

CHAPTER 16

WATER POLLUTION

Important Concepts

1. All substances, natural and artificial, cycle through the environment. The average length of time a substance remains in a system (or reservoir) can be described by its *residence time*. The substances of greatest concern in the context of pollution are the ones that are toxic and have long residence times in particular reservoirs.
2. Sources of pollution can be categorized as *point sources* and *nonpoint sources*. Point sources are those where pollutants originate from a single, readily identifiable spot. Nonpoint sources are diffuse sources of pollution having no readily identifiable origin. Generally, it is easier to control and confine pollutants from point sources than from nonpoint sources.
3. The two major sources of water pollution by anthropogenic organic and inorganic substances are industry and agriculture. In addition to a large number of chemicals of incompletely assessed toxicity every year, pollutants produced by industry include heavy metals (such as mercury and cadmium) that accumulate in the tissues of living organisms, often with toxic effects; other inorganic substances (such as chlorine, sulfuric acid, and asbestos); and toxic organic compounds (such as vinyl chloride, PCBs, and the petroleum additive MTBE).
4. *Thermal pollution*, the release of waste heat into the environment as a by-product of the generation of power, can result in the deaths of aquatic organisms, change the rates of chemical reactions in aquatic systems, and alter the chemical properties of water.
5. Agriculture contributes to water pollution through the use of fertilizers, herbicides (chemical weed-killers), and pesticides (chemicals used to kill insect pests) for growing crops, and the accumulation of polluted sediments eroded from farmlands.
6. Organic matter in water is broken down by microorganisms, especially bacteria, either *aerobically* (using oxygen) or, once the oxygen dissolved in water is depleted, *anaerobically* (without oxygen). The organic matter content of water is described by its *biochemical oxygen demand* (BOD), a measure of the amount of oxygen needed to break down the organic matter aerobically. Anaerobic decay produces a variety of noxious gases, such as hydrogen sulfide (H₂S) and methane (CH₄), the presence of which in a body of water signals oxygen depletion.
7. *Eutrophication* is the development of high levels of nutrients such as nitrates, phosphates, and sulfates in an aquatic environment. An “algal bloom” often accompanies eutrophication, thereby increasing the organic load on the system and degrading the water quality even further. Sources of excess nutrients include human and animal wastes, phosphates in detergents, and fertilizer runoff.
8. Remedial actions for surface water pollution include dredging bottom sediment, physical isolation of bottom sediment, chemical treatment of sediment, decontamination (method depends on the toxin involved), and artificial aeration.
9. Strategies for reversing ground water pollution include *in situ* treatment and treatment after extraction. Methods of *in situ* treatment consist of the chemical precipitation of toxic substances, the biological decomposition of organic pollutants, and the removal of contaminant-rich fluid (especially where petroleum products are concerned). Methods of treatment after extraction include adjusting the water’s acidity to cause the precipitation of heavy metals, biological decomposition, air stripping, and filtration through activated charcoal.

Key Terms

aeration	geochemical cycle
aerobic	heavy metals
algal bloom	nonpoint source
anaerobic	oxygen sag curve
biochemical oxygen demand	point source
decontamination	pollution
dredging	residence time
eutrophication	

Multiple Choice

1. Which of the following is not an important reservoir of calcium?
 - a. the ocean
 - b. continental crustal rocks
 - c. the atmosphere
 - d. the mantle
2. Which of the following elements has the longest oceanic residence time?
 - a. lead
 - b. iron
 - c. calcium
 - d. sodium
3. Which of the following is not an example of a point source?
 - a. pastureland
 - b. storm sewer outflow
 - c. a septic tank
 - d. a waste produced by a paper mill
4. Concerning the millions of industrial chemicals, complete toxicity assessments have been made for
 - a. almost all of them.
 - b. just over 50% of them.
 - c. relatively few of them.
 - d. none of them.
5. A toxic heavy metal that tends to accumulate in high concentrations in marine fishes at the top of the food chain is
 - a. lead.
 - b. mercury.
 - c. zinc.
 - d. copper.
6. The toxic heavy metal that is the cause of *itai-itai* disease is
 - a. lead.
 - b. mercury.
 - c. arsenic.
 - d. cadmium.

7. Which of the following statements concerning polychlorinated biphenyls (PCBs) is false?
- PCBs were once used as insulating fluid in electrical equipment.
 - No PCBs have been produced in the United States since 1977.
 - PCBs break down fairly quickly in the environment.
 - PCBs cause impairment of reproduction in animals.
8. The organic compound responsible for impairing calcium metabolism in birds, resulting in the laying of thin-shelled, fragile eggs, was
- PCB.
 - DDT.
 - vinyl chloride.
 - diisomethylphosphonate.
9. In an aquatic system, the presence of noxious gases such as hydrogen sulfide (H_2S) and methane (CH_4) is associated with
- a surplus of dissolved oxygen.
 - abundant algal growth.
 - oxygen depletion.
 - high levels of PCBs.
10. The higher the BOD of a sample of water,
- the higher the organic-matter load of the sample.
 - the lower the organic-matter load of the sample.
 - the lower the amount of oxygen needed to break down the sample's organic-matter load.
 - the higher the dissolved oxygen content of the sample.
11. Which of the following substances would not contribute to the eutrophication of a body of water?
- human or animal wastes
 - phosphates from detergents
 - agricultural fertilizers
 - agricultural herbicides
12. Surface-water pollution from point sources is a significant problem in all of the following states except
- West Virginia.
 - Indiana.
 - New Mexico.
 - Wisconsin.
13. The bacterium *Bacillus thuringiensis* is used to
- break down human wastes in sewage.
 - break down toxic organic compounds into harmless substances.
 - convert fertilizers in surface runoff into substances that will not enhance eutrophication.
 - control certain types of insect pests.
14. Mine drainage is a significant nonpoint source of surface-water pollution in the state of
- Utah.
 - West Virginia.
 - California.
 - New York.

15. Which of the following Great Lakes has experienced a dramatic improvement in water quality over the past two decades through concerted efforts to control the discharge of sewage and industrial wastes into the lake?
 - a. Lake Huron
 - b. Lake Erie
 - c. Lake Michigan
 - d. Lake Superior

16. The pollution of ground water due to saltwater intrusion is a significant problem along the coast of
 - a. Texas.
 - b. New Jersey.
 - c. Oregon.
 - d. Louisiana.

17. High levels of minerals or other dissolved solids in ground water is a problem in all of the following states except
 - a. Florida.
 - b. Montana.
 - c. Ohio.
 - d. Texas.

18. A bedrock aquifer is overlain by three to four meters of sand and gravel. The vulnerability of this aquifer to pollution from surface-water infiltration can best be described as
 - a. extreme.
 - b. high.
 - c. moderate.
 - d. low.

19. Often the only effective approach to restoring the quality of polluted bodies of water is to
 - a. reduce or stop the input of wastes and allow natural processes to remove or destroy the pollutants.
 - b. immobilize the pollutants with chemicals that cause the pollutants to precipitate out of solution.
 - c. add microorganisms to the water that will break down the pollutants.
 - d. pass the contaminated water through beds of activated charcoal.

20. Which of the following methods of treating contaminated ground water was not employed at the Rocky Mountain Arsenal near Denver, Colorado?
 - a. filtration
 - b. adjustment of pH
 - c. chemical oxidation
 - d. passage through activated charcoal

Fill In the Blanks

1. _____ is the average length of time a substance remains in a system.
2. _____ are sources from which pollutants are released from a single, identifiable spot; _____ are diffuse sources of pollutants.
3. _____ are a group of dense metals that tend to accumulate in the body tissues of living organisms and tend to become concentrated in organisms occupying the higher positions in a food chain.

4. _____ pollution is the release of excess heat as a result of the generation of power.
5. The _____ is a measure of the amount of oxygen needed for the aerobic decomposition of organic matter in an aquatic environment.
6. An _____ is a graph of dissolved-oxygen content as a function of distance from a point of waste discharge.
7. _____ is the development of high nutrient levels in a body of water.
8. _____ is a set of procedures used to increase the oxygen content of water, thus transforming the water from an anaerobic to an aerobic condition.
9. _____ is a set of methods by which volatile organic pollutants are transferred from extracted ground water into the air.
10. _____ is used in filters to absorb organic pollutants dissolved in ground water.

True or False

Indicate whether the following statements are true or false. If false, correct the statement to make it true.

- _____ 1. The residence times for some chemical compounds are limited by their rapid breakdown into other chemicals.
- _____ 2. In general, it is easier to monitor pollution from nonpoint sources than from point sources.
- _____ 3. A major problem with ground water pollution is that it can go undetected for long periods.
- _____ 4. Most new chemical compounds created each year are carbon-containing compounds.
- _____ 5. Although DDT has proven to be toxic to fish and birds, its toxic effects are minimized by its short residence time in the environment.
- _____ 6. Waste heat from automobile exhaust is a major contributor to the thermal pollution of the atmosphere.
- _____ 7. An oxygen sag curve representing conditions downstream from a point source discharging organic-rich wastewater would typically show elevated dissolved oxygen levels immediately downstream from the point source.
- _____ 8. The problem of eutrophication caused by excess fertilizer runoff can be eliminated or greatly reduced if natural fertilizers, such as animal manures, are substituted for synthetic fertilizers.
- _____ 9. Farmlands are the major source of the sediment contributing to the sediment pollution of United States waterways.

_____ 10. Farmers in the United States use more than 500 million pounds of herbicides and pesticides annually.

Review Questions

1. What is a geochemical cycle? Draw a sketch illustrating the geochemical cycle of calcium. In what way may human activities affect the geochemical cycle of calcium?
2. Explain the concept of residence time (of a pollutant) in a water reservoir, using sodium as an example. (The residence time of sodium in the oceans is estimated to be two million years.) How is this concept related to water pollution?
3. What is BOD and why is it relevant in the context of water pollution?
4. What is eutrophication? Why are eutrophic conditions generally considered undesirable?
5. What are the different sources of water pollutants? State two important pollutants for each source.
6. Explain, with appropriate examples, the difference between point and nonpoint sources of pollution.
7. List and briefly discuss the various remedial methods that may be employed for polluted (a) surface water, (b) sediments, and (c) ground water.

Surfing the Net

Information on ground water remediation technologies (Ground-Water Remediation Technologies Analysis Center):
<<http://www.gwrtac.org>>

An excellent source of information on the behavior of toxic substances in hydrologic environments (Toxic Substances Hydrology Program, U.S. Geological Survey):
<<http://toxics.usgs.gov/toxics/>>

Water quality and waste management educational resources (National Water Quality Database):
<<http://hermes.ecn.purdue.edu:8001/server/water/bib/browse.html>>

Assessment of more than fifty river basins and aquifer systems in the U.S. (National Water Quality Assessment Program, U.S. Geological Survey):
< http://www.rvares.er.usgs.gov/nawqa/nawqa_home.html>

Information on ground water and drinking water standards (Office of Water, U.S. Environmental Protection Agency):
<<http://www.epa.gov/safewater>>

CHAPTER 16 ANSWER KEY

Multiple Choice

- | | | | |
|-------------------|-------|----------------------|----------------------|
| 1. c | 6. d | 11. d | 16. a (figure 16.17) |
| 2. d (table 16.1) | 7. c | 12. c (figure 16.15) | 17. b (figure 16.17) |
| 3. a | 8. b | 13. a | 18. b |
| 4. c | 9. c | 14. b (figure 16.14) | 19. a |
| 5. b (table 16.4) | 10. a | 15. b | 20. b |

Fill In the Blanks

- | | |
|------------------------------------|---|
| 1. Residence time | 6. oxygen sag curve |
| 2. Point sources, nonpoint sources | 7. Eutrophication |
| 3. Heavy metals | 8. artificial aeration |
| 4. Thermal | 9. air stripping |
| 5. biochemical oxygen demand | 10. activated charcoal (activated carbon) |

True or False

1. True
2. False. It is easier to monitor the pollution from point sources than from nonpoint sources.
3. True
4. True
5. False. DDT remains in the environment for an extremely long time; two-thirds of all the DDT ever produced is still active.
6. False. Waste heat from automobile exhaust is considered to be an insignificant cause of atmospheric thermal pollution.
7. False. An oxygen sag curve would typically reveal a sharp reduction in dissolved oxygen immediately downstream from a point source discharging organic-rich wastewater.
8. False. Natural fertilizers, like synthetic fertilizers, contribute to the eutrophication of surface waters.
9. True
10. True