CHAPTER 18 WATER POLLUTION

Chapter Overview

This chapter explains water pollution and describes its effects. Both point source and nonpoint source pollutants are examined. Water quality and the indicators of water quality are essential information. Legislation to ensure water quality is explained.

Topics and Key Concepts

Pollution

- Describe the types of water pollutants, including thermal pollution, and the environmental impacts and human health effects of each.
- Differentiate between point source and non-point source pollution.
- Summarize the major water legislation in the United States.
- Diagram an oxygen sag curve and describe how levels of DO and BOD are reflected in biota.
- Discuss the impacts of oil spills on wildlife and local economies.
- Discuss common contaminants of groundwater in the United States.
- Conclude the efficacy of water pollution control methods.
- Explain the varied components of a municipal wastewater plant.
- Differentiate the processes occurring at each step of wastewater treatment.

Key Terms

atmospheric deposition
best available, economically achievable technology (BAT)
best practicable control technology (BPT)
biochemical oxygen demand (BOD)
coliform bacteria
cultural eutrophication
dissolved oxygen content (DO)
eutrophic
*harmful algal bloom (HAB)
nonpoint sources
oligotrophic
oxygen sag
point sources
primary treatment
red tide
*Safe Drinking Water Act
secondary treatment
tertiary treatment
thermal plume
total maximum daily loads (TMDL)

Pacing Guide

Once students have a firm grasp of the unique qualities of water from the previous chapter, spend 5–7 days examining point and nonpoint source pollution, methods used to clean up water pollution, and water testing. If possible, include an extra day to take the class to a sewage treatment plant.

Approach and Tips

As you continue your discussion on water use and pollution, begin with a review of point source and nonpoint source pollution and their effects on the ecosystem. It is also important for students to know how these pollutants affect the environment. They should look at each environmental problem as a series of events; problem→cause→effect→remedy.

Table 18.1 Major Categories of Water Pollutants

Category	Examples	Sources
A. Causes Health Problems		
1. Infectious agents	Bacteria, viruses, parasites	Human and animal excreta
2. Organic chemicals	Pesticides, plastics, detergents, oil, and gasoline	Industrial, household, and farm use
3. Inorganic chemicals	Acids, caustics, salts, metals	Industrial effluents, household cleansers, surface runoff
4. Radioactive materials production, natural sources	Uranium, thorium, cesium, iodine, radon	Mining and processing of ores, power plants, weapons
B. Causes Ecosystem Disruption		
1. Sediment	Soil, silt	Land erosion
2. Plant nutrients	Nitrates, phosphates, ammonium	Agricultural and urban fertilizers, sewage, manure
3. Oxygen-demanding wastes	Animal manure and plant residues	Sewage, agricultural runoff, paper mills, food processing
4. Thermal	Heat	Power plants, industrial cooling

Contaminants in the water supply affect plants and animals and can move up and be concentrated in the food chain. Review the food chain information covered earlier in the course and reinforce the concept of bioaccumulation. Government recommendations regarding the types and quantities of fish that are safe to consume is a great basis for the discussion of bioaccumulation and the related impacts on human health.

Another good activity is to trace the path of the cholera in London through well water contamination and Dr. John Snow's research that led to the discovery. He mapped the deaths due to cholera and saw the connection between drinking water supplies and deaths. These maps can be found online.

Water quality is a fundamental topic and can be conducted using both biotic and abiotic parameters. Students should be familiar with examples of both. Biotic parameters usually consist of the organisms present in the body of water. Macroinvertebrate biodiversity is an indicator of water quality. If possible, have

students survey a stream for macroinvertebrates. Abiotic factors include pH, dissolved oxygen, temperature, clarity, turbidity, alkalinity, and nitrates. There are others, but these are a few that seem to be significant.

If you have access to a river or a stream, the class can test the water for both biotic and abiotic factors. Some abiotic factors are listed above. The class can perform a Stream Quality Assessment by surveying macroinvertebrates. These macroinvertebrates will indicate the water quality. There are simple sampling techniques, which require a net, boots and small plastic trays for macroinvertebrates. Information on this activity can be found online.

If time permits, take the class on a field trip to a sewage treatment facility. If this is not possible, students should be able to discuss the process in detail and relate the role of wetlands to the commercial operation.

Discuss how plants and microorganisms can be used to clean water through phytoremediation and bioremediation, respectively, and how this technology can be used in domestic as well as hazardous waste treatment situations.

Students should be able to describe this legislation and should be familiar with the Safe Drinking Water Act. Introduce this concept by talking about the picture on page 410 in the textbook. Emphasize that this was not the first time this had happened. The Cuyahoga River had caught fire several times before 1972. This event gave rise to the Clean Water Act. End the discussion with the goals of the Clean Water Act and other water quality legislation. Remember that it is very important for students to be able to name and discuss important legislation on both the national and international levels.

Table 18.2 Some Important U.S. and International Water Quality Legislation
1. *Federal Water Pollution Control Act* (1972). Established uniform nationwide controls for each category of major polluting industries.
2. *Marine Protection Research and Sanctuaries Act* (1972). Regulates ocean dumping and established sanctuaries for the protection of endangered marine species.
3. *Ports and Waterways Safety Act* (1972). Regulates oil transport and the operation of oil handling facilities.
4. *Safe Drinking Water Act* (1974). Requires minimum safety standards for every community water supply. Among the contaminants regulated are bacteria, nitrates, arsenic, barium, cadmium, chromium, fluoride, lead, mercury, silver, pesticides; radioactivity and turbidity also are regulated. This act also contains provisions to protect groundwater aquifers.
5. *Resource Conservation and Recovery Act (RCRA)* (1976). Regulates the storage, shipping, processing, and disposal of hazardous wastes and sets limits on the sewering of toxic chemicals.
6. *Toxic Substances Control Act (TOSCA)* (1976). Categorizes toxic and hazardous substances, establishes a research program, and regulates the use and disposal of poisonous chemicals.
7. *Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)* (1980) and Superfund Amendments and Reauthorization Act (SARA) (1984). Provide for sealing, excavation, or remediation of toxic and hazardous waste dumps.
8. *Clean Water Act* (1985) (amending the 1972 Water Pollution Control Act). Sets as a national goal the attainment of "fishable and swimmable" quality for all surface waters in the United States.
9. *London Dumping Convention* (1990). Calls for an end to all ocean dumping of industrial wastes, tank washing effluents, and plastic trash. The United States is a signatory to this international convention.

Common Mistakes and Misconceptions

Once again it is imperative for the students to understand the role of both the hydrologic and nitrogen cycles with respect to eutrophication and algal blooms. In addition, students often do not know basic water quality tests. They should be familiar with pH, temperature, dissolved oxygen, nitrates, turbidity/TSS, and alkalinity. When changes in these abiotic factors occur, it is vital to understand what causes these changes as well as the effects to aquatic organisms.

Activities

Thermal Pollution and Its Effect on Dissolved Oxygen Activity

This activity will help students understand a type of pollution that they can't see. Heat dissipated into a body of water can be very detrimental to the organisms living in that water. During this activity, the students will monitor dissolved oxygen as a function of temperature. Graphing the results, the students should be able to determine that the two measurements vary inversely. The worksheet for this activity can be found at the end of this teacher's manual chapter.

Deep Water Drilling Critical Thinking Activity

This activity will ask the students to think critically about the effects of oil pollution resulting from deep water drilling. It would be advantageous for the students to have read a few articles on deep water drilling. The students will be presented with a scenario and a series of questions. This information can be found on a worksheet at the end of this teacher's manual chapter.

Researching Various Water Pollutants

Students should visit https://www.epa.gov/learn-issues/learn-about-water to identify specific heavy metals, pharmaceuticals/hormone compounds, and industrial pollutants found in our drinking water. The teacher can provide a list of specific pollutants to locate at the website. Students should be able to identify their sources, human health, and environmental effects. Students should further be able to determine how to remediate and prevent such pollutants from entering water initially.

Supplemental Videos

National Geographic "Troubled Waters" – Students can create a chart which identifies the organism affected, the cause, and the effect.

"Tapped" – A documentary about the bottled water industry.

Questions for Review

1. What are the major categories of water pollution? What is an example of each and what problem(s) does each create?
   See Table 18.1.

2. What is the difference between point source and nonpoint source pollution? How has the Clean Water Act reduced point source pollution?
   Point source pollution has a specific location such as a discharge pipe, while nonpoint source pollution does not. It is diffuse and scattered, like pesticide run-off from agricultural fields. Since point source pollution is identifiable it is easier to monitor and control. The Clean Water Act can monitor discharges from factories.

3. What is cultural eutrophication? How does it occur? What steps can be taken to reduce the effects of cultural eutrophication*?*
   It is human-caused increase in biological productivity caused by nutrient overload. This happens when there are too many nutrients, usually from an influx of fertilizers. Cultural eutrophication can be reduced using land management methods such as reducing fertilizer use on farm fields or golf courses, reducing or banning phosphate detergents, and upgrading water treatment plants.

4. What method is used to treat municipal sewage at a treatment plant? How does a wetland serve the same function? Why does the amount of sewage affect the outcome?
   Sewage treatment plants have primary, secondary and tertiary treatment of sewage. Primary treatment is a physical separation process. Secondary treatment is a biological treatment used to dissolve organic compounds. Tertiary treatment removes plant nutrients, mostly nitrates and phosphates. Wetlands can filter out the nutrients and organisms can degrade organic compounds. However, a wetland cannot handle large amounts of sewage. As with any living system, there are limiting factors and an overabundance of material cannot be processed.

5. "The Clean Water Act has been called the United States' most successful and popular environmental legislation?" Why? What goals of the legislation still need work?
   The Clean Water Act was a bipartisan piece of legislation that was hugely successful. Its main objectives were to make all water fishable and swimmable. It focused on point source pollution which was easier to control and monitor. The regulation of nonpoint source pollution, particularly urban run-off and agricultural run-off, needs work. Also, some believe that the regulations need to be stricter.

Practice Questions

Multiple Choice:

Directions for questions 1-5: The lettered choices below correspond to the descriptions given in questions 1-5. Select the one lettered choice that best fits each statement. Each choice may be used once, more than once, or not at all.

(A) point source
(B) nonpoint source
(C) eutrophic
(D) biochemical oxygen demand
(E) dissolved oxygen

1. useful test for organic waste in water

2. run-off of animal waste from a feedlot

3. varies with temperature

4. water rich in organisms and organic material

5. an effluent pipe from a factory

6. Hypoxia often results from
   (A) pesticide run-off
   (B) factory air pollution
   (C) habitat alteration
   (D) a nutrient decrease leading to deaths of organisms
   (E) a nutrient overload that leads to eutrophication

7. Which of the following is NOT a category of water pollution?
   (A) thermal
   (B) inorganic chemicals
   (C) animal manure
   (D) sediment
   (E) organic chemicals

8. What is the “Dead Zone”?
   (A) It is an area in the Gulf of Mexico that supports no aquatic life.
   (B) It is part of the Arctic Ocean where no life exists because of the ice.
   (C) It is the back of the AP classroom.
   (D) It is another phrase for the abyssal zones of the oceans.
   (E) It is habitat where only very limited species live.

9. Which legislation provided funding for municipal sewage treatment plants?
   (A) The Safe Drinking Water Act
   (B) The Clean Water Act
   (C) Resource Conservation and Recovery Act
   (D) Ocean Dumping Act
   (E) Federal Water Pollution Control Act

10. What event eventually led to the creation of the Clean Water Act?
   (A) Unlimited ocean dumping
   (B) Overuse of pesticides in agricultural fields
   (C) Fires on the Cuyahoga River
   (D) Unrestricted use of fertilizers on golf courses
   (E) Rachel Carson's book "Silent Spring"

Free-Response Question:

Directions: Answer all parts of the following question. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. When a calculation is required, be sure to show how you arrived at your answer.

1. Students at the Knightland School are studying stream ecology. The following data has been collected from their stream.

Date	Temperature °C	pH	Dissolved Oxygen ppm	Nitrates mg/L
9/2009	20	7.8	8	0.01
10/2009	17	8.0	8	0.01
11/2009	15	7.9	9	0.01
3/2010	10	7.7	11	0.02
4/2010	14	8.0	10	0.04
5/2010	16	7.9	8	0.07

   (a) Describe TWO abiotic factors other than the ones listed that the students could test to assess water quality.

   (b) Explain the correlation between temperature and the level of dissolved oxygen.

(c) Describe the trend for the nitrate levels.

(i) Explain a reason for this trend.

(ii) For the reason you gave in (i), describe a method that might mitigate the amount of nitrate entering the stream.

(d) Explain the concept of an indicator species. Give an example of one that might be found in the stream.

(e) Identify and describe ONE federal law that protects this waterway.

Answers to Practice Questions

Multiple Choice:

1. D
2. B
3. E
4. C
5. A
6. E
7. C
8. A
9. B
10. C

Free-Response Question:

This question is based on 1o points.

1. (a) 2 points total. One point for each abiotic factor given. Only the first two will be scored.

Factor	Description
Phosphates	Test determines the amount of phosphates in the water, usually due to fertilizers and detergents.
Turbidity/transparency	This determines clarity of the water. The amount of suspended solids in the water determine this.
Alkalinity	It is the ability to resist changes in pH.

(b) 1 point for indicating that the relationship is inverse. In other words, as the temperature decreases the DO increases.

(c) 1 point for indicating that the level of nitrates is increasing.

(i) 1 point for giving a realistic activity. Ex. Fertilizers used in the spring time may be running off into the stream.

(ii) 1 point for giving a realistic solution. Ex. Have the school stop using fertilizers for the lawns.

(d) 2 points total. 1 point for defining an indicator species and 1 point for an example that may be in the stream. An indicator species is an organism that tells something about the environment. An indicator species in the stream could be a water penny or any macroinvertebrate. Other indicator species include fish, frogs.
(e) 2 points total. 1 point for naming the Clean Water Act or any other applicable law and 1 point for a correct description of that law.

Answers to questions in the Student Edition:

Case Study AP Document-Based Question (p. 402)

(A) Industrial pollution is harder to cleanup than organic waste and requires more invasive techniques. Excavation is often used, where the contaminated areas are dug up and removed from the area. Immobilization is also often used, where the contaminated water and soil are bound together in an impenetrable mass to isolate the pollution. Organic pollution cleanup and industrial waste cleanup differ in that organic wastes can often be cleaned up using natural means like bioremediation, incineration, or other forms of heat cleanup. Oftentimes bacteria are used to break down organic waste into less harmful substances. Activated carbon can be used to bind to organic substances and remove them from the environment.
(B) Answers will vary but can include botulism, leptospirosis, *E. coli* infections, typhoid, hepatitis A, polio, or giardia.
(C) Cleanup efforts can take more time and effort than simply reducing pollution inputs because contaminated river water affects more than just the animals in the river and the people that use it. Contaminated river water can contaminate nearby soils. It can also travel much farther than the river if it is used for irrigation or as a water source for far away villages. In addition, sick animals that drink from the river can migrate and carry harmful bacteria with them.

AP Connections Review Answers (pages 424-425)

Multiple-Choice Questions

1. c. Rain washing pesticides from a field into a nearby lake is nonpoint pollution.

2. c. The Superfund Act refers to cleanup of hazardous waste sites, not nitrate pollution.

3. b. MTBE was used as an oxygenate in fuel once lead was banned and began appearing in water supplies.

4. b. Urban runoff containing high levels of salts and other pollutants that can affect the drinkability of water, while the other answer choices all relate to nitrogen oxides and sulfur which can produce acid rain and acidic water, leading to acidification in ecosystems.

5. a. ocean dumping unfortunately still happens in some countries though it is generally banned worldwide

6. e. nitrates are not persistent organic pollutants – they are degraded and used naturally in ecosystems while the others remain.

Data Analysis & Free-Response Questions

1a The stream was impaired by pathogens in 87.5% of cases. (10,500/12,000*100)

1b Thermal pollution impairs surface water because many aquatic organisms are unable to deal with the rapid temperature changes. Warmer temperatures can also increase the level of pathogens in the water, while decreasing the amount of oxygen absorbed in the water.

1c Oxygen depletion can result in areas that can support support low or no aquatic biota; the latter are called dead zones. Oxygen levels become depleted because decomposer organisms (mainly bacteria) consume available oxygen as they consume nutrients and waste. An oxygen sag curve is illustrated in Fig. 18.5.

2a Atmospheric mercury is toxic to living organisms because it settles into waterways by atmospheric deposition and ends up inside the bodies of fish where it can cause developmental problems.

2b When we consume fish that have been exposed to mercury, we consume the mercury. Too much mercury in our bodies can cause mental and developmental problems.

2c One practical method for preventing mercury from entering the food chain is by reducing the source of mercury. This has already been achieved on a large scale by reducing the emissions of mercury from coal power plants.

Thermal Pollution and Its Effect on Dissolved Oxygen Activity

*Student:*_____

Introduction:

Power plants, both coal and nuclear, produce heat in their production of electricity. This heated water is released into a body of water such as a lake or river. One characteristic of water is that the warmer the water, the less dissolved oxygen the water is able to hold. As the temperature in the lake or river increases, the dissolved oxygen leaves the water and becomes atmospheric oxygen. Though there are no pollutants in the water that the power plants release, this anthropogenic thermal pollution is extremely destructive to the aquatic environment.

In this activity you will demonstrate how thermal pollution affects the amount of dissolved oxygen available to organisms and will evaluate the environmental consequences of such actions on an aquatic ecosystem.

Materials:

Thermometer/temperature probe
Hotplate
Ice
Dissolved Oxygen Probe

Procedure:

1. Put 500 mL of water in to a 1,000-mL beaker.
2. Using a temperature probe or a thermometer, find and record the temperature of the water.
3. Using the dissolved oxygen probe, record the % dissolved oxygen at your initial temperature.
4. Slowly heat the water up 5°C. Using the thermometer, slowly stir the water and use the dissolved oxygen probe to measure the DO at this new temperature. Be sure to record temperature and dissolved oxygen.
5. Repeat step 4 at least two more times. Do NOT exceed 37°C.

Analysis:

1. Graph the results.

2. What is the relationship between the temperature and dissolved oxygen on the graph?

3. What do you think is the effect of thermal pollution on aquatic organisms? Why did you not exceed 37°C?

4. What does the term anthropogenic mean?

5. What are some ways that each of us could lessen the effect of thermal pollution on a body of water?

Deep Water Drilling Critical Thinking Activity

*Student:*_____

The large oil companies claim that regulations requiring blow-out preventers impose a financial hardship on them and their customers. They claim that the cost of these devices is passed along to the consumer in the price of the gasoline at the pump.

Questions for Discussion:

1. How much more would you be willing to pay for a gallon of gasoline in order to have these protective devices in place?

2. Is there a limit to what you would pay?

3. In light of recent events, do you think it is safe to drill that deep? Why or why not? Do you think it is necessary to drill that deep?

4. What are some of the economic and environmental costs when a blow-out preventer fails?

5. Can the risks of deep water drilling be entirely eliminated or will human error always play a role in the effectiveness of the safety system?

6. What are some alternative fuel sources that may help to reduce our dependence on oil?

7. What can you personally do to reduce your use of oil/gasoline?