Lesson #16: Precautionary Principle

<table>
<tr><th colspan="2">Stage 1 – Desired Results</th></tr>
<tr><td colspan="2">Established Goals: SLO A2: Recognize both the power and the limitations of science as a way of answering questions about the world and exploring natural phenomena.</td></tr>
<tr><td>Understandings:
Students will understand that…1. There are many different ways to view an issue such as the precautionary principle.</td><td>Essential Questions: SLO A3: How do history and culture (mental models) influence creation and use of technology (how we TAKE-MAKE-WASTE goods)?</td></tr>
<tr><td>Students will know… 1. Vocabulary associated with precautionary principle
2. Different viewpoints in regards to the precautionary principle.</td><td>Students will be able to…1. Defend a position in regards to the precautionary principle.
2. Discuss a detailed case study in relation to the precautionary principle</td></tr>
<tr><th colspan="2">Stage 2- Assessment Evidence</th></tr>
<tr><td>Knowledge:1. Assess knowledge from handout
2. Knowledge of case studies</td><td>Skills: Assess debating skills or writing skills from position paper
Assess research (if you require additional research for the case studies)</td></tr>
<tr><th colspan="2">Materials Required</th></tr>
<tr><td colspan="2">Powerpoint Presentation “Examining Our Mental Models”
HANDOUT: Precautionary Principle
Why do we know So Little About the Harmful Effects of Chemicals? (Source: Miller, G. (2005). Living in the environment (14th ed.). CA, USA: Brooks/Cole (p. 417-419).
Defending a Position about the Precautionary Principle (includes the following 3 case studies:
Case study: Revisiting DDT – from Riches to Rags (Source: Miller, G. (2005). Living in the environment (14th ed.). CA, USA: Brooks/Cole (p. 526-527).
Case Study: Chattanooga, Tennessee - From Brown to Green(Source: Miller, G. (2005). Living in the environment (14th ed.). CA, USA: Brooks/Cole (p.581).
Case Study: Pollution in the Great Lakes-Hopeful Progress(Source: Miller, G. (2005). Living in the environment (14th ed.). CA, USA: Brooks/Cole (p. 500-501).</td></tr>
<tr><th colspan="2">Stage 3 – Learning Plan</th></tr>
<tr><td colspan="2">1. Ask students to show whether they agree/disagree with the following axioms
*Better safe than sorry
*Look before you leap
*An ounce of prevention is worth a pound of cure
*Ask for forgiveness rather than permission
2. Slide 40 – Take a show of hands for “Can’t nature just “bounce back” from the waste that humans produce?
3. Have students read “Why do we know So Little About the Harmful Effects of Chemicals?” (Source: Miller, G. (2005). Living in the environment (14th ed.). CA, USA: Brooks/Cole (p. 417-419) and answer the questions on the handout.
4. Inform students that they should be prepared to argue their case FOR or AGAINST use of the precautionary principle. This is really a question of whether, in your mental model you believe that there are/are not limits to nature and whether you think science/technology can “fix” all human-made problems.

Provided here are 3 different positions with case studies to back up the position. All students should be given the info that the other groups have so that they can prepare their counterarguments. Present in the form of a debate or a position paper.</td></tr>
</table>

5. **Slide 41 –** Upon completing the debates/position paper, reflect back on the examples for fabrics and discuss that there may be necessary changes in mental models if we want to address sustainability issues.

Extension Learning Activities

See your nearest English teacher to discuss the writing of position papers.
An interesting article on treating people equally and avoiding protecting their health due to legal technicalities. Given the other issues that Hurricane Katrina raised regarding treating people equally, it is another to add to the list:
(Formaldehyde in wood from houses provided to those who lost their home after Hurricane Katrina)
http://www.healthybuilding.net/news/070530sleep_well.html

It has a link to the Science & Environmental Health Network website that advocates the adoption of the precautionary principle

http://www.sehn.org/precaution.html

Why do we Know so Little about the Harmful Effects of Chemicals?

(To complement: Miller, G. (2005). Living in the environment (14th ed.). CA, USA: Brooks/Cole (p. 417-418)

#1 Define the following:

a) Precautionary principle:

b) POP:

c) dirty dozen:

#2 The article discusses 3 reasons why we do not know much about chemicals (in the United States context). Describe them.

1.

2.

3.

Is Pollution Prevention the Answer?

#3 The European Union suggests that we should not release into the environment chemicals that we KNOW or SUSPECT can cause significant harm and offers two suggestions:

a)

b)

#4 Two advantages are described as:

a)

b)

#5 What is the difference between plausible science and frontier science?

#6 Two changes in the way we measure our “risk” are described as:

a)

b)

#7 Manufacturers and businesses make several arguments against the use of the precautionary principle. List them in your own words.

Defending a Position about the Precautionary Principle

These questions are a part of our mental model about nature.

*are limits to nature's ability to "bounce back" from some event or exposure to a harmful compound or continued physical degradation?
*can science/technology "fix" nature from human-caused problems?

Choose and defend a position. Make specific reference to the case study that is cited.

Position: Humans/science/technology cannot always "fix" nature and therefore, the precautionary principle MUST be utilized.
If we do not use the precautionary principle we might save $ in the short term but it will cost us $ in the long-term AND ruin health. Nature is often harder to "fix" than we think and there are often many unintended consequences of chemicals that we do not know about until they damage our health. Just as in the NWHP, small amounts of chemical can cause harm (another thing we did not know until recently). Science cannot solve all problems humans cause in nature. Sometimes, it's just too late.

Case Study: Pollution in the Great Lakes-Hopeful Progress
(Source: Miller, G. (2005). Living in the environment (14th ed.). CA, USA: Brooks/Cole (p.500-501).

Position: Technological fixes/science/$ can "fix" nature. It has been done in the past and will continue to happen in the future.
Most of the time we can assume that chemicals are innocent until proven guilty. When we are wrong, we can solve the resulting problems if we work together, have scientists who know enough about science and technology to address the issues, and have the money we will need. Science/technology can "keep up" with issues created by humans.

Case Study: Chattanooga, Tennessee - From Brown to Green
(Source: Miller, G. (2005). Living in the environment (14th ed.). CA, USA: Brooks/Cole (p. 581).

Position: The precautionary principle is TOO strict.
Economies will collapse and we will not be able to fully use technology to save lives. We (I) think that the majority of chemicals ARE safe, so it is nonsensical (impossible?) to think that we have to prove a chemical is safe before we use it. It is just not realistic - humans are NOT going to stop using plastic, automobiles and antibiotics. Just look at how hard it is to make our products in our project more sustainable. Nothing would ever get made and people would die as in the case of DDT (see case study). People should be protected over the environment.

Case study: Revisiting DDT – from Riches to Rags
(Source: Miller, G. (2005). Living in the environment (14th ed.). CA, USA: Brooks/Cole (p. 526-527).

If you answered YES, you think that nature can "bounce back"

*****how many parts per million do you think nature (natural systems) are TOO much of a harmful compound?
*****How should we decide how much is too much?
*Find a real-life example/event in which nature had or has trouble "bouncing back" from TOO much of a harmful compound in nature. Use the "Fact-Based Issue Analysis" sheet to tell about your example.

If you answered NO, why is there no limit?
*****Is nature always able to "bounce back" at times when there is TOO much of a harmful compound in nature? Why?
*Find a real-life example/event in which nature has "bounced back" successfully from having TOO much a harmful compound. Use the "Fact-Based Issue Analysis" sheet on the following page to tell about your example.

<u>Starting points:</u>

Here are some ideas to start with:

<u>Nature has had trouble "bouncing back":</u>

<u>Nature has had trouble "bouncing back":</u>

Case study: Revisiting DDT – from Riches to Rags (p. 526-527)

Case study: Revisiting DDT – from Riches to Rags (p. 526-527)

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approximately 165 of the active ingredients approved for use in U.S. pesticide products are known or suspected human carcinogens. By 2004, only 43 of these pesticide chemicals had been banned by the EPA or discontinued voluntarily by manufacturers.

A study of Missouri children revealed a statistically significant correlation between childhood brain cancer and use of various pesticides in the home, including flea and tick collars, no-pest strips, and chemicals used to control pests such as roaches, ants, spiders, mosquitoes, and termites. Also, EPA scientists published a report in 2000 indicating that atrazine (widely used as a weed killer by farmers) could cause uterine, prostate, and breast cancer in humans and disrupt reproductive development.

Also, according to studies by the National Academy of Sciences, federal laws regulating pesticide use in the United States are inadequate and poorly enforced by the EPA, Food and Drug Administration (FDA), and USDA. Another study by the National Academy of Sciences found that up to 98% of the potential risk of developing cancer from pesticide residues on food grown in the United States would be eliminated if EPA standards were as strict for pre-1972 pesticides as they are for later ones.

The pesticide industry disputes these findings and says that eating food grown by using pesticides for the past 50 years has never harmed anyone in the United States. The industry also claims that the benefits of pesticides far outweigh their disadvantages.

Environmentalists and a number of health officials call for strengthening U.S. pesticide laws to help prevent contamination of groundwater by pesticides, improve the safety of farm workers who are exposed to high levels of pesticides, and allow citizens to sue the EPA for not enforcing the law. Pesticide manufacturers strongly oppose such changes and lobby elected officials to weaken FIFRA.

Pesticide control laws in the United States could be improved. But most other countries (especially developing countries) have not made nearly as much progress as the United States has in regulating pesticides.

Case Study: Revisiting DDT— from Riches to Rags

Since 1972 DDT has been banned in developed countries, and there is controversy over its continuing use in some developing countries to combat malaria.

After its discovery in 1939, DDT quickly became the world's most widely used pesticide. It was a cheap and effective weapon to kill crop-devouring insects and mosquitoes and other insects that transmitted infectious diseases such as malaria. There is little doubt that single-handedly this chemical has saved many millions of lives from infectious diseases.

DDT's role as a "chemical hero" began changing in 1962 when Rachel Carson published her book *Silent Spring*, which warned of the dangers of DDT and other broad-spectrum and persistent pesticides (Individuals Matter, p. 27). This led to much closer scrutiny of such pesticides and public pressure to ban DDT and its persistent chlorinated hydrocarbon chemical cousins that were also widely used as pesticides (Table 23-1).

In 1970, the U.S. Environmental Protection Agency was established. In 1972, the earlier Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) was amended to give the EPA control over the registration and regulation of pesticides in the United States.

In that same year, the EPA banned the use of DDT (and later the use of its similar chemical cousins) in the United States. The EPA banned DDT for several reasons. *First*, it is a broad-spectrum chemical that kills many beneficial insects along with its target species. *Second*, it is a persistent chemical that remains in one chemical form or another in the environment for up to 15 years and can be biologically magnified in food webs (Figure 19-4, p. 411). *Third*, it reduced populations of many birds and other species, especially those feeding at high trophic levels in food webs, such as eagles and peregrine falcons. *Fourth*, there was some preliminary but not conclusive evidence that it could cause cancer in humans. *Fifth*, it was becoming less effective because a growing number of insect pests that consume crops and transmit diseases had developed genetic resistance to DDT and other chlorinated hydrocarbon pesticides. Some contend political pressure from the public and a growing environmental movement also played a role in the ban of this chemical.

Pesticide manufacturers opposed the ban but were more than happy to supply more expensive alternatives. Debate over the DDT ban in the United States continues today. There was considerable evidence for its ecological harm and more evidence has accumulated. But pesticide industry scientists say there was not enough evidence then (and today) that DDT can cause cancer in humans—one of the key reasons used to ban the chemical under the FIFRA pesticide law.

Critics of the ban try to separate the possible harmful effects of DDT on humans from its effects on other species and ecosystems. They pose such questions as, Do we want to protect penguins or people?

Scientists say this is too simplistic because we cannot separate harm to the environment from harm to people. This is especially true for widely used and long-lived chemicals such as DDT that can build up in food webs and are now found in even the most remote parts of the world.

This was the heart of Rachel Carson's warning. Traces of these chemicals are everywhere, including our bodies, and we should be concerned about their possible long-term effects on both the environment and human health. Critics of pesticides contend that the best way to reduce such risks is to prevent such chemicals from reaching the environment. This would spur us to look for safer, affordable alternative chemicals and for biological and ecological ways to control pests.

In addition, since 1975 there has been growing evidence that very low levels of chlorine-containing pesticides and a variety of other fat-soluble chemicals may disrupt the human immune, endocrine, and nervous systems by mimicking and disrupting the effects of natural hormones in our bodies (Case Study, p. 416). The scientific jury is still out on if or how these chemicals are harmful to humans.

Critics of the ban on DDT and other chlorinated hydrocarbon pesticides say the ban ended up increasing human deaths from exposure to pesticides. Why? Organophosphates that were less persistent and ecologically damaging replaced chlorinated hydrocarbon pesticides. But it turned out that these chemicals were hundreds and in some cases thousands of times more toxic to humans than DDT and its chemical cousins. As a result, these replacements killed a large number of farm workers and children playing in sprayed fields or otherwise coming into contact with organophosphate pesticides.

This led the EPA to ban the use of many organophosphates and then carbamates that followed them (Table 23-1). Since then new groups of pesticides such as botanicals and microbotanicals have been developed that are less harmful to humans and the environment.

Although DDT is banned in developed countries, it has not gone away. It is manufactured legally in several countries and is still used to treat crops and to kill disease-carrying insects in a number of developing countries.

In 2000, delegates from 122 countries agreed on a global pollution prevention treaty to control, reduce, phase out, and destroy stockpiles of 12 persistent organic pollutants (POPs). This list of chemicals, called the *dirty dozen*, includes DDT and eight other chlorine-containing persistent pesticides.

The treaty, which went into effect in 2004, allows 25 countries to continue using DDT to combat malaria until safer alternatives are available. This was allowed because the health benefits of using DDT to decrease malaria far outweigh the remote possibility of harm to people. Although DDT may prove to have some as-yet unknown harmful effects on humans, malaria kills about 1 million people a year—most of them children—and sickens and weakens several hundred million people.

In addition, spraying low levels of DDT indoors and on bed nets would not spread large amounts of the chemical into the environment compared to blanketing crop fields with DDT. This should slow the development of genetic resistance to DDT in malaria-carrying mosquitoes. Also, after the ban it was discovered that even when mosquitoes developed genetic resistance to DDT, it still acted as a repellent and irritant that drove nocturnal mosquitoes out of homes before they had a chance to bite. Despite this decision the World Bank and other international aid agencies do not provide loans or funds for malaria-control projects that involve the use of DDT.

Opponents argue that a complete ban on DDT will spur research efforts to find other cost-effective pesticides for killing malaria-causing mosquitoes and to find alternatives to using pesticides. They support WHO efforts to use a variety of methods to reduce the threat of malaria.

X *How Would You Vote?* Should DDT and other persistent chlorine-containing pesticides still be used to control malaria throughout the world? Cast your vote online at http://biology.brookscole.com/miller14.

23-5 ALTERNATIVES TO CONVENTIONAL CHEMICAL PESTICIDES

What Should Be the Primary Goal of Pest Control? Pest Reduction Not Eradication

Reducing crop damage to an economically tolerable level should be the primary goal of pest control efforts.

In most cases, the primary goal of spraying with conventional pesticides is to eradicate pests in the area affected. However, critics say the primary goal of any pest control strategy should be to reduce crop damage to an economically tolerable level. The point at which the economic losses caused by pest damage outweigh the cost of applying a pesticide is called the *economic threshold*. Because of the risk of increased genetic resistance and other problems, continuing to spray beyond the economic threshold can make matters worse and can cost more than it is worth.

The problem is determining when the economic threshold has been reached. This involves careful monitoring of crop fields to assess crop damage and determine pest populations.

Many farmers do not want to bother doing this and instead are likely to use additional *insurance spraying* to be on the safe side. One method used to reduce unnecessary insurance spraying is the purchase of *pest-loss insurance*. It pays farmers for losses caused by pests and is usually cheaper than using excess pesticides.

Another source of increased pesticide use is *cosmetic spraying*. Extra pesticides are used because most consumers often buy only the best-looking fruits and

Case Study: Chattanooga, Tennessee - From Brown to Green (p.581)

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powered motorcycles by 2007, and is planning a network of battery exchange and disposal centers to serve the rapidly increasing use of electric-powered bicycles and mopeds.

China has a long way to go in converting its urban sustainability goals into reality. But if successful, China could become model for the world in ecocity design.

Case Study: Chattanooga, Tennessee—From Brown to Green

Local officials and citizens have worked together to transform Chattanooga from a highly polluted city to one of the most sustainable and livable cities in the United States.

In the 1950s, Chattanooga was known as one of the dirtiest cities in the United States. Its air was so polluted by smoke from its coke ovens and steel mills that people sometimes had to turn on their headlights in the middle of the day. The Tennessee River flowing through the city's industrial wasteland bubbled with toxic waste.

People and industries fled the downtown area and left a wasteland of abandoned factories, boarded-up buildings, high unemployment, and crime.

Within two decades, Chattanooga transformed itself into one of the most livable cities in the United States. Efforts began in 1984 when civic leaders used a series of town meetings as part of a *Vision 2000* process—a 20-week series of community meetings brought together more than 1,700 citizens from all walks of life to build a consensus about what the city could be at the turn of the century. Citizens identified the city's main problems, set goals, and brainstormed thousands of ideas for solutions.

By 1995, Chattanooga had met most of its original goals, which included encouraging zero-emission industries to locate there and replacing its diesel buses with a fleet of quiet, zero-emission electric buses, made by a new local firm. The city reduced car use in the downtown by building satellite parking lots and providing free and rapid bus service to and from the city center. The city also launched an innovative recycling program after citizen activists and environmentalists blocked construction of a new garbage incinerator. Another project involved renovating much of the city's existing low-income housing and building new low-income rental units.

Chattanooga built the nation's largest freshwater aquarium, which became the centerpiece for downtown renewal. The city also developed a 35-kilometer-long (22-mile-long) riverfront park along both sides of the Tennessee River running through downtown. The park is filled with shade trees, flowers, fountains, and street musicians, and draws more than 1 million visitors per year.

As property values and living conditions have improved, people and businesses are moving back downtown. An abandoned place once filled with despair is now a vibrant community filled with hope. These accomplishments show what citizens, environmentalists, and business leaders can do when they work together to develop and achieve common goals.

In 1993, the community began the process again in *Revision 2000*. More than 2,600 participants identified additional goals and more than 120 recommendations for further improvements. One goal is to transform a blighted brownfield in South Chattanooga into an environmentally advanced, mixed community of residences, retail stores, and zero-emission industries where employees can live near their workplaces.

This new low-waste ecoindustrial park is modeled after the one in Kalundborg, Denmark (Figure 24-5, p. 537). Underground tunnels will link 30 industrial buildings to share heating, cooling, and water supplies and to use the waste matter and energy of some enterprises as resources for others. The new ecoindustrial area will also have an ecology center using a living machine (Figure 22-1, p. 491) to treat sewage, wastewater, and contaminated soils.

According to many environmentalists, urban planners, and economists, urban areas that fail to become more livable and ecologically sustainable over the next few decades are inviting economic depression and increased unemployment, pollution, and social tension. What is your community doing?

A sustainable world will be powered by the sun; constructed from materials that circulate repeatedly; made mobile by trains, buses, and bicycles; populated at sustainable levels; and centered around just, equitable, and tight-knit communities.

GARY GARDNER

CRITICAL THINKING

1. Do you prefer living in a rural, suburban, small-town, or urban environment? Describe the ideal environment in which you would like to live, and list the environmental advantages and disadvantages of living in such a place. Compare your answers with those of other members of your class.

2. Do you believe the United States or the country where you live should develop a comprehensive and integrated mass transit system over the next 20 years, including building an efficient rapid-rail network for travel within and between its major cities? How would you pay for such a system?

3. If you own a car or hope to own one, what conditions, if any, would encourage you to rely less on the automobile and to travel to school or work by bicycle, on foot, by mass transit, or by carpool or vanpool?

Case Study: Pollution in the Great Lakes-Hopeful Progress (p. 500-501)

Case Study: Pollution in the Great Lakes-Hopeful Progress (p. 500-501)

Case Study: Pollution in the Great Lakes—Hopeful Progress

Pollution of the Great Lakes has dropped significantly but there is a long way to go.

The five interconnected Great Lakes of North America (Figure 22-8) formed about 10,500 years ago when retreating glaciers melted and poured water into the land basins carved out by the slowly moving glaciers. These lakes contain at least 95% of the fresh surface water in the United States and one-fifth of the world's fresh surface water.

The Great Lakes basin is also home for about 30% of the Canadian population and 14% of the U.S. population. At least 38 million people obtain their drinking water from these lakes.

Despite their enormous size, these lakes are vulnerable to pollution from point and nonpoint sources. One reason is that less than 1% of the water entering these lakes flows out to the St. Lawrence River each year. Another reason is that in addition to land runoff these lakes get atmospheric deposition of large quanti-

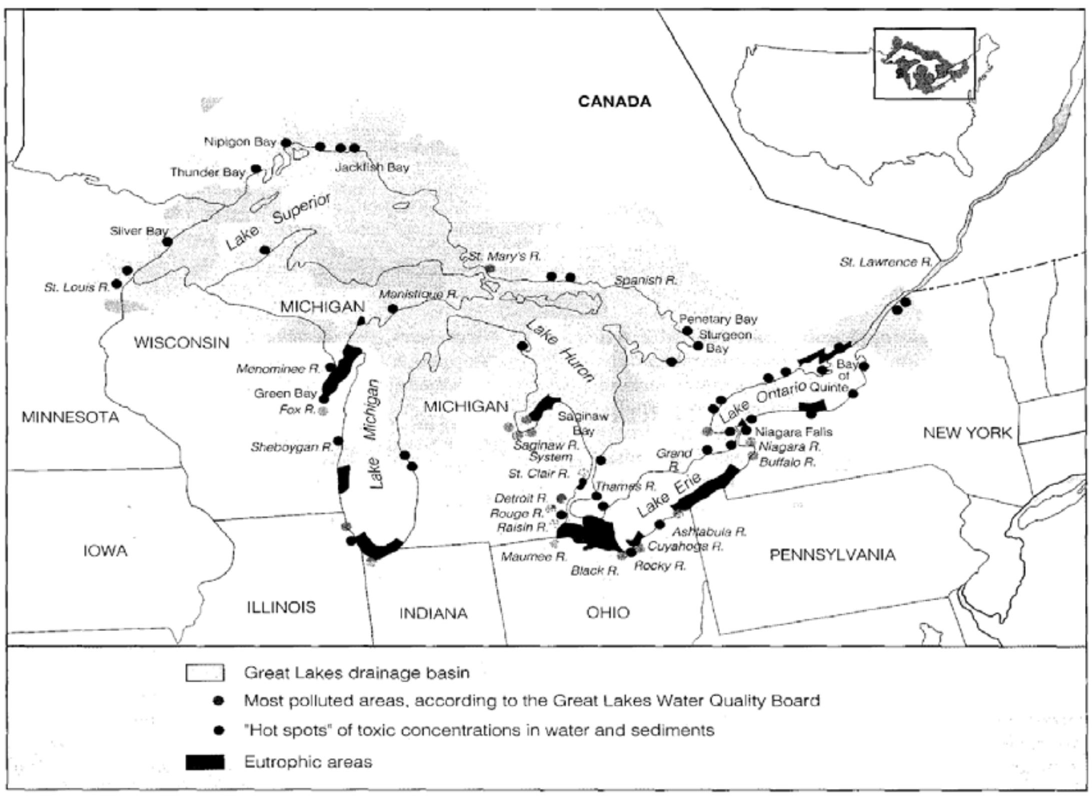

Figure 22-8 Natural capital degradation: the *Great Lakes basin* and the locations of some of its water quality problems. The Great Lakes region is dotted with several hundred abandoned toxic waste sites listed by the EPA as Superfund sites to receive cleanup priority. (Data from U.S. Environmental Protection Agency)

ties of acids, pesticides, and other toxic chemicals, often blown in from hundreds or thousands of kilometers away.

By the 1960s, many areas of the Great Lakes were suffering from severe cultural eutrophication, huge fish kills, and contamination from bacteria and a variety of toxic industrial wastes. The impact on Lake Erie was particularly intense because it is the shallowest of the Great Lakes and has the highest concentrations of people and industrial activity along its shores. Many bathing beaches had to be closed, and by 1970 the lake had lost most of its native fish.

Since 1972, Canada and the United States have joined forces and spent more than $20 billion on a Great Lakes pollution control program. This program has decreased algal blooms, increased dissolved oxygen levels and sport and commercial fishing catches in Lake Erie, and allowed most swimming beaches to reopen.

These improvements occurred mainly because of new or upgraded sewage treatment plants, better treatment of industrial wastes, and bans on use of detergents, household cleaners, and water conditioners that contained phosphates.

Despite this important progress many problems remain. Each August a large zone severely depleted of dissolved oxygen is likely to stretch across the center of Lake Erie. The oxygen-poor water in this zone kills fish and microorganisms that support the lake's food web. During the last 10 years, the time that the zone lasts has increased from two weeks to a month and scientists do not know why. Possible causes include oxygen depletion by zebra mussels (Case Study, p. 267), undetected inputs of phosphates from fertilizers through storm runoff sewers, an unknown naturally occurring cycle, or climate change.

More bad news. According to a 2000 survey by the EPA, more than three-fourths of the shoreline of the Great Lakes is not clean enough for swimming or for supplying drinking water. The EPA and Environment Canada have identified 43 highly polluted shoreline areas. Nonpoint land runoff of pesticides and fertilizers from urban sprawl now surpasses industrial pollution as the greatest threat to the lakes. Sediments in 26 toxic hot spots (Figure 22-8) remain heavily polluted.

About half of the toxic compounds entering the lakes come from atmospheric deposition of pesticides, mercury from coal-burning plants, and other toxic chemicals from as far away as Mexico and Russia. Toxic chemicals such as PCBs have built up in food chains and webs (Figure 22-6), contaminating many types of sport fish and depleting populations of birds, river otters, and other animals feeding on contaminated fish. A recent survey by Wisconsin biologists found that one fish in four taken from the Great Lakes is unsafe for human consumption. Another problem has been an 80% drop in EPA funding for cleanup of the Great Lakes since 1992.

Some environmentalists call for banning the use of toxic chlorine compounds such as bleach in the pulp and paper industry around the Great Lakes. They would also ban new incinerators (which can release toxic chemicals into the atmosphere) in the area, and they would stop the discharge into the lakes of 70 toxic chemicals that threaten human health and wildlife. Officials in the industries involved have successfully opposed such bans.

22-4 POLLUTION OF GROUNDWATER

Why Is Groundwater Pollution Such a Serious Problem? Not Easily Cleaned

Groundwater can become contaminated with a variety of chemicals because it cannot effectively cleanse itself and dilute and disperse pollutants.

According to many scientists, a serious threat to human health is the out-of-sight pollution of groundwater, a prime source of water for drinking and irrigation. Studies show that groundwater pollution comes from numerous sources (Figure 22-9, p. 502). People who dump or spill gasoline, oil, and paint thinners and other organic solvents onto the ground also contaminate groundwater.

Although experts rate groundwater pollution as a low-risk ecological problem, they consider pollutants in drinking water (much of it from groundwater) a high-risk health problem. Once a pollutant from a leaking underground tank or other source contaminates groundwater it permeates the nearby porous layers of sand, gravel, or bedrock in the aquifer like water saturating a sponge. This makes removal of the contaminant difficult and costly.

Then the contaminated water slowly flows through the aquifer and creates a widening *plume* of contaminated water. If this plume reaches a well used to extract groundwater, the polluted water can get into drinking water and into water used to irrigate crops.

When groundwater becomes contaminated, it cannot cleanse itself of *degradable wastes* as flowing surface water does (Figure 22-5). One reason is that groundwater flows so slowly—usually less than 0.3 meter or 1 foot per day—that contaminants are not diluted and dispersed effectively. Another problem is that groundwater usually has much lower concentrations of dissolved oxygen (which helps decompose many contaminants) and smaller populations of decomposing bacteria. Also, the usually cold temperatures of groundwater slow down chemical reactions that decompose wastes.