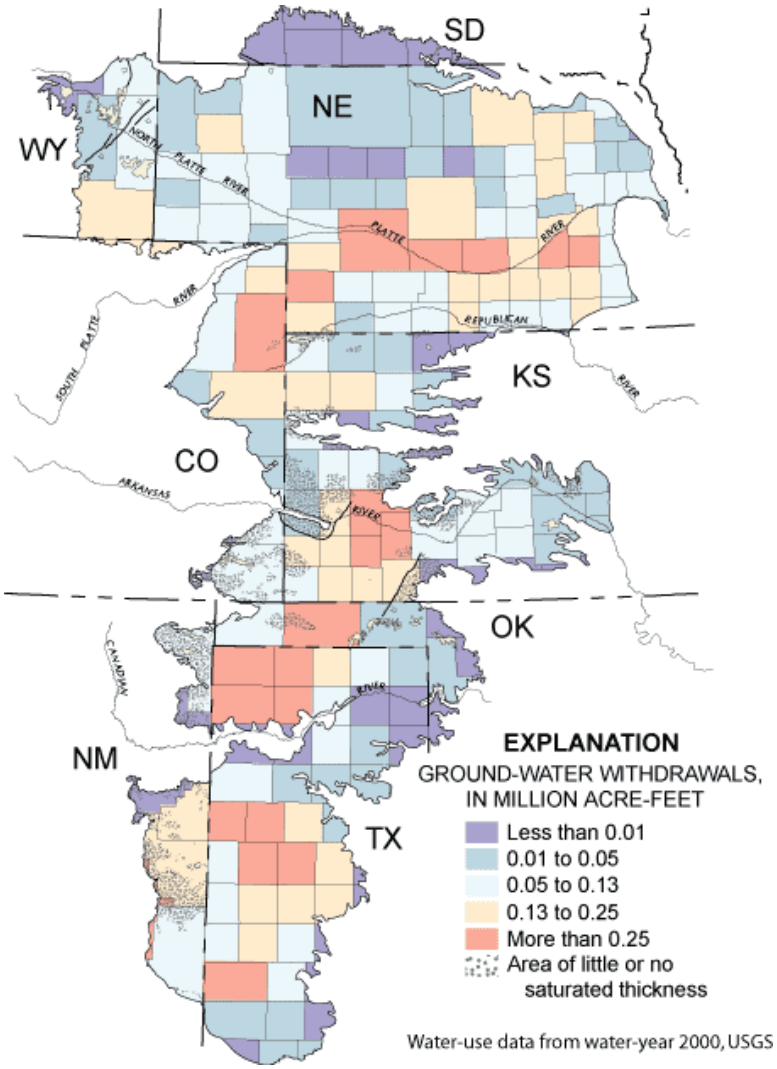


FIGURE 1.41

The Ogallala Aquifer is found beneath eight states and is heavily used.

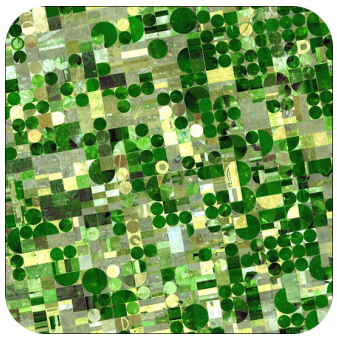


FIGURE 1.42

Farms in Kansas use central pivot irrigation, which is more efficient since water falls directly on the crops instead of being shot in the air. These fields are between 800 and 1600 meters (0.5 and 1 mile) in diameter.

MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/1549

FIGURE 1.43

The San Joaquin Valley of California is one of the world's major agricultural areas. So much groundwater has been pumped that the land has subsided many tens of feet.

1. How has irrigation changed farming?
2. What is leading to people's demands for additional water?
3. What do scientists need to see to better plan for future water use?
4. What is the GRACE satellite doing?
5. How does GRACE find groundwater aquifers?
6. How people know the aquifers are being depleted?
7. What is happening in India? what will happen if the water continues to decline?
8. What is the future of water?

Practice Answers

1. We have gone from demanding almost exclusively on rainfall but now use irrigation to grow where it is naturally too dry.
2. In some areas people are using water faster than its being replenished.
3. See how water moves through the water cycle. It is a big picture view to see where we get water from today and where we will find ourselves tomorrow.
4. Looking at groundwater from space.
5. Delicately mapping gravity because water bodies pull more on the satellite.
6. GRACE is finding how gravity changes over time; it feels the changes in groundwater.
7. Groundwater aquifers are being depleted rapidly. Agriculture and populations will not have the water they need.
8. Resources will become even scarcer. We need to shape the future better.

Review

1. What are some of the problems that come from overuse of groundwater?
2. How does salt water enter an aquifer?
3. In a location where the ground has subsided due to the extraction of groundwater from an aquifer, what do you think would happen if people tried to pump water back into the aquifer?

Review Answers

1. To get water wells need to be dug deeper; the ground can subside or salt water can intrude into the fresh water aquifer.
2. Fresh water is used near a coast; salt water enters the aquifer to fill the empty pore spaces.
3. The ground collapses and so water can't be pumped in.

1.17 Groundwater Pollution

- Describe how pollutants enter groundwater.

How could the water in this well be polluted?

Such an idyllic scene. The water from the well must taste as fresh as the springtime air. Of course, the water may be contaminated. Industrial waste from a factory down the road, or any number of other things, could have polluted the aquifer.

How Pollutants Enter Groundwater

Groundwater pollutants are the same as surface water pollutants: municipal, agricultural, and industrial. Groundwater is more susceptible to some sources of pollution. For example, irrigation water infiltrates into the ground, bringing with it the pesticides, fertilizers, and herbicides that were sprayed on the fields. Water that seeps through landfills also carries toxins into the ground. Toxic substances and things like gasoline are kept in underground storage tanks; more than 100,000 of the tanks are currently leaking and many more may develop leaks.

Filtered Water

Groundwater is a bit safer from pollution than surface water from some types of pollution because some pollutants are filtered out by the rock and soil that water travels through as it travels through the ground or once it is in the aquifer. But rock and soil can't get out everything, depending on the type of rock and soil and on the types of pollutants. As it is, about 25% of the usable groundwater and 45% of the municipal groundwater supplies in the United States are polluted.

FIGURE 1.44

Tanks may break and leak whatever toxins they contain into the ground.

Pollutant Plume

When the pollutant enters the aquifer, contamination spreads in the water outward from the source and travels in the direction that the water is moving. This pollutant plume may travel very slowly, only a few inches a day, but over time can contaminate a large portion of the aquifer. Many wells that are currently in use are contaminated. In Florida, for example, more than 90% of wells have detectible contaminants and thousands have been closed.

Summary

- Groundwater is susceptible to pollutants that infiltrate into the ground from underground storage tanks or agricultural fields.
- Rock and soil filters some pollutants as water travels down to and through an aquifer.
- A plume containing pollutants travels outward from the source and through the aquifer in the direction the water is moving.

Practice

Use this resource to answer the questions that follow.

http://www.youtube.com/watch?v=5xs1jLlbztE

MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/1543

1. What chemicals get into drinking water?
2. How does water get into the groundwater aquifer?
3. How does rock dissolve?
4. How does karst aquifers groundwater get contaminated?

5. What are the three types of contaminants?
6. What happens to these contaminates when it rains above a karst aquifer?
7. What do sediments increase pollution in an aquifer?

Practice Answers

1. cosmetics, pharmaceuticals, motor oil, paint, etc.
2. It infiltrates from the surface down into the aquifer.
3. Some types of rock dissolves; limestone dissolves in mild acids.
4. In karst aquifers water moves very quickly and it doesn't filter water and pollutants as much.
5. Pesticides, insecticides, herbicides; petroleum products; sediment and associated contaminants.
6. They are easily picked up by water and enter the karst aquifer.
7. Some phases of chemicals attach to the sediments and can go with them to contaminate the aquifer.

Review

1. Is groundwater always cleaner than surface water?
2. Is water that is advertised as spring water necessarily free of contaminants? Why or why not?
3. How does groundwater move into and through an aquifer?

Review Answers

1. No. Groundwater is more susceptible to some types of pollution and it's much harder to clean so it may be more polluted than surface water.
2. Spring water isn't necessarily pollutant free since 25% of groundwater is polluted and that's the source of spring water.
3. It infiltrates into the ground and also has inputs and outputs at streams. It has outputs at springs.

1.18 Cleaning Up Groundwater

- Describe how to clean up groundwater and explain why it is difficult and expensive.

Would you drink this water?

This water is obviously dirty, but some of the worst contaminants that can be in water are invisible. Those contaminants, especially when they are in groundwater, are extremely difficult to remove.

Cleaning Groundwater

Preventing groundwater contamination is much easier and cheaper than cleaning it. To clean groundwater, the water, as well as the rock and soil through which it travels, must be cleansed. Thoroughly cleaning an aquifer would require cleansing each pore within the soil or rock unit. For this reason, cleaning polluted groundwater is very costly, takes years, and is sometimes not technically feasible. If the toxic materials can be removed from the aquifer, disposing of them is another challenge.

Stages of Groundwater Cleaning

Elimination of the Pollution Source

If the source is an underground tank, the tank will be pumped dry and then dug out from the ground. If the source is a factory that is releasing toxic chemicals that are ending up in the groundwater, the factory may be required to stop the discharge.

Monitoring the Extent of the Pollutant

Hydrologists must determine how far, in what direction, and how rapidly the plume is moving. They must determine the concentration of the contaminant to determine how much it is being diluted. The scientists will use existing wells and may drill test wells to check for concentrations and monitor the movement of the plume.

FIGURE 1.45

Test wells are drilled to monitor groundwater pollution.

Modeling the Contaminant Plume

Using the well data, the hydrologist uses a computer program with information on the permeability of the aquifer and the direction and rate of groundwater flow, then models the plume to predict the dispersal of the contaminant through the aquifer. Drilling test wells to monitor pollution is expensive.

Remediation

First, an underground barrier is constructed to isolate the contaminated groundwater from the rest of the aquifer. Next, the contaminated groundwater may be treated in place.

Bioremediation is relatively inexpensive. Bioengineered microorganisms are injected into the contaminant plume and allowed to consume the pollutant. Air may be pumped into the polluted region to encourage the growth and reproduction of the microbes. With **chemical remediation**, a chemical is pumped into the aquifer so the contaminant is destroyed. Acids or bases can neutralize contaminants or cause pollutants to precipitate from the water.

The most difficult and expensive option is for reclamation teams to pump the water to the surface, cleanse it using chemical or biological methods, then re-inject it into the aquifer. The contaminated portions of the aquifer must be dug up and the pollutant destroyed by incinerating or chemically processing the soil, which is then returned to the ground. This technique is often prohibitively expensive and is done only in extreme cases.

Summary

- There are four stages needed to clean groundwater: remove the pollutant source, monitor the pollutant, model the contaminant plume, and perform remediation.
- By testing the water in many wells for a contaminant, scientists can model the contaminant plume in an aquifer.
- Cleaning groundwater in an aquifer usually requires bioremediation, the use of microorganisms that are bioengineered to consume a pollutant, or chemical remediation, which causes neutralizing chemical reactions.

Practice

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=-wdkGhJnCac End at 3:03.

1. What is the goal of project 6 at UC Berkeley?
2. For this project: What does oxidation refer to? What is in situ?
3. What is in situ chemical oxidation (ISCO)?
4. How does ISCO work?
5. What is the speaker using for an oxidant? What must be done to this chemical before it can be used for this purpose?
6. What makes this work difficult to accomplish?

Practice Answers

1. It is to develop and test new methods for treating contaminants using existing technologies.
2. Oxidation: breakdown or transformation into forms that may be less harmful; in situ: the treatment happens within the aquifer?
3. An oxidant is added to the aquifer; the oxidant reacts with the contaminant, which degrades it; the degradation reduces toxicity.
4. Wells are injected into the aquifer and oxidative solution is added to mix with contaminants to degrade them in place.
5. Persulfate; the persulfate must be activated and he is working on how to make it faster.
6. It's all happening underground.

Review

1. Why does cleaning groundwater in an aquifer also require cleaning the soil or rock that the water travels through?
2. Describe how bioremediation works. Why is this a good way to clean an aquifer without removing the water?
3. How do scientists monitor and model a contaminant plume?

Review Answers

1. If the rock isn't cleaned the water will just get contaminated again when it is reintroduced to the aquifer.
2. Bioengineered microorganisms are injected into the contaminant plume and allowed to consume the pollutant. The water and rock doesn't have to be removed because the microorganisms work in place.
3. Scientists use well data entered into a computer program to predict the direction and rate of groundwater flow and therefore how the plume will advance.

1.19 Conserving Water

- Describe ways to conserve water.

You can help to use less water by conserving in your own home. One way is to install a low-flow shower head to reduce the amount water used during showers.

How Society Can Conserve Water

Water consumption per person has been going down for the past few decades. There are many ways that water conservation can be encouraged. Charging more for water gives a financial incentive for careful water use. Water use may be restricted by time of day, season, or activity. Good behavior can be encouraged; for example, people can be given an incentive to replace grass with desert plants in arid regions.

FIGURE 1.46

This colorful adobe house in Tucson, Arizona is surrounded by native cactus, which needs little water to thrive.

How You Can Conserve Water

As human population growth continues, water conservation will become increasingly important globally, especially in developed countries where people use an enormous amount of water. What are some of the ways you can conserve water in and around your home?

- Avoid polluting water so that less is needed.
- Convert to more efficient irrigation methods on farms and in gardens.
- Reduce household demand by installing water-saving devices such as low-flow shower heads and toilets.
- Reduce personal demand by turning off the tap when water is not being used and taking shorter showers.
- Engage in water-saving practices: for instance, water lawns less and sweep rather than hose down sidewalks.

How you can conserve water at home is the subject of this National Geographic video, "Conserve Water": http://video.nationalgeographic.com/video/environment/going-green-environment/green-home-makeover/conserve-water-greenguide/ . Other videos for making your home greener are found on that page as well.

At Earth Summit 2002, many governments approved a Plan of Action to address the scarcity of water and safe drinking water in developing countries. One goal of this plan was to cut in half the number of people without access to safe drinking water by 2015. Although this is a very important goal, it will not be met. Goals like these are made more difficult as population continues to grow.

Summary

- Society can reduce water consumption by making policies that encourage or require conservation.
- People can reduce water consumption by taking shorter showers, installing water-saving devices, and many other methods.
- Financial incentives can work to encourage people to conserve water and other resources.

Practice

Use this resource to answer the questions that follow.

http://www.youtube.com/watch?v=4MDLpVHY8LE

MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/1526

1. What percentage of water is used in the bathroom?
2. How do low-flow toilets conserve water?
3. What does an aerator do?
4. List additional tips for saving water that don't cost anything.
5. How much water does a professional car war wash use?
6. Why shouldn't you use the garden hose to wash a car?

Practice Answers

1. 60% of all water in the home

2. They use only 1/3 as much water.
3. Aerators mix air bubbles into the stream so you get as much pressure without as much water.
4. Turn water off while brushing teeth; fill sink with water and turn it off while shaving; fill toilet with container of rocks to displace water to reduce amount used per flush; fix any leaks immediately; don't use toilet as trash can; reduce time spent showering; fill tub with water to irrigate lawn.
5. Professional car wash uses 35 gallons.
6. It uses too much water and adds pollutants to water stream.

Review

1. Why does your choice of garden plants affect the water consumption of your household?
2. How does water pollution reduce the amount of water that is available for people to use?
3. Why is providing clean water to all people so difficult? Why is it so important?

Review Answers

1. Plants should be adapted to the water of a region. If high water plants are used in low water areas, a lot more water will need to be put on the plants.
2. If polluted water can't be used then the amount will be reduced.
3. It is difficult and costly to clean water, but it is necessary due to waterborne diseases.

1.20 Coastal Pollution

- Explain the relationship between coastal pollution and marine dead zones.

Fertilizer makes things grow. How could it cause a dead zone?

Fertilizer from farms and yards carried from the Mississippi River into the Gulf of Mexico creates an enormous dead zone, where algae use up all the oxygen and nothing else can live. The largest, in 2002, was about 22,000 square kilometers (8,400 mi^2).

Ocean Pollution

Most ocean pollution comes as runoff from land and originates as agricultural, industrial, and municipal wastes (**Figure** 1.47). The remaining 20% of water pollution enters the ocean directly from oil spills and people dumping wastes directly into the water. Ships at sea empty their wastes directly into the ocean, for example.

Coastal pollution can make coastal water unsafe for humans and wildlife. After rainfall, there can be enough runoff pollution that beaches must be closed to prevent the spread of disease from pollutants. A surprising number of beaches are closed because of possible health hazards each year.

A large proportion of the fish we rely on for food live in the coastal wetlands or lay their eggs there. Coastal runoff from farm waste often carries water-borne organisms that cause lesions that kill fish. Humans who come in

FIGURE 1.47

In some areas of the world, ocean pollution is all too obvious.

contact with polluted waters and affected fish can also experience harmful symptoms. More than one-third of the shellfish-growing waters of the United States are adversely affected by coastal pollution.

A National Geographic video, "Why the Ocean Matters," has beautiful footage and a brief introduction to some of the problems facing the seas: http://video.nationalgeographic.com/video/environment/habitats-environment/habitats-oceans-env/why-ocean-matters/ .

Dead Zones

Fertilizers that run off of lawns and farm fields are extremely harmful to the environment. Nutrients, such as nitrates, in the fertilizer promote algae growth in the water they flow into. With the excess nutrients, lakes, rivers, and bays become clogged with algae and aquatic plants. Eventually these organisms die and decompose. Decomposition uses up all the dissolved oxygen in the water. Without oxygen, large numbers of plants, fish, and bottom-dwelling animals die.

Every year dead zones appear in lakes and nearshore waters. A dead zone is an area of hundreds of kilometers of ocean without fish or plant life.

The Mississippi is not the only river that carries the nutrients necessary to cause a dead zone. Rivers that drain regions where human population density is high and where crops are grown create dead zones all over the world (**Figure** 1.48).

Summary

- Most ocean pollution comes from land and much congregates in the coastal regions.
- Excess fertilizer travels in rivers to the sea and causes algae to bloom. These algae die and decomposition uses up the oxygen in an area, causing a dead zone.
- The dead zone in the Gulf of Mexico from Mississippi River runoff is getting larger each year.

Practice

Use these resources to answer the questions that follow

http://www.youtube.com/watch?v=xLv1vPEQyM0

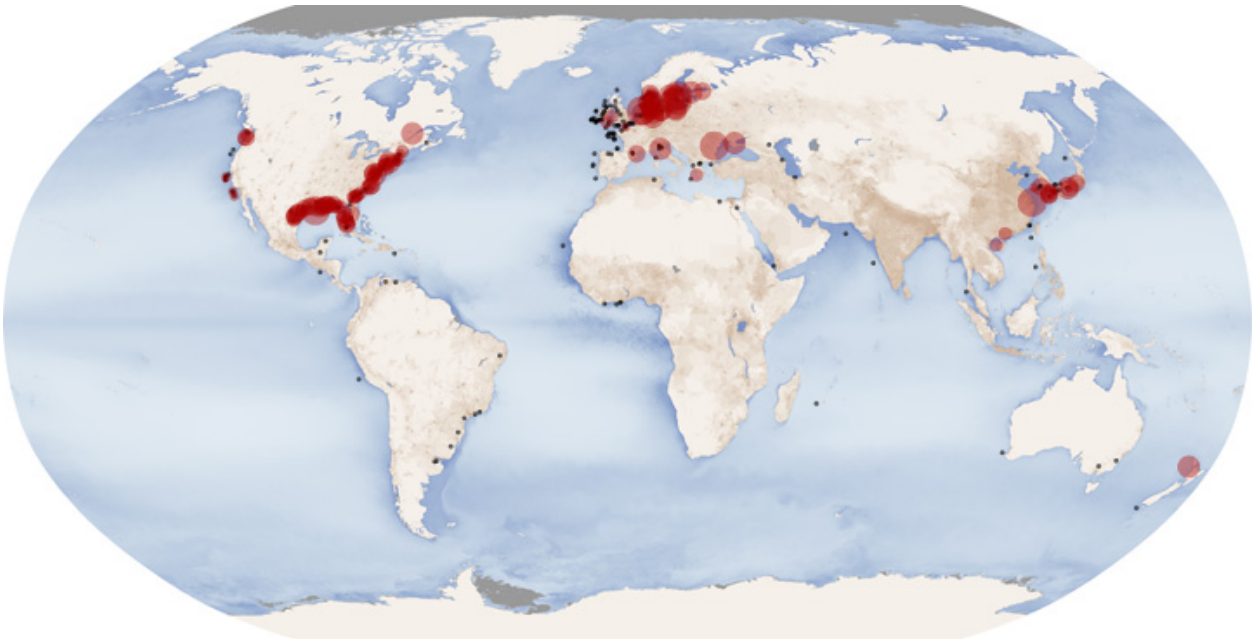


FIGURE 1.48

Dead zones off the coasts. Red dots show the location and size of the dead zone; black circles show the location but the size is unknown. Darker blue regions of the oceans indicate that organic particulates are high and may lead to a dead zone.

MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/1520

1. Why does the US Coast Guard do vehicle patrols?
2. Why are storm drains under US Coast Guard jurisdiction?
3. What is the purpose of the pollution fines?

http://www.youtube.com/watch?v=MBpnuYul7B8

MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/1521

1. What typically makes a beach unfit for swimming?

2. What percent of samples violated public health standards for the year this video was made?
3. What is the danger of swimming in contaminated water?
4. What is the danger of digging in the sand?

Practice Answers

- Coast Guard

1. They do this to enforce the Clean Water Act on anything that may end up in the coastal water.
2. The material in the storm drain ends up in coastal waters.
3. To prevent oil spills; if someone gets fined they may not do the same thing again.

- Beach Contamination

1. Runoff after a big storm brings in lots of pollutants.
2. 7%
3. skin rash, pink eye, gastrointestinal illnesses
4. Sand can be contaminated; diggers are 13% more likely to end up with a stomach ailment

Review

1. What are the consequences of coastal pollution?
2. What are the sources of coastal pollution?
3. What sequence of events causes a dead zone?

Review Answers

1. The water is unsafe for humans and wildlife due to diseases and other health hazards.
2. Rainfall brings in wastes that are found on land. They can be from agriculture, industry and cities.
3. Fertilizers run off lawns and farms and enter coastal water. This promotes algae growth and aquatic plants. The organisms die and decompose, which uses all the oxygen in the water. Without oxygen all the other organisms die.

1.21 Ocean Garbage Patch

- Explain how trash ends up as ocean debris.
- Trace the path of trash to the ocean garbage patch.

How could these balloons kill a sea turtle?

Balloons flying off into the sky symbolize freedom and happiness. Eventually those balloons pop and the plastic falls to the surface. Much of this plastic will end up in the sea where it may be accidentally ingested by a marine organism —with dire results.

Marine Trash

Trash from land may end up as trash in the ocean, sometimes extremely far from land. Some of it will eventually wash ashore, possibly far from where it originated (**Figure** 1.49).

Sources of Trash

Although people had once thought that the trash found everywhere at sea was from ships, it turns out that 80% is from land. Some of that is from runoff, some is blown from nearshore landfills, and some is dumped directly into the sea.

The 20% that comes from ships at sea includes trash thrown overboard by large cruise ships and many other vessels. It also includes lines and nets from fishing vessels. Ghost nets, nets abandoned by fishermen intentionally or not, float the seas and entangle animals so that they cannot escape. Containers sometimes go overboard in storms. Some noteworthy events, like a container of rubber ducks that entered the sea in 1992, are used to better understand ocean currents. The ducks went everywhere!

FIGURE 1.49
Trash has washed up on this beach.

Makeup of Trash

About 80% of the trash that ends up in the oceans is plastic. This is because a large amount of the trash produced since World War II is plastic. Also many types of plastic do not biodegrade, so they simply accumulate. While many types of plastic photodegrade —that is, they break up in sunlight —this process only works when the plastics are dry. Plastic trash in the water does break down into smaller pieces, eventually becoming molecule-sized polymers. Other trash in the oceans includes chemical sludge and materials that do biodegrade, like wood.

Toxic chemicals

Some plastics contain toxic chemicals, such as bisphenol A. Plastics can also absorb organic pollutants that may be floating in the water, such as the pesticide DDT (which is banned in the U.S. but not in other nations) and some endocrine disruptors.

Effect on Organisms

Marine birds, such as albatross, or animals like sea turtles, live most of their lives at sea and just come ashore to mate. These organisms can't break down the plastic and they may eventually die (**Figure** 1.50). Boats may be affected. Plastic waste is estimated to kill 100,000 sea turtles and marine mammals annually, but exact numbers are unknown.

Plastic shopping bags are extremely abundant in the oceans. If an organism accidentally ingests one, it may clog digestion and cause starvation by stopping food from moving through or making the animal not feel hungry.

The Great Pacific Garbage Patch

Trash from the lands all around the North Pacific is caught up in currents. The currents bring the trash into the center of the North Pacific Gyre. Scientists estimate that it takes about six years for trash to move from west coast of North America to the center of the gyre. The concentration of trash increases toward the center of the gyre.

While recognizable pieces of garbage are visible, much of the trash is tiny plastic polymers that are invisible but can be detected in water samples. The particles are at or just below the surface within the gyre. Plastic confetti-like pieces are visible beneath the surface at the gyre's center.

FIGURE 1.50
This albatross likely died from the plastic it had ingested.

FIGURE 1.51
Plastic bags in the ocean can be mistaken for food by an unsuspecting marine predator.

The size of the garbage patch is unknown, since it can't be seen from above. Some people estimate that it's twice the size of continental U.S, with a mass of 100 million tons.

Effect on Organisms

In some areas, plastics have seven times the concentration of zooplankton. This means that filter feeders are ingesting a lot of plastics. This may kill the organisms or the plastics may remain in their bodies. They are then eaten by larger organisms that store the plastics and may eventually die. Fish may eat organisms that have eaten plastic and then be eaten by people. This also exposes humans to toxic chemicals that the fish may have ingested with the plastic.

There are similar patches of trash in the gyres of the North Atlantic and Indian oceans. The Southern Hemisphere has less trash buildup because less of the region is continent.

Summary

- Trash from land (80%) or human activities at sea (20%) ends up in the oceans; about 80% of this trash is plastic.
- Plastic trash does not usually biodegrade in the ocean but just forms tiny polymers that resemble plankton.
- Plastic pieces of trash and plastic molecules can kill marine organisms by becoming lodged in their digestive systems or by trapping them so they can't swim.

Practice

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=_pRy88R-4BI

1. Why is plastic different from every other substance on Earth? What does that mean?
2. If it never deteriorates, where does it go?
3. Where is the Great Pacific Garbage Patch?
4. What is found on Midway Island?
5. Where does the debris come from?
6. What happens to ocean animals that run into the plastic?

Practice Answers

1. It never goes away. It's virtually indestructible. Every molecule of plastic ever created is somewhere on this planet.
2. A lot goes into the oceans.
3. Midway in the Pacific Ocean.
4. Albatross and tens of thousands of pounds of garbage wash up every year.
5. The big cities of North America and Asia.
6. They eat it so they can't eat food; they get trapped in it so they can't escape.

Review

1. How can plastic kill marine organisms?
2. Since plastic doesn't biodegrade in the oceans, what does the future hold? What can be done to make the future better?
3. Some people say that the Great Pacific Garbage Patch is a hoax. What can scientists do to show people that it is real?

Review Answers

1. they eat it thinking it's food; they get trapped in it and can't escape.
2. All the plastic that has been created and will be created will continue to exist for a very long time.
3. Take water samples; show photos of the patch; take news organizations to it. Some people are just not going to believe anything they don't want to believe so write them off.

1.22 Oil Spills

- Describe the damage that occurs from oil spills.

Will this oil spill victim live?

After every oil spill, photos are released of marine organisms covered with oil. Sometimes people are trying to clean them. Seabirds are especially vulnerable; they dive into a slick because the surface looks like calmer water. Oil-coated birds cannot regulate their body temperatures and will die. After cleanup, some birds will live and some will not.

Oil Spills

Large oil spills, like the Exxon Valdez in Alaska in 1989, get a lot of attention, as they should. Besides these large spills, though, much more oil enters the oceans from small leaks that are only a problem locally. In this concept, we'll take a look at a large recent oil spill in the Gulf of Mexico.

The Gulf of Mexico Oil Spill

New drilling techniques have allowed oil companies to drill in deeper waters than ever before. This allows us to access oil deposits that were never before accessible, but only with great technological difficulty. The risks from deepwater drilling and the consequences when something goes wrong are greater than those associated with shallower wells.

Explosion

Working on oil platforms is dangerous. Workers are exposed to harsh ocean conditions and gas explosions. The danger was never more obvious than on April 20, 2010, when 11 workers were killed and 17 injured in an explosion on a deepwater oil rig in the Gulf of Mexico (**Figure** 1.52). The drilling rig, operated by BP, was 77 km (48 miles) offshore and the depth to the well was more than 5,000 feet.

FIGURE 1.52

The U.S. Coast Guard tries to put out the fire and search for missing workers after the explosion on the Deepwater Horizon drilling rig. Eleven workers were killed.

Spill

Two days after the explosion, the drill rig sank. The 5,000-foot pipe that connected the wellhead to the drilling platform bent. Oil was free to gush into the Gulf of Mexico from nearly a mile deep (**Figure** 1.53). Initial efforts to cap or contain the spill at or near its source all failed to stop the vast oil spill. It was not until July 15, nearly three months after the accident, that the well was successfully capped.

Estimating the flow of oil into the Gulf from the well was extremely difficult because the leak was so far below the surface. The U.S. government estimates that about 4.9 million barrels entered the Gulf at a rate of 35,000 to 60,000 barrels a day. The largest previous oil spill in the United States was of 300,000 barrels by the Exxon Valdez in 1989 in Prince William Sound, Alaska.

Cleanup

Once the oil is in the water, there are three types of methods for dealing with it:

1. Removal: Oil is corralled and then burned; natural gas is flared off (**Figure** 1.54). Machines that can separate oil from the water are placed aboard ships stationed in the area. These ships cleaned tens of thousands of barrels of contaminated seawater each day.

2. Containment: Floating containment booms are placed on the surface offshore of the most sensitive coastal areas in an attempt to attempt to trap the oil. But the seas must be calm for the booms to be effective, and so were not very useful in the Gulf (**Figure** 1.55). Sand berms have been constructed off of the Louisiana coast to keep the oil from reaching shore.

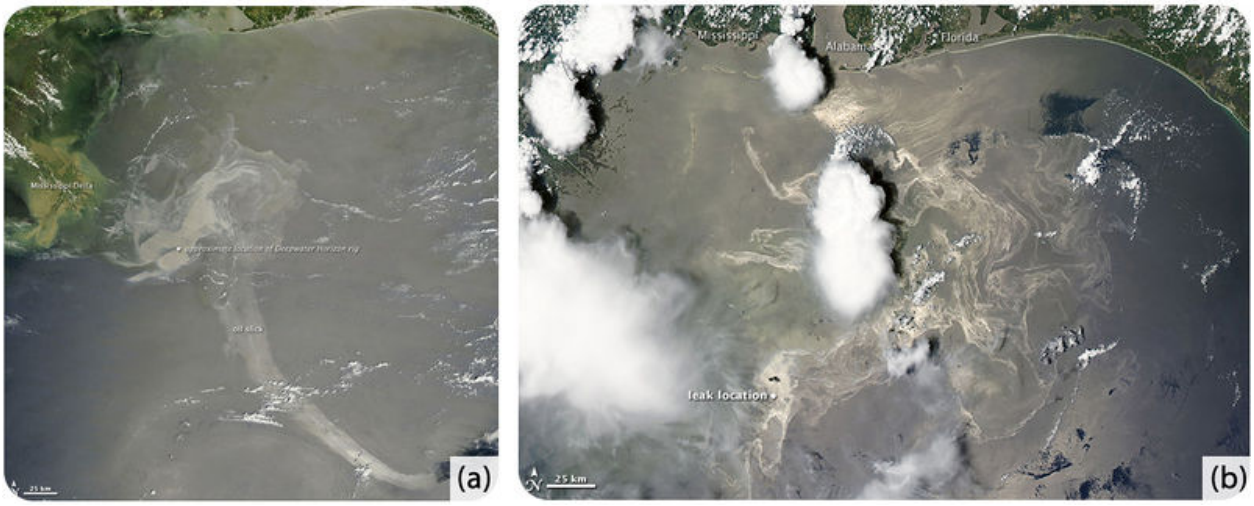


FIGURE 1.53

(a) On May 17, 2010, oil had been leaking into the Gulf for nearly one month. On that date government estimates put the maximum total oil leak at 1,600,000 barrels, according to the New York Times. (b) The BP oil spill on June 19, 2010. The government estimates for total oil leaked by this date was 3,200,000 barrels.

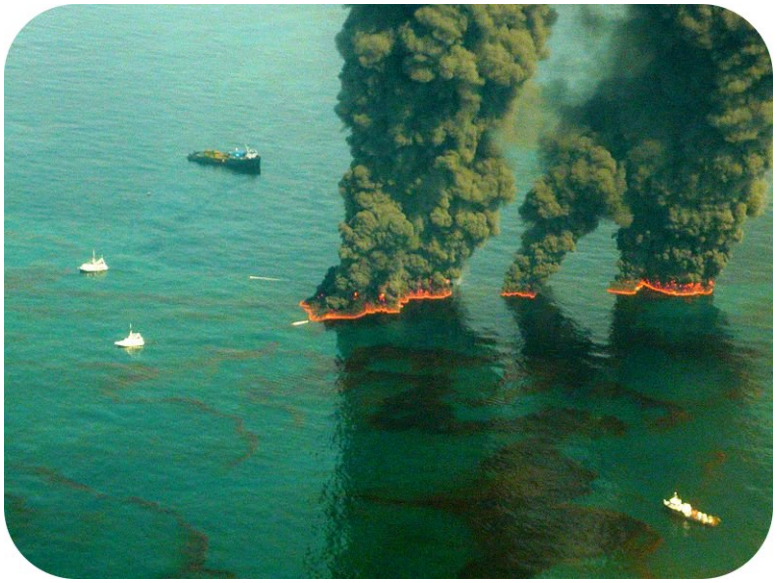


FIGURE 1.54

Burning the oil can reduce the amount in the water.

3. Dispersal: Oil disperses naturally over time because it mixes with the water. However, such large amounts of oil will take decades to disperse. To speed the process up, BP has sprayed unprecedented amounts of chemical dispersants on the spill. That action did not receive support from the scientific community since no one knows the risks to people and the environment from such a large amount of these harmful chemicals. Some workers may have become ill from exposure to the chemicals.

FIGURE 1.55
A containment boom holds back oil, but it is only effective in calm water.

Plugging the Well

BP drilled two relief wells into the original well. When the relief wells entered the original borehole, specialized liquids were pumped into the original well to stop the flow. Operation of the relief wells began in August 2010. The original well was declared effectively dead on September 19, 2010.

Impact

The economic and environmental impact of this spill will be felt for many years. Many people rely on the Gulf for their livelihoods or for recreation. Commercial fishing, tourism, and oil-related jobs are the economic engines of the region. Fearing contamination, NOAA imposed a fishing ban on approximately one-third of the Gulf (**Figure** 1.56). Tourism is down in the region as beach goers find other ways to spend their time. Real estate prices along the Gulf have declined precipitously.

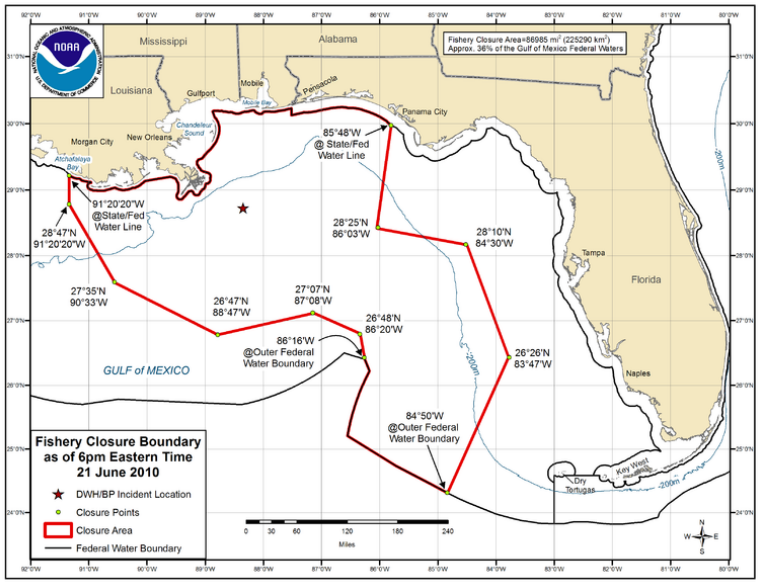


FIGURE 1.56
This was the extent of the banned area on June 21, 2010.

The toll on wildlife is felt throughout the Gulf. Plankton, which form the base of the food chain, are killed by the oil, leaving other organisms without food. Islands and marshlands around the Gulf have many species that are already at risk, including four endangered species of sea turtles. With such low numbers, rebuilding their populations after the spill will be difficult.

The Gulf of Mexico is one of only two places in the world where bluefin tuna spawn and they are also already endangered. Marine mammals in the Gulf may come up into the slick as they come to the surface to breathe.

Eight national parks and seashores are found along the Gulf shores. Other locations may be ecologically sensitive habitats such as mangroves or marshlands.

Long-Term Effects

There is still oil on beaches and in sediment on the seafloor in the region. Chemicals from the oil dispersants are still in the water. In October 2011 a report was issued that showed that whales and dolphins are dying in the Gulf at twice their normal rate. The long-term effects will be with us for a long time.

Summary

- As oil becomes scarcer, there are economic incentives to drill in deeper water, but this is a technologically difficult undertaking.
- There are still chemicals in the water that cause damage to wildlife.
- Massive amounts of oil that have been spilled into a water body can be removed, contained, or dispersed. These actions are difficult and may have negative consequences.
- Birds or beaches coated with oil are the most visible evidence of a spill, but there are many consequences that we can't see, like oil on the seabed or chemical dispersants in the water.

Practice

Use the resource below to answer the questions that follow.

https://www.youtube.com/watch?v=VaRdUHrUnBs

1. What were the causes of the Exxon Valdez disaster?
2. What were the oil industry's response plans?
3. What was the industry's response actually?
4. What were chemical dispersants used for?
5. What were the concerns brought about by the use of chemical dispersants?
6. How much of the oil was recovered?
7. Who was assigned responsibility for the spill? What was lost?
8. When plan for the Alaska pipeline was drawn up, how was the environment to be protected? What was the mistake made by the state?
9. What happened when the state passed its own safety law?
10. How did the passage of ships change from when the oil first was passing through the area to when the Exxon Valdez spill happened?
11. What was supposed to be done during the time the ship was going through the channel, who was supposed to do it, and what was actually happening?
12. What was the long-term damage?
13. What are the safeties now in place?
14. What does it mean that the offense got ahead of the defense in the Gulf of Mexico?
15. How had cleanup changed in two decades?
16. Have we really learned the lessons of Exxon Valdez and Gulf of Mexico spills?

Practice Answers

1. The captain had been drinking and safety was not up to what it should have been.
2. The promised a swift cleanup in the event of a spill with a response within 6 hours.
3. They weren't ready for such a large spill. The response team had been disbanded. The Coast Guard didn't know what to do. Equipment had to be flow in in from far way.
4. They were used to break up the oil.
5. The chemicals themselves are harmful to marine life.
6. Less than 15%.
7. The captain was called responsible but the companies shirked responsibility.
8. The environment would be protected by double hulled tankers and advanced navigation systems. The state did not get these assurances in writing.
9. Oil companies sued saying that the law infringed on federal authority. The courts threw out the state's plan.
10. Initially the ships were supposed to stay in the shipping lanes even if they were clogged with ice. They were supposed to slow down. Later the ships left the channel to avoid the ice.
11. The Coast Guard was supposed to be watching the ship but wasn't; the captain was supposed to be piloting the ship but he left it to the third mate. Tanker crews were overworked and the third mate was probably tired so he ran aground.
12. Pockets of oil remain two decades later; the community is depressed because the local economy never recovered.
13. Double hulled tankers, tug boat escorts for ships in the sound, cleanup research, better contingency planning.
14. The potential risks increased dramatically but there was no increase in capability of avoiding or responding to accidents.
15. Response plans didn't change much; chemical dispersents were used and no one knows if they do more harm than good.
16. We'll need to see in 20 years.

Review

1. What precautions should be made to be sure that there is little chance of negative consequences from an oil spill?
2. How do chemical dispersants work? Should they always be used?
3. What are the long-term effects of a major oil spill?

Review Answers

1. The best thing to do is for the spill not to happen because they are very hard to clean up. If oil does spill it should be contained and removed or burned. Oil disperses naturally over time, although a large spill could take decades.
2. Dispersents break up the oil, but they are harmful chemicals and no one knows if they are better or worse for the environment than the spilled oil.
3. Beaches have oil buried beneath the surface layer. Chemicals from dispersents remain in the water. Organisms have long term effects on their reproduction and length of life.

1.23 Air Quality

- Explain how air pollution affects air quality.

What is this in the air?

People have euphemisms for smog; sometimes it's fog, sometimes it's haze. It's hard to know sometimes whether the air is full of something natural, like water vapor, or something man-made, like ozone. But in cities like this the air is often being marred by air pollution.

Air Quality

Pollutants include materials that are naturally occurring but are added to the atmosphere so that they are there in larger quantities than normal. Pollutants may also be human-made compounds that have never before been found in the atmosphere. Pollutants dirty the air, change natural processes in the atmosphere, and harm living things.

Problems with Air Quality

Air pollution started to be a problem when early people burned wood for heat and cooking fires in enclosed spaces such as caves and small tents or houses. But the problems became more widespread as fossil fuels such as coal began to be burned during the Industrial Revolution.

Smog

Air pollution started to be a problem when early people burned wood for heat and cooking fires in enclosed spaces such as caves and small tents or houses. But the problems became more widespread as fossil fuels such as coal began to be burned during the Industrial Revolution (**Figure** 1.57).

FIGURE 1.57

The 2012 Olympic Games in London opening ceremony contained a reenactment of the Industrial Revolution - complete with pollution streaming from smokestacks.

Photochemical Smog

Photochemical smog, a different type of air pollution, first became a problem in Southern California after World War II. The abundance of cars and sunshine provided the perfect setting for a chemical reaction between some of the molecules in auto exhaust or oil refinery emissions and sunshine (**Figure** 1.58). Photochemical smog consists of more than 100 compounds, most importantly ozone.

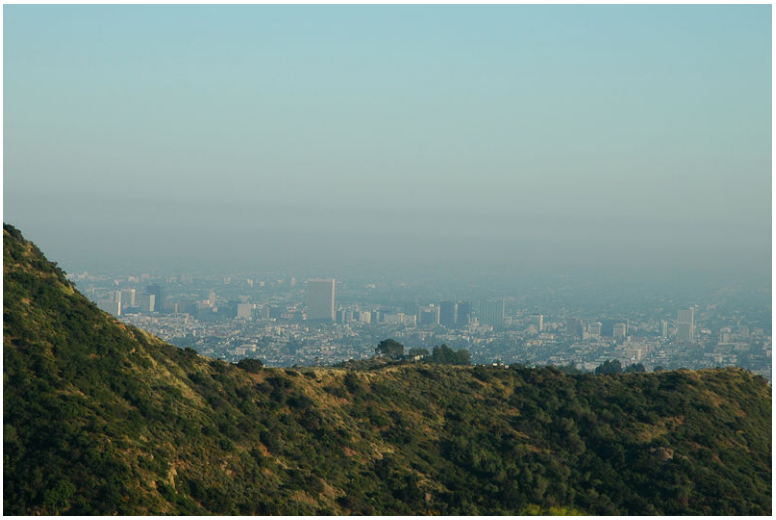


FIGURE 1.58

Smog over Los Angeles as viewed from the Hollywood Hills.

The Clean Air Act

Terrible air pollution events in Pennsylvania and London, in which many people died, plus the recognition of the hazards of photochemical smog, led to the passage of the Clean Air Act in 1970 in the United States. The act now regulates 189 pollutants. The six most important pollutants regulated by the Act are ozone, particulate matter, sulfur dioxide, nitrogen dioxide, carbon monoxide, and the heavy metal lead. Other important regulated pollutants include benzene, perchloroethylene, methylene chloride, dioxin, asbestos, toluene, and metals such as cadmium, mercury, chromium, and lead compounds.

What is the result of the Clean Air Act? In short, the air in the United States is much cleaner. Visibility is better and people are no longer incapacitated by industrial smog. However, despite the Act, industry, power plants, and vehicles put 160 million tons of pollutants into the air each year. Some of this smog is invisible and some contributes to the orange or blue haze that affects many cities.

Regional Air Quality

Air quality in a region is not just affected by the amount of pollutants released into the atmosphere in that location but by other geographical and atmospheric factors. Winds can move pollutants into or out of a region and a mountain range can trap pollutants on its leeward side. Inversions commonly trap pollutants within a cool air mass. If the inversion lasts long enough, pollution can reach dangerous levels.

Pollutants remain over a region until they are transported out of the area by wind, diluted by air blown in from another region, transformed into other compounds, or carried to the ground when mixed with rain or snow.

Table 1.3 lists the smoggiest cities in 2013: 7 of the 10 are in California. Why do you think California cities are among those with the worst air pollution?

The state has the right conditions for collecting pollutants including mountain ranges that trap smoggy air, arid and sometimes windless conditions, agriculture, industry, and lots and lots of cars.

TABLE 1.3: Smoggiest U.S. Cities, 2013

Rank	City, State
1	Los Angeles area, California
2	Visalia-Porterville, California
3	Bakersfield-Delano, California
4	Fresno-Madera, California
5	Hanford-Corcoran, California
6	Sacramento area, California
7	Houston area, Texas
8	Dallas-Fort Worth, Texas
9	Washington D.C. area
10	El Centro, California

Summary

- Air is polluted by natural compounds in unnatural quantities or by unnatural compounds.
- Some pollutants enter the air directly and others are created by chemical reactions, such as those that are part of photochemical smog.
- Regions that are chronically polluted experience the release of a lot of pollutants into the air. The effects of pollution may also be amplified by geographical and atmospheric factors.

Practice

Use this resource to answer the questions that follow.

http://www.youtube.com/watch?v=CRmR9MDjPK4

MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/1535

1. What causes air quality problems on the East Coast?
2. What is NASA trying to do with this mission?
3. What problems do satellites have?
4. What 5 pollutants can be seen from space?
5. Why does the airplane spiral up and down?
6. How do the scientists study the 1000 feet closest to the ground?
7. What is the goal of the research?

Practice Answers

1. Local sources like motor vehicle traffic, plus upwind sources like power plants and population center.
2. Take a picture of the atmosphere that's complete. Take a satellite measurement of a column of atmosphere and relate that to what's going on at the surface.
3. Satellites have a hard time distinguishing between pollution that's aloft and pollution that's at ground level.
4. particulate matter, ozone, nitrogen dioxide, formaldehyde, carbon dioxide
5. To see what's happening vertically and compare it with what's happening on the ground.
6. They have to use balloons.
7. To predict air quality, to provide information to improve models.

Review

1. How does photochemical smog differ from other types of air pollution?
2. What does the Clean Air Act regulate? what are the most important pollutants it regulates?
3. Why do parts of California have such bad air pollution?

Review Answers

1. Photochemical smog is the result of a chemical reaction between pollutants and sunshine. It does not come directly from the burning of fossil fuels.
2. The Act regulates 189 pollutants including the most important six: ozone, particulates, sulfur dioxide, nitrogen dioxide, carbon monoxide and lead.
3. California gets lots of sunshine so there is lots of secondary pollution. The culture is very car oriented. Mountains are east of the major urban areas and they trap the pollution over the cities.

1.24 Types of Air Pollution

- Distinguish between primary and secondary pollutants and identify examples of each.

Why is there a lid over that smog?

The gray smog pictured above is stuck between two layers of air. The bottom layer is more dense than the top layer, so there is no mixing between the two layers. In winter, an inversion traps all of the pollutants that are emitted into the air over a region.

Types of Air Pollution

The two types of air pollutants are primary pollutants, which enter the atmosphere directly, and secondary pollutants, which form from a chemical reaction.

Primary Pollutants

Some primary pollutants are natural, such as volcanic ash. Dust is natural but exacerbated by human activities; for example, when the ground is torn up for agriculture or development. Most primary pollutants are the result of human activities, the direct emissions from vehicles and smokestacks. Primary pollutants include:

- Carbon oxides include carbon monoxide (CO) and carbon dioxide (CO_2) (**Figure** 1.59). Both are colorless, odorless gases. CO is toxic to both plants and animals. CO and CO_2 are both greenhouse gases.

- Nitrogen oxides are produced when nitrogen and oxygen from the atmosphere come together at high temperatures. This occurs in hot exhaust gas from vehicles, power plants, or factories. Nitrogen oxide (NO) and nitrogen dioxide (NO_2) are greenhouse gases. Nitrogen oxides contribute to acid rain.
- Sulfur oxides include sulfur dioxide (SO_2) and sulfur trioxide (SO_3). These form when sulfur from burning coal reaches the air. Sulfur oxides are components of acid rain.
- Particulates are solid particles, such as ash, dust, and fecal matter (**Figure** 1.60). They are commonly formed from combustion of fossil fuels, and can produce smog. Particulates can contribute to asthma, heart disease, and some types of cancers.

- Lead was once widely used in automobile fuels, paint, and pipes. This heavy metal can cause brain damage or blood poisoning.

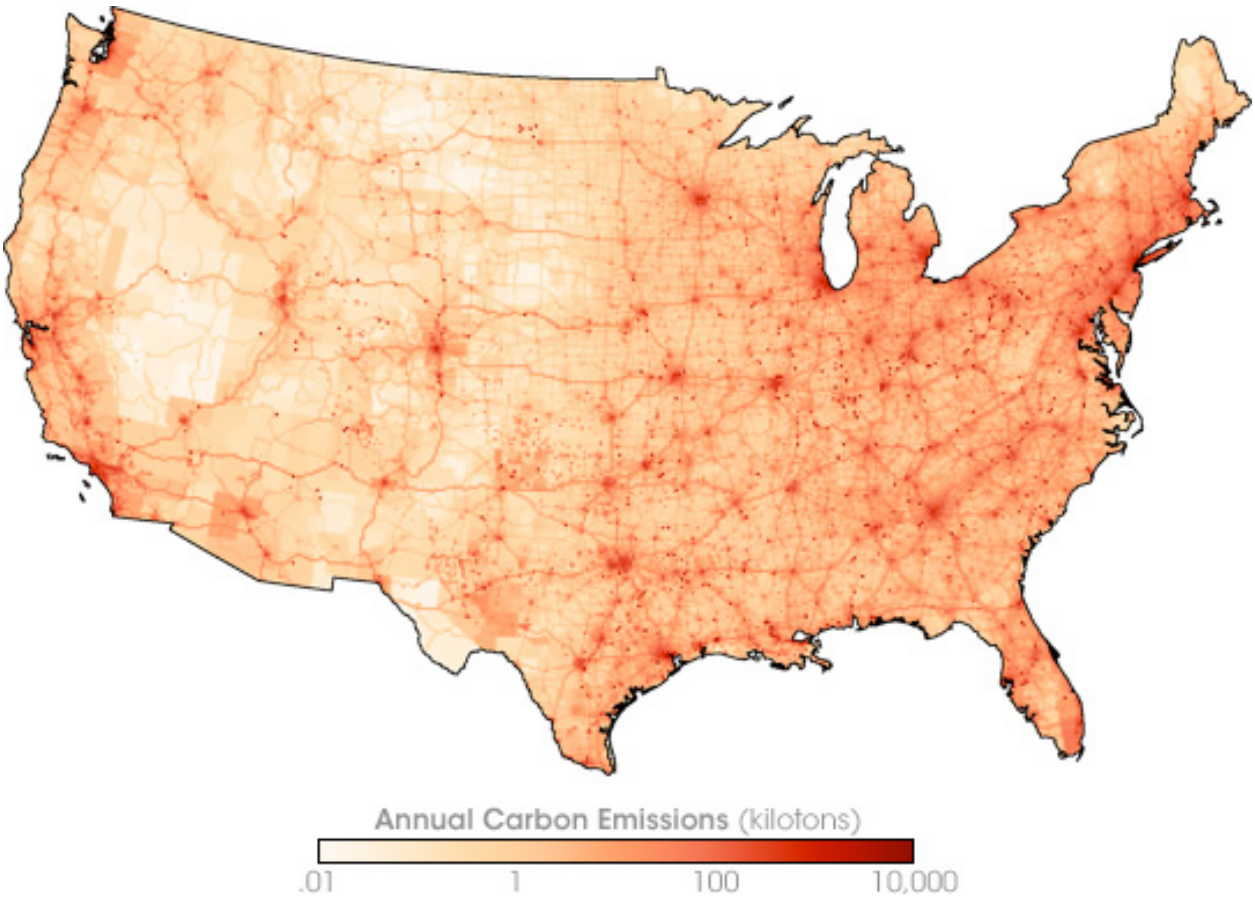


FIGURE 1.59

High CO_2 levels are found in major metropolitan areas and along the major interstate highways.

FIGURE 1.60

Particulates from a brush fire give the sky a strange glow in Arizona.

- Volatile organic compounds (VOCs) are mostly hydrocarbons. Important VOCs include methane (a naturally occurring greenhouse gas that is increasing because of human activities), chlorofluorocarbons (human-made compounds that are being phased out because of their effect on the ozone layer), and dioxin (a byproduct of chemical production that serves no useful purpose, but is harmful to humans and other organisms).

Secondary Pollutants

Any city can have photochemical smog, but it is most common in sunny, dry locations. A rise in the number of vehicles in cities worldwide has increased photochemical smog. Nitrogen oxides, ozone, and several other compounds are some of the components of this type of air pollution.

Photochemical smog forms when car exhaust is exposed to sunlight. Nitrogen oxide is created by gas combustion in cars and then into the air (**Figure** 1.61). In the presence of sunshine, the NO_2 splits and releases an oxygen ion (O). The O then combines with an oxygen molecule (O_2) to form ozone (O_3). This reaction can also go in reverse: Nitric oxide (NO) removes an oxygen atom from ozone to make it O_2. The direction the reaction goes depends on how much NO_2 and NO there is. If NO_2 is three times more abundant than NO, ozone will be produced. If nitric oxide levels are high, ozone will not be created.

FIGURE 1.61

The brown color of the air behind the Golden Gate Bridge is typical of California cities, because of nitrogen oxides.

Ozone is one of the major secondary pollutants. It is created by a chemical reaction that takes place in exhaust and in the presence of sunlight. The gas is acrid-smelling and whitish. Warm, dry cities surrounded by mountains, such as Los Angeles, Phoenix, and Denver, are especially prone to photochemical smog. Photochemical smog peaks at midday on the hottest days of summer. Ozone is also a greenhouse gas.

Summary

- There are many types of primary pollutants, including carbon oxides, nitrogen oxides, sulfur oxides, particulates, lead, and volatile organic compounds.
- Secondary pollutants form from chemical reactions that occur when pollution is exposed to sunlight.
- Ozone is a secondary pollutant that is also a greenhouse gas.

Practice

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=UtdKRvWC1yQ

1. Does pollution stay over the city where it originates?
2. What causes vehicle pollution? What can you do to reduce it?
3. What accounts for the majority of all air pollution? Is that source increasing or decreasing overall?
4. What else causes air pollution?
5. What is a major source of pollution in rural areas and why?
6. What are the sources of particulate matter?
7. What is particulate matter?
8. What colors the air on a smoggy day?
9. Why are particulates dangerous?
10. Why are very small particulates dangerous? Why are they more dangerous than larger particles?
11. What is making a difference?

Practice Answers

1. No, it travels within a region.
2. Driving and idling both cause pollution. Turn off your vehicle if you expect to be idling more than 10 seconds.
3. Cars account for the most and they are increasing.
4. lawn mowers, especially older models; diesel trucks, buses, construction industry vehicles, ships
5. Smoke from wood stoves; trucks.
6. The sources include wood smoke, land clearing, tailpipe emissions.
7. Particulates are fine solids that hang in the air.
8. Particulates and nitrogen dioxide color the air.
9. They are small particles that can interfere with breathing but they can also carry toxic compounds like benzene.
10. The smallest particles can penetrate into the deepest part of the lungs. Larger particles get filtered out by the nose.
11. Hybrid cars and biofuels with low sulfur; ships can plug into electrical grid.

Review

1. How are primary and secondary pollutants different?
2. Explain how nitrogen oxide pollutants form.
3. What is ozone and how does it form as part of photochemical smog?

Review Answers

1. Primary pollutants come straight from the source. Secondary pollutants arise from a chemical reaction.
2. Nitrogen oxides come together when nitrogen and oxygen meet at high temperature such as in vehicle exhaust or a power plant or factory.
3. Ozone is a molecule with three oxygen atoms. Nitrogen oxide is create in the exhaust stream of a car. In the presence of sunshine, the oxygen comes off the molecule and combines with oxygen to form ozone.

1.25 Causes Of Air Pollution

- Describe the sources of air pollution.

How come we don't see emissions like this too often any more?

This photo of a power plant was taken before emission control equipment was added. Emissions are down since laws have been enacted to protect the air.

Causes of Air Pollution

Most air pollutants come from burning fossil fuels or plant material. Some are the result of evaporation from human-made materials. Nearly half (49%) of air pollution comes from transportation, 28% from factories and power plants, and the remaining pollution from a variety of other sources.

Fossil Fuels

Fossil fuels are burned in most motor vehicles and power plants. These non-renewable resources are the power for nearly all manufacturing and other industries. Pure coal and petroleum can burn cleanly and emit only carbon dioxide and water, but most of the time these fossil fuels do not burn completely and the incomplete chemical reactions produce pollutants. Few sources of these fossil fuels are pure, so other pollutants are usually released. These pollutants include carbon monoxide, nitrogen dioxide, sulfur dioxide, and hydrocarbons.

In large car-dependent cities such as Los Angeles and Mexico City, 80% to 85% of air pollution is from motor vehicles (**Figure** 1.62). Ozone, carbon monoxide, and nitrous oxides come from vehicle exhaust.

See the relative amounts of CO_2 released by different fossil fuels in this animation: http://www.nature.nps.gov/GEOLOGY/usgsnps/oilgas/CO2BTU_3.MPG .

FIGURE 1.62
Auto exhaust like this means that the fuels is not burning efficiently.

A few pollutants come primarily from power plants or industrial plants that burn coal or oil. Sulfur dioxide (SO_2) is a major component of industrial air pollution that is released whenever coal and petroleum are burned. SO_2 mixes with H_2O in the air to produce sulfuric acid (H_2SO_4).

Mercury is released when coal and some types of wastes are burned. Mercury is emitted as a gas, but as it cools, it becomes a droplet. Mercury droplets eventually fall to the ground. If they fall into sediments, bacteria convert them to the most dangerous form of mercury: methyl mercury. Highly toxic, methyl mercury is one of the metal's organic forms.

Biomass Burning

Fossil fuels are ancient plants and animals that have been converted into usable hydrocarbons. Burning plant and animal material directly also produces pollutants. Biomass is the total amount of living material found in an environment. The biomass of a rainforest is the amount of living material found in that rainforest.

The primary way biomass is burned is for **slash-and-burn agriculture** (**Figure** 1.63). The rainforest is slashed down and then the waste is burned to clear the land for farming. Biomass from other biomes, such as the savannah, is also burned to clear farmland. The pollutants are much the same as from burning fossil fuels: CO_2, carbon monoxide, methane, particulates, nitrous oxide, hydrocarbons, and organic and elemental carbon. Burning forests increases greenhouse gases in the atmosphere by releasing the CO_2 stored in the biomass and also by removing the forest so that it cannot store CO_2 in the future. As with all forms of air pollution, the smoke from biomass burning often spreads far and pollutants can plague neighboring states or countries.

Particulates result when anything is burned. About 40% of the particulates that enter the atmosphere above the United States are from industry and about 17% are from vehicles. Particulates also occur naturally from volcanic eruptions or windblown dust. Like other pollutants, they travel all around the world on atmospheric currents.

FIGURE 1.63
A forest that has been slash-and-burned to make new farmland.

Evaporation

Volatile organic compounds (VOCs) enter the atmosphere by evaporation. VOCs evaporate from human-made substances, such as paint thinners, dry cleaning solvents, petroleum, wood preservatives, and other liquids. Naturally occurring VOCs evaporate off of pine and citrus trees. The atmosphere contains tens of thousands of different VOCs, nearly 100 of which are monitored. The most common is methane, a greenhouse gas (**Figure** 1.64). Methane occurs naturally, but human agriculture is increasing the amount of methane in the atmosphere.

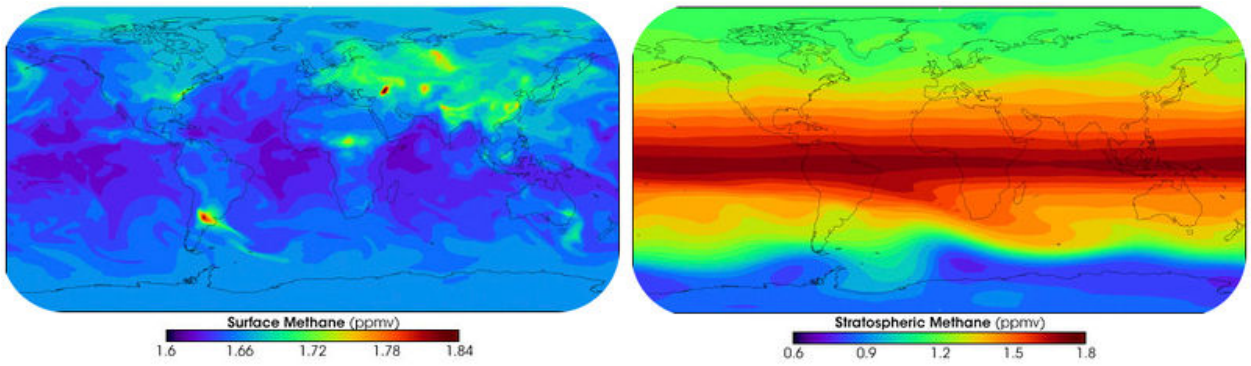


FIGURE 1.64
Methane forms when organic material decomposes in an oxygen-poor environment. In the top image, surface methane production is shown. Stratospheric methane concentrations in the bottom image show that methane is carried up into the stratosphere by the upward flow of air in the tropics.

Summary

- Most fossil fuels are dirty and release pollutants such as carbon monoxide, nitrogen dioxide, sulfur dioxide, and hydrocarbons.

- Burning plants and other biomass releases pollutants including carbon monoxide, methane, particulates, nitrous oxide, hydrocarbons, and organic and elemental carbon.
- Volatile organic compounds evaporate into the air and become pollutants.

Practice

Use this resource to answer the questions that follow.

http://www.universetoday.com/81977/causes-of-air-pollution/

1. What is air pollution?
2. What are the results of air pollution?
3. How does manufacturing cause pollution? What are the pollutants?
4. What does the burning of fossil fuels contribute to air pollution?
5. How does the Earth contribute to air pollution?
6. If air pollution is natural, why is it a problem when humans cause it?

Practice Answers

1. Air pollution is the introduction into the atmosphere of chemicals, particulates and biological matter that cause harm to humans, other living organisms, or cause damage to the natural environment.
2. acid rain, smog, and health problems
3. Particulates and chemicals spew into the atmosphere including sulfur oxides, nitrogen oxides, carbon monoxide and carbon dioxide and well as volatile organic compounds and particulates.
4. Fossil fuel burning contributes primary pollutants and secondary pollutants. These include sulfur and nitrogen oxides, carbon monoxide, heavy metals and particulates.
5. Natural causes of air pollution include volcanic eruptions, wildfires and other natural processes.
6. The amount of pollution is well beyond what Earth can clean by natural processes over the short term.

Review

1. What is slash-and-burn agriculture and what pollutants does it release?
2. What are volatile organic compounds and why are they pollutants?
3. Name a compound that occurs in the atmosphere naturally but is a pollutant in excess amounts due to human activities.

Review Answers

1. Slash-and-burn is when the rainforest is slashed down and the waste is burned to clear land for farming. Pollutants are the same as for burning fossil fuels: carbon dioxide, carbon monoxide, methane, particulates, nitrous oxide, hydrocarbons, and organic and elemental carbon.
2. VOCs are compounds that enter the atmosphere by evaporation. They include paint thinners, dry cleaning solvents and other liquids. They are present in the atmosphere in higher quantities.
3. carbon dioxide

1.26 Effects of Air Pollution on the Environment

- Explain how air pollution damages the environment.

Did you ever see a sky without contrails?

In the three days after the terrorists attacks on September 11, 2001, jet airplanes did not fly over the United States. Without the gases from jet contrails blocking sunlight, air temperature increased 1°C (1.8°F) across the United States. This is just one of the effects air pollution has on the environment.

Smog Effects on the Environment

All air pollutants cause some damage to living creatures and the environment. Different types of pollutants cause different types of harm.

Particulates

Particulates reduce visibility. In the western United States, people can now ordinarily see only about 100 to 150 kilometers (60 to 90 miles), which is one-half to two-thirds the natural (pre-pollution) range on a clear day. In the East, people can only see about 40 to 60 kilometers (25-35 miles), about one-fifth the distance they could see without any air pollution (**Figure** 1.65).

Particulates reduce the amount of sunshine that reaches the ground, which may reduce photosynthesis. Since particulates form the nucleus for raindrops, snowflakes, or other forms of precipitation, precipitation may increase when particulates are high. An increase in particles in the air seems to increase the number of raindrops, but often decreases their size.

FIGURE 1.65
Smog in New York City.

By reducing sunshine, particulates can also alter air temperature as mentioned above. Imagine how much all of the sources of particulates combine to reduce temperatures. What affect might this have on global warming?

Ozone

Ozone damages some plants. Since ozone effects accumulate, plants that live a long time show the most damage. Some species of trees appear to be the most susceptible. If a forest contains ozone-sensitive trees, they may die out and be replaced by species that are not as easily harmed. This can change an entire ecosystem, because animals and plants may not be able to survive without the habitats created by the native trees.

Some crop plants show ozone damage (**Figure** 1.66). When exposed to ozone, spinach leaves become spotted. Soybeans and other crops have reduced productivity. In developing nations, where getting every last bit of food energy out of the agricultural system is critical, any loss is keenly felt.

FIGURE 1.66
The spots on this leaf are caused by ozone damage.

Oxides

Oxide air pollutants also damage the environment. NO_2 is a toxic, orange-brown colored gas that gives air a distinctive orange color and an unpleasant odor. Nitrogen and sulfur-oxides in the atmosphere create acids that fall as acid rain.

Lichen get a lot of their nutrients from the air so they may be good indicators of changes in the atmosphere such as increased nitrogen. In Yosemite National Park, this could change the ecosystem of the region and lead to fires and other problems.

Find out more at http://science.kqed.org/quest/audio/lichen-point-to-pollution/.

MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/60940

Summary

- An increase in particulates may reduce photosynthesis, increase precipitation, and reduce temperatures.
- Ozone may damage native plants and some crop plants by slowing growth or damaging leaves.
- Nitrogen and sulfur-oxides are pollutants. They also create acids in the atmosphere that fall as acid rain.

Practice

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=rXlbcbh23_M Start with 3:58, end with 10:00

1. What was the first smog caused by in Britain?
2. What caused smog to increase greatly in Britain and when?
3. What happened in London in 1952?
4. What type of fog is found in Los Angeles and what causes it?
5. What is smog in Beijing caused by?
6. How much has the lifespan of residents been reduced? What other health effects are there?
7. How many micrograms of fine particulates are recommended as a limit by the World Health Organization? How many were in the air in Beijing in January 2014?
8. What was the result of this smog?
9. What are the human health consequences?
10. What does acid rain do to the environment?
11. What do sulfur dioxide do to stone and metal?
12. Does smog affect plant growth?

Practice Answers

1. coal burning
2. The Industrial Revolution.
3. Weather patterns trapped coal pollution over the city for four days. The smog reduced visibility to 5 yards and 4000 were killed by respiratory diseases and many more from later effects.

4. It is photochemical smog from vehicles and sunshine.
5. It is industrial smog caused by coal burning.
6. 15 years; respiratory diseases
7. 25 micrograms; 671 micrograms
8. Highways were shut down because of bad visibility.
9. Increased lung illnesses, deceased life expectancy.
10. It reduces pH and harms some species of plants and animals.
11. It corrodes it.
12. Yes.

Review

1. What is the effect of an increase in particulates on the environment?
2. What is the effect of ozone on native and crop plants?
3. What happened to air temperature when jet airplanes could not fly over the United States for three days? Why? If smog were reduced what effect might that have on temperature?

Review Answers

1. Particulates reduce visibility; they reduce the amount of sunshine that reaches the ground and may reduce photosynthesis. They may increase precipitation since particulates form the nucleus of raindrops and snowflakes.
2. Ozone causes damage to some plants; the leaves may become spotted, crops may reduce productivity.
3. Air temperature increased by 1-degree C or 1.8-degrees F because the contrails weren't there to block the sunlight. A reduction of smog might also increase temperate for the same reason.

1.27 Effects of Air Pollution on Human Health

- Describe the affects of air pollution on are on the rise.

How is breathing on a smoggy day like breathing trash?

On a smoggy day, you're breathing garbage. No different from tossing trash out of a car window with no intention of picking it up, we spew trash into the air as we drive, as we heat our homes, and as we manufacture goods. Would we tolerate all this trash if it were in our houses laying on the ground?

Smog Effects on Human Health

Human health suffers in locations with high levels of air pollution.

Pollutants and their Effects

Different pollutants have different health effects:

- Lead is the most common toxic material and is responsible for lead poisoning.
- Carbon monoxide can kill people in poorly ventilated spaces, such as tunnels.
- Nitrogen and sulfur-oxides cause lung disease and increased rates of asthma, emphysema, and viral infections such as the flu.
- Ozone damages the human respiratory system, causing lung disease. High ozone levels are also associated with increased heart disease and cancer.
- Particulates enter the lungs and cause heart or lung disease. When particulate levels are high, asthma attacks are more common. By some estimates, 30,000 deaths a year in the United States are caused by fine particle pollution.

Human Illnesses from Air Pollution

Many but not all cases of asthma can be linked to air pollution. During the 1996 Olympic Games, Atlanta, Georgia, closed off their downtown to private vehicles. This action decreased ozone levels by 28%. At the same time, there were 40% fewer hospital visits for asthma. Can scientists conclude without a shadow of a doubt that the reduction in ozone caused the reduction in hospital visits? What could they do to make that determination?

Lung cancer among people who have never smoked is around 15% and is increasing. One study showed that the risk of being afflicted with lung cancer increases directly with a person's exposure to air pollution (**Figure** 1.67). The study concluded that no level of air pollution should be considered safe. Exposure to smog also increased the risk of dying from any cause, including heart disease.

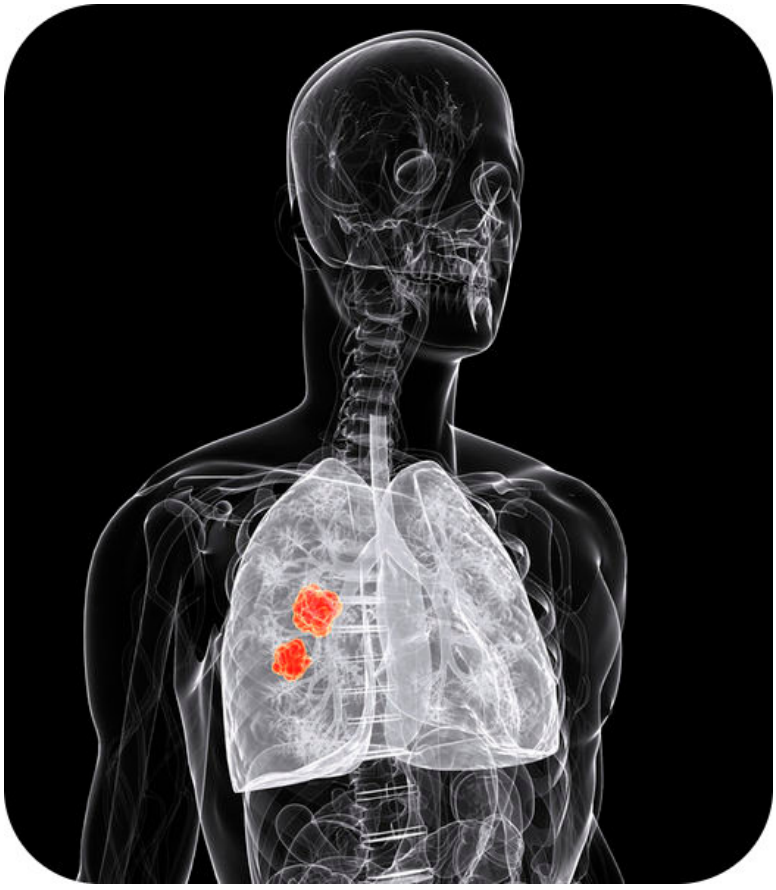


FIGURE 1.67

A lung tumor is highlighted in this illustration.

One study found that in the United States, children develop asthma at more than twice the rate of two decades ago and at four times the rate of children in Canada. Adults also suffer from air pollution-related illnesses that include lung disease, heart disease, lung cancer, and weakened immune systems. The asthma rate worldwide is rising 20% to 50% every decade.

Summary

- Pollutants emitted into the air cause lung and other diseases in humans.
- Asthma, lung cancer, and other lung diseases are linked to air pollution.
- Disease rates for air pollutant related diseases are rising.

Practice

Use this resource to answer the questions that follow.

http://www.youtube.com/watch?v=IjpKnoHOu8M

MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/1516

1. What is the your body's first line of defense against air pollutants?
2. What happens when people breath in air pollutants?
3. Besides lung problems, what other types of problems can air pollutants cause?
4. Which populations are most effected by air pollution?
5. Why is air population especially dangerous for infants and toddlers?
6. When does pollution affect everybody?
7. What else does poor air affect negatively?
8. How much does poor air cost Washington state each year?

Practice Answers

1. The nose is the first line of defense. The body has natural mechanisms such as hairs that clean, mucus that traps; together they try to clean the pollutants.
2. Air pollutants can get deep into the lungs: people who already have breathing problems can have breathing made worse.
3. Particulates can cause a reaction in the body that leads to heart problems and may lead to sudden death or more heart problems.
4. asthmatics, the elderly and young people
5. Babies and toddlers don't have fully developed. If the development is stunted the child finds it harder to breathe later in life.
6. Pollution can affect even healthy people on a very bad day or when they are getting lots of outdoor exercise.
7. It can reduce tourism and stunt crops; hospital visits increase.
8. $75 million or more a year

Review

1. Lung cancer is on the rise in people who've never smoked. To what might you attribute this fact?
2. What experiments have been done, deliberately or inadvertently, to test the effects of air pollution on asthma?
3. How might the increase in asthma be related to air pollution?

Review Answers

1. The rise in air pollution can cause lung cancer.
2. During the 1996 Atlanta Olympic games closing the downtown decreased ozone and decreased hospital visits for asthma.
3. Air pollution has increased and asthma in children has increased. It rises every decade.

1.28 Mercury Pollution

- Explain the health hazards posed by mercury pollution.

How much fish should you eat?

On the one hand, you hear fish is good for you. On the other, you hear that you're not supposed to eat too much of some types of fish, like tuna. How can something that's supposed to be good for you be harmful to your health?

Mercury Pollution

Mercury is released into the atmosphere when coal is burned (**Figure** 1.68). But breathing the mercury is not harmful. In the atmosphere, the mercury forms small droplets that are deposited in water or sediments.

Bioaccumulation

Do you know why you are supposed to eat large predatory fish like tuna infrequently? It is because of the **bioaccumulation** of mercury in those species.

Some pollutants remain in an organism throughout its life, a phenomenon called bioaccumulation. In this process, an organism accumulates the entire amount of a toxic compound that it consumes over its lifetime. Not all substances bioaccumulate. Can you name one that does not? Aspirin does not bioaccumulate; if it did, a person would quickly accumulate a toxic amount in her body. Compounds that bioaccumulate are usually stored in the organism's fat.

In the sediments, bacteria convert the droplets to the hazardous compound methyl mercury. Bacteria and plankton store all of the mercury from all of the seawater they ingest (**Figure** 1.69). A small fish that eats bacteria and plankton accumulates all of the mercury from all of the tiny creatures it eats over its lifetime. A big fish accumulates all of the mercury from all of the small fish it eats over its lifetime. For a tuna at the top of the food chain, that's a lot of mercury.

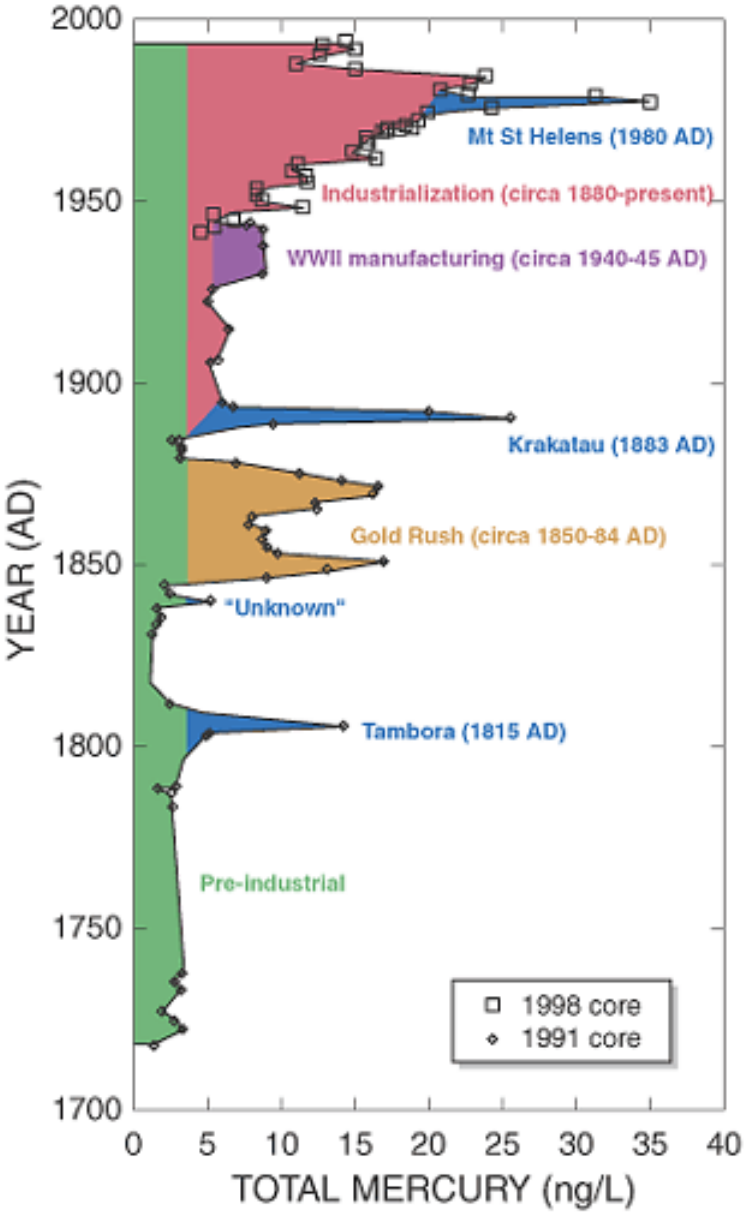


FIGURE 1.68

Historic increases of mercury in the atmosphere: blue is volcanic eruptions; brown, purple, and pink are human-caused. The red region shows the effect of industrialization on atmospheric mercury.

So tuna pose a health hazard to anything that eats them because their bodies are so high in mercury. This is why the government recommends limits on the amount of tuna that people eat. Limiting intake of large predatory fish is especially important for children and pregnant women. If the mercury just stayed in a person's fat, it would not be harmful, but that fat is used when a woman is pregnant or nursing a baby. A person will also get the mercury into her system when she (or he) burns the fat while losing weight.

Mad As a Hatter

Methyl mercury poisoning can cause nervous system or brain damage, especially in infants and children. Children may experience brain damage or developmental delays. The phrase "mad as a hatter" was common when Lewis Carroll wrote his Alice in Wonderland stories. It was based on symptoms suffered by hatters who were exposed to mercury and experienced mercury poisoning while using the metal to make hats (**Figure** 1.70). Like mercury, other

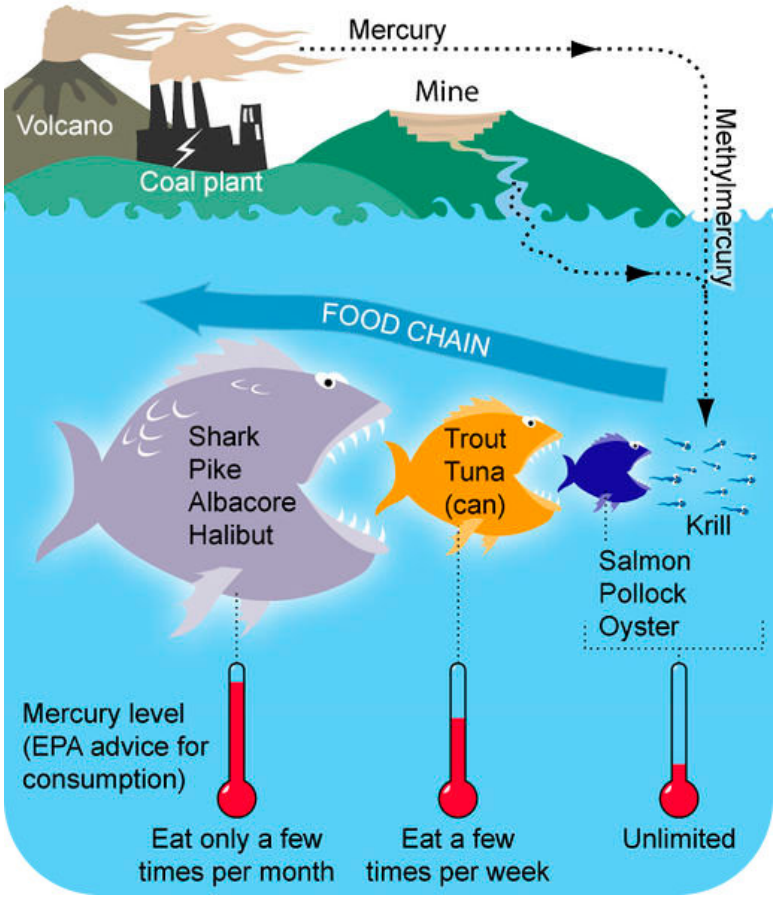


FIGURE 1.69
Methyl mercury bioaccumulates up the food chain.

metals and VOCS can bioaccumulate, causing harm to animals and people high on the food chain.

Mercury, a potent neurotoxin, has been flowing into the San Francisco Bay since the Gold Rush Era. It has settled in the bay's mud and made its way up the food chain, endangering wildlife and making many fish unsafe to eat. Now a multi-billion-dollar plan aims to clean it up.

Find out more at http://science.kqed.org/quest/video/mercury-in-san-francisco-bay/ .

MEDIA
Click image to the left for use the URL below.
URL: http://gamma.ck12.org/flx/render/embeddedobject/116514

Summary

- Burning coal releases mercury into the atmosphere. It falls into sediments and is converted into methyl mercury by bacteria.
- Creatures ingest the methyl mercury and store it. Then, larger creatures eat them and store all of that methyl mercury, on up the food chain.
- Mercury poisoning causes nervous system damage.

FIGURE 1.70
The Mad Hatter.

Practice

Use this resource to answer the questions that follow.

http://www.youtube.com/watch?v=xRqAS4Eow-c

MEDIA
Click image to the left for use the URL below.
URL: http://gamma.ck12.org/flx/render/embeddedobject/1537

1. What is a natural source of mercury in the air?
2. What the are the human-made sources of mercury?
3. Where does mercury come from relative to the location of Acadia National Park?
4. Why is Acadia National Park concerned about mercury?
5. How is mercury an example of biomagnification?
6. What are the toxic effects of mercury?
7. Where does mercury enter the park ecosystem from?
8. How much mercury is deposited relative to the amount scientists think existed before industrialization?
9. Explain what people can do to reduce mercury in the environment.

Practice Answers

1. volcanoes
2. burning coal and burning waste
3. Mercury can travel great distances before it precipitates out. The same smog that obscures the view can precipitate out mercury.
4. Mercury can harm wildlife and human health.
5. Mercury builds up in bodies over time and increases in concentration in organisms up the food chain.
6. Mercury can cause reproductive and neurological impairment and decreased survival.
7. It rains down from spruce and fir canopies.
8. about 4-times as much
9. People can conserve electricity and purchase fewer mercury containing products.

Review

1. What is bioaccumulation?
2. How does mercury change from something benign to something harmful?
3. Why should you restrict your intake of tuna and other large predatory fish but continue to eat or even increase your consumption of small fish that are low on the food chain, like anchovies?

Review Answers

1. Bioaccumulation occurs when an organism accumulates all of a substance that it takes in during its lifetime into its body.
2. Mercury is converted by bacteria in sediments into methyl mercury, an organic form of mercury that bioaccumulates and is toxic.
3. Mercury is a potent neurotoxin and large predatory fish bioaccumulate all of it over their lives so if you eat them you get a lot of mercury. Anchovies eat lower on the food chain so the organisms they eat contain less so they bioaccumulate less.

1.29 Acid Rain

- Describe the causes and consequences of acid rain.

What made the pits in this gargoyle?

This gargoyle, on Notre Dame Cathedral in Paris, has pits and rounded edges, which are the results of acid rain. Acid rain damages statues and architecture in developed nations.

Acid Rain

Acid rain is caused by sulfur and nitrogen oxides emanating from power plants or metal refineries. The smokestacks have been built tall so that pollutants don't sit over cities (**Figure** 1.71).

As they move, these pollutants combine with water vapor to form sulfuric and nitric acids. The acid droplets form acid fog, rain, snow, or they may be deposited dry. Most typical is acid rain (**Figure** 1.72).

pH and Acid Rain

Acid rain water is more acidic than normal rain water. Acidity is measured on the **pH scale**. Lower numbers are more acidic and higher numbers are less acidic (also called more **alkaline**) (**Figure** 1.73). Natural rain is somewhat acidic, with a pH of 5.6; acid rain must have a pH of less than 5.0. A small change in pH represents a large change in acidity: rain with a pH of 4.6 is 10 times more acidic than normal rain (with a pH of 5.6). Rain with a pH of 3.6 is 100 times more acidic.

FIGURE 1.71

Tall smokestacks allow the emissions to rise high into the atmosphere and travel up to 1,000 km (600 miles) downwind.

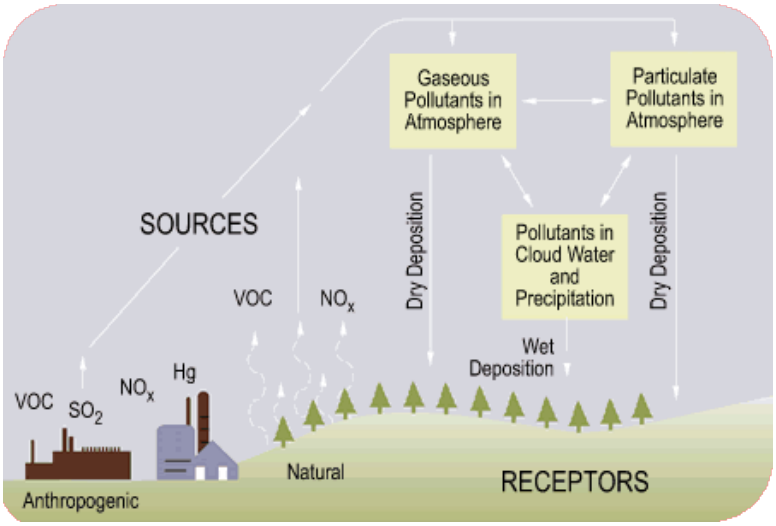


FIGURE 1.72

Pollutants are deposited dry or in precipitation.

Regions with a lot of coal-burning power plants have the most acidic rain. The acidity of average rainwater in the northeastern United States has fallen to between 4.0 and 4.6. Acid fog has even lower pH with an average of around 3.4. One fog in Southern California in 1986 had a pH of 1.7, equal to toilet-bowl cleaner.

In arid climates, such as in Southern California, acids deposit on the ground dry. Acid precipitation ends up on the land surface and in water bodies. Some forest soils in the northeast are five to ten times more acidic than they were two or three decades ago. Acid droplets move down through acidic soils to lower the pH of streams and lakes even more. Acids strip soil of metals and nutrients, which collect in streams and lakes. As a result, stripped soils may no longer provide the nutrients that native plants need.

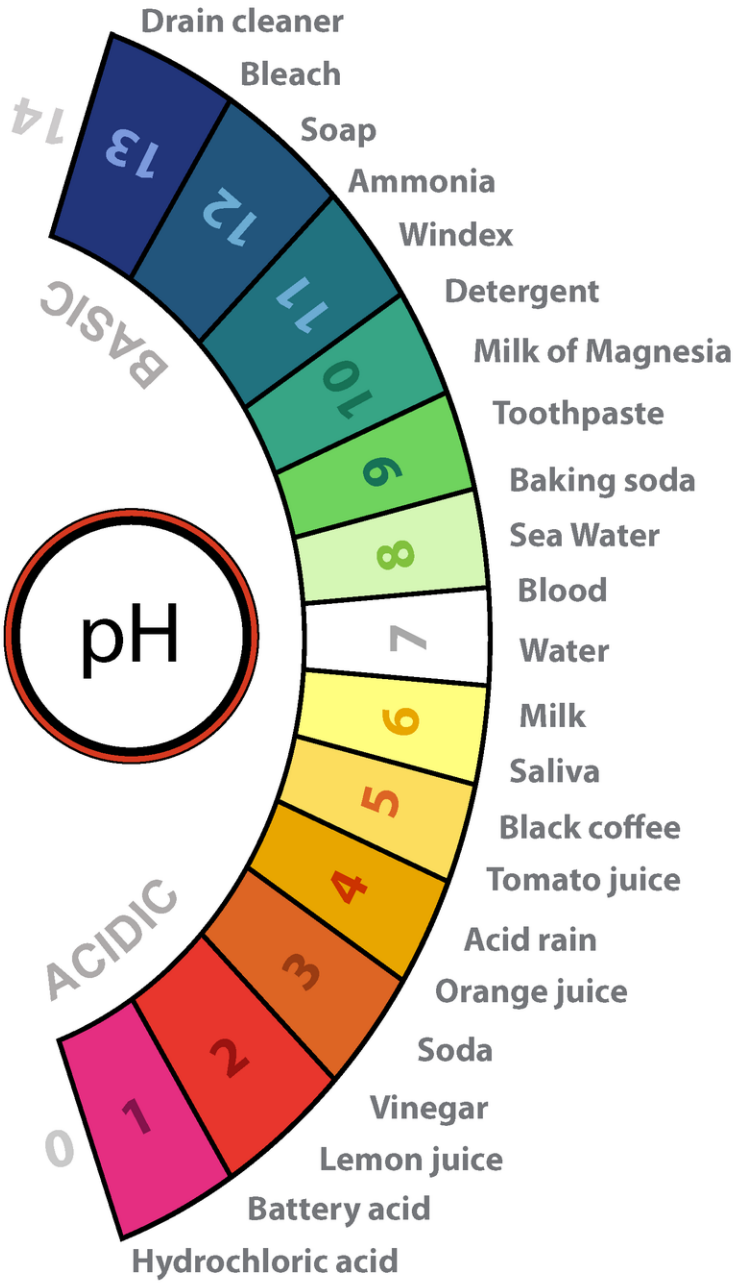


FIGURE 1.73

A pH scale goes from 1 to 14; numbers are shown with the pH of some common substances. A value of 7 is neutral. The strongest acids are at the low end of the scale and the strongest bases are at the high end.

Effects of Acid Rain

Acid rain takes a toll on ecosystems (**Figure** 1.74). Plants that are exposed to acids become weak and are more likely to be damaged by bad weather, insect pests, or disease. Snails die in acid soils, so songbirds do not have as much food to eat. Young birds and mammals do not build bones as well and may not be as strong. Eggshells may also be weak and break more easily.

As lakes become acidic, organisms die off. No fish can live if the pH drops below 4.5. Organic material cannot decay, and mosses take over the lake. Wildlife that depend on the lake for drinking water suffer population declines.

Crops are damaged by acid rain. This is most noticeable in poor nations where people can't afford to fix the problems with fertilizers or other technology.

FIGURE 1.74

Acid rain has killed trees in this forest in the Czech Republic.

Acid rain damages cultural monuments like buildings and statues. These include the U.S. Capitol and many buildings in Europe, such as Westminster Abbey.

Carbonate rocks neutralize acids and so some regions do not suffer the effects of acid rain nearly as much. Limestone in the midwestern United States protects the area. One reason that the northeastern United States is so vulnerable to acid rain damage is that the rocks are not carbonates.

Because pollutants can travel so far, much of the acid rain that falls hurts states or nations other than ones where the pollutants were released. All the rain that falls in Sweden is acidic and fish in lakes all over the country are dying. The pollutants come from the United Kingdom and Western Europe, which are now working to decrease their emissions. Canada also suffers from acid rain that originates in the United States, a problem that is also improving. Southeast Asia is experiencing more acid rain between nations as the region industrializes.

Summary

- Nitrogen and sulfur compounds emitted high into the atmosphere create acids that later fall as acid rain.
- Acidity is measured on a pH scale. Rain that is 5.0 or less on that scale is considered acid rain.
- Acid rain weakens plants and animals and damages cultural treasures.

Practice

Use this resource to answer the questions that follow.

http://butane.chem.uiuc.edu/pshapley/Environmental/L24/1.html

1. What are the sources of sulfur and nitrogen oxides in the atmosphere?
2. What forms the acids that make up acid rain?
3. Why do acids created in the Midwest fall in New England?
4. What did the Clean Air Act regulate that relates to acid rain formation?
5. If the Clean Air Act regulates emissions, why is there still acid rain?
6. What were the effects of the Clean Air Act on acid rain?

Practice Answers

1. Most are from burning fossil fuels. Ammonia is also given off during manure handling.
2. Sulfur and nitrogen oxides mix with hydrogen in the atmosphere to create sulfuric and nitric acids.
3. Nitric acid falls to Earth in 1 day or less and sulfuric acid stays in the atmosphere a few days. For acids created over the Midwest that air is over New England by the time the rain falls.
4. The Act required reductions in sulfur oxide emissions from power plants.
5. While sulfur oxide emissions were reduced, they were not eliminated. Nitrogen oxides releases continue.
6. Sulfur oxides have been reduced by nitrogen has stayed constant.

Review

1. Why do acids travel so far before they fall as acid rain?
2. Where does the acid that comes out of the atmosphere go?
3. What damage does acid rain do to organisms and cultural structures?
4. One problem with acid rain is that the pollutants that cause it may be emitted far upwind from where it falls in a different country. How can nations deal with this problem?

Review Answers

1. The oxides are emitted high into the atmosphere where they travel fast in high winds.
2. In arid locations it is deposited dry. It can go as acid precipitation into water bodies and soil.
3. Ecosystems are damaged as plants are unable to survive. Prey like snails may die leaving songbirds without food. Egg layers may not have strong enough shells. Eventually lakes die. Cultural monuments can be destroyed as acid dissolves carbonate rocks.
4. The victims must work together with the nations that are putting the oxides into the air to reduce emissions.

1.30 Ozone Depletion

- Explain how a hole in the ozone layer forms, and describe the effects that follow.

Why can't the children in Punta Arenas go outside in the spring?

Children in Punta Arenas, Chile, the world's most southern city, look forward to spring as much as anyone who lives through a frigid, dark winter. But unlike the children pictured above, some years, the children in Punta Arenas are instructed not to go outside because the ozone hole has moved north and the UV radiation is too high.

Ozone Depletion

At this point you might be asking yourself, "Is ozone bad or is ozone good?" There is no simple answer to that question: It depends on where the ozone is located (**Figure** 1.75).

- In the troposphere, ozone is a pollutant.
- In the ozone layer in the stratosphere, ozone screens out high energy ultraviolet radiation and makes Earth habitable.

How Ozone is Destroyed

Human-made chemicals are breaking ozone molecules in the ozone layer. Chlorofluorocarbons (CFCs) are the most common, but there are others, including halons, methyl bromide, carbon tetrachloride, and methyl chloroform. CFCs were once widely used because they are cheap, nontoxic, nonflammable, and non-reactive. They were used as spray-can propellants, refrigerants, and in many other products.

Once they are released into the air, CFCs float up to the stratosphere. Air currents move them toward the poles. In the winter, they freeze onto nitric acid molecules in **polar stratospheric clouds (PSC)** (**Figure** 1.76). In the spring,

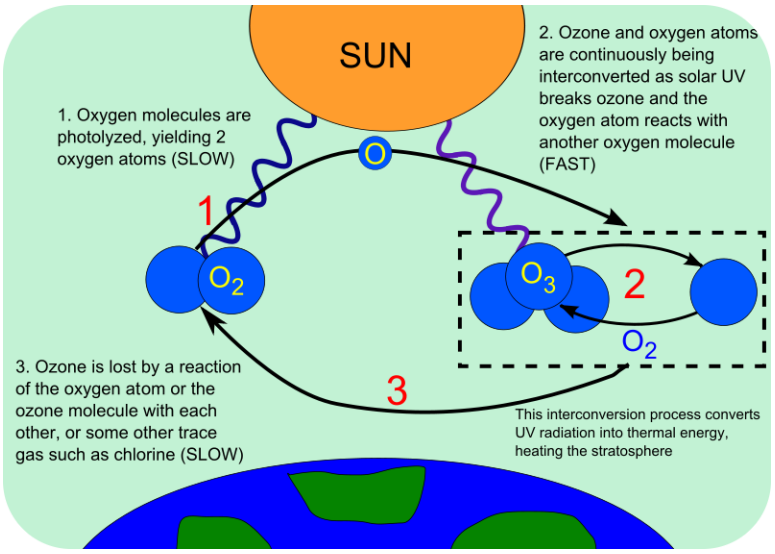


FIGURE 1.75

(1) Solar energy breaks apart oxygen molecules into two oxygen atoms. (2) Ozone forms when oxygen atoms bond together as O_3. UV rays break apart the ozone molecules into one oxygen molecule (O_2) and one oxygen atom (O). These processes convert UV radiation into heat, which is how the Sun heats the stratosphere. (3) Under natural circumstances, the amount of ozone created equals the amount destroyed. When O_3 interacts with chlorine or some other gases the O_3 breaks down into O_2 and O and so the ozone layer loses its ability to filter out UV.

the Sun's warmth starts the air moving, and ultraviolet light breaks the CFCs apart. The chlorine atom floats away and attaches to one of the oxygen atoms on an ozone molecule. The chlorine pulls the oxygen atom away, leaving behind an O_2 molecule, which provides no UV protection. The chlorine then releases the oxygen atom and moves on to destroy another ozone molecule. One CFC molecule can destroy as many as 100,000 ozone molecules.

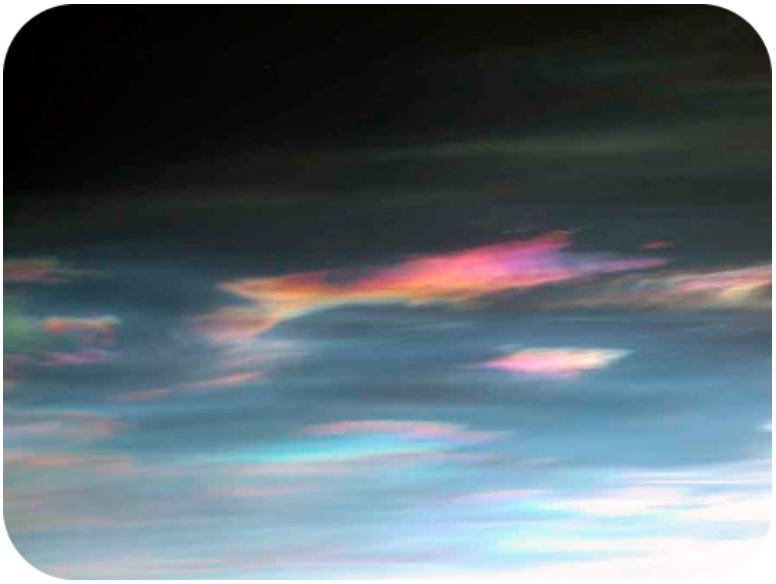


FIGURE 1.76

PSCs form only where the stratosphere is coldest, and are most common above Antarctica in the wintertime. PSCs are needed for stratospheric ozone to be destroyed.

The Ozone Hole

Ozone destruction creates the **ozone hole** where the layer is dangerously thin (**Figure** 1.77). As air circulates over Antarctica in the spring, the ozone hole expands northward over the southern continents, including Australia, New Zealand, southern South America, and southern Africa. UV levels may rise as much as 20% beneath the ozone hole.

The hole was first measured in 1981 when it was 2 million square km (900,000 square miles). The 2006 hole was the largest ever observed at 28 million square km (11.4 million square miles). The size of the ozone hole each year depends on many factors, including whether conditions are right for the formation of PSCs.

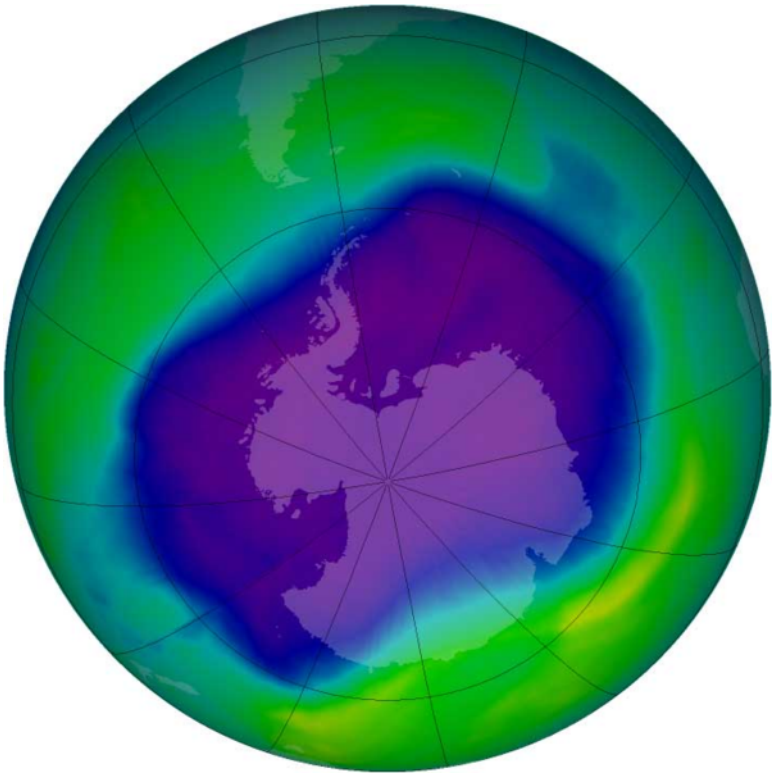


FIGURE 1.77

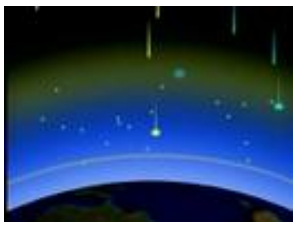
The September 2006 ozone hole, the largest observed (through 2013). Blue and purple colors show particularly low levels of ozone.

Find out how the ozone hole forms and view the hole over time on this National Geographic video: http://news.nationalgeographic.com/news/2008/11/081103-ozone-video-vin.html .

Ozone Loss in the North

Ozone loss also occurs over the North Polar Region, but it is not enough for scientists to call it a hole. Why do you think there is less ozone loss over the North Pole area? The region of low ozone levels is small because the atmosphere is not as cold and PSCs do not form as readily. Still, springtime ozone levels are relatively low. This low moves south over some of the world's most populated areas in Europe, North America, and Asia. At 40^{o}N, the latitude of New York City, UV-B has increased about 4% per decade since 1978. At 55^{o}N, the approximate latitude of Moscow and Copenhagen, the increase has been 6.8% per decade since 1978.

This video explains an importance of the stratospheric ozone layer to life on Earth: http://www.youtube.com/watch?v=I1wrEvc2URE (1:52).



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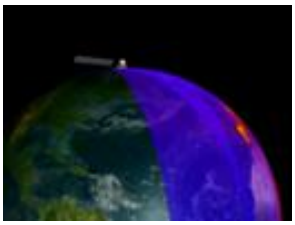
URL: http://gamma.ck12.org/flx/render/embeddedobject/1550

This NASA video discusses the ingredients of ozone depletion of Antarctica and the future of the ozone hole, including the effect of climate change: http://www.youtube.com/watch?v=qUfVMogIdr8 (2:20).



MEDIA

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Effects of Ozone Loss

Ozone losses on human health and environment include:

- Increases in sunburns, cataracts (clouding of the lens of the eye), and skin cancers. A loss of ozone of only 1% is estimated to increase skin cancer cases by 5% to 6%.
- Decreases in the human immune system's ability to fight off infectious diseases.
- Reduction in crop yields because many plants are sensitive to ultraviolet light.
- Decreases in phytoplankton productivity. A decrease of 6% to 12% has been measured around Antarctica, which may be at least partly related to the ozone hole. The effects of excess UV on other organisms is not known.
- Whales in the Gulf of California have been found to have sunburned cells in their lowest skin layers, indicating very severe sunburns. The problem is greatest with light colored species or species that spend more time near the sea surface.

When the problem with ozone depletion was recognized, world leaders took action. CFCs were banned in spray cans in some nations in 1978. The greatest production of CFCs was in 1986, but it has declined since then. This will be discussed more in the next concept.

Summary

- CFCs float up into the stratosphere where they break apart. The chlorine pulls an oxygen ion off of an ozone molecule and destroys it.
- The ozone hole is where there is less ozone than normal at that altitude. It forms in the spring.
- Ozone loss increases the amount of high-energy ultraviolet radiation that can strike Earth, causing ecological and health problems.

Practice

Use these resources to answer the questions that follow. https://www.youtube.com/watch?v=k2kpz_8ntJY

1. What does ozone in the stratosphere do?
2. What is the ozone molecule? How does it form?
3. How does stratospheric ozone absorb ultraviolet radiation?
4. What is one of the major properties of the ozone molecule? What does it react with?
5. What happens when a chlorine atom comes intersects an ozone molecule?
6. What happens when the chlorine monoxide collides with a free oxygen atom.What happens next to the chlorine?
7. What has altered the balance between ozone creation and ozone loss in the stratosphere?

8. Why are CFCs damaging?
9. What happens to CFCs in the stratosphere? What happens next?
10. Where did scientists first discover the ozone depletion in the atmosphere? What is this called?
11. What is the good news?

Practice Answers

1. It protects us from the Sun's ultraviolet radiation.
2. The ozone molecule is three oxygen atoms put together. Ultraviolet radiation breaks an oxygen molecule apart into two oxygen atoms. Each joins an oxygen molecule to make ozone.
3. The UV breaks an ozone molecule apart so that it forms an oxygen molecule and an oxygen atom.
4. It is highly reactive and will react with nitrogen, hydrogen, bromine and chlorine.
5. It steals an oxygen atom from the ozone to form chlorine monoxide and leaves behind an oxygen molecule.
6. They form an oxygen molecule and leave the chlorine, which can go on to destroy another ozone molecule.
7. The 5-fold increase in production of chlorine, particularly chlorofluorocarbons.
8. They do not break down in the lower atmosphere and rise up into the stratosphere.
9. UV radiation breaks CFCs apart so the chlorine atoms are freed and can break apart ozone.
10. Near the South Pole; the ozone layer.
11. Nations signed a treaty to reduce and eliminate CFCs and other ozone-destroying compounds.

Review

1. How do CFCs destroy ozone?
2. What is the ozone hole and where is it found? Is there an equivalent hole in the Northern Hemisphere?
3. What are some of the consequences of ozone loss that have been identified?

Review Answers

1. Ultraviolet light breaks apart the CFC and released chlorine. The chlorine attaches to an ozone molecule and takes away one oxygen atom, leaving behind an oxygen molecule. A free oxygen atom takes the oxygen away from the chlorine and the chlorine goes on to destroy another ozone molecule.
2. The ozone hole is found in the Southern Hemisphere. there is not an equivalent hole in the Northern Hemisphere although there is ozone depletion.
3. An increase in sunburns, cataracts and skin cancers; a decrease in immune responses; a reduction in some crop yields; a decease in phytoplankton productivity; sunburned whales.

1.31 Reducing Air Pollution

- Describe ways to reduce air pollution.

What does a catalytic converter do anyway?

In the days before catalytic converters, cars spewed lots of smoke. Laws governing emissions have helped to clean up the air.

The Clean Air Act

The Clean Air Act of 1970 and the amendments since then have done a great job in requiring people to clean up the air over the United States. Emissions of the six major pollutants regulated by the Clean Air Act —carbon monoxide, lead, nitrous oxides, ozone, sulfur dioxide, and particulates —have decreased by more than 50%. Cars, power plants, and factories individually release less pollution than they did in the mid-20th century. But there are many more cars, power plants, and factories. Many pollutants are still being released and some substances have been found to be pollutants that were not known to be pollutants in the past. There is still much work to be done to continue to clean up the air.

Reducing Air Pollution from Vehicles

Reducing air pollution from vehicles can be done in a number of ways.

- Breaking down pollutants before they are released into the atmosphere. Motor vehicles emit less pollution than they once did because of **catalytic converters** (**Figure** 1.78). Catalytic converters contain a **catalyst** that speeds up chemical reactions and breaks down nitrous oxides, carbon monoxide, and VOCs. Catalytic converters only work when they are hot, so a lot of exhaust escapes as the car is warming up.

FIGURE 1.78

Catalytic converters are placed on modern cars in the United States.

- Making a vehicle more fuel efficient. Lighter, more streamlined vehicles need less energy. **Hybrid vehicles** have an electric motor and a rechargeable battery. The energy that would be lost during braking is funneled into charging the battery, which then can power the car. The internal combustion engine only takes over when power in the battery has run out. Hybrids can reduce auto emissions by 90% or more, but many models do not maximize the possible fuel efficiency of the vehicle.

A plug-in hybrid is plugged into an electricity source when it is not in use, perhaps in a garage, to make sure that the battery is charged. Plug-in hybrids run for a longer time on electricity and so are less polluting than regular hybrids. Plug-in hybrids began to become available in 2010.

- Developing new technologies that do not use fossil fuels. Fueling a car with something other than a liquid organic-based fuel is difficult. A **fuel cell** converts chemical energy into electrical energy. Hydrogen fuel cells harness the energy released when hydrogen and oxygen come together to create water (**Figure** 1.79). Fuel cells are extremely efficient and they produce no pollutants. But developing fuel-cell technology has had many problems and no one knows when or if they will become practical.

Reducing Industrial Air Pollution

Pollutants are removed from the exhaust streams of power plants and industrial plants before they enter the atmosphere. Particulates can be filtered out, and sulfur and nitric oxides can be broken down by catalysts. Removing these oxides reduces the pollutants that cause acid rain.

Particles are relatively easy to remove from emissions by using motion or electricity to separate particles from the gases. Scrubbers remove particles and waste gases from exhaust using liquids or neutralizing materials (**Figure** 1.80). Gases, such as nitrogen oxides, can be broken down at very high temperatures.

FIGURE 1.79

A hydrogen fuel-cell car looks like a gasoline-powered car.

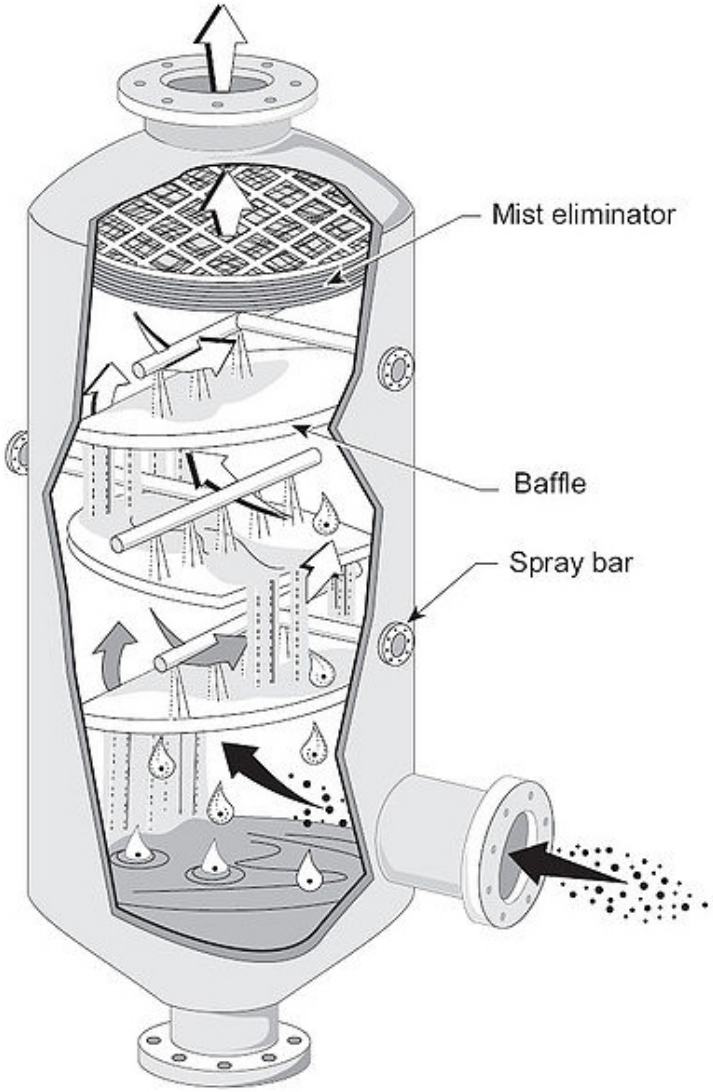


FIGURE 1.80

Scrubbers remove particles and waste gases from exhaust.

Gasification

Gasification is a developing technology. In gasification, coal (rarely is another organic material used) is heated to extremely high temperatures to create syngas, which is then filtered. The energy goes on to drive a generator. Syngas releases about 80% less pollution than regular coal plants, and greenhouse gases are also lower. Clean coal plants do not need scrubbers or other pollution control devices. Although the technology is ready, clean coal plants are more expensive to construct and operate. Also, heating the coal to high enough temperatures uses a great deal of energy, so the technology is not energy efficient. In addition, large amounts of the greenhouse gas CO_2 are still released with clean coal technology. Nonetheless, a few of these plants are operating in the United States and around the world.

Ways You Can Reduce Air Pollution

How can air pollution be reduced? Using less fossil fuel is one way to lessen pollution. Some examples of ways to conserve fossil fuels are:

- Riding a bike or walking instead of driving.
- Taking a bus or carpooling.
- Buying a car that has greater fuel efficiency.
- Turning off lights and appliances when they are not in use.
- Using energy efficient light bulbs and appliances.
- Buying fewer things that are manufactured using fossil fuels.

All these actions reduce the amount of energy that power plants need to produce.

Developing alternative energy sources is important. What are some of the problems facing wider adoption of alternative energy sources?

- The technologies for several sources of alternative energy, including solar and wind, are still being developed.
- Solar and wind are still expensive relative to using fossil fuels. The technology needs to advance so that the price falls.
- Some areas get low amounts of sunlight and are not suited for solar. Others do not have much wind. It is important that regions develop what best suits them. While the desert Southwest will need to develop solar, the Great Plains can use wind energy as its energy source. Perhaps some locations will rely on nuclear power plants, although current nuclear power plants have major problems with safety and waste disposal.

Sometimes technological approaches are what is needed.

National Geographic videos exploring energy conservation are found in Environment Videos, Energy: http://video.nationalgeographic.com/video/environment/energy-environment .

- Alternative Energy
- Fuel Cells
- Solar Power

What you can do to your home to help reduce energy use: http://www.youtube.com/watch?v=6h8QjZvcp0I .

A very simple thing you can do to conserve energy is discussed in "This Bulb": http://www.youtube.com/watch?v=FvOBHMb6Cqc .

Summary

- Catalytic converters break down some pollutants, but only when they are hot.

- Hybrid vehicles use the energy that is usually wasted as a car slows to charge a battery that then powers the car.
- Different types of clean energy can be developed for different locations, such as solar for the desert southwest and wind for coastal regions.

Practice

Use this resource to answer the questions that follow.

1. What is a hybrid car a hybrid of?
2. Why are hybrids efficient?
3. What is the problem with running a car that was just battery powered?
4. What is the disadvantage of using batteries?
5. What is the advantage of hybrids over only electric cars?

Practice Answer

1. A standard internal combustion engine combined with an electric motor powered by batteries.
2. The electric motor runs wen it can and it can join in with the regular motor if you need both.
3. It takes a lot of battery power so you can't drive great distances or at great speeds.
4. Batteries are expensive and heavy and you need a lot of them to run more on electricity.
5. They don't need such enormous batteries because they have the other engine.

Review

1. How do fuel cells work, what are their advantages, and why are they not used in every vehicle?
2. What is gasification technology and what role could it play in reducing air pollution?
3. What can you do to reduce the amount of air pollution you produce?

Review Answers

1. A fuel cells converts chemical energy to electrical energy. They are extremely efficient and produce no pollutants. They are not yet practical.
2. Coal is hated to very high temperatures to create syngas, which is then filtered. The energy drives a generator. Syngas causes less pollution and greenhouse gases and the coal plants don't need pollution control devices.
3. Transport yourself using methods other than internal combustion engines or at least carpool or ride a bus. Turn off lights and appliances. Buy less. Use alternative energy when possible.

1.32 Reducing Ozone Destruction

- Describe efforts to reduce ozone destruction.

What would have happened if CFCs had not been phased out?

Had CFCs not been phased out, by 2050 there would have been 10 times more skin cancer cases than in 1980. The result would have been about 20 million more cases of skin cancer in the United States and 130 million cases globally.

Reducing Ozone Destruction

One success story in reducing pollutants that harm the atmosphere concerns ozone-destroying chemicals. In 1973, scientists calculated that CFCs could reach the stratosphere and break apart. This would release chlorine atoms, which would then destroy ozone. Based only on their calculations, the United States and most Scandinavian countries banned CFCs in spray cans in 1978.

More confirmation that CFCs break down ozone was needed before more was done to reduce production of ozone-destroying chemicals. In 1985, members of the British Antarctic Survey reported that a 50% reduction in the ozone layer had been found over Antarctica in the previous three springs.

The Montreal Protocol

Two years after the British Antarctic Survey report, the "Montreal Protocol on Substances that Deplete the Ozone Layer" was ratified by nations all over the world.

The Montreal Protocol controls the production and consumption of 96 chemicals that damage the ozone layer (**Figure** 1.81). Hazardous substances are phased out first by developed nations and one decade later by developing

nations. More hazardous substances are phased out more quickly. CFCs have been mostly phased out since 1995, although were used in developing nations until 2010. Some of the less hazardous substances will not be phased out until 2030. The Protocol also requires that wealthier nations donate money to develop technologies that will replace these chemicals.

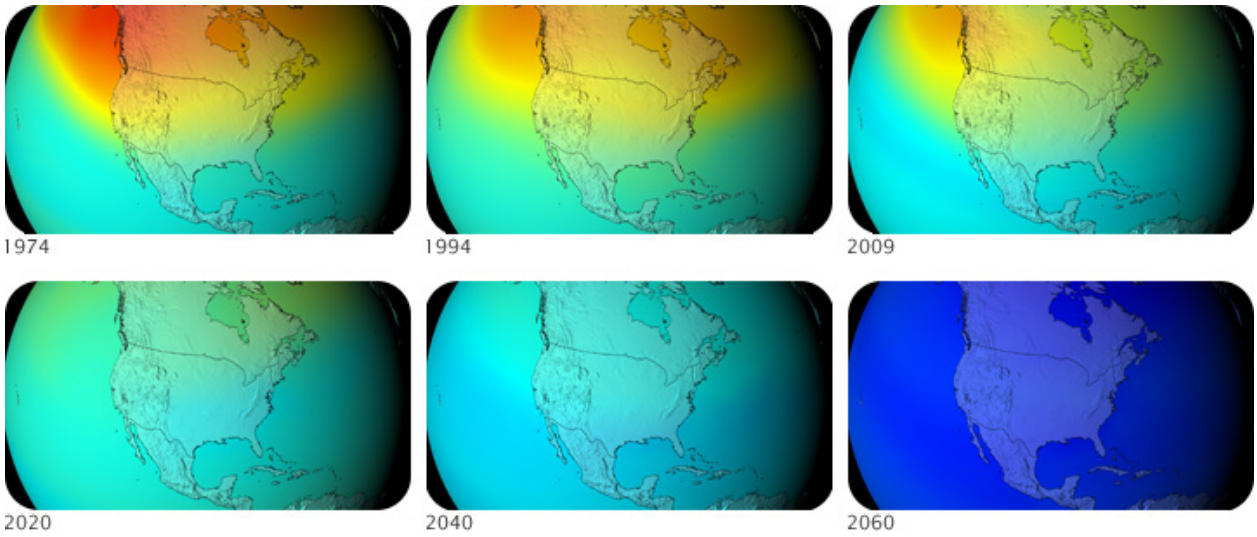


FIGURE 1.81

Ozone levels over North America decreased between 1974 and 2009. Models of the future predict what ozone levels would have been if CFCs were not being phased out. Warmer colors indicate more ozone.

Since CFCs take many years to reach the stratosphere and can survive there a long time before they break down, the ozone hole will probably continue to grow for some time before it begins to shrink. The ozone layer will reach the same levels it had before 1980 around 2068 and 1950 levels in one or two centuries.

Summary

- Calculations of ozone destruction prompted governments to ban some CFCs in 1978.
- The Montreal Protocol protects the ozone layer by regulating the production and consumption of ozone-destroying chemicals.
- Ozone levels continue to decrease, but the ozone hole will eventually begin to get smaller.

Practice

Use this resource to answer the questions that follow:

https://www.youtube.com/watch?v=AU0eNa4GrgU End at 11:00

1. What was the value of the ozone data collected by the British Antarctic Survey since the 1950s? What did Jonathan Shanklin do with this data?
2. What did Shanklin discover with this data?
3. What did the first pictures of the ozone layer look like from satellites?
4. Why is the fact that CFCs are non-reactive dangerous?

5. Why was the chemical destruction of ozone over Antarctica?
6. Why was the Montreal Protocol a landmark agreement?
7. What happened to ozone depleting substances by the mid-1990s?
8. What has happened to ozone depleting substances in the atmosphere since then?
9. What is the status of ozone depletion in the ozone layer? Has the hole healed?
10. What would have happened without the Montreal Protocol and there was no regulation of chlorine?
11. What would have happened with a much reduced ozone layer?
12. When will the ozone hole heal?
13. What is the relationship between ozone depleting substances and climate change?
14. What is the problem with hydrochlorofluorocarbons?

Practice Answers

1. It contained the data over time needed to see that ozone was being depleted. He took that raw data and processed it for the ozone amount. He plotted the lowest 11 day running mean from each Antarctic spring.
2. He discovered that ozone levels were falling off the charts they had gone so low. Every year spring ozone levels would fall over Antarctica.
3. It looked like a hole in the ozone layer.
4. Because they could travel into the stratosphere without breaking down.
5. Temperature in the stratosphere in the polar regions is extremely cold in winter. Polar stratospheric clouds permit chemical reactions to convert chlorine compounds. The polar vortex keeps everything in that region.
6. It needed a scientific foundation, policy makers and industry people needed to figure out what to substitute, and it needed to be negotiated.
7. Developed nations had ceased production and developing nations were on track to also.
8. Emissions have been reduced and there is a change in concentration in lower atmosphere and stratosphere.
9. Ozone has stabilized, but it has not started to heal.
10. By 2065, 2/3 of ozone layer would have been gone.
11. Severe sunburn, cataracts, skin cancer; crop failure, political instability.
12. Near the end of teh century.
13. The substances are powerful greenhouse gases.
14. They are greenhouse gases so they need to be phased out too.

Review

1. How did mathematical calculations and observations of depletion of ozone over Antarctica prompt society to act to protect the ozone layer?
2. What is the Montreal Protocol?
3. Why doesn't the ozone hole repair itself now that CFCs are banned?

Review Answers

1. The calculations frightened everyone and they convinced people that action needed to be taken.
2. The Montreal Protocol controls the production and consumption of 96 ozone damaging chemicals.
3. CFCs take a long time to reach the stratosphere and so they are still in the atmosphere.

1.33 Climate Change in Earth History

- Explain how Earth's climate has changed in the past.

How important is climate in the history of life?

Dinosaurs lived a long time, geologically speaking, in part because the weather was favorable to them. Giant mammals lived during the ice ages because conditions were favorable. Earth's climate has been warmer and colder in Earth history, but mostly it's been warmer.

Climate Change in Earth History

Climate has changed throughout Earth history. Much of the time Earth's climate was hotter and more humid than it is today, but climate has also been colder, as when glaciers covered much more of the planet. The most recent ice ages were in the Pleistocene Epoch, between 1.8 million and 10,000 years ago (**Figure** 1.82). Glaciers advanced and retreated in cycles, known as glacial and interglacial periods. With so much of the world's water bound into the ice, sea level was about 125 meters (395 feet) lower than it is today. Many scientists think that we are now in a warm, interglacial period that has lasted about 10,000 years.

For the past 1500 years, climate has been relatively mild and stable when compared with much of Earth's history. Why has climate stability been beneficial for human civilization? Stability has allowed the expansion of agriculture and the development of towns and cities.

Fairly small temperature changes can have major effects on global climate. The average global temperature during glacial periods was only about 5.5^{o}C (10^{o}F) less than Earth's current average temperature. Temperatures during the interglacial periods were about 1.1^{o}C (2.0^{o}F) higher than today (**Figure** 1.83).

Since the end of the Pleistocene, the global average temperature has risen about 4^{o}C (7^{o}F). Glaciers are retreating and sea level is rising. While climate is getting steadily warmer, there have been a few more extreme warm and cool times in the last 10,000 years. Changes in climate have had effects on human civilization.

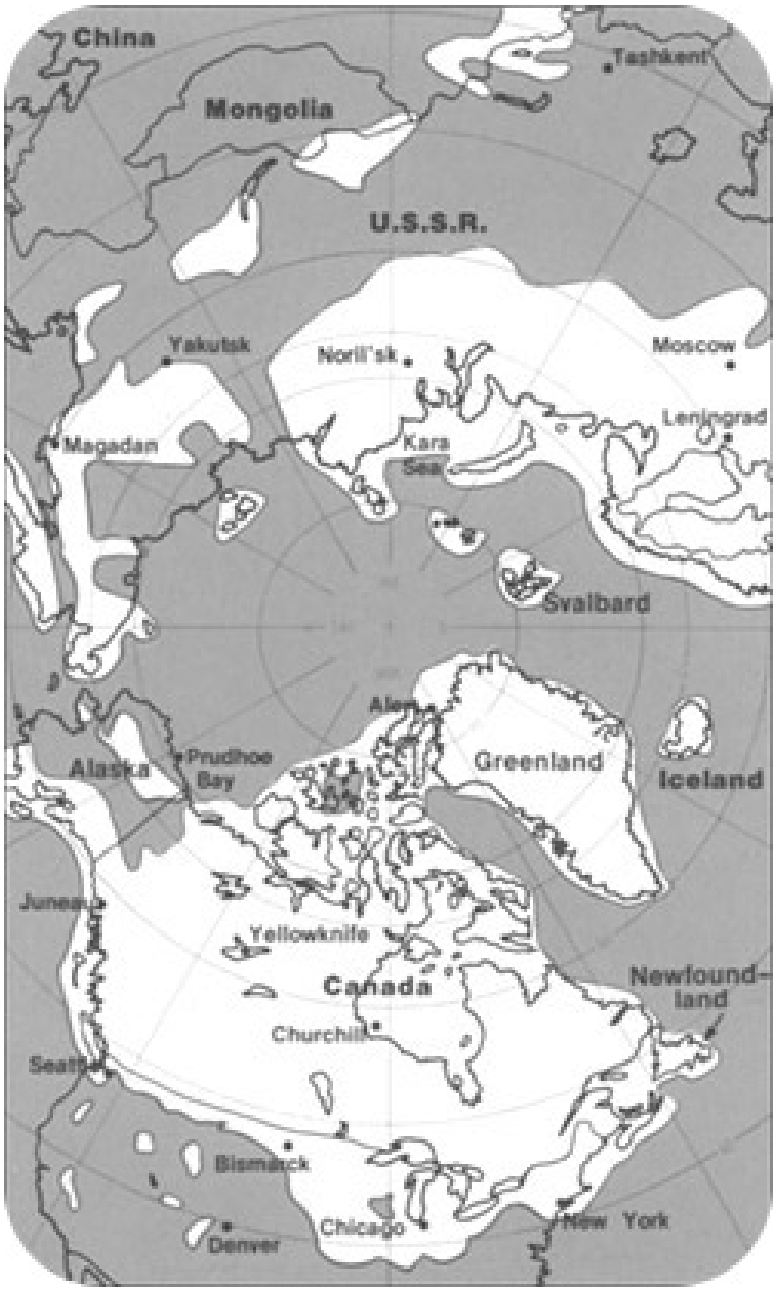


FIGURE 1.82

The maximum extent of Northern Hemisphere glaciers during the Pleistocene epoch.

- The Medieval Warm Period from 900 to 1300 A.D. allowed Vikings to colonize Greenland and Great Britain to grow wine grapes.
- The Little Ice Age, from the 14th to 19th centuries, the Vikings were forced out of Greenland and humans had to plant crops further south.

Summary

- Earth's climate has been warmer and colder, but mostly warmer, through Earth history.
- For the past 2,000 years, when human society has really blossomed, climate has been relatively stable.
- An increase in glaciers lowers sea level and a decrease in glaciers raises sea level.

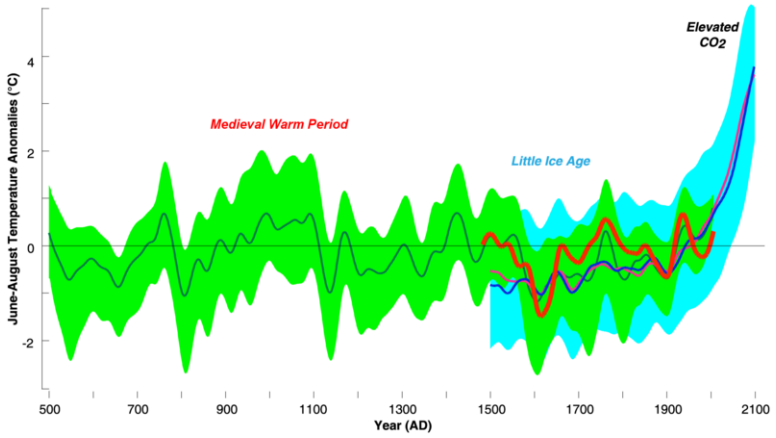


FIGURE 1.83

The graph is a compilation of 5 reconstructions (the green line is the mean of the five records) of mean temperature changes. This illustrates the high temperatures of the Medieval Warm Period, the lows of the Little Ice Age, and the very high (and climbing) temperature of this decade.

Practice

Use this resource to answer the questions that follow.

http://climate.nasa.gov/evidence/

1. What event and when was the beginning of modern climate?
2. What is most climate variation attributed to?
3. What has occurred in the last 1,300 years?
4. What have ice cores shown? What is the rate of climate change?
5. What is the evidence for rapid climate change we see today?

Practice Answers

1. The end of the ice age about 7,000 years ago.
2. Most climate variation is attributed to small variations in Earth's orbit that change the amount of solar energy we receive.
3. An unprecedented rate of warming that is likely human-induced.
4. Earth's climate responds to changes in solar output, in Earth's orbit and in greenhouse gas levels. The rate of climate change is fast, in tens of years.
5. Sea level rise, global average temperature rise, ocean warming, shrinking ice sheets, declining Arctic sea ice, retreat of glaciers, extreme weather events, and ocean acidification.

Review

1. How has climate changed in the past 1,100 years?
2. What were the temperatures of the glacial and interglacial periods of the Pleistocene ice ages?
3. Why is the fact that climate has changed a lot during Earth history important to a discussion of climate change today?

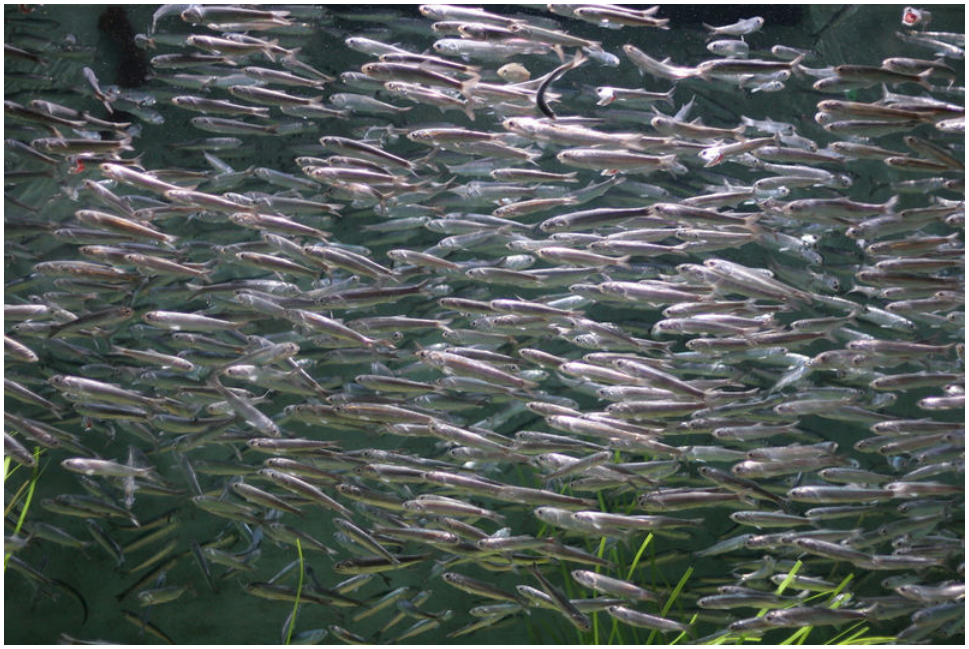
Review Answers

1. It has gone from being warm, during the Medieval Warm Period, to being very cold, in the Little Ice Age.
2. Temperatures in the glacial periods were about 5.5^{o}C (10^{o}F) less than Earth's current average temperature. Temperatures during the interglacial periods were about 1.1^{o}C (2.0^{o}F) higher than today.

3. We know that climate changes; the climate now is well within the normal range for Earth's climate. It's important to know how this climate change is different and what the effects will be.

1.34 Short-Term Climate Change

- Describe common short-term climate variations.



Why is El Niño important to a discussion on climate change?

In 1973 a severe El Niño shut off upwelling off of South America, resulting in the collapse of the anchovetta fishery. Without small fish to eat, larger marine organisms died off. Since then, severe El Niño events have become more frequent.

El Niño Southern Oscillation

Short-term changes in climate are common and they have many causes (**Figure** 1.84). The largest and most important of these is the oscillation between El Niño and La Niña conditions. This cycle is called the ENSO (El Niño Southern Oscillation). The ENSO drives changes in climate that are felt around the world about every two to seven years.

Normal Conditions

In a normal year, the trade winds blow across the Pacific Ocean near the Equator from east to west (toward Asia). A low pressure cell rises above the western equatorial Pacific. Warm water in the western Pacific Ocean raises sea levels by half a meter. Along the western coast of South America, the Peru Current carries cold water northward, and then westward along the Equator with the trade winds. Upwelling brings cold, nutrient-rich waters from the deep sea.

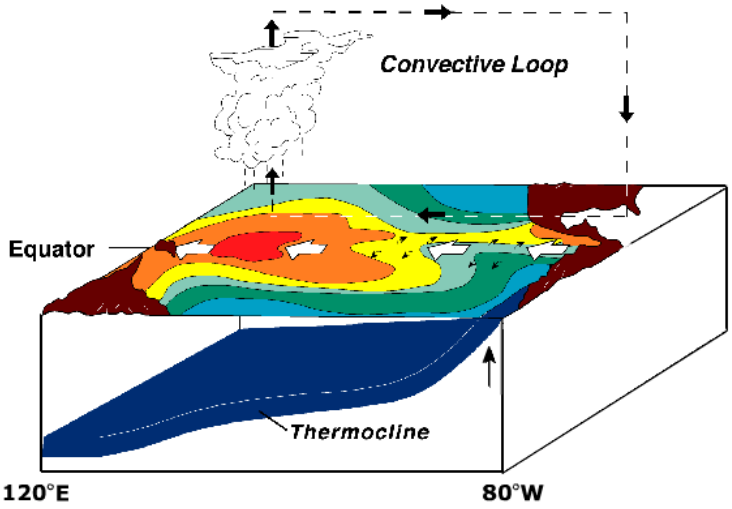


FIGURE 1.84

Under normal conditions, low pressure and warm water (shown in red) build up in the western Pacific Ocean. Notice that continents are shown in brown in the image. North and South America are on the right in this image.

El Niño

In an **El Niño** year, when water temperature reaches around 28^{o}C (82^{o}F), the trade winds weaken or reverse direction and blow east (toward South America) (**Figure** 1.85). Warm water is dragged back across the Pacific Ocean and piles up off the west coast of South America. With warm, low-density water at the surface, upwelling stops. Without upwelling, nutrients are scarce and plankton populations decline. Since plankton form the base of the food web, fish cannot find food, and fish numbers decrease as well. All the animals that eat fish, including birds and humans, are affected by the decline in fish.

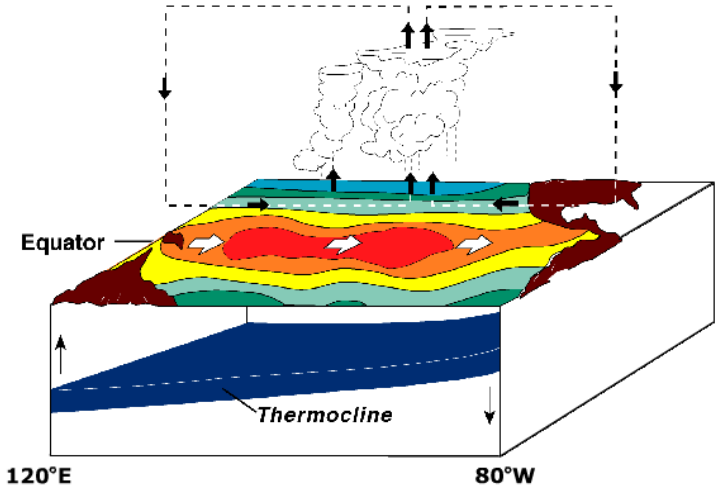


FIGURE 1.85

In El Niño conditions, the trade winds weaken or reverse directions. Warm water moves eastward across the Pacific Ocean and piles up against South America.

By altering atmospheric and oceanic circulation, El Niño events change global climate patterns.

- Some regions receive more than average rainfall, including the west coast of North and South America, the southern United States, and Western Europe.
- Drought occurs in other parts of South America, the western Pacific, southern and northern Africa, and

southern Europe.

An El Niño cycle lasts one to two years. Often, normal circulation patterns resume. Sometimes circulation patterns bounce back quickly and extremely (**Figure** 1.86). This is a **La Niña**.

La Niña

In a La Niña year, as in a normal year, trade winds moves from east to west and warm water piles up in the western Pacific Ocean. Ocean temperatures along coastal South America are colder than normal (instead of warmer, as in El Niño). Cold water reaches farther into the western Pacific than normal.

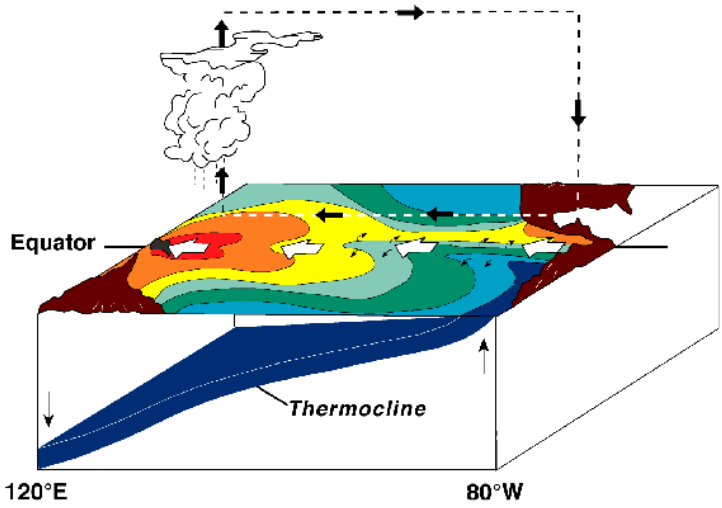


FIGURE 1.86

A La Niña year is like a normal year but the circulation patterns are more extreme.

An online guide to El Niño and La Niña events from the University of Illinois is found here: http://ww2010.atmos.uiuc.edu/%28Gh%29/guides/mtr/eln/home.rxml .

Other important oscillations are smaller and have a local, rather than global, effect. The North Atlantic Oscillation mostly alters climate in Europe. The Mediterranean also goes through cycles, varying between being dry at some times and warm and wet at others.

This ABC News video explores the relationship of El Niño to global warming. El Niño is named as the cause of strange weather across the United States in the winter of 2007 in this video: http://www.youtube.com/watch?v=5uk9nwtAOio (3:33).

MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/1524

Summary

- El Niño and La Niña are two examples of short-term climate changes lasting one to a few years.

- In an El Niño, the trade winds reverse direction, as do the equatorial surface currents, causing warm water to pool off of South America and stop upwelling.
- A La Niña is like normal conditions only more so.

Practice

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=ovDp1crqdOU

1. What are El Niño and La Niña characterized by?
2. What is the temperature situation like in the equatorial Pacific during a La Niña?
3. What is the temperature situation like in the equatorial Pacific during a El Niño?
4. What happens when upwelling is shut off offshore of South America?
5. What happens to the United States during an El Niño?
6. What happens to the United States during an La Niña?

Practice Answers

1. They are the variations in the temperature of the surface of the tropical eastern pacific. For El Niño the temperature is warmer due to lack of upwelling and for La Niña the temperature is cooler due to typical upwelling.
2. The Trade Winds blow from east to west in a typical La Niña year, which blows the warm water to the west. The warm water that piles up in the wast cause the deep water to move to the east and causes upwelling off of South America.
3. The trade winds weaken and do no force the warm water to the west shutting off upwelling. This changes weather around the world.
4. Nutrients are shut down and organisms die. Fishing is bad.
5. The jet stream is over the northern Gulf of Mexico and Florida, so they get more storms in the southeast and it is wetter there.
6. The jet stream is over the central Rockies through the eastern Great Lakes so the storms are more northern. Heavy rain with strong storms are in the northern regions.

Review

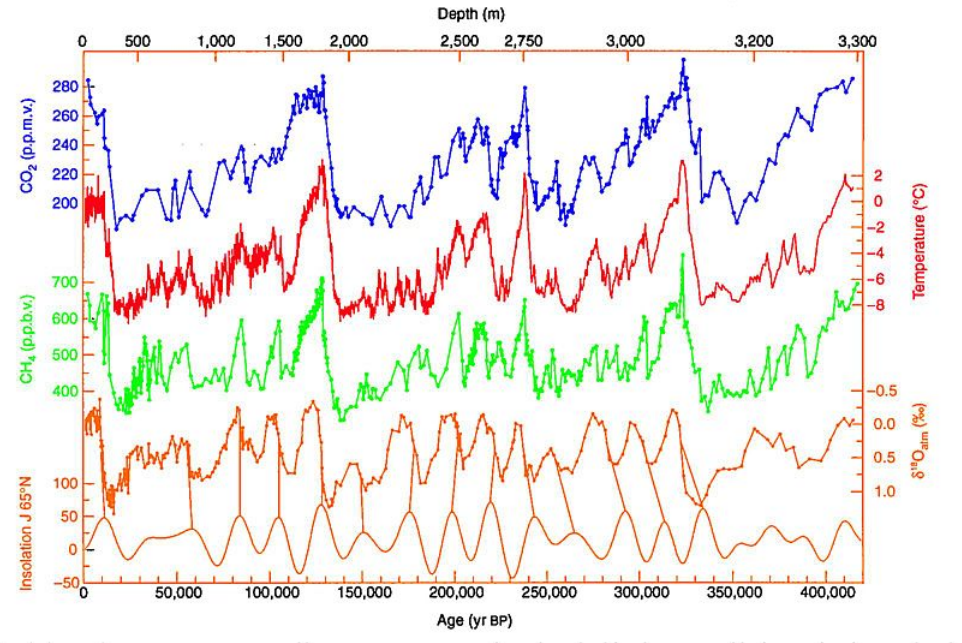
1. Describe what happens with wind and current directions during an El Niño event.
2. Why does an El Niño cause a collapse of the food chain off of South America?
3. How does a La Niña event compare with an El Niño event?

Review Answers

1. During an El Niño event the trade winds weaken or reverse direction,which bring warm water back across the Pacific to the west coast of South America.
2. The warm water that collects off South America shuts down upwelling. This means that nutrient-rich water can't rise to the surface so plankton have no nutrients and then there is no food for larger organisms.
3. It is the reverse. The trade winds blow from east to west more strongly than normal so upwelling off of South America is strong.

1.35 Long-Term Climate Change

- Explain mechanisms that can change climate over the long term.



Why do the blue, green and red lines go in the same direction at the same time?

This is a complicated graph, but extremely interesting. The data are from the 3600 meter-long Vostok ice core, which gave climate scientists an unprecedented look into the history of Earth's climate. The red line is temperature. You can see that carbon dioxide and methane are correlated with temperature. When these greenhouse gases are high, temperature is high. This holds true for the 440,000 years revealed in the core.

Causes of Long-term Climate Change

Many processes can cause climate to change. These include changes:

- In the amount of energy the Sun produces over years.
- In the positions of the continents over millions of years.
- In the tilt of Earth's axis and orbit over thousands of years.
- That are sudden and dramatic because of random catastrophic events, such as a large asteroid impact.
- In greenhouse gases in the atmosphere, caused naturally or by human activities.

Solar Variation

The amount of energy the Sun radiates is variable. **Sunspots** are magnetic storms on the Sun's surface that increase and decrease over an 11-year cycle (**Figure** 1.87). When the number of sunspots is high, solar radiation is also relatively high. But the entire variation in solar radiation is tiny relative to the total amount of solar radiation that there is, and there is no known 11-year cycle in climate variability. The Little Ice Age corresponded to a time when there were no sunspots on the Sun.

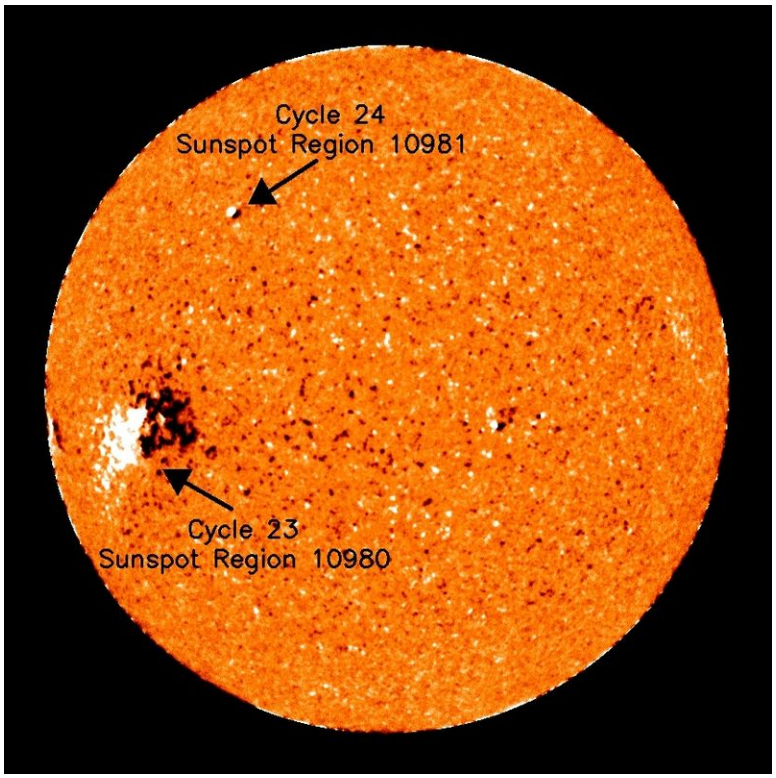


FIGURE 1.87
Sunspots on the face of the Sun.

Plate Tectonics

Plate tectonic movements can alter climate. Over millions of years as seas open and close, ocean currents may distribute heat differently. For example, when all the continents are joined into one supercontinent (such as Pangaea), nearly all locations experience a continental climate. When the continents separate, heat is more evenly distributed.

Plate tectonic movements may help start an ice age. When continents are located near the poles, ice can accumulate, which may increase albedo and lower global temperature. Low enough temperatures may start a global ice age.

Plate motions trigger volcanic eruptions, which release dust and CO_2 into the atmosphere. Ordinary eruptions, even large ones, have only a short-term effect on weather (**Figure** 1.88). Massive eruptions of the fluid lavas that create lava plateaus release much more gas and dust, and can change climate for many years. This type of eruption is exceedingly rare; none has occurred since humans have lived on Earth.

Milankovitch Cycles

The most extreme climate of recent Earth history was the Pleistocene. Scientists attribute a series of ice ages to variation in the Earth's position relative to the Sun, known as **Milankovitch cycles**.

The Earth goes through regular variations in its position relative to the Sun:

1. The shape of the Earth's orbit changes slightly as it goes around the Sun. The orbit varies from more circular to more elliptical in a cycle lasting between 90,000 and 100,000 years. When the orbit is more elliptical, there is a greater difference in solar radiation between winter and summer.

2. The planet wobbles on its axis of rotation. At one extreme of this 27,000 year cycle, the Northern Hemisphere points toward the Sun when the Earth is closest to the Sun. Summers are much warmer and winters are much colder than now. At the opposite extreme, the Northern Hemisphere points toward the Sun when it is farthest from the Sun.

FIGURE 1.88
An eruption like Sarychev Volcano (Kuril Islands, northeast of Japan) in 2009 would have very little impact on weather.

This results in chilly summers and warmer winters.

3. The planet's tilt on its axis varies between 22.1^o and 24.5^o. Seasons are caused by the tilt of Earth's axis of rotation, which is at a 23.5^o angle now. When the tilt angle is smaller, summers and winters differ less in temperature. This cycle lasts 41,000 years.

When these three variations are charted out, a climate pattern of about 100,000 years emerges. Ice ages correspond closely with Milankovitch cycles. Since glaciers can form only over land, ice ages only occur when landmasses cover the polar regions. Therefore, Milankovitch cycles are also connected to plate tectonics.

Changes in Atmospheric Greenhouse Gas Levels

Since greenhouse gases trap the heat that radiates off the planet's surfaces, what would happen to global temperatures if atmospheric greenhouse gas levels decreased? What if greenhouse gases increased? A decrease in greenhouse gas levels decreases global temperature and an increase raises global temperature.

Greenhouse gas levels have varied throughout Earth history. For example, CO_2 has been present at concentrations less than 200 parts per million (ppm) and more than 5,000 ppm. But for at least 650,000 years, CO_2 has never risen above 300 ppm, during either glacial or interglacial periods (**Figure** 1.89).

Natural processes add and remove CO_2 from the atmosphere.

- Processes that add CO_2:
  - volcanic eruptions
  - decay or burning of organic matter.
- Processes that remove CO_2:
  - absorption by plant and animal tissue.

When plants are turned into fossil fuels, the CO_2 in their tissue is stored with them. So CO_2 is removed from the atmosphere. What does this do to Earth's average temperature?

What happens to atmospheric CO_2 when the fossil fuels are burned? What happens to global temperatures?

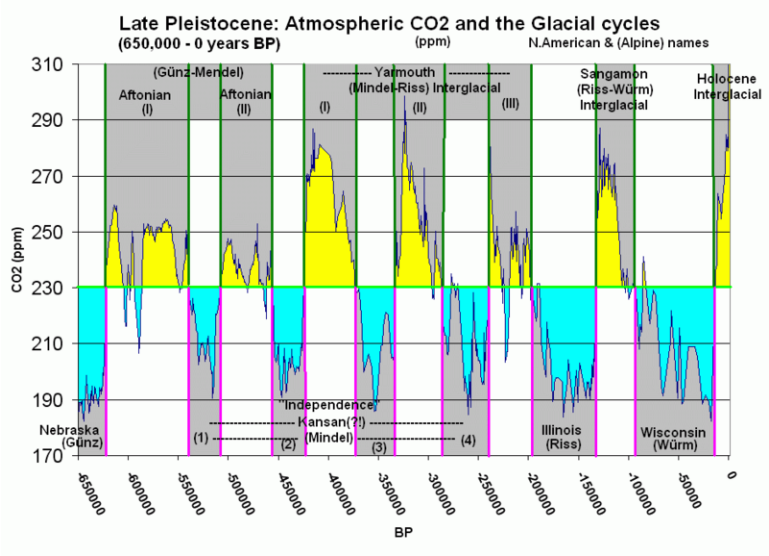


FIGURE 1.89

CO_2 levels during glacial (blue) and interglacial (yellow) periods. Are CO_2 levels relatively high or relatively low during interglacial periods? Current carbon dioxide levels are at around 400 ppm, the highest level for the last 650,000 years. BP means years before present.

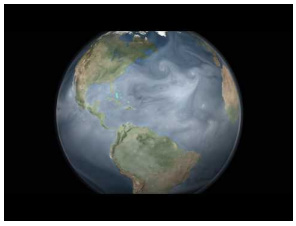
Summary

- The positions of continents, the sizes of oceans and the amount of volcanic activity that takes place are all ways that plate tectonics processes can affect climate.
- Milankovitch cycles affect the way Earth relates to the Sun due to the shape of the planet's orbit, its axial tilt, and its wobble.
- Atmospheric greenhouse gas levels correlate with average global temperatures.

Practice

Use these resources to answer the questions that follow.

http://www.youtube.com/watch?v=VlzQ1i2caj4



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1. What do Milankovitch cycles initiate?
2. How often do Milankovitch cycles produce a warm period lately?
3. What is the Holecene?
4. When should we enter another ice age?
5. What is happening to climate now?

Practice Answers

1. Milankovitch cycles initiate changes in global average temperatures between current or interglacial and glacial temperatures due to changes in the distribution of sunlight.

2. About every 100,000 years.
3. The Holocene is the time in the last 10,000 years.
4. Thousands of years from now.
5. Climate is warming and the warming is accelerating.

Review

1. How do Milankovitch cycles affect global temperatures?
2. How do plate tectonics processes affect global climate?
3. How are atmospheric greenhouse gas levels correlated with global temperatures?
4. What are carbon dioxide levels now? How often in the past 650,000 years have they been that high?

Review Answers

1. Milankovitch crates a climate pattern of 100,000 years. ice ages correspond closely with these cycles, but ice ages only occur when landmasses cover the polar regions.
2. For ice ages to happen landmasses must cover the polar regions when Milankovitch is lined up right. When landmasses are large there will be more continental climate, when they are small oceans will dominate more.
3. A rise in greenhouse gases equals a rise in temperature and a fall in one is a fall in the other.
4. The levels are about 400 ppm. They have not been that high in that amount of time.

1.36 Carbon Cycle and Climate

- Explain the carbon cycle.

What is a diamond?

Carbon takes all sorts of forms as an element and as a compound. A diamond is just carbon, pure carbon. A diamond is good for cutting things, but it's not good for breathing or building proteins out of, yet other forms of carbon are. Carbon is essential for life on Earth and, as carbon dioxide, it is an important atmospheric gas.

The Carbon Cycle

Carbon is a very important element to living things. As the second most common element in the human body, we know that human life without carbon would not be possible. Protein, **carbohydrates**, and fats are all part of the body and all contain carbon. When your body breaks down food to produce energy, you break down protein, carbohydrates, and fat, and you breathe out carbon dioxide.

Carbon occurs in many forms on Earth. The element moves through organisms and then returns to the environment. When all this happens in balance, the ecosystem remains in balance too.

Short Term Cycling of Carbon

The short term cycling of carbon begins with carbon dioxide (CO_2) in the atmosphere.

Photosynthesis

Through photosynthesis, the inorganic carbon in carbon dioxide plus water and energy from sunlight is transformed into organic carbon (food) with oxygen given off as a waste product. The chemical equation for photosynthesis is:

$$\underset{\text{carbon dioxide}}{6\ CO_2} + \underset{\text{water}}{6\ H_2O} + \text{Energy from sunlight} \rightarrow \underset{\text{glucose (sugar)}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6\ O_2}$$

Respiration

Plants and animals engage in the reverse of photosynthesis, which is respiration. In respiration, animals use oxygen to convert the organic carbon in sugar into food energy they can use. Plants also go through respiration and consume some of the sugars they produce.

The chemical reaction for respiration is:

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ + useable energy

Photosynthesis and respiration are a gas exchange process. In photosynthesis, CO_2 is converted to O_2; in respiration, O_2 is converted to CO_2.

Remember that plants do not create energy. They change the energy from sunlight into chemical energy that plants and animals can use as food (**Figure** 1.90).

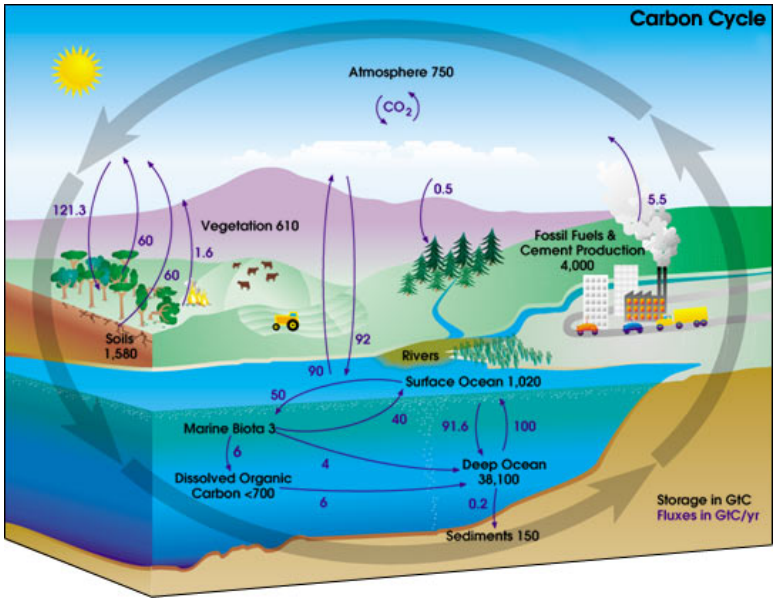


FIGURE 1.90

The carbon cycle shows where a carbon atom might be found. The black numbers indicate how much carbon is stored in various reservoirs, in billions of tons ("GtC" stands for gigatons of carbon). The purple numbers indicate how much carbon moves between reservoirs each year. The sediments, as defined in this diagram, do not include the ~70 million GtC of carbonate rock and kerogen.

Long-Term Carbon Cycling

Carbon Sinks and Carbon Sources

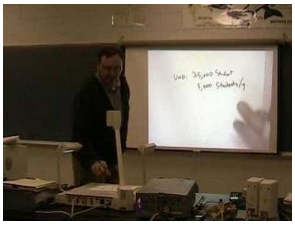
Places in the ecosystem that store carbon are reservoirs. Places that supply and remove carbon are **carbon sources** and **carbon sinks**, respectively. If more carbon is provided than stored, the place is a carbon source. If more carbon dioxide is absorbed than is emitted, the reservoir is a carbon sink. What are some examples of carbon sources and sinks?

- Carbon sinks are reservoirs where carbon is stored. Healthy living forests and the oceans act as carbon sinks.
- Carbon sources are reservoirs from which carbon can enter the environment. The mantle is a source of carbon from volcanic gases.

A reservoir can change from a sink to a source and vice versa. A forest is a sink, but when the forest burns it becomes a source.

The amount of time that carbon stays, on average, in a reservoir is the residence time of carbon in that reservoir.

The concept of residence times is explored using the undergraduate population at UGA as an example. In this example the reservoir is the university: http://www.youtube.com/watch?v=cIuaedcVvQg (2:44).



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Atmospheric Carbon Dioxide

Remember that the amount of CO_2 in the atmosphere is very low. This means that a small increase or decrease in the atmospheric CO_2 can have a large effect.

By measuring the composition of air bubbles trapped in glacial ice, scientists can learn the amount of atmospheric CO_2 at times in the past. Of particular interest is the time just before the Industrial Revolution, when society began to use fossil fuels. That value is thought to be the natural content of CO_2 for this time period; that number was 280 parts per million (ppm).

By 1958, when scientists began to directly measure CO_2 content from the atmosphere at Mauna Loa volcano in the Pacific Ocean, the amount was 316 ppm (**Figure** 1.91). In 2014, the atmospheric CO_2 content had risen to around 400 ppm.

This is an increase in atmospheric CO_2 of 40% since the before the Industrial Revolution. About 65% of that increase has occurred since the first CO_2 measurements were made on Mauna Loa Volcano, Hawaii, in 1958.

Human Actions Impact the Carbon Cycle

Humans have changed the natural balance of the carbon cycle because we use coal, oil, and natural gas to supply our energy demands. Fossil fuels are a sink for CO_2 when they form, but they are a source for CO_2 when they are burned.

The equation for combustion of propane, which is a simple hydrocarbon looks like this:

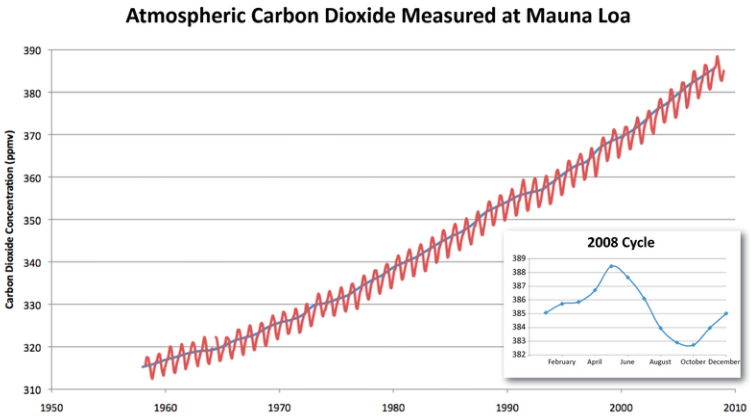


FIGURE 1.91

The amount of CO_2 in the atmosphere has been measured at Mauna Loa Observatory since 1958. The blue line shows yearly averaged CO_2. The red line shows seasonal variations in CO_2.

$$\underset{\text{propane}}{C_3H_8} + \underset{\text{oxygen}}{5\,O_2} \rightarrow \underset{\text{carbon dioxide}}{3\,CO_2} + \underset{\text{water}}{4\,H_2O}$$

The equation shows that when propane burns, it uses oxygen and produces carbon dioxide and water. So when a car burns a tank of gas, the amount of CO_2 in the atmosphere increases just a little. Added over millions of tanks of gas and coal burned for electricity in power plants and all of the other sources of CO_2, the result is the increase in atmospheric CO_2 seen in the **Figure** 1.91.

The second largest source of atmospheric CO_2 is **deforestation** (**Figure** 1.92). Trees naturally absorb CO_2 while they are alive. Trees that are cut down lose their ability to absorb CO_2. If the tree is burned or decomposes, it becomes a source of CO_2. A forest can go from being a carbon sink to being a carbon source.

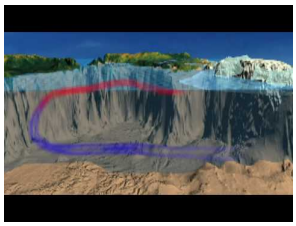
FIGURE 1.92

This forest in Mexico has been cut down and burned to clear forested land for agriculture.

Why the Carbon Cycle is Important

Why is such a small amount of carbon dioxide in the atmosphere even important? Carbon dioxide is a greenhouse gas. Greenhouse gases trap heat energy that would otherwise radiate out into space, which warms Earth. These gases were discussed in the chapter Atmospheric Processes.

This video *Keeping up with Carbon* from NASA, focuses on the oceans. Topics include what will happen as temperature warms and the oceans can hold less carbon, and ocean acidification: http://www.youtube.com/watch?v=HrIr3xDhQ0E (5:39).



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A very thorough but basic summary of the carbon cycle, including the effect of carbon dioxide in the atmosphere, is found in this video: http://www.youtube.com/watch?v=U3SZKJVKRxQ (4:37).

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Summary

- Carbon is essential for life as part of proteins, carbohydrates, and fats.
- The amount of carbon dioxide in the atmosphere is extremely low, but it is extremely important since carbon dioxide is a greenhouse gas, which helps to keep Earth's climate moderate.
- The amount of carbon dioxide in the atmosphere is rising, a fact that has been documented on Mauna Loa volcano since 1958.

Practice

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=aLuSi_6Ol8M

1. What do greenhouse gases do?
2. Where did most of the carbon dioxide that was present in the early atmosphere go?
3. What did the early plants add to the atmosphere and why was that important? What else did they create?
4. What do organisms do with the organic carbon?
5. What are the two major things that carbon does?
6. What is the 30 second version of the carbon cycle?
7. What does carbon fixation do with carbon dioxide?
8. How do organisms use the carbohydrates produced by carbon fixing reactions?
9. What is cellular respiration the reverse of?
10. After the organisms metabolize carbohydrates, how is the carbon released back into the environment?
11. What happens when carbon dioxide mixes with water and what does it cause?
12. What happens to the carbonate ions in the marine environment?
13. What happens when shell building organisms die? What happens if those organisms are buried deeply?
14. How much carbon is wrapped up in fossil fuels compared to the total amount of carbon?

15. Where does the carbon dioxide go that is released from fossil fuels? Where does the excess carbon dioxide go?

Practice Answers

1. They absorb heat energy increasing the average temperature on Earth.
2. It was used up by photosynthesis in plants.
3. They added free oxygen,which was important because it was necessary for animals to evolve and they created organic forms of carbon.
4. They feed on organic carbon compounds and oxidizing the reduced carbon back to carbon dioxide.
5. It is the main route for transporting energy between organisms and it is the main way we trap heat in our atmosphere.
6. Plants use the carbon in atmospheric CO2 to make sugars and carbohydrates to grow and reproduce. Lots are eaten and supply the other organisms with carbon. After being metabolized the carbon returns to the environment. It is extracted by organisms and returned to the atmosphere as CO2.
7. It converts carbon dioxide gas from the atmosphere and solidifies it into solid carbon compounds.
8. They can use them as building blocks for growth or as fuel.
9. The reverse of photosynthesis.
10. Lots is released as a product of cellular respiration - exhale.
11. It forms weak carbonic acid and can cause weathering. .
12. Organisms use them to build their shells and skeletons in the form of calcium carbonate.
13. Their materials break down on huge and very slow time scales. If calcium carbonate is lithified it becomes limestone.
14. 0.006% of all the carbon on Earth
15. It goes back into the environment. The excess joins greenhouse gases in the atmosphere.

Review

1. What does it mean to say that photosynthesis and respiration are gas exchange processes?
2. How do scientists learn about carbon levels in the past?
3. How do human activities affect the carbon cycle?

Review Answers

1. Photosynthesis and respiration are a gas exchange process. In photosynthesis, CO_2 is converted to O_2; in respiration, O_2 is converted to CO_2.
2. By measuring the amount of atmospheric CO2 in air bubbles in glacial ice they can learn about old times but they can learn about values since 1958 from measurement records.
3. Humans release a lot of carbon that was trapped in fossil fuels or forests back into the atmosphere so there is a lot more there.

1.37 Global Warming

- Describe the consequences of global warming.

Do polar bears belong in garbage dumps?

Changes due to warmer temperatures are becoming more visible. The Arctic is covered with ice less of the year, so polar bears can't hunt and are raiding garbage dumps for food. Extreme weather events are becoming more common as weather becomes stranger. Sea level is rising, which is a problem during storms.

Global Warming

With more greenhouse gases trapping heat, average annual global temperatures are rising. This is known as **global warming**.

Global warming - How Humans are Affecting our Planet from NASA, discusses the basics of global warming science: http://www.youtube.com/watch?v=VXvGPbHXxtc (7:58).

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Increasing Temperatures

While temperatures have risen since the end of the Pleistocene, 10,000 years ago, this rate of increase has been more rapid in the past century, and has risen even faster since 1990. The 10 warmest years in the 134-year record have all occurred since in the 21st century, and only one year during the 20th century (1998) was warmer than 2013, the 4th warmest year on record (through 2013) (**Figure** 1.93). The 2000s were the warmest decade yet.

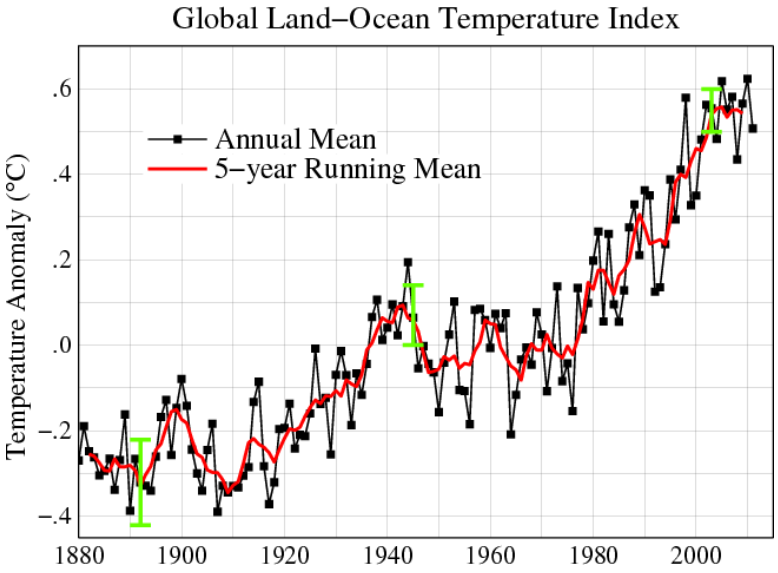

FIGURE 1.93

Recent temperature increases show how much temperature has risen since the Industrial Revolution began.

Annual variations aside, the average global temperature increased about 0.8^{o}C (1.5^{o}F) between 1880 and 2010, according to the Goddard Institute for Space Studies, NOAA. This number doesn't seem very large. Why is it important? http://www.giss.nasa.gov/research/news/20100121/

Greenhouse Gas Emissions

The United States has long been the largest emitter of greenhouse gases, with about 20% of total emissions in 2004. As a result of China's rapid economic growth, its emissions surpassed those of the United States in 2008. However, it's also important to keep in mind that the United States has only about one-fifth the population of China. What's the significance of this? The average United States citizen produces far more greenhouse gas emissions than the average Chinese person.

An animation of CO_2 released by different fossil fuels is seen here: http://www.nature.nps.gov/GEOLOGY/usgsnps/oilgas/CO2BTU_3.MPG .

Changes Due to Warming Temperatures

The following images show changes in the Earth and organisms as a result of global warming: **Figure** 1.94, **Figure** 1.95, **Figure** 1.96.

The timing of events for species is changing. Mating and migrations take place earlier in the spring months. Species that can are moving their ranges uphill. Some regions that were already marginal for agriculture are no longer arable because they have become too warm or dry.

Modeled Climate-Induced Glacier Change in Glacier National Park, 1850-2100: http://www.nrmsc.usgs.gov/research/glacier_model.htm .

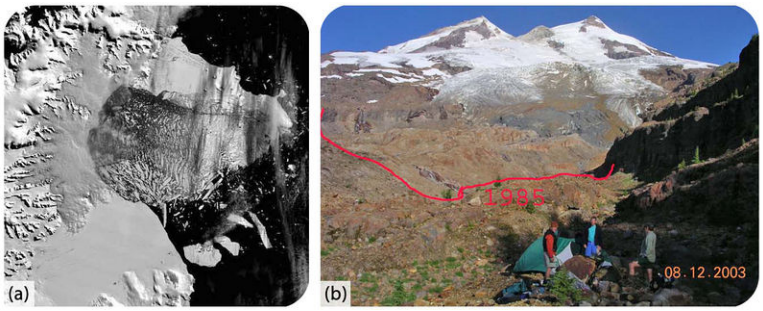

FIGURE 1.94

(a) Breakup of the Larsen Ice Shelf in Antarctica in 2002 was related to climate warming in the region. (b) The Boulder Glacier has melted back tremendously since 1985. Other mountain glaciers around the world are also melting.

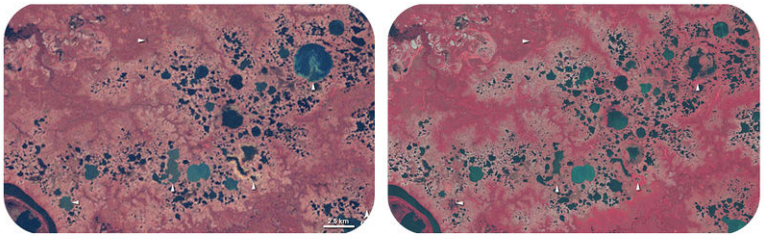

FIGURE 1.95

Permafrost is melting and its extent decreasing. There are now fewer summer lakes in Siberia.

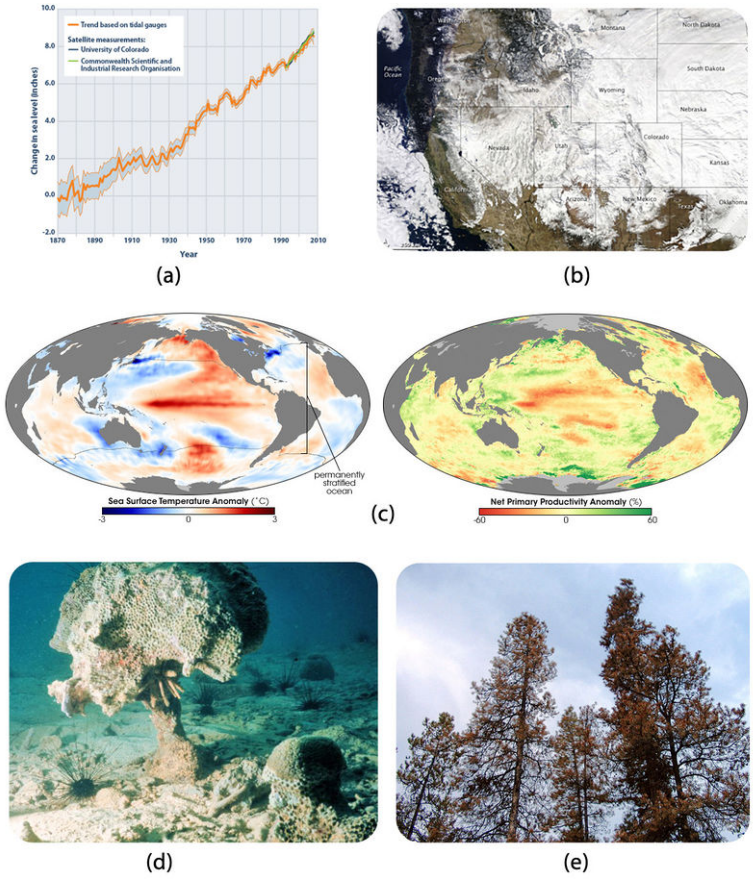

FIGURE 1.96

(a) Melting ice caps add water to the oceans, so sea level is rising. Remember that water slightly expands as it warms —this expansion is also causing sea level to rise. (b) Weather is becoming more variable with more severe storms and droughts. Snow blanketed the western United States in December 2009. (c) As surface seas warm, phytoplankton productivity has decreased. (d) Coral reefs are dying worldwide; corals that are stressed by high temperatures turn white. (e) Pine beetle infestations have killed trees in western North America The insects have expanded their ranges into areas that were once too cold.

What are the two major effects being seen in this animation? Glaciers are melting and vegetation zones are moving uphill. If fossil fuel use exploded in the 1950s, why do these changes begin early in the animation? Does this mean that the climate change we are seeing is caused by natural processes and not by fossil fuel use?

A number of videos on the National Geographic site deal with global warming: http://video.nationalgeographic.com/video/environment/global-warming-environment .

- A no-nonsense look at global warming and what we can do about it is found in "A Way Forward: Facing Climate Change."
- "Antarctic Ice" describes the changes that are already happening to Antarctica and what the consequences of future melting will be.
- "Glacier Melt" looks at melting in a large alpine glacier and the effects of glacier loss to Europe.
- In "Greenhouse Gases," researchers look at the effects of additional greenhouse gases on future forests.
- Researchers look for changes in the range of a mountain-top dwelling mammal, the pika, in "Hamster-like Pika in Peril."
- "State of Polar Bears" show how polar bears, in their specialized habitat in the Arctic, are among the species already affected by warming temperatures.

Warming temperatures are bringing changes to much of the planet, including California. Sea level is rising, snow pack is changing, and the ecology of the state is responding to these changes.

Find out more at http://science.kqed.org/quest/video/climate-watch-california-at-the-tipping-point/ .

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Summary

- Greenhouse gases trap heat in the atmosphere; burning fossil fuels and other human activities release greenhouse gases into the atmosphere; greenhouse gas levels in the atmosphere are increasing; and global temperatures are increasing.
- Average global temperature has been rising since the end of the ice ages but the rate of its rise has increased in recent decades.
- Changes due to increasing temperatures are seen around the globe but are most dramatic in the polar regions.

Practice

Use the resource below to answer the questions that follow.

- **Global Warming 101** at http://www.youtube.com/watch?v=oJAbATJCugs (3:03)

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1. How much has the global temperature risen in the last century?
2. What is the major human activity that contributes to global warming and why?
3. What is the greenhouse effect?
4. Is average global temperature rising? What is your evidence?
5. Which greenhouse gases are at their highest levels in history? When was the last time they were as high?
6. What do researchers predict will happen?
7. What can we do now to slow the rise in temperatures?

Practice Answers

1. Between 1.2 and 1.4-degrees F.
2. Fossil fuel burning because it releases the greenhouse gas carbon dioxide.
3. Greenhouse effect traps heat in the atmosphere. The Sun radiates energy onto Earth, the land absorbs some but radiates some back into the atmosphere. This radiation is heat and may be trapped by greenhouse gases.
4. Yes. The warmest year on records kept by humans was 1998 and then 2005. (Update: 13 of the 14 warmest years on record have been in the 21st century.)
5. Carbon dioxide and methane are at their highest in 420,000 years.
6. If greenhouse gases continue to rise, average global temperatures will increase by 2 to 10-degrees F by the end of the century.
7. Drive less; save energy around the house.

Review

1. The first point in the summary above is a set of facts. Does it logically follow that human activities are causing global temperatures to rise? Is there a different explanation that fits with the facts?
2. Why is average global temperature the most important value when talking about climate change?
3. What are some of the effects of climate change that are already being seen?

Review Answers

1. Since greenhouse gas levels are rising and greenhouse gases cause temperatures to increase it does logically follow. There is no other logical explanation.
2. We can determine that value back into Earth history; it is the crux of what the issue is about.
3. Ice is melting, glaciers are retreating, ice sheets are breaking up; permafrost is melting; sea level is rising; sea surface temperatures are up, coral reefs are dying, phytoplankton productivity is decreasing; weather is getting weirder; pests are moving to different ranges; mating and migrations are taking place earlier in the spring; crop seasons are changing.

1.38 Impact of Continued Global Warming

- Describe likely impacts of continued global warming.

"The Inuit see this and the world should know this..."

"It's happening right before our eyes. If we're going to be ignored, it's like putting a shotgun in our mouth and pulling the trigger." —23-year-old Jordan Konek, one of the native people of the Canadian Arctic, to the 2011 Climate Change Conference in Durban, South Africa.

Future Warming

The amount CO_2 levels will rise in the next decades is unknown. What will this number depend on in the developed nations? What will it depend on in the developing nations? In the developed nations it will depend on technological advances or lifestyle changes that decrease emissions. In the developing nations, it will depend on how much their lifestyles improve and how these improvements are made.

If nothing is done to decrease the rate of CO_2 emissions, by 2030, CO_2 emissions are projected to be 63% greater than they were in 2002.

Temperature Scenarios

Computer models are used to predict the effects of greenhouse gas increases on climate for the planet as a whole and also for specific regions. If nothing is done to control greenhouse gas emissions and they continue to increase at current rates, the surface temperature of the Earth can be expected to increase between 0.5^oC and 2.0^oC (0.9^oF and 3.6^oF) by 2050 and between 2^o and 4.5^oC (3.5^o and 8^oF) by 2100, with CO_2 levels over 800 parts per million (ppm). On the other hand, if severe limits on CO_2 emissions begin soon, temperatures could rise less than 1.1^oC (2^oF) by 2100.

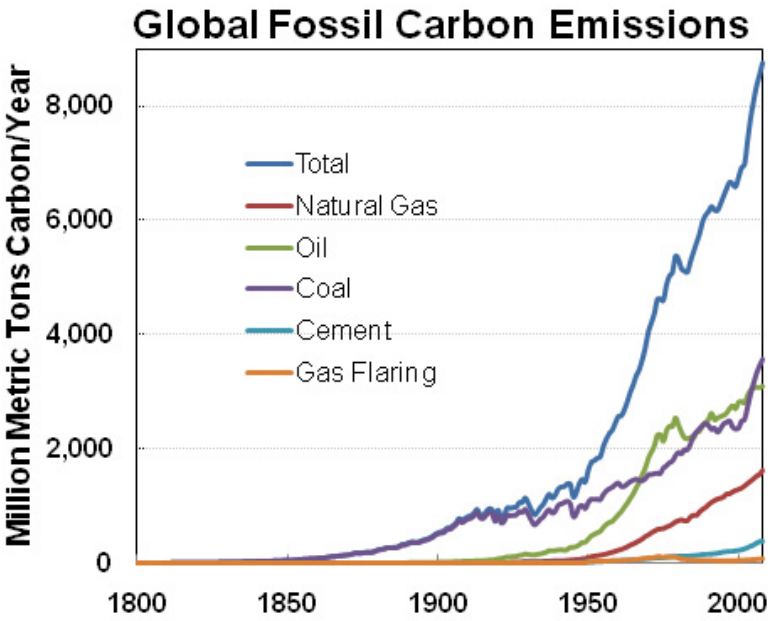
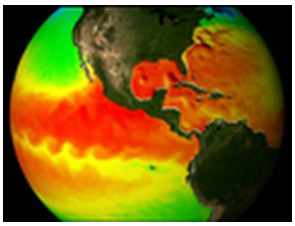


FIGURE 1.97

Global CO_2 emissions are rising rapidly. The industrial revolution began about 1850 and industrialization has been accelerating.

This video explores the tools NASA scientists use to determine how the climate is changing: http://www.youtube.com/watch?v=JRayIgKublg (4:00).



MEDIA

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URL: http://gamma.ck12.org/flx/render/embeddedobject/1436

Whatever the temperature increase, it will not be uniform around the globe. A rise of 2.8°C (5°F) would result in 0.6° to 1.2°C (1° to 2°F) at the Equator, but up to 6.7°C (12°F) at the poles. So far, global warming has affected the North Pole more than the South Pole, but temperatures are still increasing at Antarctica (**Figure** 1.98).

Animations of temperature anomalies for 5- and 10-year periods: http://data.giss.nasa.gov/gistemp/animations/ .

Global Changes

As greenhouse gases increase, changes will be more extreme. Oceans will become more acidic, making it more difficult for creatures with carbonate shells to grow, and that includes coral reefs. A study monitoring ocean acidity in the Pacific Northwest found ocean acidity increasing ten times faster than expected and 10% to 20% of shellfish (mussels) being replaced by acid-tolerant algae.

Plant and animal species seeking cooler temperatures will need to move poleward 100 to 150 km (60 to 90 miles) or upward 150 m (500 feet) for each 1.0°C (8°F) rise in global temperature. There will be a tremendous loss of biodiversity because forest species can't migrate that rapidly. Biologists have already documented the extinction of high-altitude species that have nowhere higher to go.

Decreased snow packs, shrinking glaciers, and the earlier arrival of spring will all lessen the amount of water available in some regions of the world, including the western United States and much of Asia. Ice will continue

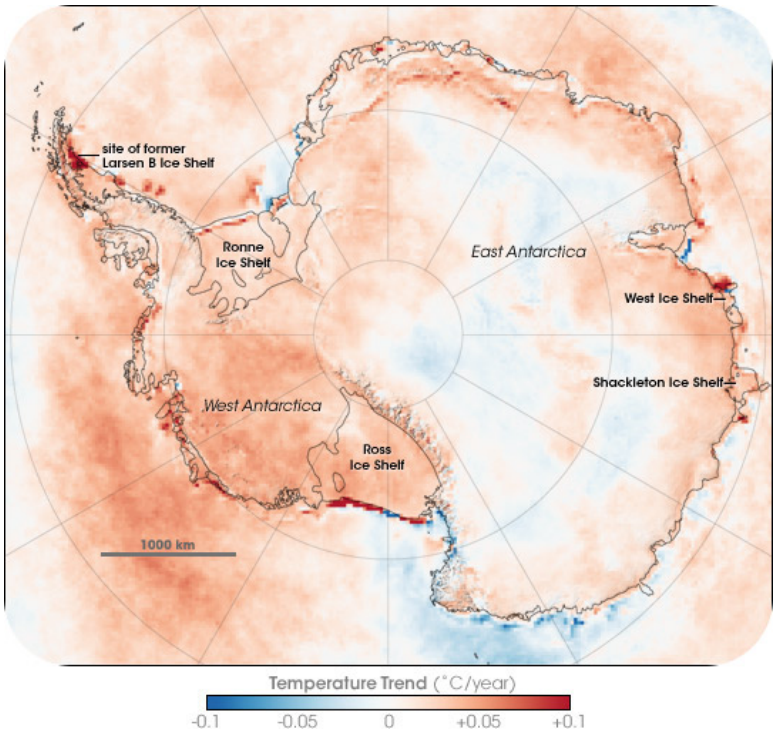

FIGURE 1.98

Temperature changes over Antarctica.

to melt and sea level is predicted to rise 18 to 97 cm (7 to 38 inches) by 2100 (**Figure** 1.99). An increase this large will gradually flood coastal regions, where about one-third of the world's population lives, forcing billions of people to move inland.

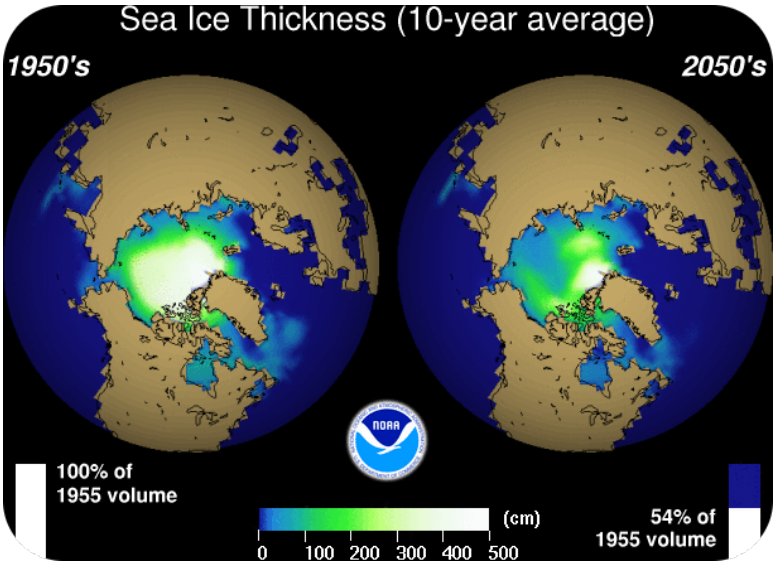

FIGURE 1.99

Sea ice thickness around the North Pole has been decreasing in recent decades and will continue to decrease in the coming decades.

Weather will become more extreme, with more frequent and more intense heat waves and droughts. Some modelers predict that the midwestern United States will become too dry to support agriculture and that Canada will become the new breadbasket. In all, about 10% to 50% of current cropland worldwide may become unusable if CO_2 doubles.

Although scientists do not all agree, hurricanes are likely to become more severe and possibly more frequent.

Tropical and subtropical insects will expand their ranges, resulting in the spread of tropical diseases such as malaria, encephalitis, yellow fever, and dengue fever.

You may notice that the numerical predictions above contain wide ranges. Sea level, for example, is expected to rise somewhere between 18 and 97 cm —quite a wide range. What is the reason for this uncertainty? It is partly because scientists cannot predict exactly how the Earth will respond to increased levels of greenhouses gases. How quickly greenhouse gases continue to build up in the atmosphere depends in part on the choices we make.

An important question people ask is this: Are the increases in global temperature natural? In other words, can natural variations in temperature account for the increase in temperature that we see? The answer is no. Changes in the Sun's irradiance, El Niño and La Niña cycles, natural changes in greenhouse gas, and other atmospheric gases cannot account for the increase in temperature that has already happened in the past decades.

This video discusses how, by using the CERES satellite, scientists monitor energy in the atmosphere, including incoming solar energy and reflected and absorbed energy. Greenhouse warming that results from atmospheric greenhouse gasses is also monitored: http://www.youtube.com/watch?v=JFfD6jn_OvA (4:31).

MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/1518

Along with the rest of the world's oceans, San Francisco Bay is rising. Changes are happening slowly in the coastal arena of the San Francisco Bay Area and even the most optimistic estimates about how high and how quickly this rise will occur indicate potentially huge problems for the region.

Find out more at http://science.kqed.org/quest/video/going-up-sea-level-rise-in-san-francisco-bay/ .

MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/116515

How Bad Could a Few Degrees Be?

How bad could a few degrees be? National Geographic has a set of videos about what to expect if temperature rises by each of these amounts by degree Celsius.

- 1^o: http://www.youtube.com/watch?v=2_ZQRIsn2pA
- 2^o: http://www.youtube.com/watch?v=P-0_gDXqYeQ
- 3^o: http://www.youtube.com/watch?v=6rdLu7wiZOE
- 4^o: http://www.youtube.com/watch?v=skFrR3g4BRQ
- 5^o: http://www.youtube.com/watch?v=7nRf2RTqANg
- 6^o: http://www.youtube.com/watch?v=O8qmaAMK4cM

Summary

- An increase in greenhouse gases will increase the changes that are already being seen including in ocean acidity.
- A decrease in snow pack will cause a shortage of water in a lot of regions that depend on a summer melt to supply water in the dry months.
- Temperature changes are not uniform around the globe. The largest changes are being seen in the polar regions.

Practice

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=pAA7FEqYTjA

1. What have the world's top scientists concluded? What are the main causes?
2. What has happened over the past 250 years and why?
3. What changes are happening to the atmosphere?
4. What is causing sea level to rise? What will happen to small island nations?
5. What happens to biodiversity?
6. What could happen to food supplies?
7. Who is the most vulnerable to climate changes?
8. What will happen to coastal areas?
9. What must we do to change this future?
10. What must each of us do? Governments?
11. What should be reflected in the costs of fossil fuels?

Practice Answers

1. Our climate is changing. Global warming is a fact and human activity including the burning of fossil fuels and deforestation is to blame.
2. There has been a dramatic rise of greenhouse gases in the atmosphere, particularly carbon dioxide.
3. Changes in precipitation patterns intensify drought and aggregates flooding in different regions.
4. Sea level is rising because ice is melting and water is warming. Small island nations could be lost.
5. Natures balance is lost on land and i oceans.
6. Changes in the ability to grow crops could compound growing population to reduce food availability.
7. The poor who rely on rain for agriculture, melting glaciers for summer water.
8. They will be more vulnerable to storms and will flood lower areas.
9. Stabilize greenhouse gases to limit temperature rise to 2-degrees C.
10. Improve energy efficiency and conservation. More efficient modes of transportation; better management of our forests.
11. The impacts on climate to encourage alternative energy sources.

Review

1. What factors does a computer model that predicts environmental changes due to increases in atmospheric greenhouse gases need to take into account?
2. Why does a small change in average global temperature have a large effect on the planet?
3. Why do you think that scientists do not have a firm understanding of how Earth will respond to increases in global temperature in the future?

Review Answers

1. There are many factors: temperature, cloud cover, albedo, and many others.
2. There are positive feedback mechanisms. For example, as the poles lower albedo, warming is increased which causes more ice to melt.
3. They study what's happened in Earth's past and how changes that we see so far are predicted by the models to work on the prediction of future warming.

1.39 Reducing Greenhouse Gas Pollution

- Describe how greenhouse gas pollution can be reduced.

"The chance of averting catastrophic climate change is slipping through our hands with every passing year that nations fail to agree on a rescue plan for the planet." —Greenpeace International director Kumi Naidoo, at the Durban, South Africa Climate Change Conference in 2011.

Reducing Greenhouse Gases

Climate scientists agree that climate change is a global problem that must be attacked by a unified world with a single goal. All nations must come together to reduce greenhouse gas emissions. However, getting nations to agree on anything has proven to be difficult. A few ideas have been proposed and in some nations are being enacted.

International Agreements

The first attempt to cap greenhouse gas emissions was the Kyoto Protocol, which climate scientists agree did not do enough in terms of cutting emissions or in getting nations to participate. The Kyoto Protocol set up a **cap-and-trade system**. Cap-and-trade provides a monetary incentive for nations to develop technologies that will reduce emissions and to conserve energy. Some states and cities within the United States have begun their own cap-and-trade systems.

The United Nations Climate Change Conference meets in a different location annually. Although recommendations are made each year, the group has not gotten the nations to sign on to a binding agreement. By doing nothing we are doing something - continuing to raise greenhouse gas levels and failing to prepare for the coming environmental changes.

Carbon Tax

The easiest and quickest way is to reduce greenhouse gas emissions is to increase energy efficiency. One effective way to encourage efficiency is financial. A **carbon tax** can be placed on CO_2 emissions to encourage conservation. The tax would be placed on gasoline, carbon dioxide emitted by factories, and home energy bills so people or businesses that emit more carbon would pay more money. This would encourage conservation since when people purchase a new car, for example, they would be more likely to purchase an energy-efficient model. The money from the carbon tax would be used for research into alternative energy sources. All plans for a carbon tax allow a tax credit for people who cannot afford to pay more for energy so that they do not suffer unfairly.

New technologies can be developed, such as renewable sources that were discussed in the chapter Natural Resources. **Biofuels** can replace gasoline in vehicles, but they must be developed sensibly (**Figure** 1.100). So far much of the biofuel is produced from crops such as corn. But when food crops are used for fuel, the price of food goes up. Modern agriculture is also extremely reliant on fossil fuels for pesticides, fertilizers, and the work of farming. This means that not much energy is gained from using a biofuel over using the fossil fuels directly. More promising crops for biofuels are now being researched. Surprisingly, algae is being investigated as a source of fuel! The algae can be grown in areas that are not useful for agriculture, and it also contains much more usable oil than crops such as corn.

FIGURE 1.100
A bus that runs on soybean oil shows the potential of biofuels.

Carbon Capture and Sequestration

If climate change becomes bad enough, people can attempt to remove greenhouse gases from the atmosphere after they are emitted. **Carbon sequestration** occurs naturally when carbon dioxide is removed from the atmosphere by trees in a forest. One way to remove carbon would be to plant more trees, but unfortunately, more forest land is currently being lost than gained.

Carbon can also be artificially sequestered. For example, carbon can be captured from the emissions from gasification plants and then stored underground in salt layers or coal seams. While some small sequestration projects are in development, large-scale sequestration has not yet been attempted.

This type of carbon capture and sequestration comes under the heading of geoengineering. There are many other fascinating ideas in geoengineering that people have proposed that are worth looking at. One wild example is to shadow the planet with large orbiting objects. A large mirror in orbit could reflect about 2% of incoming solar radiation back into space. These sorts of solutions would be expensive in cost and energy.

Just as individuals can diminish other types of air pollution, people can fight global warming by conserving energy. Also, people can become involved in local, regional, and national efforts to make sound choices on energy policy.

Summary

- A cap-and-trade system gives nations a cap on the greenhouse gas emissions they're allowed and allows them to trade allowances with other nations so that they can meet their cap.
- A carbon tax taxes carbon emissions to encourage conservation.
- Carbon capture and sequestration is a geoengineering solution for removing excess carbon dioxide from the atmosphere.

Practice

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=kJEzSwceKVA Watch between 2:12 and 4:25

1. What are the four strategies that California will use together to meet their greenhouse gas reduction target?
2. What does cap and trade do?
3. What does the cap in cap-and-trade refer to?
4. How will California meet its cap?
5. What does the trade in cap-and-trade refer to? What is the incentive to reduce emissions?
6. Why is cap-and-trade a good system?
7. Has this system worked in another environmental area?

Practice Answers

1. Increase vehicle efficiency; reduce dependency on fossil fuels; generate 1/3 of electricity from renewable sources; lower methane emissions from landfills
2. It sets a limit on greenhouse gas emissions for the state.
3. The cap is the limit on greenhouse gas emissions allowed that will be reduced over time until the goal is reached.
4. the 600 emitters that release 80% of greenhouse gases will e issued or buy allowances for metric tons of carbon dioxide.
5. Entities buy and sell these allowances on the open market. It is possible to sell extra allowances to make money.
6. It is a market based system that offers incentives for new technologies to be invented.
7. Yes, it worked in acid rain.

Review

1. Why would a carbon tax be effective at reducing greenhouse gas emissions?
2. How does a carbon tax not penalize people who can't afford to pay more for fuel and other items?
3. What are the advantages and disadvantages of using geoengineering solutions to reduce climate change rather than things like cap-and-trade or a carbon tax?

Review Answers

1. If people have to pay more for the carbon they use they are encouraged to be more efficient. The money helps to fund research that can further reduce emissions.

2. A tax credit would exist for people below a certain income level.
3. Geoengineering involves a lot of technology that needs to be developed and in some cases it's pretty far-fetched; no one knows if it will work.

Summary

Human population grew by 1 billion in the past 12 years to reach 7 billion. In 1960, the human population was only 3 billion. The population growth of every species on Earth is limited by some limiting factor so that within each ecosystem the carrying capacity for each species is set. Human ingenuity due to our brains and our hands, has allowed us to blow past any previously held idea of what Earth's carrying capacity for humans is. The development of and advances in agriculture over for the past 10,000 years have been the largest factors. How long can human population continue to grow? No one knows, and no one knows what the planet's ultimate carrying capacity for humans will be. The enormous number of people, and the tremendous consumption of the percentage of the world's population that does more than just meet its basic needs, has put a strain on Earth's resources and generated a tremendous amount of waste. Land is used for farming and other activities and also for the disposal of hazardous wastes. Water is used for drinking, bathing, agricultural and industrial uses, which may deplete supplies and pollute water sources. Much of what has fueled development in agriculture and industry has been the availability of cheap fossil fuels, which pollute the air and emit carbon dioxide into the atmosphere. Carbon dioxide is one of the greenhouse gases that trap heat and moderate Earth's temperature. As the levels of carbon dioxide and other greenhouse gases in the atmosphere rise, they can trap more heat, which causes global temperatures to warm. The effects of global warming are already being seen as ice melts and sea level rises, species are forced to move uphill or higher in latitude seeking a suitable habitat, the oceans become ore acidic, and many other consequences.

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