Stinky Clean

HOW WASTEWATER IS CLEANED

Respect Rule: Look, Listen, Learn, and Leave Alone (until instructed).

Overview

Students will study how water used in their homes is treated. Wastewater treatment is an excellent example of how science, particularly microbiology and chemistry, is applied to solve an everyday problem of waste disposal. A trip to a local wastewater treatment plant is an integral part of this lesson.

Background

General Waste Water Treatment

In the United States, each person uses an average of 150 gallons of water a day. All clean water comes into a home or business by one set of pipes and leaves those structures by another set of pipes. Clean water becomes wastewater. Wastewater comes from homes, schools, businesses, industry, and storm runoff.

In most cities across the United States, wastewater goes into sewers and then to wastewater treatment plants. In some rural parts of the nation, wastewater goes into large underground tanks called septic tanks. In the foothills of the Sierra, there is a combination of wastewater treatment facilities and septic tanks. If one lives in a town such as Jackson or Angels Camp, used water travels through sewage pipes to a wastewater treatment facility. If one lives in a more rural community like Pine Grove or West Point, used water is confined in a septic tank on this property. This lesson focuses on the ways water is cleaned at a local treatment plant.

Treatment of wastewater at a treatment plant includes the following steps: primary, secondary, and advanced treatment.

- **The primary treatment** of wastewater relies on physical barriers and gravity for treatment. Bar screens filter out objects like sticks, rags, and rocks. Then sedimentation tanks settle out suspended solids. Suspended solids are pumped from the bottom into another settling tank.
- **Secondary treatment** uses biological processes. Bacteria break down wastes. The wastewater passes through aeration tanks where air is added to aid the growth of bacteria. The bacteria attach to suspended solids; these settle out in the secondary sedimentation tank.
- **Advanced treatment** processes include filtering through sand and gravel and disinfecting with chlorine, ultraviolet light, or ozone to kill dangerous or pathogenic (disease-causing) bacteria.

The cleaned wastewater can be used for irrigation or released back into a lake or river. For discharge and disposal, wastewater must meet standards set by federal and state governments. Wastewater solids, meeting additional criteria for beneficial use, are called biosolids. They can be used as a nutrient-rich fertilizer. The average person produces approximately 200 pounds of biosolids per year.

Biological Wastewater Treatment Processes

In biological wastewater treatment processes, microorganisms metabolize or break down organic constituents (or pollutants) in household wastewater to carbon dioxide and water. While breakdown is commonly not 100% complete, for purposes of demonstrating the chemical changes in wastewater treatment, it can be assumed that reactions are completed as summarized by:

$$\text{Constituent} + O_2 \xrightarrow{\text{aerobic microbes}} CO_2 + H_2O$$

These are called "oxidation" reactions because oxygen is required for the reactions to occur. Oxygen in the above equation is supplied by aeration in activated sludge treatment plants or trickling filters and by photosynthesis and surface wind action in ponds and lagoons.

Biological treatment of wastewater has evolved almost in its entirety since the beginning of the 20th century. Many methods and techniques of biological treatment have been adapted to meet many waste-specific, site-specific, or other needs such as economic constraints, reliability, energy efficiency, space

Objectives
Students will:
1. label and understand the processes of treating wastewater; 2. use flow chart symbols to diagram the wastewater process; 3. use stoichiometric principles to balance chemical reactions that take place in wastewater treatment; 4. observe microbes that decompose waste; 5. research and complete a paper on a wastewater topic.

Grade Levels
6–12

Adult/Student Ratio
Normal class size

Where
Science classroom and wastewater treatment facility

Skills
Observing, researching, communicating, comparing, applying

Key Words
Activated sludge, Aeration, Biosolids, Decomposition, Effluent, Grit chamber, Lagoons (treatment ponds), Primary treatment, Secondary treatment, Sedimentation, Sludge, Stoichiometric, Tertiary treatment, Trickling filter process, Wastewater

> **The highest blessing is our commitment to the land which will measure our success.**
>
> —Arveda Fisher

constraints, variability of wastewater, organic characteristics, operational simplicity, ease of maintenance, removal of specific pollutants, and many other criteria that may affect a given application. Two examples of wastewater treatment plants are: the West Point Waste Water Treatment Plant and the treatment plant in the City of Eureka.

Biological organisms that provide treatment may be either suspended growth organisms (in activated sludge, ponds, or lagoons) or attached growth organisms (in trickling filters, rotating biological contactors or biological towers). These microorganisms use most of the suspended and dissolved material found in the wastewater as their food source. The microorganisms depicted on the Student Sheets are aerobic and, therefore, require a supply of oxygen to function. Their need for food and oxygen is similar to the needs of humans and other animals.

The biological treatment process provides the environment necessary for microorganisms to remove most of the solids from wastewater as its passes through the treatment facility.

The purpose of a biological treatment process is to decompose as much organic matter from the wastewater as possible and produce a high quality effluent (outflow from the plant). The process is critical to the protection of the environment. An example of improper treated effluent may result in a high organic load from the waste lowering dissolved oxygen enough to kill fish or release harmful bacteria into a stream used for fishing or swimming.

Before-the-Field-Trip Activities

Activity 1: Inside the Treatment Facility
Time: Class period
Materials: KWL chart (see chart in the introduction), Down the Drain transparency, Typical Wastewater Treatment Facility Student Worksheet and Answer Key

1. Using the Down the Drain transparency, lead a discussion to determine student's knowledge of wastewater processes. Start with the picture of the home and inquire where water goes once it flows down the drain. Capture information on a KWL chart. Possible discussion threads include:
   a. **Water flow**—Clean water is used in the home, goes down the drain into sewage pipes, and out to a septic tank, or into larger drainage pipes that lead to a wastewater treatment plant. Do the students know where the treatment plant is? What happens to the wastewater once it is at the facility? Where does the water go after it leaves the facility? Is the water used again?
   b. **Wastewater Processes**—How is dirty water cleaned up? What pollutants would likely be in the water? Discuss chemical elements (organic, inorganic, metals) that could be in water. What might be the worst pollutant they contribute to the waste stream at home or at school? (For example: paint, household cleaners, medications, pesticides, solvents.) How much waste do they think they produce annually? Where is it now?
   c. **Microbiology**—Can microorganisms help in the decomposition of waste products? What types of microorganisms are beneficial? Under what conditions can microorganisms decompose waste?
2. DistributeTypical Wastewater Treatment Facility Student Worksheet.
3. Using a transparency, discuss the processes of wastewater treatment. Have students fill in missing information. Questions generated during this discussion should be recorded by the student for future study on a KWL. The following information should provide the background to lead this discussion. Key words to be filled in on the Student Sheet are in bold.
   a. The first step in treatment is primary treatment. Primary treatment focuses on physical removal through screening and settling. This is a very important first step in clean up, and removes about 40% of solids suspended in wastewater. Gravity is the work horse of primary treatment. The process involves these steps.
      - **Screening**—Bar screens remove large objects such as stones or sticks that could plug pipes or damage pumps at the treatment plant.
      - **Grit Chamber**—This chamber carefully controls the velocity of the wastewater. It must be slow

enough for inorganic grit and sand to settle but fast enough for most organic waste to flow through the chamber. Surface scum like grease and plastic is also removed.

- **Settling Tank or Sedimentation Tank**—At this stage some organic solids settle out and are scraped away (see sludge treatment) while oils float to the top and are skimmed off. Some organic waste remains suspended in the wastewater and is ready for secondary treatment.

b. The second step is secondary treatment. The work horses of secondary treatment are the microorganisms that degrade human waste, food waste, soap, detergent and other organic waste. A treatment facility will use one of these three options:

- **Activated Sludge**—This is the most common option. Microorganisms break down organic material. The process requires aeration and agitation because the microorganisms require oxygen for respiration and decomposition. Microorganisms and organic material together make up "activated sludge." This sludge settles during sedimentation. However, the sludge is continually recirculated back to the aeration basin to improve decomposition.
- **Trickling Filters**—These are beds of coarse media (often stones or plastic) three to ten feet deep. Wastewater is sprayed into the air, and then allowed to trickle through the media. Microorganisms, growing on the media like a biofilm, break down organic material in the wastewater. Trickling filters drain at the bottom; the wastewater is collected in sedimentation basins where solids settle out.
- **Treatment Ponds or Lagoons**—These constructed ponds rely on sunlight, algae, microorganisms, and oxygen to slowly decompose organic waste.

c. The final step after primary and secondary treatment is advanced or tertiary treatment. A treatment plant may use one or more of the procedures, although disinfection is always the final step. If chlorine is used to disinfect, chlorine may need to be removed by the addition of other chemicals. Chlorine can be harmful to aquatic organisms in the receiving waters. Furthermore, it might bind to natural compounds in the water and produce trihalomethane, a chemical harmful to humans.

- **Nitrogen Removal**—Ammonia, present in wastewater, can be toxic to fish and other aquatic organisms. Reducing its concentration is critical if the plant's effluent (treated wastewater) is going to flow into a creek, river, or stream. Bacteria convert ammonia to nitrate and then to nitrogen gas.
- **Phosphorus Removal**—Phosphorus can also be removed from the wastewater when special bacteria take it into their cells. These bacteria and organic solids can be removed and sold as fertilizer. Phosphorus can also be removed chemically by precipitation with the addition of salts of iron or aluminum.
- **Filter**—At this stage, additional filtering through carbon can remove more pollutants.
- **Disinfection**—The final wastewater is treated with a disinfectant like chlorine to kill harmful microbes. Chlorination is the most common method, but other techniques like ultraviolet radiation or ozonation are in use. Treatment plants may also chlorinate their effluent, then dechlorinate it before they discharge it to a water way since chlorine at certain concentrations can be harmful to aquatic organisms.

d. Sludge must also be treated and disposed of safely. Sludge from primary and secondary treatment can be treated through anaerobic or aerobic digestion, or composting.

- **Anaerobic Digestion**—In the absence of oxygen, specific microbes further decompose organic waste.
- **Heat-Loving** (thermophilic) bacteria ferment the sludge.
- **Dewatering**—Water is removed from the sludge.

- **Use or Disposal**—Human waste is disposed at landfills. Treatment plants that do not contain human waste can be composted.

Activity 2: Local Wastewater Issues
Time: 20–30 minutes
Materials: KWL chart, Typical Wastewater Treatment Facility transparency

1. Using the KWL chart and information learned from Before-the-Field-Trip Activity 1, have students write questions to ask a plant operator at the local wastewater treatment facility. Possible questions include:
   Which types of treatment (primary, secondary, and tertiary) and specific processes are used at the local treatment plant?
   How efficient is the plant at removing specific pollutants?
   What contaminants are hardest to remove, and what processes remove them?
   How many homes and businesses does the plant serve?
   What happens when more homes are built?
   Where does the effluent go?
   What effects does the effluent have on the environment?
   How are biosolids disposed?

Activity 3: Wastewater Flow Chart
Time: 20–30 minutes
Materials: Flow Chart Student Worksheets

1. Explain or review what a flow chart is. (A chart showing a step by step process.)
2. Discuss uses of flow charts in applied science and computerized models of natural processes (e.g. mechanical engineering, industrial design, computer simulations of animal populations, global warming, and weather patterns).
3. Discuss flow chart symbols and the need for different symbols for different types of processes.
4. Use modeling and guided instruction to help students fill out processes 1–5 in the flow chart.
5. Discuss what data would be needed to make this flow chart valuable to a treatment plant operator. For example, the initial arrow would have a value reflecting the amount of wastewater entering the treatment plant. This rate (volume per time interval, e.g. gallons per minute), is monitored at the treatment facility. The next step, the square called collection (not pictured on the transparency) could be a holding tank with a specific volume and a rate at which wastewater flows through the tank. In addition, chemicals are added at a certain rate. These examples will help the student understand the data that is monitored by computers at the treatment facility.
6. Students work individually or in pairs to complete the flow chart. For extra credit, students use the back side of the flow chart to indicate rates or volumes that would likely be monitored at the treatment plant.
7. Review and discuss final flow charts. Students should generate additional questions to ask plant operator when visiting the treatment facility. These questions would focus on what processes are monitored, how the plant processes are monitored, and how computerized the operation, maintenance, and monitoring are.
8. Discuss potential problems that could be detected using data from the flow chart. Some examples: What would happen if the output flow at the collection tank suddenly dropped. Why do they keep track of the rate of chlorine added? How would you need to redesign the facility if your community put in 200 new homes? Do treatment plants have wastewater surges like electrical surges when people all turn on their air conditioners on a hot day? What parameters keep the facility from having an overflow? Do you think facilities that collect rain water and treat it along with wastewater would cause design changes? What kind of changes?

Activity 4: Biological Treatment
Time: Class period
Materials: Biodegradable Balancing Student Worksheets and Answer Key, Organic Constituents Student Worksheet

1. Review or instruct students on how to balance chemical equations.
2. Model and guide instruction on balancing several equations.
3. Students work individually or in pairs to balance the equations on Student Worksheet.

4. Discuss oxidation reactions and how microorganisms mediate these reactions.
5. In higher level science courses, discuss incomplete decomposition. What products would be formed if decomposition was not complete? What would happen if there was insufficient oxygen for decomposition?

Field Trip Activity

Activity: Tour of a Wastewater Treatment Facility or Guest Speaker
Time: 1 class period (guest speaker) or part-day field trip
Materials: Student generated questions, paper and pen to take notes

1. Visit the local municipal wastewater treatment plant and/or invite a speaker from the plant to talk to the class.
2. Students view wastewater treatment processes and compare and contrast processes to those learned in class.
3. Students ask questions to use as background information for a news article about local or national issues pertaining to wastewater treatment.
4. Students view activated sludge at the treatment plant to identify microorganisms that decompose waste.

After-the-Field-Trip Activity

Activity: Wastewater Issues
Time: 2 class periods
Materials: Students notes from guest speaker or field trip, Internet access

1. Students choose one of the following research topics:
   - Regional Wastewater Treatment: Build it and they will come—How local growth affects wastewater treatment
   - Wastewater Treatment: the latest technology (e.g. advanced treatment, disinfection options, improving decomposition efficiency)
   - Homeowner's Guide—How to reduce pollutants that go down the drain
   - Environmental Regulations—Too many or too few?
   - Dirty Jobs for Humans—Write up career requirements and skills needed for various wastewater jobs such as plant operator, environmental engineer, microbiologist.
   - Good, Bad and Ugly Microbes—Describe desirable and undesirable microorganisms that exist within the wastewater stream and wastewater facility.
2. Students work in groups to discuss topics and how to find information. As an alternative, consider students debate whether the local treatment plant should be expanded to meet the needs of a growing community. Students would take the position of an interest group: county wastewater agency, county government, city government, local residents, environmental group, business organization, trade or contractors associations.
3. Determine government officials or experts that students need to interview.
4. Teach or review outline elements for a research paper.
5. Teach or review how to cite research sources.
6. Students write a research paper on their topic.

Extension:

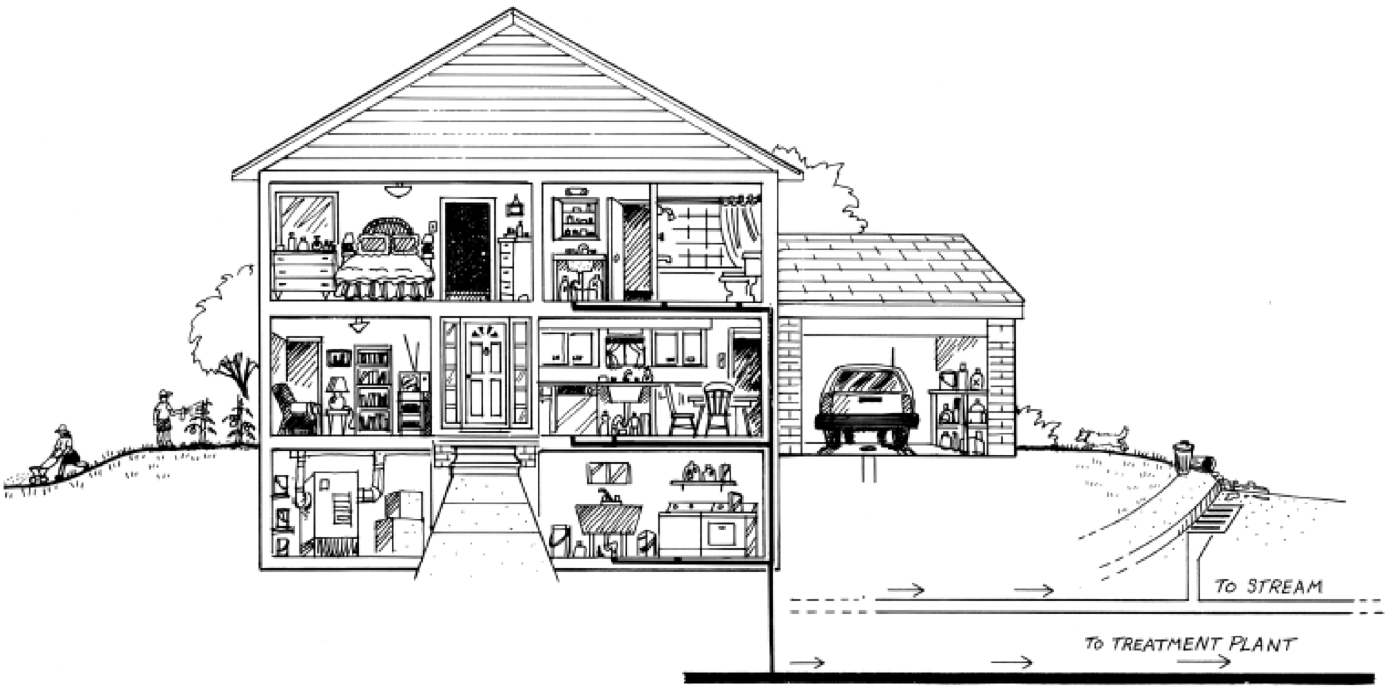
Have students complete the experiment Settle Down Student Worksheet.

Source

Adapted with permission from
The Water Sourcebooks, U. S. EPA Office of Drinking Water and Ground Water (online at http://www.epa.gov/safewater/kids/wsb)

Down the Drain

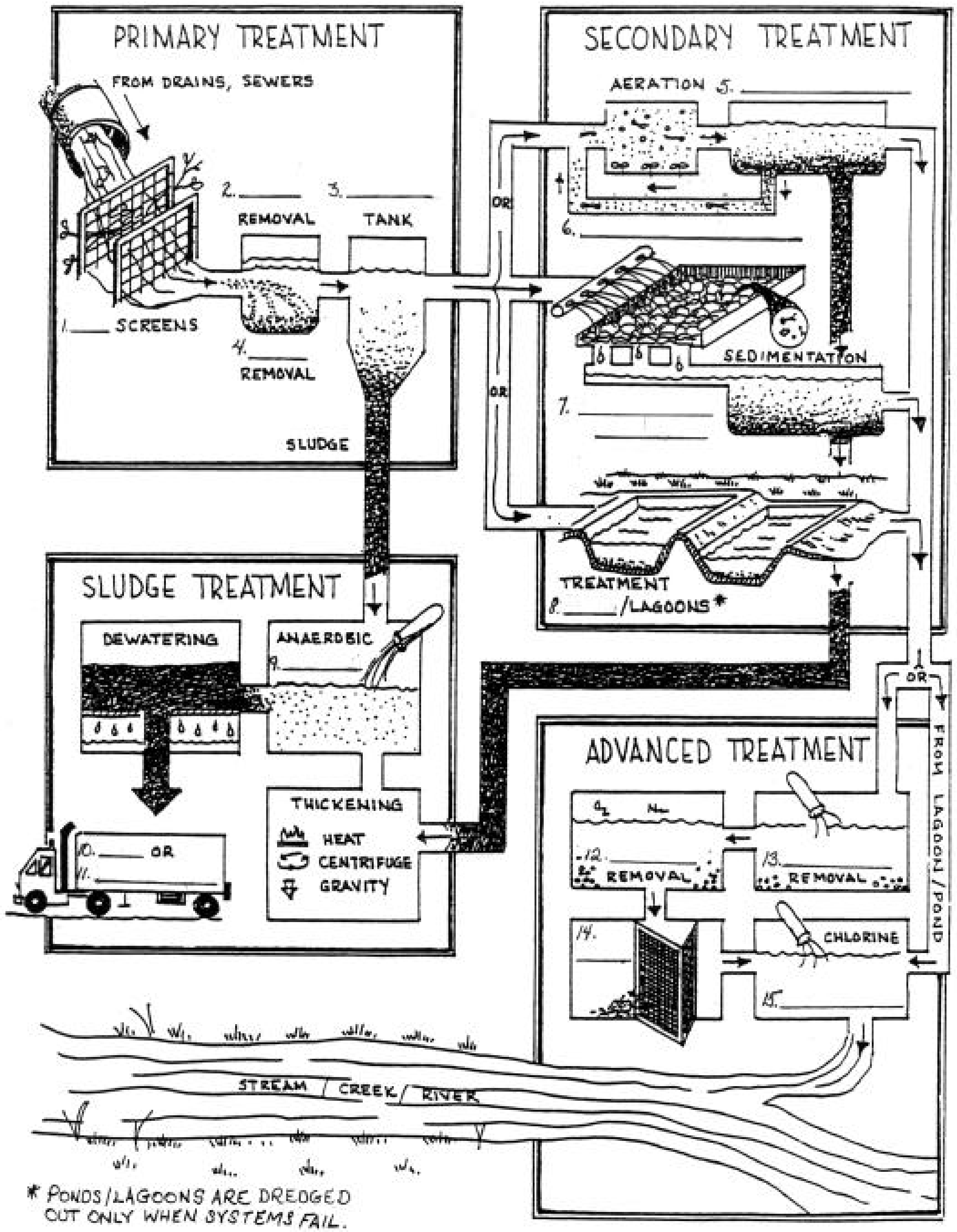
Transparency



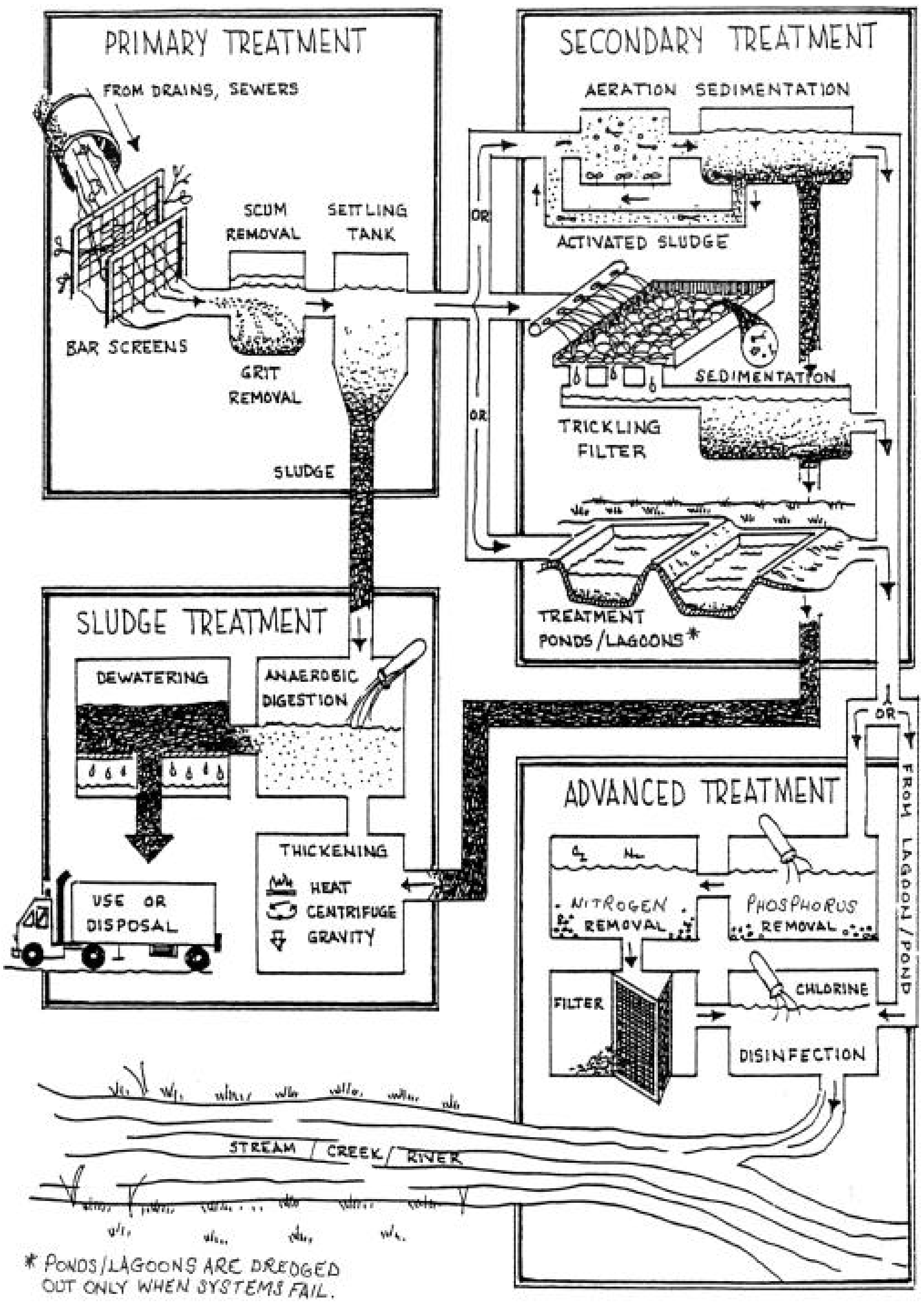
Name Date

Typical Wastewater Treatment Facility

Student Worksheet



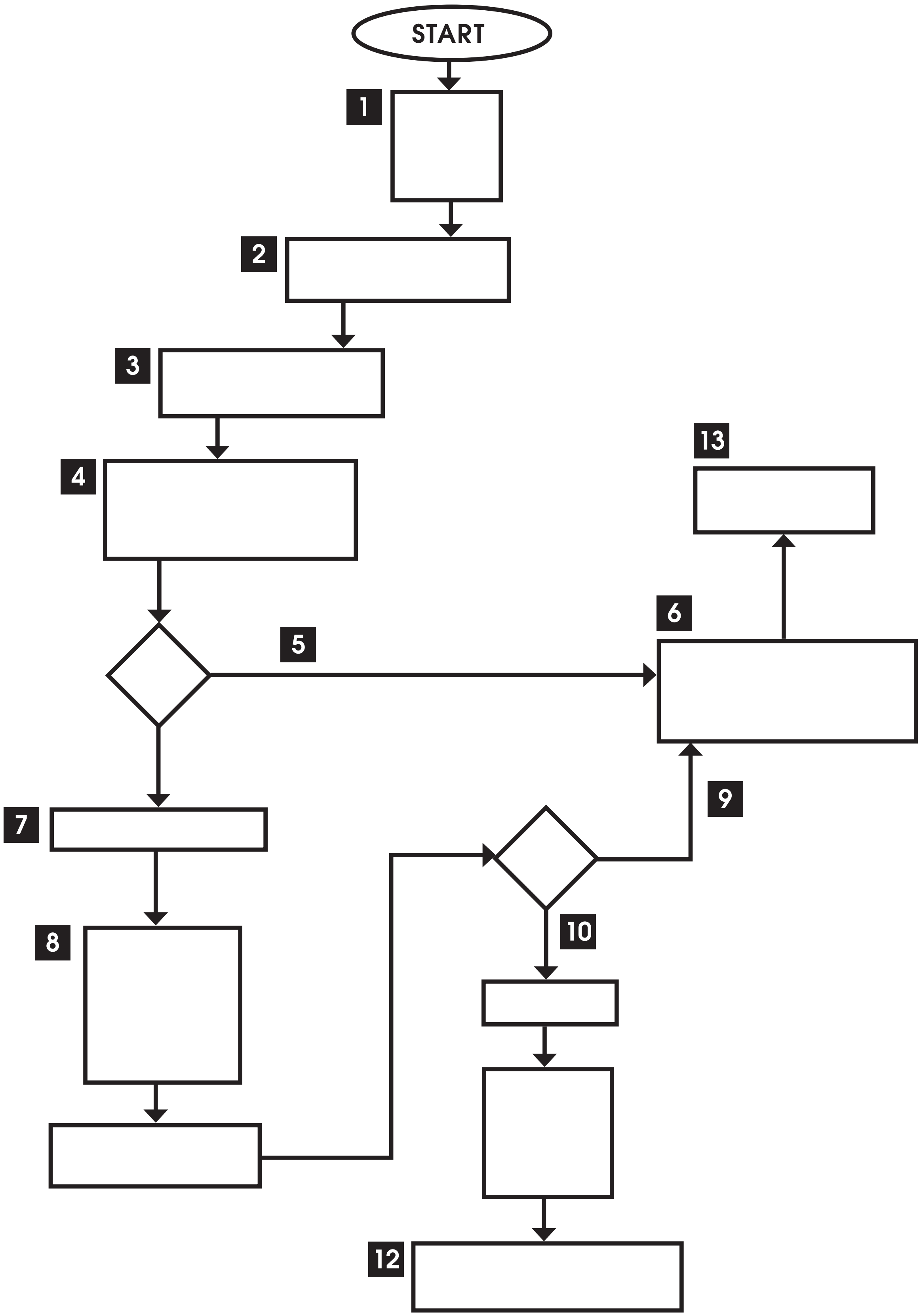
Typical Wastewater Treatment Facility
Answer Key



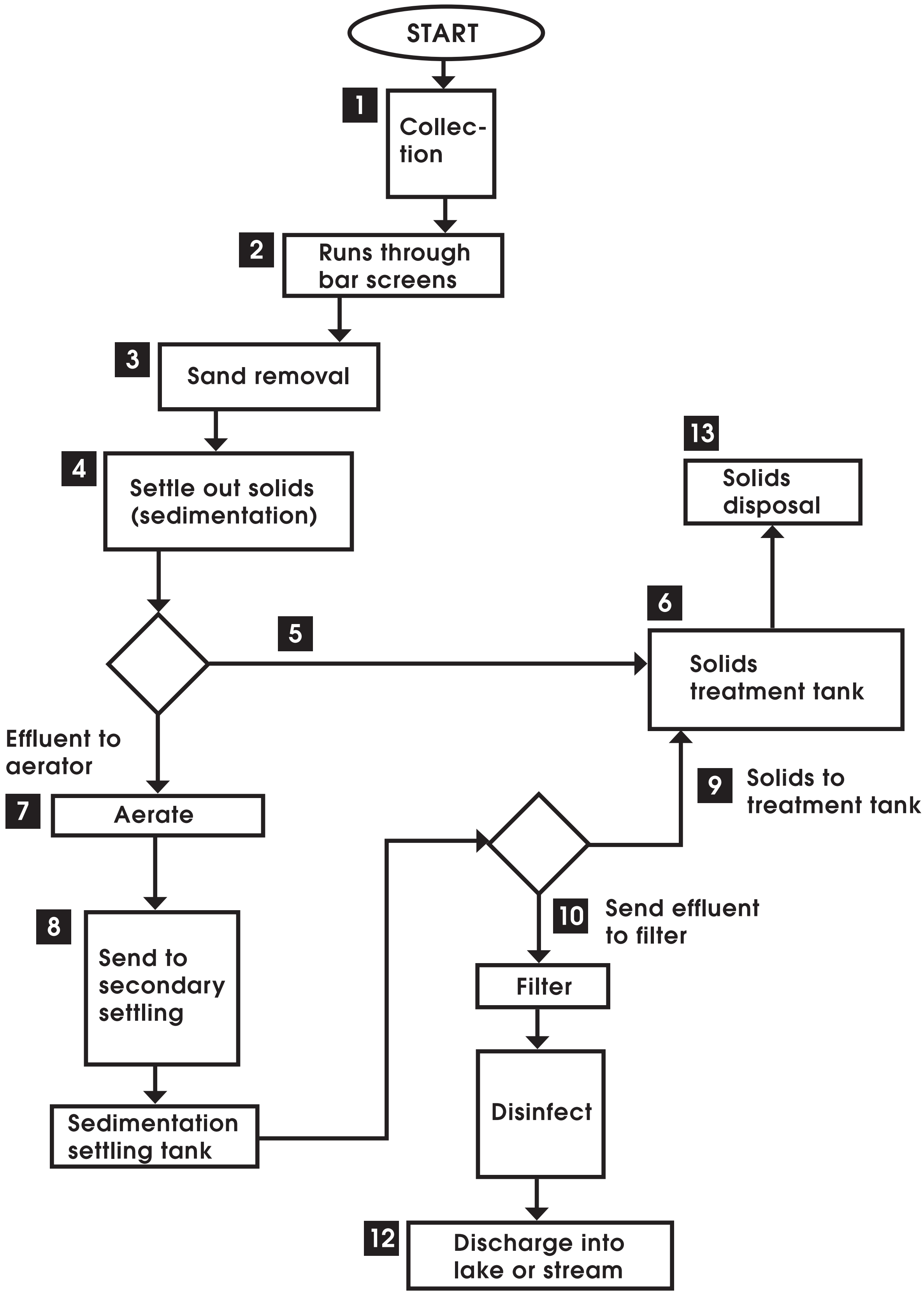
Name Date

Flow Chart

Student Worksheet



Flow Chart
Answer Key



Name Date

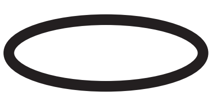
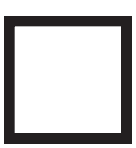
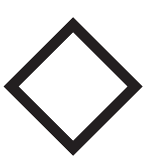
Flow Chart Directions

Student Worksheet

Steps To Clean Water:

1. Intake wastewater (collection)
2. Run through bar screens
3. Remove sand
4. Settle out solids (sedimentation)
5. Send solids to wastewater solids treatment tank
6. Treat solids for disposal
7. Add bacteria to effluent and aerate
8. Send to secondary settling tank (sedimentation)
9. Send solids to wastewater solids treatment tank
10. Send through filtration
11. Disinfect using chlorine, ultraviolet light or ozone
12. Discharge into lake or stream
13. Dispose of solids

Flow Chart Symbols:

	**Arrows**	Arrows show the direction of the flow of wastewater from process to process.
	**Start/Stop**	An oval is used to show where the treatment process starts and stops.
	**Square**	A square is used to show when chemicals are added to or materials are removed from the wastewater.
	**Rectangle**	A rectangle is used to show when a treatment process is taking place.
	**Diamond**	A diamond is used to show when parts of the wastewater flow go in two different directions.

Name Date

Organic Constituents

Student Worksheet

Bacteria

(Constituent + O_2 CO_2 + H_2O)

Substituting the chemical formula for common household constituents, the equation may be balanced to show complete reactions. Some examples of common household constituents of wastewater are listed below. Common household constituents and their formulas are below.

1. Acetic Acid (vinegar) CH_3COOH
2. Acetone (nail polish remover) CH_3COCH_3
3. Citric Acid (orange juice) $C_6H_8O_7$
4. Sucrose (sugar) $C_{12}H_{22}O_{11}$
5. Benzene (a component of gasoline) C_6H_6
6. Phenol (present in mouthwash) C_6H_5OH
7. Naphthalene (mothballs) $C_{10}H_8$
8. Uric Acid $C_5H_4N_4O_3$
9. Caffeine $C_8H_{10}N_4O_2$
10. Acetylsalicylic Acid (aspirin) $CH_3COOC_6H_4COOH$
11. Vitamin A $C_{20}H_{30}O$
12. Thiamine (Vitamin B_1) $C_{12}H_{17}N_4SOCl$
13. Ascorbic Acid (Vitamin C) $C_6H_8O_6$
14. Vitamin D_2 $C_{28}H_{44}O$
15. Tocopherol (Vitamin E) $C_{29}H_{50}O_2$
16. Riboflavin (Vitamin B_2) $C_{17}H_{20}N_4O_6$
17. Alanine (a constituent of most proteins) $C_3H_4NH_2O_2H$
18. Stearic Acid (soap) $C_{17}H_{35}COOH$
19. Ethanol (the alcohol contained in beer, wine, etc.) C_2H_5OH
20. Starch $(C_6H_{10}O_5)n$ where n = a whole number

Name Date

Biodegradable Balancing

Student Worksheet

Procedure: Balance the following equations that use common household constituents found in wastewater treatment plants.

1. Acetic Acid (vinegar)
   $CH_3COOH + 2O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O$

2. Acetone (nail polish remover, will not stay in solution—very volatile)
   $CH_3COCH_3 + 4O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O$

3. Citric Acid (orange juice)
   $2C_6H_8O_7 + 9O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O$

4. Sucrose (sugar)
   $C_{12}H_{22}O_{11} + 12O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O$

5. Benzene (a component of gasoline)
   $2C_6H_6 + 15O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O$

6. Phenol (present in mouthwash, toxic to microorganisms at low concentrations)
   $C_6H_5OH + 7O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O$

7. Naphthalene (mothballs, will sublime rather than dissolve)
   $C_{10}H_8 + 12O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O$

8. Uric Acid
   $2C_5H_4N_4O_3 + 9O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O + N_2$
   Some of these compounds will not be effectively treated with biological stabilization.

9. Caffeine
   $2C_8H_{10}N_4O_2 + 19O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O + N_2$

Name Date

Biodegradable Balancing

Student Worksheet (continued)

10. Acetylsalicylic Acid (aspirin)

$CH_3COOC_6H_4COOH + 9O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O$

11. Vitamin A

$C_{20}H_{29}OH + 27O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O$

12. Vitamin B_1 (thiamine)

$2C_{12}H_{17}N_4SOC1 + 31O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O + N_2\uparrow + S_2 + HCl$

13. Ascorbic Acid (Vitamin C)

$C_6H_8O_6 + 5O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O$

14. Vitamin D_2

$2C_{28}H_{43}OH + 77O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O$

15. Tocopherol (Vitamin E)

$2C_{29}H_{50}O_2 + 81O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O$

16. Riboflavin (Vitamin B_2)

$C_{17}H_{20}N_4O_6 + 19O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O + N_2$

17. Alanine (a constituent of most proteins)

$4C_3H_4NH_2O_2H + 15O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O + N_2$

18. Stearic Acid (soap)

$C_{17}H_{35}COOH + 26O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O$

19. Ethanol (the alcohol contained in beer, wine, etc.)

$C_2H_5OH + 3O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O$

20. Starch

$(C_6H_{10}O_5)n + 6O_2 \xrightarrow{\text{Microorganisms}} CO_2 + H_2O$

where n = 1

Biodegradable Balancing

Answer Key

1. Acetic Acid (vinegar)
   $CH_3COOH + 2O_2 \xrightarrow{\text{Microorganisms}} 2CO_2 + 2H_2O$

2. Acetone (nail polish remover)
   $CH_3COCH_3 + 4O_2 \xrightarrow{\text{Microorganisms}} 3CO_2 + 3H_2O$

3. Citric Acid (orange juice)
   $2C_6H_8O_7 + 9O_2 \xrightarrow{\text{Microorganisms}} 12CO_2 + 8H_2O$

4. Sucrose (sugar)
   $C_{12}H_{22}O_{11} + 12O_2 \xrightarrow{\text{Microorganisms}} 12CO_2 + 11H_2O$

5. Benzene (a component of gasoline)
   $2C_6H_6 + 15O_2 \xrightarrow{\text{Microorganisms}} 12CO_2 + 6H_2O$

6. Phenol (present in mouthwash)
   $C_6H_5OH + 7O_2 \xrightarrow{\text{Microorganisms}} 6CO_2 + 3H_2O$

7. Naphthalene (mothballs)
   $C_{10}H_8 + 12O_2 \xrightarrow{\text{Microorganisms}} 10CO_2 + 4H_2O$

8. Uric Acid
   $2C_5H_4N_4O_3 + 9O_2 \xrightarrow{\text{Microorganisms}} 10CO_2 + 4H_2O + 4N_2$

9. Caffeine
   $2C_8H_{10}N_4O_2 + 19O_2 \xrightarrow{\text{Microorganisms}} 16CO_2 + 10H_2O + 4N_2$

10. Acetylsalicylic Acid (aspirin)
    $CH_3COOC_6H_4COOH + 9O_2 \xrightarrow{\text{Microorganisms}} 9CO_2 + 4H_2O$

11. Vitamin A
    $C_{20}H_{29}OH + 27O_2 \xrightarrow{\text{Microorganisms}} 20CO_2 + 15H_2O$

12. Vitamin B_1 (thiamine)
    $2C_{12}H_{17}N_4SOC1 + 31O_2 \xrightarrow{\text{Microorganisms}} 24CO_2 + 16H_2O + 4N_2 + S_2 + 2HCl$

Answer Key (continued)

13. Ascorbic Acid (Vitamin C)
$C_6H_8O_6 + 5O_2 \xrightarrow{\text{Microorganisms}} 6CO_2 + 4H_2O$

14. Vitamin D_2
$2C_{28}H_{43}OH + 77O_2 \xrightarrow{\text{Microorganisms}} 56CO_2 + 44H_2O$

15. Tocopherol (Vitamin E)
$2C_{29}H_{50}O_2 + 81O_2 \xrightarrow{\text{Microorganisms}} 58CO_2 + 50H_2O$

16. Riboflavin (Vitamin B_2)
$C_{17}H_{20}N_4O_6 + 19O_2 \xrightarrow{\text{Microorganisms}} 17CO_2 + 10H_2O + 2N_2$

17. Alanine (a constituent of most proteins)
$4C_3H_4NH_2O_2H + 15O_2 \xrightarrow{\text{Microorganisms}} 12CO_2 + 14H_2O + 2N_2$

18. Stearic Acid (soap)
$C_{17}H_{35}COOH + 26O_2 \xrightarrow{\text{Microorganisms}} 18CO_2 + 18H_2O$

19. Ethanol (the alcohol contained in beer, wine, etc.)
$C_2H_5OH + 3O_2 \xrightarrow{\text{Microorganisms}} 2CO_2 + 3H_2O$

20. Starch
$(C_6H_{10}O_5)n + 6O_2 \xrightarrow{\text{Microorganisms}} 6CO_2 + 5H_2O$
where n = 1