

APES SPECIAL STUDY GUIDE 2: Excerpt from “Living in the Environment”
Start at “Stream Pollution in Less Developed Countries”.

1. What reason does the World Commission on Water for the 21st Century provide for half of the world’s major rivers being so heavily polluted with untreated sewage?
2. **Identify** TWO pollutants that may be carried by runoff in more developed countries.
3. **Explain** why lakes and reservoirs are often more vulnerable than streams to contamination by runoff.
4. **Discuss** the terms *eutrophic and oligotrophic and cultural eutrophication*
5. **Describe** how nitrate levels from municipal sewage treatment plants or farmland can negatively affect water quality in some aquatic ecosystems. **Be specific and detailed. Memorize this!**
6. **Describe** THREE ways to mitigate nutrient pollution/cultural eutrophication of aquatic ecosystems.
7. **Describe** THREE WAYS TO CLEAN UP waters suffering from cultural eutrophication.

8. **Explain** how cultural eutrophication might have negative effects on marine food webs.

9. What effect did levees and draining of wetlands along the Mississippi River have on creating dead zones in Gulf of Mexico.

10. How many people rely on the Great Lakes for their drinking water?

11. **Think.** Select one of the 3 strategies used in the clean up of *Lake Erie* and **explain** how this measure resulted in cleaner water in the lake.

Figure 20-7 Natural capital degradation: This portion of China's Yangtze River near the Three Gorges dam is heavily polluted with chemicals, sediment, and trash.

Fish kills and drinking water contamination still occur occasionally in some of the rivers and lakes of more-developed countries such as the United States. Some of these problems are caused by the accidental or deliberate release of toxic inorganic and organic chemicals by industries and mining operations (see Figure 14-15, p. 360, and Figure 20-4). Another cause is malfunctioning sewage treatment plants. A third cause is nonpoint runoff of pesticides and excess plant nutrients from cropland and animal feedlots.

Stream Pollution in Less-Developed Countries

In most less-developed countries, stream pollution from discharges of untreated sewage and industrial wastes is a serious and growing problem. According to the Global Water Policy Project, most cities in less-developed countries discharge 80–90% of their untreated sewage directly into rivers, streams, and lakes whose waters are often used also for drinking, bathing, and washing clothes.

According to the World Commission on Water for the 21st Century, half of the world's 500 major rivers are heavily polluted, and most of these polluted waterways run through less-developed countries. A majority of these countries cannot afford to build waste treatment plants and do not have, or do not enforce, laws for controlling water pollution.

In Latin America and Africa, most streams passing through urban or industrial areas suffer from severe pollution. Industrial wastes and sewage pollute more than two-thirds of India's water resources and 54 of the 78 rivers and streams monitored in China. In some parts of China, river water is too toxic to touch, much less drink. Liver and stomach cancer, linked in some cases to water pollution, are among the leading causes of death in the Chinese countryside where many industries have been relocated.

In 2010, Chinese officials reported that huge islands of garbage are threatening to jam the flow of water over the country's massive Three Gorges Dam on the Yangtze River (Figure 20-7). As it decays, this garbage will pollute the water.

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Too Little Mixing and Low Flow Rates Make Lakes and Reservoirs Vulnerable to Water Pollution

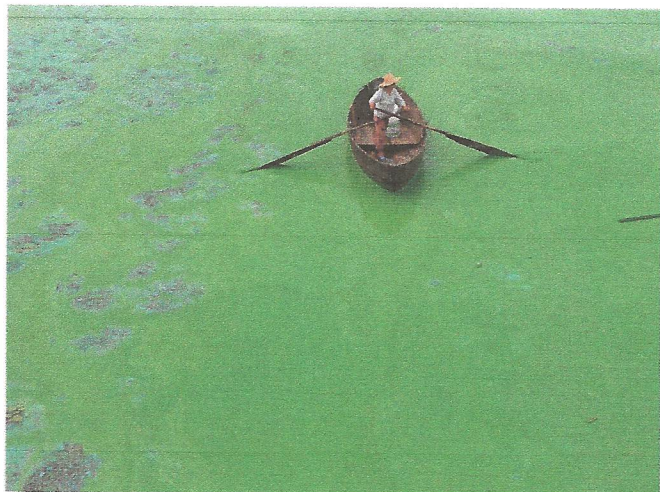
Lakes and reservoirs are generally less effective at diluting pollutants than streams are, for two reasons. *First*, lakes and reservoirs often contain stratified layers (see Figure 8-16, p. 179) that undergo little vertical mixing. *Second*, they have low flow rates or no flow at all. The flushing and changing of water in lakes and large artificial reservoirs can take from 1 to 100 years, compared with several days to several weeks for streams.

As a result, lakes and reservoirs are more vulnerable than streams are to contamination by runoff or discharge of plant nutrients, oil, pesticides, and nondegradable toxic substances, such as lead, mercury, and arsenic. These contaminants can kill bottom-dwelling organisms and fish as well as birds that feed on contaminated aquatic organisms. Many toxic chemicals and acids also enter lakes and reservoirs from the atmosphere (see Figure 18-12, p. 485).

Due to the stratified layers and reduced flows in lakes and reservoirs, the concentrations of some harmful chemicals are biologically magnified as they pass through food webs in these waters. Examples include DDT (see Figure 9-13, p. 202), PCBs (see Chapter 17, Case Study, p. 453), some radioactive isotopes, and some mercury compounds.

Cultural Eutrophication Is Too Much of a Good Thing

Eutrophication is the name given to the natural nutrient enrichment of a body of water such as a lake, coastal areas at the mouth of a river (**Core Case Study**), or a slow



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Figure 20-8 In 2010, severe cultural eutrophication affected Chaohu Lake near Hefei City in China's Anhui Province.

moving stream. It is caused mostly by runoff of plant nutrients such as nitrates and phosphates from land bordering such bodies of water.

An *oligotrophic lake* is low in nutrients and its water is clear (see Figure 8-15, p. 179). Over time, some lakes become more eutrophic (see Figure 8-17, p. 180) as nutrients are added from natural and human sources in the surrounding watersheds. Near urban or agricultural areas, human activities can greatly accelerate the input of plant nutrients to a lake—a process called **cultural eutrophication**. Such inputs involve mostly nitrate- and phosphate-containing effluents from various sources, including farmland, feedlots, urban streets and parking lots, chemically fertilized suburban yards, mining sites, and municipal sewage treatment plants. Some nitrogen also reaches lakes by deposition from the atmosphere (Figure 18-12, p. 485).

During hot weather or drought, this nutrient overload can produce dense growths, or “blooms,” of organisms such as algae and cyanobacteria in slow-moving surface waters (see Figure 8-17, p. 180). When the algae die, they are decomposed by swelling populations of aerobic bacteria, which deplete the dissolved oxygen in the surface layer of water near the shore, as well as in the bottom layer of a lake or coastal area. This can kill fish, shellfish, and other aerobic aquatic animals that cannot move to safer waters. If excess nutrients continue to flow into a lake, anaerobic bacteria take over and produce gaseous products such as smelly, highly toxic hydrogen sulfide and methane.

According to the EPA, about one-third of the 100,000 medium to large lakes and 85% of the large lakes near major U.S. population centers have some degree of cultural eutrophication. The International Water Association estimates that more than half of the lakes in China, along with some of its coastal zones, suffer from cultural eutrophication (Figure 20-8).

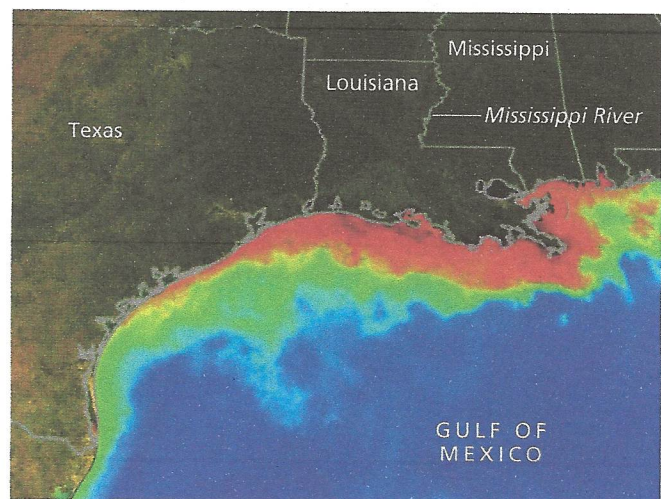


Figure 20-9 The colored area in this satellite image of the northern Gulf of Mexico represents the seasonal dead zone of 2012 with the red area having the lowest oxygen level.

There are several ways to *prevent* or *reduce* cultural eutrophication. We can use advanced (but expensive) waste treatment processes to remove nitrates and phosphates from wastewater before it enters a body of water. We can also use a preventive approach by banning or limiting the use of phosphates in household detergents and other cleaning agents, and by employing soil conservation (see Chapter 12, p. 304) and other controls to reduce nutrient runoff (**Concept 20-2B**).

There are several ways to *clean up* waters suffering from cultural eutrophication. They include mechanically removing excess weeds, controlling undesirable plant growth with herbicides and algaecides, and pumping air into lakes and reservoirs to prevent oxygen depletion, all of which are expensive and energy-intensive methods.

As usual, pollution prevention is more effective and quite often cheaper in the long run than cleanup. Most lakes and other surface waters can recover from cultural eutrophication, if excessive inputs of plant nutrients are stopped. In addition to cultural eutrophication, pollution causes other problems that plague many lakes (Case Study that follows).

Revisiting the Gulf of Mexico: An Extreme Case of Cultural Eutrophication

Since the 1950s, the level of nitrates discharged from the Mississippi River into the northern Gulf of Mexico has nearly tripled (**Core Case Study**). This has disrupted the nitrogen cycle and animal life in the area's affected coastal waters. Figure 20-9 provides a closer look at the severe oxygen depletion (shown in red) in 2012 in the dead zone of the northern Gulf of Mexico, where dissolved oxygen levels were typically less than 2 parts per million (Figure 20-B)—low enough to kill bottom-dwelling shellfish.

Excess nutrients fueling an explosive growth of algae (eutrophication) is a natural process that often occurs in

some areas of the ocean where upwellings bring nutrients from the ocean bottom to surface waters (see Figure 7-2, p. 145). However, excessive inputs of plant nutrients, especially nitrates, from human activities (cultural eutrophication) is the primary cause of the annual dead zone in the northern Gulf of Mexico and in many other hypoxic zones around the world, including parts of Chesapeake Bay (see Figure 8-13, p. 177) and the San Francisco Bay.

In more detail, here is how the Gulf's seasonal dead zone forms. During the spring and summer, nitrate-laden freshwater flowing into the Gulf forms an oxygen-rich layer on top of the Gulf's cooler and more dense saltwater. Because there are few storms at this time of year, this sun-heated upper layer of water remains fairly calm and does not mix with the bottom layer of low-oxygen water. The combination of sunlight and large inputs of nitrate plant nutrients from fertilizer and sewage into the freshwater layer leads to massive blooms of phytoplankton, mostly blue-green algae.

When these algae die, they sink into the saltier water below where they are decomposed by oxygen-consuming bacteria, which use up nearly all of the dissolved oxygen, leaving less than 2 parts per million in the deeper water. Mobile species can survive this lack of oxygen by migrating to oxygen-rich waters, but certain species of fish, shellfish, and other organisms are not able to escape, and they die off.

Thus, the oxygen-depleted bottom layer of water becomes a dead zone for certain species. This disrupts the Gulf's food web, because die-offs of such species lead to the deaths of seabird and marine mammal species that depend on the dying fish and shellfish for their survival. The dead zone breaks up, beginning in early fall when cooler weather, storms, and hurricanes mix the top and lower layers of water and distribute dissolved oxygen throughout the layers.

In addition to greatly increased nitrate levels from human inputs, other human factors have contributed to the formation of the dead zone. In efforts to control flooding along the upper Mississippi River, engineers have dredged and straightened parts of the river and raised its banks with levees in many places. This has had the effect of speeding the river's flow of nutrients and sediment pollution into the Gulf. Also, most of the river basin's original freshwater wetlands, which acted as natural filters that helped to remove excess nutrients and sediments from flood water, have been drained for farming and urban development.

The seasonal formation of dead zones in the northern Gulf of Mexico, mostly resulting from human activities, is a reminder that in nature, everything is connected. Plant nutrients flowing into the Mississippi from a farm in Iowa or a sewage treatment plant in Wisconsin help to cause fish kills (Figure 20-10) a thousand miles away on the gulf coast of Texas. Researchers fear that if the size of the Gulf's annual dead zone is not sharply reduced, its long-term effects could permanently alter the ecological makeup of these coastal waters.



Figure 20-10 On August 13, 2012, hundreds of thousands of dead shad fish washed ashore on Jamaica Beach near Galveston, Texas. The likely cause of this die-off was low oxygen levels in the Gulf of Mexico.

CASE STUDY

Pollution in the Great Lakes

The five interconnected Great Lakes of North America (Figure 20-11) contain about 95% of the fresh surface water in the United States and one-fifth of the world's fresh surface water. At least 38 million people in the United States and Canada 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 each year, less than 1% of the water entering these lakes flows east into the St. Lawrence River and then out to the Atlantic Ocean, meaning that pollutants can take as long as 100 years to be flushed out to sea.

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.

In 1972, the United States and Canada signed the Great Lakes Water Quality Agreement, which is considered a model of international cooperation. They agreed to spend more than \$20 billion to maintain and restore the chemical, physical, and biological integrity of the Great Lakes basin ecosystem. This program has helped to cut the number and sizes of algal blooms, raised dissolved oxygen levels, boosted sport and commercial fishing catches in Lake Erie, and allowed most swimming beaches to reopen—making this one of the nations' greatest environmental success stories. These improvements resulted mainly from the use of new or upgraded

GOOD NEWS

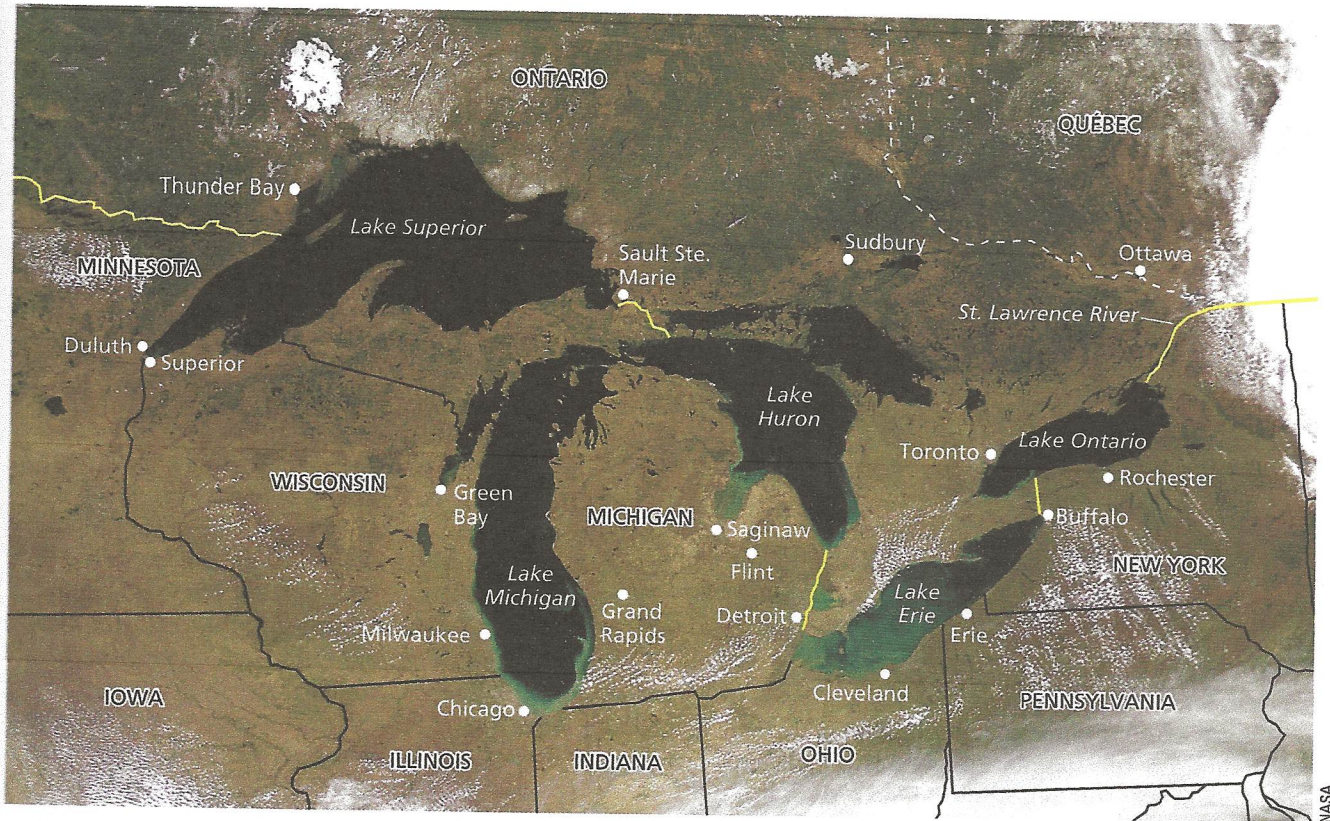


Figure 20-11 The five Great Lakes of North America make up the world's largest freshwater system. Dozens of major cities in the United States and Canada are located on their shores, and water pollution in the lakes is a growing problem.

sewage treatment plants, better treatment of industrial wastes, and bans on the use of detergents, household cleaners, and water conditioners that contain phosphates. Most of these measures were instituted largely as a result of bottom-up citizen pressure.

Despite this important progress, many problems remain. Increasing nonpoint runoff of pesticides and fertilizers resulting from urban sprawl, fueled by population growth, now surpasses industrial pollution as the greatest threat to the lakes. Bottom sediments in 26 toxic hotspots remain heavily polluted. In addition, *biological pollution* in the form of growing populations of zebra mussels (Figure 11-20, p. 268) and more than 180 other invasive species threaten some native aquatic species and cause at least \$200 million a year in damages (see Chapter 11, Case Study, p. 268).

Air quality over the Great Lakes has generally improved, but about half of the toxic compounds entering the lakes still come from atmospheric deposition of pesticides, mercury from coal-burning plants, and other toxic chemicals from as far away as Mexico and Russia.

A survey done by Wisconsin biologists found that one of every four fish taken from the Great Lakes was unsafe for human consumption.

Current efforts are aimed at improving the water quality of the lakes and other aquatic systems within the Great Lakes basin. To that end, the major goals are to clean up contaminated river bottoms, prevent erosion and runoff into lakes and streams, protect and restore wetlands, clean up toxic hotspots, and reduce the number of invasive species entering the lakes.

Some environmental and health scientists call for taking a prevention approach and banning the use of toxic chlorine compounds, such as bleach used in the pulp and paper industry, which is prominent around the Great Lakes. They would also ban new waste incinerators, which can release toxic chemicals into the atmosphere, and they would stop the discharge into the lakes of 70 toxic chemicals that threaten human health and wildlife. So far, officials in the industries involved have successfully opposed such bans.