9-12

WATER WORKS

OBJECTIVES

The student will do the following:

1. Describe the process that water treatment plants use to purify water for drinking.

2. Demonstrate how a water treatment plant works.

SUBJECTS:
Science (Physical, Earth, & Biology)

TIME:
2 class periods

MATERIALS:
student sheets
2-gallon (8 L) jug of water
5 cups (600 ml) soil or mud
acetate sheet
many 2-liter plastic bottles
funnels, scissors, stirring rods
alum, bleach, fine sand
coarse sand, fine gravel
coarse gravel
activated charcoal
cotton for plugs, tap water
tablespoons, clock
small piece of cheese cloth, rubber band

BACKGROUND INFORMATION

Our drinking water comes from both surface water and groundwater. Water in lakes, rivers, and swamps contains impurities that may make it look and smell bad. Water that looks clean may contain harmful chemicals or bacteria and other organisms that can cause disease.

Waterborne diseases have been and continue to be a major public health concern. Waterborne disease outbreaks, such as occurred in Milwaukee, WI in 1993 with 400,000 sick and over 100 deaths, give cause for continued vigilance in drinking water protection and treatment.

It takes the efforts of federal, state, and local governments, as well as local water suppliers, to keep our drinking water safe. The Safe Drinking Water Act and its amendments set the standards for public drinking water supplies. The Environmental Protection Agency is charged with ensuring that these standards are met. Technicians working in drinking water facility laboratories conduct thousands of tests each year to ensure that our drinking water supply is free of disease-causing bacteria and other pathogens. These test results are reported to state and local governments.

Drinking water treatment plants clean and maintain the quality of our water supplies through the following processes: (1) aeration, (2) coagulation/flocculation, (3) sedimentation, (4) filtration, and (5) disinfection. (See definitions in "Terms.")

<u>Terms</u>

aeration: exposing to circulating air; addition of oxygen to wastewater or water, as in first step of both activated sludge wastewater treatment process and drinking water treatment.

alum: aluminum salt (typically, aluminum sulfate) used as a flocculant

coagulant: a substance added to a mixture that will cause precipitates (flocs) to form; also called "flocculant"

coagulation: the process by which dirt and other small suspended solid particles are chemically bound, forming flocs using a coagulant (flocculant) so they can be removed from the water (the second step in drinking water treatment)

disinfection: the use of chemicals and/or other means to kill potentially harmful microorganisms in the water (the fifth step in drinking water treatment)

filtration: the process of passing a liquid or gas through a porous article or mass (e.g., paper, membrane sand) to separate out matter in suspension (the fourth step in drinking water treatment)

flocculant: a substance added to a mixture that will cause precipitates (flocs) to form; also called "coagulant"

flocs: lumpy or fluffy masses of particles agglomerated by a flocculant or coagulant

flocculation: physical process of growing of flocs from smaller flocs or particles

microbe: microorganism (microbiological organism)

microbiology: study of microorganisms, a large and diverse group of organisms that exists as single cells or cell clusters

sedimentation: the drinking water process of letting heavy particles in raw water settle out into holding ponds or basins before filtration

sludge: any solid, semisolid, or liquid waste that settles to the bottom of sedimentation tanks (in wastewater treatment plants or drinking water treatment plants) or septic tanks

waterborne diseases: diseases spread by contaminated water

water treatment: a method of cleaning water for a specific purpose such as drinking

ADVANCE PREPARATION

A. Make a copy of the diagram of a water treatment plant or use as a transparency.

B. Gather materials for students to demonstrate the drinking water treatment process.

C. Prepare “dirty water”; add approximately 5 cups (600 ml) of soil or mud to 2 gallons (8 L) of water.

D. Alum (flocculant) can be found at the grocery store in the spices section. It is commonly used for making pickles.

PROCEDURE

I. Setting the stage

A. Discuss the water treatment plant and what it does.

B. Hand out the diagram of a Water Treatment Plant and Data Form.

C. Discuss each step of water treatment. (An overhead transparency of the Student Sheet may be helpful.) Use the definitions given to explain each step.

II. Activity

A. Divide the students into working groups. Have each group perform the following steps and answer the following questions on the Student Sheet - Data Form:

1. Pour about 1.5 quarts (1.4 L) of “dirty water” into the uncut 2-liter bottle with the cap. (Use a funnel.) Describe the water.

2. Put the cap on the bottle and shake for 30 seconds. Continue the process by pouring the water back and forth between two bottles 10 times. What part of the treatment process does this represent?

3. Pour the aerated water into the 2-liter bottle with top cut off. Add 2 tablespoons (30 ml) of alum to the water. Stir the mixture slowly for 5 minutes. What process is occurring?

4. Allow the water to stand undisturbed for 20 minutes. Ask the students to observe the water at 5-minute intervals and record their observations. What process is

occurring? (Note: some members of the group could be constructing the filter during this time according to the diagram on page 2-8 - see #5 below)

5. Cut the bottom from another 2-liter or 3-liter bottle. Construct the filter. Turn the bottle upside down. Loosely put a cotton plug in the neck of the bottle, then cover the neck of the bottle with a piece of cheese cloth secured with a rubber band. Pour the fine sand over the cotton plug followed by activated charcoal, coarse sand, fine gravel, and coarse gravel. Clean the filter by slowly and carefully pouring through 1-2 gallons (4-8L) of clean tap water. Place the filter over the bottom part of the bottle. Without disturbing the sediment in the container with the alum, pour the top two-thirds of the water through the filter. What process is occurring?

6. After waiting until more than half of the water poured through the filter has been collected, add 2 tablespoons (30 ml) of bleach to the filtered water. What part of the treatment process does the addition of bleach represent?

B. Compare the treated and untreated water.

1. Record differences in appearance and odor.

2. Examine water with a microscope (both treated and untreated). Record observations.

C. Have students find out if there is any special treatment that is done to "smelly" water. (Note: Activated charcoal is often used.)

III. Follow-up

A. Have students write a report on how a water treatment plant purifies water. They must include all the steps.

B. Visit the local water treatment plant. If this is not possible, ask a representative from the water utility to visit the class.

RESOURCES

"Science Demonstration Projects in Drinking Water: Grades K-12," U.S. Environmental Protection Agency, Washington, D.C., 1990.

"The Official Captain Hydro Water Conservation Workbook," East Bay Municipal Utility District, Oakland, California, 1982.

"The Story of Drinking Water" (student booklet), American Water Works Association, Denver, Colorado, 1984.

"The Story of Drinking Water: Teachers Guide, Intermediate Level, Grades 4, 5, 6," 2nd Ed., American Water Works Association, Denver, Colorado, 1988.

Student Sheet

Data Form

II. Activity

A. 2. Answer to question:

3. Answer to question:

4. Observations -----

Answer to question:

6. Answer to question:

B. 1. Differences in appearance and odor.

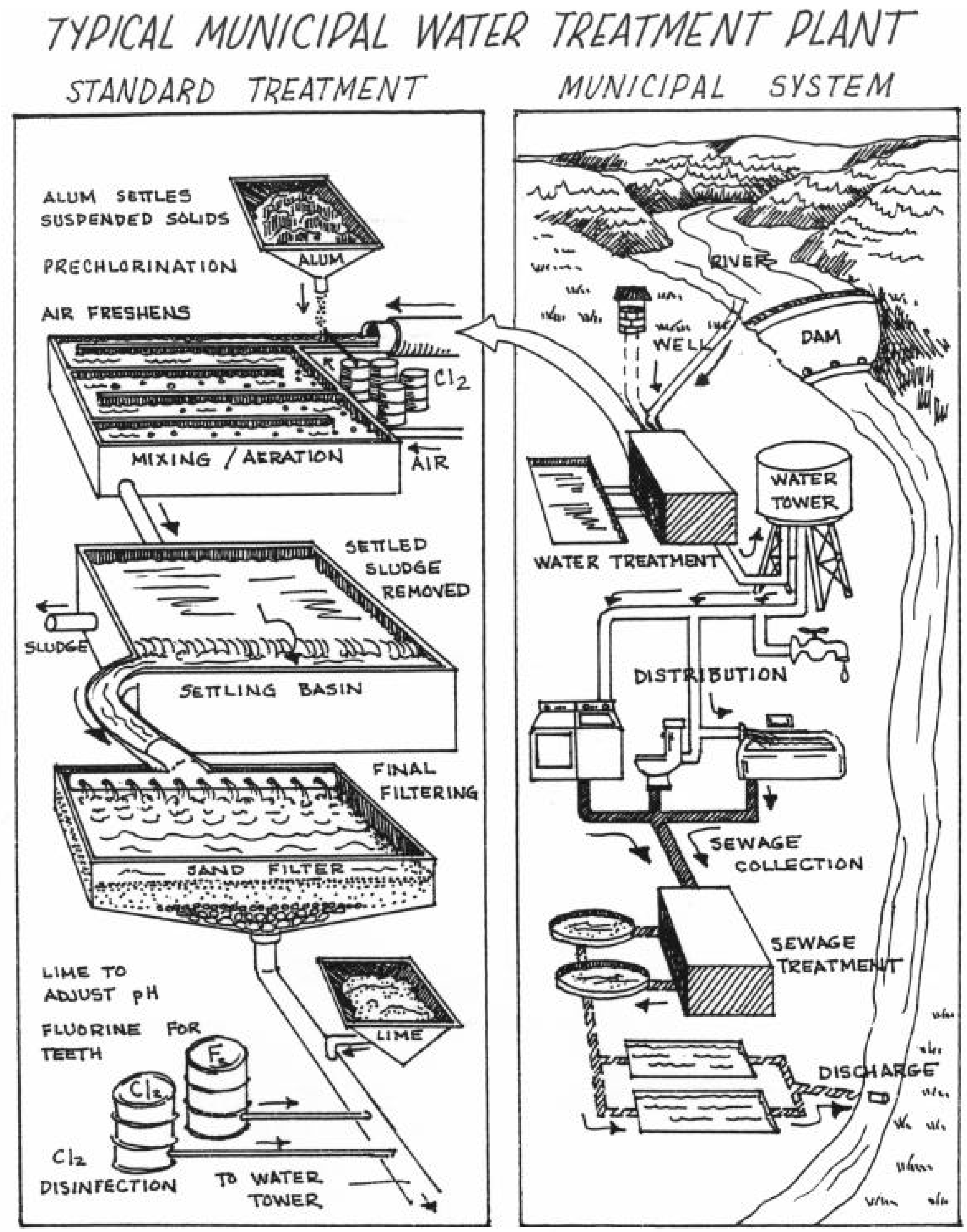
<u>Treated Water</u> <u>Untreated Water</u>

2. Microscope Observations

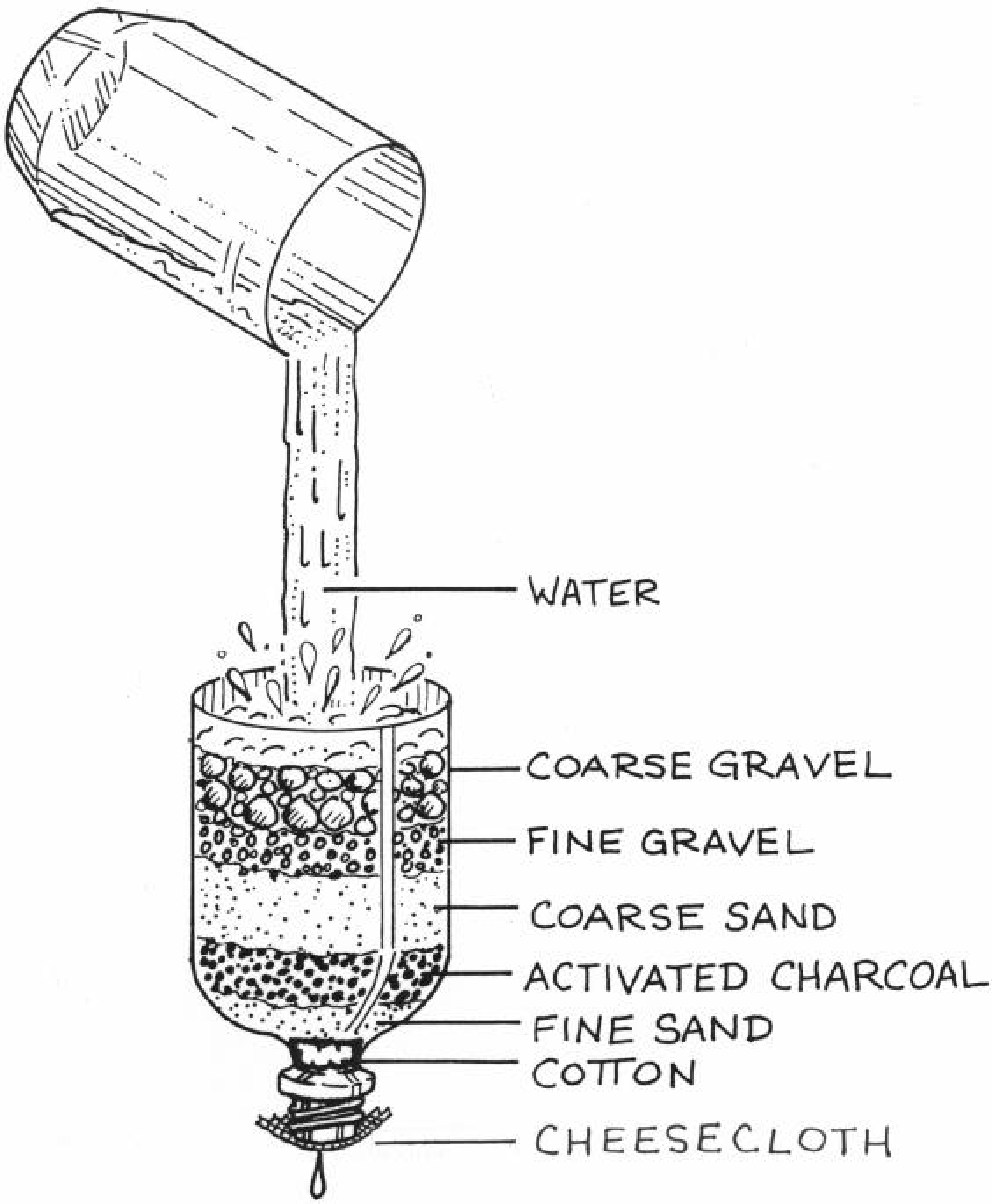
<u>Treated Water</u> <u>Untreated Water</u>

III. Follow-up

Write a one-page report on how a water treatment plant purifies water for drinking.



TYPICAL MUNICIPAL WATER TREATMENT PLANT
STANDARD TREATMENT
MUNICIPAL SYSTEM
ALUM SETTLES SUSPENDED SOLIDS
PRECHLORINATION
AIR FRESHENS
ALUM
Cl2
MIXING / AERATION
AIR
SETTLED SLUDGE REMOVED
SLUDGE
SETTLING BASIN
FINAL FILTERING
SAND FILTER
LIME TO ADJUST pH
FLUORINE FOR TEETH
LIME
Cl2 DISINFECTION
TO WATER TOWER
RIVER
WELL
DAM
WATER TOWER
WATER TREATMENT
DISTRIBUTION
SEWAGE COLLECTION
SEWAGE TREATMENT
DISCHARGE


WATER
COARSE GRAVEL
FINE GRAVEL
COARSE SAND
ACTIVATED CHARCOAL
FINE SAND
COTTON
CHEESECLOTH

CARBON TREATMENT FOR WATER POLLUTION CONTROL

9-12

OBJECTIVES

The student will do the following:

1. Describe different types of carbon.

2. Determine which type of carbon is most effective for removing organic pollutants.

3. Explain how carbon removes organic pollutants from water.

SUBJECTS:
Science (Chemistry, Ecology)

TIME:
1 class period

MATERIALS:
pulverized coal
activated charcoal(carbon)
charcoal (ground)
food coloring
16 capped containers
color pencils

BACKGROUND INFORMATION

Granular activated carbon selectively removes soluble organics from water or wastewater by adsorption of these molecules to the carbon particle surfaces. Granulated carbon has an extremely large surface area per unit weight (approximately 1000 m^2/gram) due to the many pores within the carbon particles and the vast areas of the walls within these pores.

In aqueous environments, carbon has a preference for large molecules and for substances nonpolar in nature. The forces of attraction between the carbon and adsorbed organic molecules are greater the closer the molecules are to the size of the pores in the carbon.

Carbon is used in multimedia filters in drinking water treatment plants to remove organics, in carbon columns for treatment or advanced treatment of wastewater, and in the powder form (powdered activated carbon or PAC) in biological treatment plants to remove the organics where treatment organisms may be slow or unable to remove them.

Carbon treatment has advantages and disadvantages. It is very effective for pollutants of a large or complex molecular structure (pesticides, color, ringed organics, branched organics). It is ineffective for most simple organics (formaldehyde, simple alcohols). However, it requires regeneration (usually by burning off adsorbed organics), which is very expensive, is sophisticated to operate, and may have unforeseen side results as production of sulfides or odorous chemicals. Carbon beds may also become plugged. With its positives and negatives, however, carbon adsorption is often the treatment of choice if treatment needs and surrounding circumstances are appropriate.

Terms

activated carbon (charcoal): material made from coal by driving off hydrocarbons under intense heat without oxygen, leaving a tremendous surface area on which many chemicals can be adsorbed

adsorption: phenomenon by which molecules in a fluid phase are attracted to a solid surface (e.g., activated carbon) and are held there by physical or weak chemical bonds

aqueous: of, pertaining to, or dissolved in water

biological treatment: treatment of wastewater using microorganisms to decompose undesirable organic compounds in an aqueous waste stream

carbon column: compressed activated carbon in a tube; used for adsorption processes

filtration: the process of passing a liquid or gas through a porous article or mass (e.g., paper, sand, gravel, membrane) to separate out matter in suspension; used in both wastewater and drinking water treatment

multimedia filters: filters that contain more than one type of filtering material

nonpolar molecule: covalent molecule that does not exhibit any partial (+) or (-) charges or fields

organic molecule: any molecule that contains carbon and hydrogen

polar molecule: covalent molecule that has a partial (+) and partial (-) end

regeneration: the process of being renewed or reconstituted

PROCEDURE

I. Setting the stage

A. Have three types of carbon in class - pulverized coal, ground up activated charcoal (sold with aquarium supplies), and ground charcoal.

B. Mix different solutions of different food coloring (red, yellow, green, and blue). Record what colors were used for each mixture on Data Sheet. (If 4 mixtures are made, 16 capped containers will be needed.)

II. Activity

A. Add equal amounts of each color to three capped containers with equal amounts of carbon in each (each color mixture having one of each carbon source).

B. Shake each of the containers thoroughly mixing the carbon sources and food coloring.

C. Observe, record, and compare the color of each solution after settling or filtering to the color of the original food coloring solution in the containers without carbon. Use coloring pencils to indicate the results.

III. Follow-up

A. What happened to the food coloring? This same thing happens to some types of pollutants in an actual application.

B. Were certain colors removed better than others? Why?

C. Determine the clarity of each of the food colors. What does this tell you about the chemistry of each of the food colorings?

D. What does this tell you about matching carbon pore size to the molecular pollutant to be removed?

E. Find out how many acres (approximately 1000 m^2/gram) of surface area one pound of activated charcoal has.

IV. Extensions

A. Call the local water and wastewater treatment facilities to see if they use activated carbon in their plants. Find out what pollutants they are removing.

B. Locate the source (sources) of organic pollutants in water in the area. Discuss means of reducing these pollutants.

C. Try the same process with non-organic dyes.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Culp, R.L. and G.L. Culp, Advanced Wastewater Treatment, Van Nostrand Reinhold Company, 1971, pp.133-140.

Cunningham, William P. and Barbara Woodworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, IA, 1997.

EPA Facts About Activated Carbon Treatment, June 1992.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

Data Sheet

Colors Used

Mixture 1 -

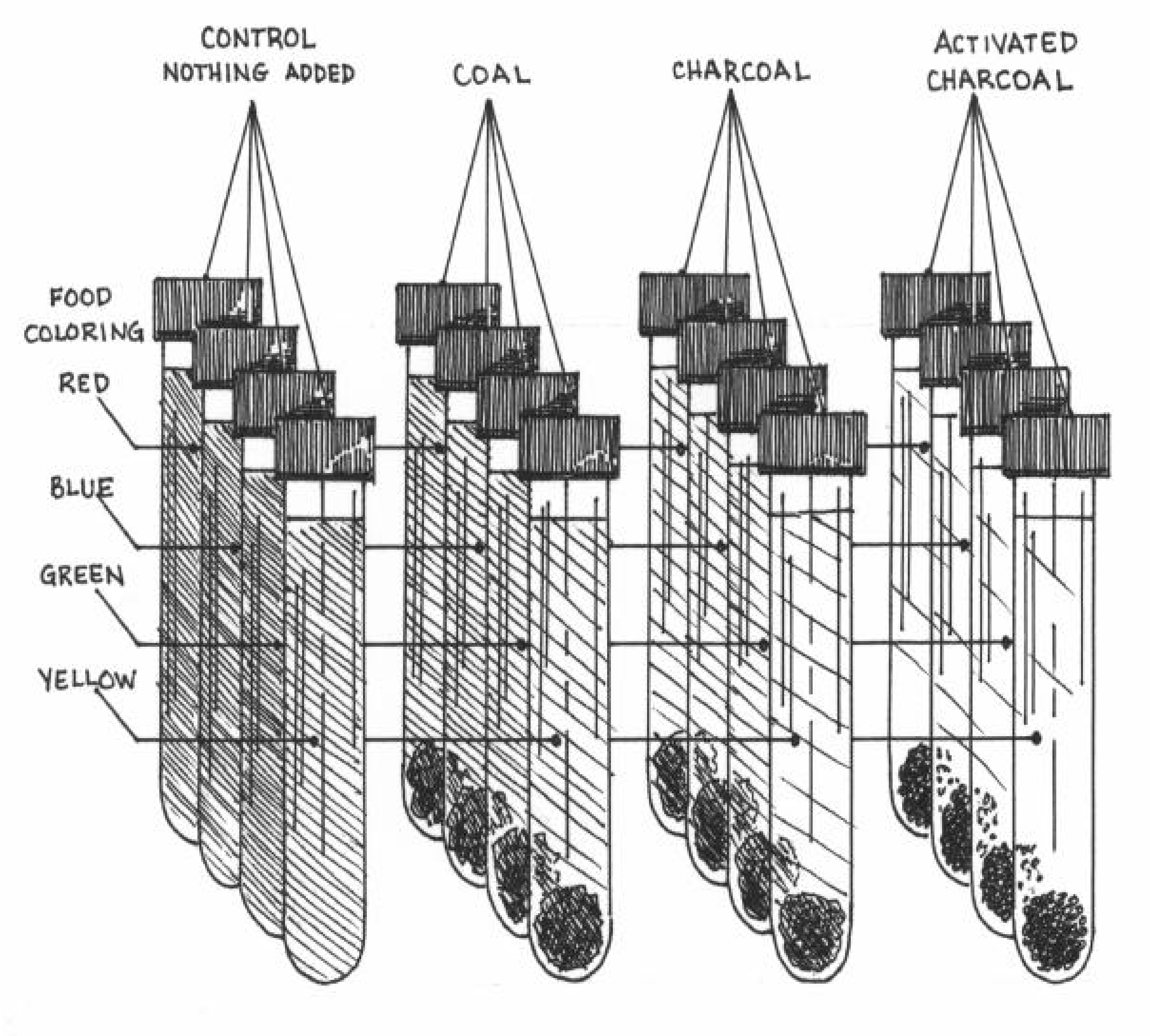
Mixture 2 -

Mixture 3 -

Mixture 4 -

Change in Color

	Pulverized Coal	Activated Charcoal	Ground Charcoal
Mixture 1			
Mixture 2			
Mixture 3			
Mixture 4			


CONTROL
NOTHING ADDED
COAL
CHARCOAL
ACTIVATED
CHARCOAL
FOOD
COLORING
RED
BLUE
GREEN
YELLOW

CHLORINATION FOR DISINFECTION

9-12

OBJECTIVES

The student will do the following:

1. Explain how chlorine works.
2. Describe what it is used for and why.
3. Show effects on pond or wastewater.
4. Discuss the consequences of its use.

SUBJECTS:
Science (Chemistry, Biology, Environmental Science)

TIME:
1 class period

MATERIALS:
four 2-L bottles
pond water
bleach (NaOCl)
microscopes
slides
stain (crystal violet)
eye droppers
stirring rods

BACKGROUND INFORMATION

Chlorine belongs to the class of elements termed the halogens. Each halogen has one less electron than the noble gas that follows it in the periodic table. Since there is only one electron missing from the *3p* shell, chlorine's outermost electron shell, there is a very large tendency for chlorine to form a single covalent bond or a (Cl^-) ion. Under ordinary conditions, chlorine exists as a diatomic molecule that is written as Cl_2. Of the groups in the periodic table, the halogen group is the most reactive nonmetal.

Chlorine is used in, both drinking water and wastewater treatment, as a disinfectant. Its germicidal action is due to the hypochlorous acid (HOCl) that forms when chlorine is added to water. Exactly how this acid exerts its killing power is not yet fully known. It possibly releases a reactive form of oxygen that combines with the protoplasm of the microbial cell and, therefore, destroys it. The hypochlorite ion OCl^- also has some killing potential. The following equations describe the chemical action when chlorine is added to water.

Cl_2	+	H_2O	]	H^+	+	Cl^-	+	HOCl
Chlorine		Water		Hydrogen ion		Chloride ion		Hypochlorous acid

$$HOCl \rightleftharpoons H^+ + OCl^-$$

Hypochlorous acid — Hydrogen ion — Hypochlorite ion

A liquid form of compressed chlorine gas is widely used in wastewater treatment plants, drinking water treatment facilities, and swimming pools. Other compounds containing chlorine also are widely used for disinfection. Calcium hypochlorite, $Ca(OCl)_2$, is used for disinfection of dairies and barns, slaughter houses, and restaurants' eating utensils. Sodium hypochlorite, NaOCl, known commonly as bleach, is also used in dairies as well as food processors and hemodialysis systems. When the quality of drinking water is in question, household bleach can achieve a rough equivalent of municipal chlorination. For purification of water in emergency situations, add 2 drops of NaOCl (bleach) to a liter of water (4 drops if it is cloudy). Let the water sit for 30 minutes before drinking. THIS IS ONLY FOR EMERGENCY SITUATIONS.

Chloramine compounds consisting of chlorine and ammonia are also widely used disinfectants. They also are used as antiseptics and sanitizing agents. Chloramines are very stable compounds that release chlorine over long periods of time. They are used when a long residual time is necessary.

Terms

covalent bond: bond formed between two atoms when they share pairs of electrons

diatomic molecule: molecule made of two atoms

residual: the quantity left over at the end of a process; remainder

ADVANCE PREPARATION

Acquire some pond water or wastewater in four 2L bottles that have been thoroughly washed.

PROCEDURE

I. Setting the stage

A. Discuss Background Information with students. Ask students these questions.

1. When is chlorine added to drinking water during the treatment process?

2. What are some household products that might contain chlorine? What is the purpose of having chlorine in these products?

B. Write the chemical equation for the breakdown of chlorine in water on the board and have students copy it.

C. Define terms on board and have students record.

II. Activity

A. Use the first gallon bottle of collected water as a control.

B. To the second bottle add 1 drop of NaOCl (bleach).

C. To the third bottle add 2 drops of NaOCl.

D. To the fourth bottle add 4 drops. Let them sit for 30 minutes.

E. Make up some microscope slides with water from each bottle and observe.

F. Record observations on Data Sheet. (Optional: prepare some slides for bacterial observation by using a stain such as crystal violet.)

III. Follow-up

A. Based on student observations, what was the most effective concentration of chlorine for "killing" organisms in water?

B. Why is it important to keep a residual concentration of chlorine in drinking water?

C. What effect do students think the chlorine in drinking water has on them? Do the benefits outweigh the problems?

IV. Extensions

A. Have students research diseases caused by microorganisms found in water. What effect has chlorinating water had on the reduction of these diseases?

B. Discover what other types of treatment can be used to disinfect water. Why are these not used as often as chlorine?

C. Have students research human health concerns related to chlorine (the chemical itself and its disinfection by-products). How do the relatively low chlorine levels used in drinking water disinfection (below 2 mg/l) relate to the students' findings?

D. Have students research human health concerns related to alternative drinking water disinfectants such as chloramines, chlorine dioxide, and ozone. Also note the disinfection by-products associated with each of these alternative disinfectants. Compare this information to the concerns related to chlorine in item C. above.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Cunningham, William P. and Barbara Woodworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, IA, 1997.

Enger, Eldon D. and Bradley F. Smith, Environmental Science: A Study of Interrelationships, 5th Edition, Wm. C. Brown Publishers, Dubuque, IA, 1983.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

Data Sheet

1. Observation of bottle 1. Describe and/or draw all types of organisms found under microscope.

2. Observation of bottle 2. Describe and/or draw all types of organisms found under microscope.

3. Observation of bottle 3. Describe and/or draw all types of organisms found under microscope.

4. Observation of bottle 4. Describe and/or draw all types of organisms found under microscope.

DRINKING WATER JEOPARDY

9-12

OBJECTIVES

The student will do the following:

1. List the characteristics of contaminated water.
2. List the characteristics of clean (non-contaminated) water.
3. Discuss what makes water contaminated.
4. List ways to prevent water contamination.

SUBJECTS:
Science (Biology, Chemistry)

TIME:
2 class periods

MATERIALS:
sets of questions
rules
index cards

BACKGROUND INFORMATION

Most Americans believe that their drinking water is the best in the world. Many U.S. citizens who travel abroad know the familiar problems of unsafe drinking water. At home, most of us seldom give it a thought. We believe that the purity of our water can be depended upon, and usually we are right.

Yet, every year, some Americans get sick from their drinking water. The Centers for Disease Control and Prevention reports that there were almost 7,400 yearly cases (on average) of illness in the U. S. linked to drinking water from 1971 to 1985. And a devastating 1993 waterborne cryptosporidiosis outbreak in Milwaukee, WI, sickened 400,000 and caused over 100 deaths.

Terms

acute (toxic) effects: adverse health effects which are observed rather quickly after exposure to a toxin; illness with rapid onset caused by a toxin.

agriculture: science of cultivating the soil, producing crops, and raising livestock; farming

blackwater: domestic wastewater containing human or animal waste or other sources of pathogens

"blue baby" syndrome (methemoglobulinemia): pathological condition where the skin of infants (or other sensitive groups) turns blue due to nitrates bonding with red blood cells, which prevent the transport of oxygen throughout the body; can be caused by nitrate contamination in drinking water

chemical water pollution: introduction of chemicals into a waterbody

chlorine: a chemical compound used as disinfectant in wastewater treatment and drinking water treatment processes; symbol $C1_2$

chronic (toxic) effects: adverse health effects that are either the result of long-term (chronic) exposure or those that are permanent or long-lasting (e.g., cancer)

Clean Water Act (CWA): water pollution control law passed to restore and maintain the nation's waters; the nation's primary source of federal legislation that specifies the methods to be used in determining how much treatment is required for discharges (effluents) from publicly owned treatment works (POTWs)

cryptosporidiosis: acute, highly infectious disease caused by the protozoan *Cryptosporidium parvum* that can be transmitted by contaminated food or water

disinfection: the use of chemicals and/or other means to kill potentially harmful microorganisms in water (the fifth step in drinking water treatment)

Environmental Protection Agency (EPA): the U.S. agency responsible for efforts to control air, land, and water pollution, radiation, and pesticide hazards, and to promote ecological research, pollution prevention, and proper solid waste disposal

epidemic diseases: diseases that spread rapidly by infection among many individuals in an area

fecal coliform bacteria: a type of coliform bacteria found in the intestines of humans and warm-blooded animals that aids in the digestion process and is used as an indicator of fecal contamination and/or possible presence of pathogens

feed lots: confined areas where livestock is kept

fertilizer: natural and synthetic materials including manure, nitrogen, phosphorus and treated sewage sludge that are worked into the soil to provide nutrients and increase its fertility

fluoride: a binary compound of fluorine added to drinking water to help prevent tooth decay

groundwater: water that infiltrates into the Earth and is stored in usable amounts in the soil and rock below the Earth's surface; water within the zone of saturation

leachate: a liquid that results from water collecting contaminants as it trickles through wastes, or soil containing agricultural pesticides or fertilizers

leaking underground storage tank: underground storage tank which has spilled, leaked, emitted, discharged, leached, disposed, or otherwise allowed an escape of its contents into groundwater, surface water, or subsurface soils

microbiology: study of microorganisms, a large and diverse group of organisms that exists as single cells or cell clusters

microorganisms: microscopic or ultramicroscopic organisms (e.g., bacteria, protozoa, viruses)

nitrates: compounds containing nitrogen as nitrates (NO_3-). In the environment, these compounds are found in animal wastes, fertilizers, and in septic tanks and untreated municipal sewage. Their primary public health hazard is the cause of methemoglobulinemia or "blue baby" syndrome.

pathogens: disease-causing agents, especially disease-producing microorganisms

percolate: to drain or seep through a porous and permeable substance; to filter such as a liquid passing through a porous body (water through soil to the aquifer)

pH: a measure of the concentration of hydrogen ions (H^+) in a solution; the pH scale ranges from 0 to 14, where 7 is neutral, values less than 7 are acidic, and values greater than 7 are basic or alkaline. It is measured by an inverted logarithmic scale so that every unit decrease in pH means a 10-fold increase in hydrogen ion concentration. Thus, a pH of 3 is 10 times as acidic as a pH of 4 and 100 times as acidic as a pH of 5.

pollution: an unwanted change in air, water, or soil (usually through the introduction of pollutants or contaminants) that can affect the health and survival of humans and other organisms

privy: an outhouse; a latrine

radionuclides: types of atoms which spontaneously undergo radioactive decay; usually naturally occurring, and can contaminate water or indoor air (e.g., radon)

radon: colorless, odorless, tasteless, naturally occurring radioactive gas formed from natural deposits of uranium that can cause lung cancer. It can enter the home around plumbing pipes and/or through cracks and openings in the foundation.

sewage contamination: the introduction of untreated or improperly treated sewage into a water body

sulfuric acid: (chemical formula, H_2SO_4) the most widely used industrial chemical; a major component of acid rain that is formed by sulfur oxides combining with atmospheric moisture

surface water: precipitation that does not soak into the ground or return to the atmosphere by evaporation or transpiration. It is stored in streams, lakes, rivers, ponds, wetlands, oceans, and reservoirs.

toxic chemical: a chemical with the potential of causing death or damage to humans, animals, plants, or protists; poison

typhoid fever: acute, highly infectious disease caused by *Salmonella typhosa* bacteria that can be transmitted by contaminated food or water

underground storage tank (UST): any tank, including underground piping connected to the tank, that has at least 10% of its volume underground and contains petroleum products or hazardous substances (except heating oil tanks and some motor fuel tanks used for farming or residential purposes)

waterborne diseases: diseases spread by contaminated water

water quality: the condition of water with respect to its content of contaminants, natural or anthropogenic

ADVANCE PREPARATION

A. Put the questions and answers on the index cards and put the categories on the board. (See Teacher Sheets.)

Ex.

> Level: 3
> Q: What is the chemical formula for water?
> A: H_2O

B. Give students a list of the terms and definitions to study the day before the game.

PROCEDURE

I. Setting the stage

A. Duties

1. Moderator: reads the questions

2. Scorekeeper: records each team's scores on the board

3. Timekeeper: allows only the specified amount of time for each question

4. Judge: makes the final decision about answers and rules (teacher)

B. Divide the class into 2 groups (teams). Decide which team will go first. Select a captain for each team.

C. Rules

1. Ahead of time, place the categories on the board.

Ex.		
	Level 4*	40, 40, 40, 40, 40, 40, 40, 40, 40, 40
	Level 3*	30, 30, 30, 30, 30, 30, 30, 30, 30, 30
	Level 2*	20, 20, 20, 20, 20, 20, 20, 20, 20, 20
	Level 1*	10, 10, 10, 10, 10, 10, 10, 10, 10, 10

2. Each time a team chooses a <u>level</u>, the scorekeeper needs to eliminate that item (ex. Level 2-- , 20, 20) by marking over or erasing it. If a team correctly answers the question on any chosen level, those points are awarded to that team.

Allow 5 seconds for each question to be answered. If the question is correctly answered [the answer must come from the person who raised his/her hand first], the moderator will read a bonus question. The team will have 15 seconds to discuss the bonus question. The bonus answer must be given by the captain. Bonus questions are worth the same amount as the original question.

3. If one team misses the answer, the opposite team may have a choice to answer the question. If a team member answers incorrectly, the amount of points are subtracted from the team's total points. If both teams answer incorrectly, the moderator answers the question. At the end of a certain amount of time (20 minutes) or the end of the questions, the team with the most points wins the game.

II. Activity - Play the game.

RESOURCES

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

National Drinking Water Clearinghouse, West Virginia University, Morgantown, WV, 26506-6064, 800-624-8301.

Safe Drinking Water Hotline: 800-426-4791.

Questions & Answers

Level 1 Questions and Answers

1. Immediate illnesses which can come from a virus or poison. ***acute illnesses***

2. Define waterborne diseases. ***diseases spread by contaminated water***

3. Long-term illnesses that are developed over many years. ***chronic illnesses***

4. Sources of water supply are being endangered by chemicals. ***True***/False

5. Contaminated water may increase cancer and heart disease rates. ***True***/False

6. What does CDC stand for? ***Centers for Disease Control and Prevention***

7. Who is responsible for making laws to ensure that our drinking water is safe? ***U.S. Congress***

8. What can cause typhoid fever? ***drinking contaminated water***

9. The Safe Drinking Water Act of 1986 banned all future use of what kind of pipes in public drinking water systems? ***lead***

10. What does EPA stand for? ***Environmental Protection Agency***

11. Why should water system owner/operators disinfect the drinking water supplies? ***to help kill harmful microorganisms***

12. If a public water system is contaminated and its water causes acute illnesses, the owner/operator of the water system must notify the water users within 72 hours by way of radio and television. ***True***/False

Level 2 Questions and Answers

1. What is the name of the bacteria that comes from human and animal waste that can contaminate drinking water? ***Coliform bacteria***

2. Boiling water will eliminate nitrate contamination. True/***False***

3. What is the chemical formula for water? H_2O

4. Clear water is always clean and safe to use. True/**False**

5. What is the suggested pH level range of drinking water? ***6.5 to 8.5***

6. Too much fluoride causes a brownish discoloration of teeth. ***True***/False

7. Where is the main office of the Centers for Disease Control and Prevention located? ***Atlanta, GA***

8. What are microorganisms? ***microscopic or ultramicroscopic organisms too small to be seen with the unaided eye***

9. Pesticides can contaminate drinking water sources. ***True***/False

10. Owners/operators of water plants must check water samples regularly for contaminants. ***True***/False

11. Is drinking water from private household wells subject to regulation by federal drinking water standards? ***No***

Level 3 Questions and Answers

1. Nitrates present in large amounts can reduce the amounts of oxygen in an infant's blood. What is the chemical symbol for nitrates? NO_3^-

2. What can the ingestion of radon in water cause? ***cancer***

3. Excessive levels of copper in drinking water cause a metallic taste. ***True***/False

4. What are pathogens? ***disease - causing agents, especially microorganisms***

5. What type of microorganism is a virus? ***a parasite***

6. What is surface water? ***precipitation that does not soak into the ground. It is stored in streams, lakes, rivers, ponds, wetlands, oceans, and reservoirs.***

7. What is groundwater? ***water that is stored below the Earth's surface***

8. Is radon more of a problem in groundwater or surface water? Explain. ***groundwater - because radon in surface water usually escapes to outside air***

9. Is there more exposure to radon in the bedroom or the bathroom of your house? Explain. ***could be bathroom if water use is from a well and the radon in water levels are high***

10. How does radon from the soil enter into a home? ***through cracks and openings in the foundations, floors, or walls that are in contact with the soil or through plumbing***

11. Define microbiology. ***the study of microorganisms, a large and diverse group of organisms that exist as single cells or cell clusters.***

Level 4 Questions and Answers

1. Define water quality. ***the condition of water with respect to the amount of pollutants in it***

2. Define underground storage tanks. ***tanks such as gasoline tanks that are buried underground***

3. Define toxic chemicals. ***chemicals with the potential of causing death or damage to humans, animals, plants, or protists***

4. Define sulfuric acid. ***a product that forms when sulfur oxides combine with atmospheric moisture; a component of acid rain***

5. Define septic tank. ***a tank, commonly buried, to which all of the wastewaters from the home should flow; the main part of a septic system where scum and sludge accumulate***

6. Define percolate. ***to drain or seep through a porous and permeable substance***

7. Define sewage contamination. ***the introduction of untreated or improperly treated sewage into a waterbody***

8. Define agriculture. ***the science of cultivating the soil, producing crops, and raising livestock***

9. Define epidemic disease. ***disease that spreads rapidly by infection among many individuals in an area***

10. Define Clean Water Act. ***a water pollution control law intended to restore and maintain the nation's waters***

11. Show the chemical formula for sulfuric acid. H_2SO_4

Bonus

1. Name 3 reasons why the body needs water.

    Examples:
    To dilute harmful substances (all may not be poisonous)
    To have healthier skin
    To regulate body temperature
    To deliver oxygen and other nutrients to organs

2. Water has a nutritional value. True/***False***

3. What is the function of CDC? ***to study and monitor disease control and health issues and to facilitate disease prevention***

4. Why was the Safe Drinking Water Act established? ***to ensure safe public water supplies primarily through the establishment of drinking water standards and source water protection***

5. Name 3 types of waterborne diseases. ***Examples: typhoid fever, cholera, infectious hepatitis, dysentery, cryptosporidiosis***

6. What is the "blue baby" syndrome? ***pathological condition where blood is incapable of carrying oxygen resulting in the skin turning blue in infants; can be caused by nitrate contamination of drinking water***

7. Why is fluoride added to drinking water? ***to help prevent tooth decay***

8. Why is chlorine added to drinking water? ***to help kill microorganisms***

9. What are pesticides? ***chemicals that kill plant or animal pests*** (usually insects)

10. Name 2 ways that farming practices could cause drinking water contamination. ***Examples: excess fertilizers, oil and gas leakage from storage tanks, livestock waste, improper or excessive use of pesticides***

11. What is the source of radon? ***naturally occurring uranium found in soil and rock***

12. Name 3 groups of microorganisms. ***Examples: bacteria, protozoa, viruses, some algae***

13. Hepatitis is caused by the smallest and simplest common form of microorganism that is known as a ________________. ***Virus***

14. How do you recognize radon as a problem in your home? ***Test***

15. Name 2 sources of surface water. ***Examples: streams, rivers, lakes, ponds, wetlands oceans, and reservoirs***

16. Name 2 sources of groundwater. ***Examples: wells and springs***

17. What is hydrology? ***the study of water, its properties, distribution, and circulation on Earth***

18. Name 3 activities or land uses that can threaten and contaminate water supplies. ***Examples: septic tanks, landfills, agricultural activities, lawn and crop fertilizer, transporting chemicals or waste by road, wastewater discharges, abandoned wells***

19. Why is radon from well water more of a problem and more present in the bathroom, kitchen, and laundry rooms? ***It escapes to the air (comes out of solution) when faucets, toilets, showers, washing machines, etc. are used.***

20. Define chemical pollution of water. ***introduction of harmful chemicals into a waterbody***

21. How could a leaking underground storage tank cause groundwater contamination? ***The contents in the tank or the associated piping could leak into the soil and groundwater.***

22. What is blackwater? ***domestic wastewater containing human or animal waste or other sources of pathogens***

23. How does the privy (outdoor toilet) contribute to groundwater contamination? ***The bacteria in human waste percolate through the soil to the groundwater.***

24. Describe the purpose of the Resource Conservation & Recovery Act with respect to water protection. ***a law intended to protect waterways and groundwater from hazardous waste contamination***

25. Explain why Congress decided to pass the Clean Water Act. ***to protect the nation's waters***

26. What agency is responsible for enforcing federal water-related regulations? ***EPA***

27. What should you do if you suspect contamination in a public water supply? ***Don't use it and notify your water supplier immediately.***

28. Boiling water kills all microorganisms. True/**False**

29. How can oil spills contribute to groundwater contamination? ***The chemicals could seep into the ground and release contaminants into the water.***

30. What is the chemical symbol for chlorine gas? ***Cl_2***

SOURCE WATER PROTECTION: Surface Water Sources

9-12

OBJECTIVES

The student will do the following:

1. Identify sources of contamination to water.

2. Describe management methods to protect water supply sources.

3. Develop a plan to improve watershed management.

SUBJECTS:
Science (Ecology, Physical Science), Social Studies (Economics, Government)

TIME:
2 class periods
field trips

MATERIALS:
student sheets
bus for field trip
writing materials

BACKGROUND INFORMATION

Many towns and cities obtain their drinking water from a nearby river, lake or reservoir. The quality of this source water is influenced by the quality of streams flowing into it, the land uses and activities conducted near it, and any air deposition that might occur.

EPA's Source Water Protection (SWP) Program was established to help states and communities protect their drinking water supply sources. Surface source water protection is a 3-step process involving: delineating areas contributing water to a surface water intake, identifying potential contaminant sources that may threaten the water supply, and protecting the supply using a combination of watershed management strategies for specific communities or watersheds. (Since water does not flow only within politically-established boundaries, some strategies may extend beyond these boundaries and address the entire watershed.)

Watershed management strategies incorporate broad concepts such as land use control and/or management, best management practices, and pollution prevention. They emphasize prevention of both point source and nonpoint source contamination. Specific watershed management strategies may include the following or others: protection of inland wetlands that serve as filters for pollutants, appropriate forestry management practices, erosion controls, control of adjacent zoning and urbanization, creation of buffer zones along reservoir edges, reservoir access and activity control, and community education. Homeowners, businesses, farmers, and industries may also be encouraged to use pollution prevention and best management practices to prevent surface water contamination.

Terms

best management practices (BMPs): techniques that are determined to be currently effective, practical means of preventing or reducing pollutants from point or nonpoint sources, in order to protect water quality. BMPs include, but are not limited to structural and nonstructural controls, operation and maintenance procedures, and other practices. Usually, BMPs are applied as a system of practices rather than as a single practice.

buffer zone: an area between the water supply source and the possible contamination sources where no contamination activities are likely to occur

pollution prevention: preventing the creation of pollutants or reducing the amount created at the source of generation, as well as protecting natural resources through conservation or increased efficiency in the use of energy, water, or other materials

Source Water Protection: process that involves delineating areas contributing water to a water well or surface water intake; identifying potential contaminant sources that threaten the water supply; and using management strategies to protect the source water from contamination. Source water protection is applied to both surface water and groundwater supply sources.

watershed: land area from which water drains to a particular surface waterbody

zoning: to divide into areas determined by specific restrictions; any section or district in a city restricted by law for a particular use

ADVANCE PREPARATION

1. Copy Student Sheets.

2. Arrange for field trips.

PROCEDURE

I. Setting the stage

   A. Discuss Background Information with students.

   B. Contact the local drinking water treatment plant and find out the water source in the community.

II. Activity

   A. Schedule a visit to the water supply reservoir with a water system representative and ask about source water protection methods that are used, including upstream management methods in the watershed. If a field trip is not possible, have a water system representative visit the class.

   B. From local, state, or other sources, define the water supply watershed on a topographic or other map and locate potential pollutant sources. (Use Student Sheet to determine potential pollution problems.)

   C. Visit each pollutant source, or a location downstream of each one, to determine the type and extent of pollutants to the reservoir. (Students could be assigned this as an out-of-class assignment and report to the class.)

D. Note any pollution prevention or best management practices in place or, where none exist, make notes of recommendations (not just what is needed but how to do what is needed).

E. Make a compilation of all notes from the class into a report on protection of the water supply watershed. Include recommendations as to the location and type of pollution prevention or best management practices used or needed, and other water quality management steps which should be taken.

III. Follow-up

Share compiled information or reports with local watershed managers and ask them to comment on the class ideas.

IV. Extensions

Have students construct a solar evaporator using the materials you have provided or some they may want to bring to class. They can follow the directions on the Student Sheet or try their own design. Students should wash hands and dip a finger in salt solution and taste. Place solar evaporators in a warm, sunny place for 24 hours. Taste water in beaker (glass) using finger method after washing, and answer questions on Activity Student Sheet. Finally discuss the findings.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Cunningham, William P. and Barbara Woodworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, IA, 1997.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

Roberts, Susan A. and S. K. Krishnaswaini, "Protecting the Source," Water Engineering and Management, Scranton Gillette Communication Inc., March 1982, p. 28.

Activities Harmful to Water Supply Reservoir

1. Unauthorized disposal of sludge, solid, septic and hazardous waste, dredge spoil
2. Erosion/sedimentation
3. Uncontrolled/illegal access
4. Atmospheric transfer of contaminants
5. Unauthorized/illegal impounding of upstream watercourses
6. Unauthorized use of pesticides
7. Accidental loss of hazardous materials from surface storage or transport
8. Discharges of animal wastes/agricultural runoff
9. Urban drainage
10. Point source discharges

Constructing a Solar Evaporator or Solar Still

1. Follow the illustration to set up your lab materials. The water level should be at least an inch below the top of the beaker.

2. Be sure that your plastic completely covers the top bucket. The plastic should sag enough when the weight is placed on it so that a cone shape is formed that points down to the open beaker. Make sure that the plastic does not touch the mouth of the beaker.

3. Place your apparatus in the heat of the sun and leave it there for a few hours.

4. During class the next day, remove the plastic covering and taste the water in the beaker.

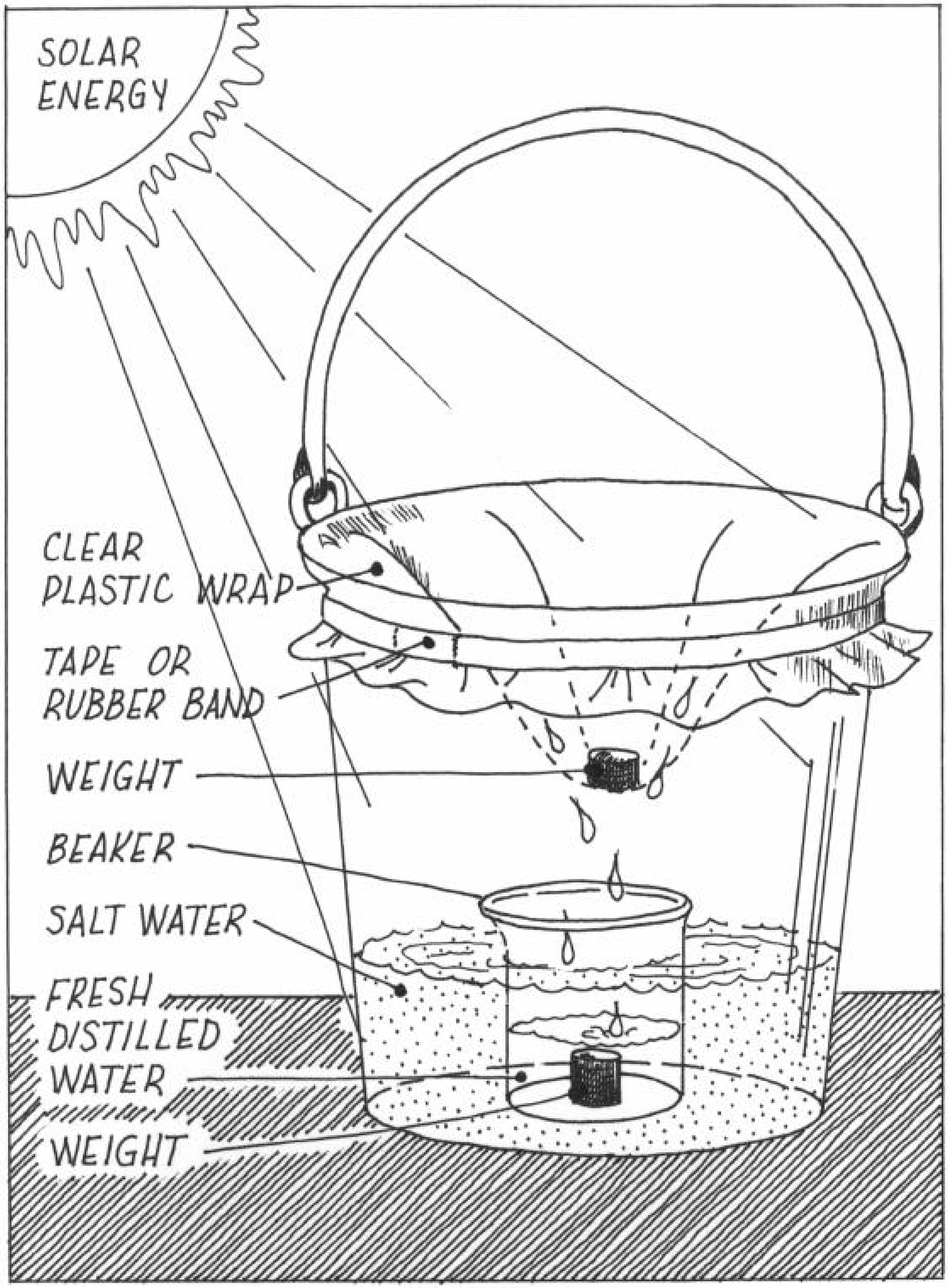
Results

1. How does it taste? _______________ Is it fresh or salty? ___________

2. What was the energy source that caused the water to change states? __________________
____
____
__

3. What are the three states of water? ____
____

2-41


SOLAR ENERGY
CLEAR PLASTIC WRAP
TAPE OR RUBBER BAND
WEIGHT
BEAKER
SALT WATER
FRESH DISTILLED WATER
WEIGHT

Potential sources of surface water/groundwater contamination (based upon lists compiled by U.S. EPA and ADEM)

1. Gas stations/service stations
2. Truck terminals
3. Fuel oil distributors/storage
4. Oil pipelines
5. Auto repair shops
6. Body shops
7. Rustproofers
8. Auto chemical suppliers/wholesalers/retailers
9. Pesticide/herbicide/insecticide wholesalers/retailers
10. Small engine repair shops
11. Dry cleaners
12. Furniture strippers
13. Painters/finishers
14. Photographic processors
15. Printers
16. Automobile washers
17. Laundromats
18. Beauty salons
19. Medical/dental/veterinarian offices
20. Research laboratories
21. Food processors
22. Meat packers/slaughter houses
23. Concrete/asphalt/tar/coal companies
24. Treatment plant lagoons
25. On-site sewage
26. Railroad yards
27. Storm water impoundment
28. Cemeteries
29. Airport maintenance shops
30. Airport fueling areas
31. Airport firefighter training areas
32. Industrial manufacturers
33. Machine shops
34. Metal platers
35. Heat treaters/smelters/descalers
36. Wood preservers
37. Chemical reclamation sites

38. Boat builders/refinishers
39. Industrial waste disposal sites
40. Wastewater impoundment areas
41. Municipal wastewater treatment plants and land application areas
42. Landfills/dumps/transfer stations
43. Junk/salvage yards
44. Subdivisions
45. Individual residences
46. Heating oil storage (consumptive use) sites
47. Golf courses/parks/nurseries
48. Sand and gravel mining/other mining
49. Abandoned wells
50. Manure piles/other animal waste
51. Feed lots
52. Agricultural chemical spreading/spraying
53. Agricultural chemical storage sites
54. Construction sites
55. Transportation corridors
56. Fertilized fields/agricultural areas
57. Petroleum tank farms
58. Existing wells
59. Nonagricultural applicator sites
60. Sinkholes
61. Recharge areas of shallow and highly permeable aquifers
62. Injection wells
63. Drainage wells
64. Waste piles
65. Materials stockpiles
66. Animal burial
67. Open burning sites
68. Radioactive disposal sites
69. Saltwater intrusion
70. Mines and mine tailings
71. Other

SOURCE WATER PROTECTION: Groundwater Sources

9-12

OBJECTIVES

The student will do the following:

1. Define a Wellhead Protection Program.
2. List 25 common groundwater pollutants.
3. List 25 potential sources of groundwater pollution.
4. Identify problems involved in starting a Wellhead Protection Program in a developed area.

SUBJECTS:
Social Studies (Economics, Government), Science (Physical, Ecology, Earth, Chemistry), Ethics

TIME:
1-2 class periods

MATERIALS:
copies of student sheets

BACKGROUND INFORMATION

It is important to be aware of the source of your drinking water. If the water is pumped from a well, the source is groundwater from an aquifer. Just like rivers and lakes, aquifers need to be protected from contamination. Chemicals spilled on or applied to the ground can move down and eventually contaminate an aquifer, sometimes making groundwater unsafe to drink. It is especially important to protect areas immediately around wells from releases of harmful chemicals, because it is from within these sensitive areas that chemicals can most quickly and profoundly affect the quality of water pumped from a well.

EPA's Source Water Protection (SWP) Program was established to help states and communities protect their drinking water supply sources. Wellhead Protection Programs may serve as Source Water Protection Programs for communities relying on groundwater as their source of drinking water. Wellhead protection is a 5-step process involving: (1) forming a community planning team; (2) delineating the area contributing groundwater to a water supply well; (3) identifying potential contaminant sources within the delineated area that pose threats to the well; (4) using a combination of management strategies to ensure that identified sources don't impact the well; and (5) developing a contingency plans in case there is a release of contaminants within the delineated area.

Wellhead protection management strategies incorporate broad concepts such as land use control and/or management, best management practices, and pollution prevention. Specific strategies may include the following: zoning controls, local ordinances governing pesticide/herbicide use, enforcement of septic tank regulations, and community education. Homeowners, businesses, farmers, and industries may also be encouraged to use pollution prevention and best management practices to prevent contamination in the delineated areas. For example, waste oil collection centers may be set up in convenient locations so that oil can be brought in for proper disposal or recycling (rather than citizens dumping it illegally onto the ground).

The illustration in Figure 4 shows a wellhead protection area with the zone of influence (Zone I), a 10-year time-of-travel (Zone II), and the rest of the recharge area for the well (Zone III). Potential pollutants and potential pollutant sources are listed in Student Sheets, Figures 2 and 3 respectively. Various activities in the recharge area are illustrated in Figure 4.

<u>Terms</u>

Source Water Protection: process that involves delineating areas contributing water to a water well or surface water intake; identifying potential contaminant sources that may threaten the water supply; and using management strategies to protect the source water from contamination. Source water protection is applied to both surface water and groundwater supply sources.

time-of-travel: the time required for groundwater to move from a specific point beneath the surface to a well

Wellhead Protection Area: the surface and subsurface area surrounding a public water supply well through which contaminants are reasonably likely to move toward and reach such well

Wellhead Protection Program (WHPP): a groundwater-based source water protection program

zone of influence: area surrounding a pumping well within which the potentiometric surface has been changed due to groundwater withdrawal

zoning: to divide into areas determined by specific restrictions; any section or district in a city restricted by law for a particular use

ADVANCE PREPARATION

A. Copy Student Sheets for each group or individual.

B. Make overhead transparency of Student Sheets.

PROCEDURE

I. Setting the stage

A. Discuss the concept of Wellhead Protection and go over terms.

B. Put up overhead transparencies of Figure 1 and Figure 4.

1. Discuss land use zones and time-of-travel.

2. Discuss groundwater pollutants and potential sources. (Students may wish to read over Student Sheets - Figures 2 & 3.)

C. Break into study/discussion groups to complete activities.

II. Activity

A. Assume you are a mayor considering a WHPP. List the considerations (pros and cons) of establishing such a program.

B. If you are a farmer or businessperson in the same town, what concerns would you have if this program were instituted?

C. As a citizen drinking the water produced by the well, what concerns would you have? What form would you prefer the WHPP take? Why?

D. You are an employee of the state environmental agency and would like to see a WHPP put into place by all small towns. What position would you take relative to this town after learning the above positions?

E. Is a WHPP a good groundwater protection approach? Why or why not?

III. Follow-up

A. Each group should have a spokesperson report its conclusions to the class. Allow some discussion and debate over the “best” policies.

B. Give quiz over groundwater pollutants and potential sources of pollution to groundwater.

C. Have students write a short essay about what they think they could do to protect groundwater in the area.

IV. Extensions

A. Students should find out if their state or city has a WHPP and what is or is not being done in its implementation.

B. Locate a city well and visit it. Have students identify pollutants and potential pollution sources in the wellhead protection area.

C. Learn about Environmental Ethics. Read “Jay’s Situation” and “Ethics”. Respond to the questions. Students should look for ethical, win-win compromise solutions.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Case Studies in Wellhead Protection, EPA Office of Water, EPA 440-6-90-004, April 1990.

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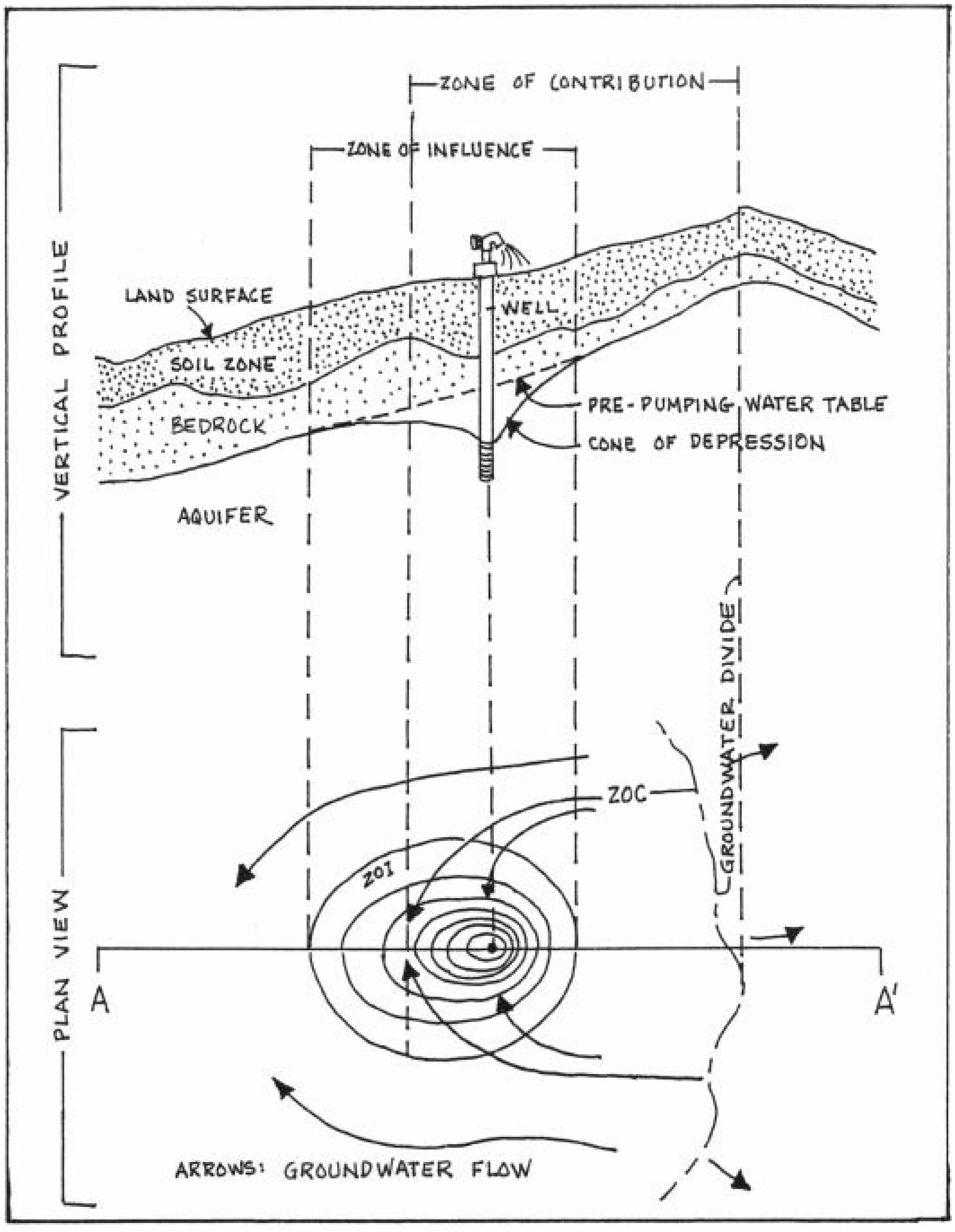
Enger, Eldon D. and Bradley F. Smith, Environmental Science: A Study of Interrelationships, 5th Edition, Wm. C. Brown Publishers, Dubuque, IA, 1983.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

DETERMINING A WELLHEAD AREA



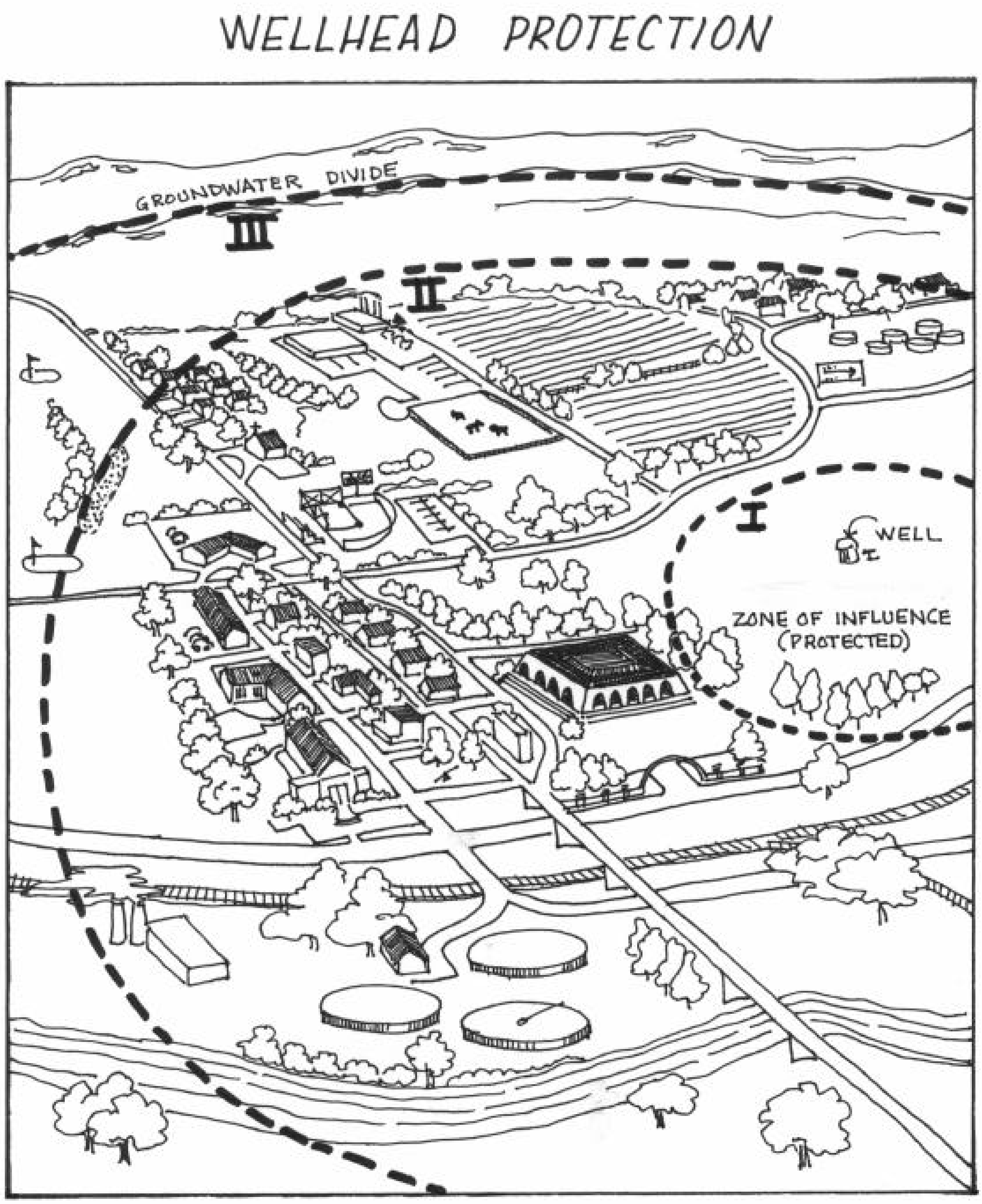
COMMON GROUNDWATER POLLUTANTS

FIGURE 2

1. Antifreeze (for gasoline coolant system)
2. Automatic transmission fluid
3. Engine and radiator flushes
4. Hydraulic fluid (including brake fluid)
5. Motor oils/waste fuels/grease lubricants
6. Gasoline, jet fuel
7. Diesel fuel, kerosene, #2 heating oil
8. Degreasers for driveways and garages
9. Battery acid (electrolyte)
10. Rust proofers
11. Car wash detergents, waxes, and polishes
12. Asphalt and roofing tar
13. Paints, lacquer thinners, and brush cleaners
14. Floor and furniture strippers
15. Metal polishes
16. Laundry soil and stain removers (including bleach)
17. Spot removers, cleaning solvents
18. Disinfectants
19. Household cleaners (oven, drain, toilet)
20. Cesspool cleaners
21. Road salt (Halite)
21. Refrigerants
22. Pesticides (insecticides, herbicides, rodenticides)
23. Photochemicals/ Printing ink
24. Wood preservative (creosote)
25. Swimming pool chlorine or bromine compounds
26. Lye or caustic soda
27. Jewelry cleaners
28. Leather dyes
29. Fertilizers (if stored outdoors)
30. PCBs
31. Other chlorinated hydrocarbons, including carbon tetrachloride)
32. Any other product with “Poison” labels (including chloroform, formaldehyde, hydrochloric acid, and other acids)
33. Other products not listed that you feel may be toxic or hazardous (please list):

POTENTIAL SOURCES OF GROUNDWATER POLLUTION
FIGURE 3

1. Truck terminals and service stations
2. Petroleum pipelines, stores, and tank farms
3. Auto repair, body shop, and auto supplies
4. Rust proofers
5. Pesticide, herbicide wholesalers and retailers
6. Dry cleaner
7. Painters, finishers, furniture strippers
8. Printers, photo processor
9. Auto washes, laundromat
10. Beauty salons
11. Medical, dental, and vet offices
12. Food processors, meat packers, and slaughter houses
13. Concrete, asphalt, tar, and coal companies
14. On-site sewage disposal
15. Railroad yards, industrial sites
16. Storm water impoundment
17. Cemeteries
18. Airport maintenance, fueling
19. Machine shops
20. Metal platers
21. Heat treaters, smelters, annealers, descalers
22. Wood preservers
23. Chemical reclamation
24. Industrial waste disposal
25. Municipal and private waste wastewater treatment plants, lagoons
26. Landfills, dumps, and transfer stations
27. Junk, salvage yards, recycle centers
28. Subdivisions, individual residences
29. Heating oil storage (consumptive use)
30. Golf courses, parks, nurseries
31. Sand, gravel, other mining
32. Abandoned wells, existing wells, sinkholes
33. Feed lots, manure piles
34. Agricultural chemical storage, handling, spreading, spraying
35. Construction sites
36. Transportation corridors
37. Fertilized fields, agricultural area


WELLHEAD PROTECTION
GROUNDWATER DIVIDE
III
II
I
WELL
ZONE OF INFLUENCE
(PROTECTED)

JAY'S SITUATION

Jay Barlow is sitting with his elbows on his desk. His face is pressed into his hands. He feels a small hand pull his hand away from his face. "Daddy?" Jay looks down into his daughter's sparkling brown eyes. He is still her hero, and that trusting smile just increases the pressure he already felt.

Last week Jay was on top of the world. He was hired onto an environmental project as a consultant. The state of Florida had finally passed a regulation that would require a zone of protection around wellheads. The state's minimum requirement is a 500-ft. radius around the well. The suburb he lives in has adopted more stringent measures. He was given a map showing several public wells from which drinking water is pumped. His task is to recommend a viable zone of protection and report any potential contamination hazards.

Interestingly, the very area in which he lives is included on the map. He is familiar with a large land development that has been in construction for two years. His neighbor has told him many details as he is the construction foreman. The massive construction effort has provided 200 jobs. Jay decides to meet with a company representative. They discuss the scope of the project. To his dismay, he discovers that the final two years of the company's project involve developing land directly over the aquifer within the state's minimum protection zone from the well.

The land developers purchased the land at high cost before the state laws were passed. The company has invested millions in pre-development and will not respond positively to any attempt to block the contract. They have plenty of resources to fight a legal battle against the state.

Jay's uncle calls him for advice on a leaking UST (underground storage tank). He thought to call Jay because Jay knows about environmental issues. His uncle cannot afford to have the tank dug up and replaced; it would bankrupt his small business. Jay has no idea what to tell his uncle except that the leaking gasoline is a serious threat to groundwater. Jay's uncle laments that he has owned the station for 30 years and would have no income without it. As if Jay didn't have enough to think about, he realizes that his uncle's gas station is also located above the aquifer.

1. What do you think is Jay’s primary responsibility as an environmental professional?

2. Does Jay have a responsibility to his uncle?

3. Are the construction workers Jay’s problem?

4. Should he be worrying about the drinking water in his own region?

5. Should the above concerns affect Jay’s recommendations to the state about the wellhead protection for that particular aquifer? If so, in what way?

ETHICS

As part of this lesson, the instructor may wish to include a brief discussion on ethics. The environmental industry is dependent on ethical decision making. For an intensive treatment of this issue, Michael Josephson's *Making Ethical Decisions* (1993) is perfect. In *Making Ethical Decisions,* Josephson describes "The Six Pillars of Character: (1) Trustworthiness, (2) Respect, (3) Responsibility, (4) Justice and Fairness, (5) Caring, (6) Civic Virtue and Citizenship."[1]

Most students of this age will be surprised to learn that acting with "Caring" (being sensitive to human suffering such as job loss and family distress) is an integral part of the decision-making process at the professional level. The teacher will most likely find that the majority of the class will choose extreme action in one direction or the other. The middle road seems a taboo place to choose; yet, in reality, it is often the only reasonable one. With the added responsibility of ethics, students will find achieving that "balance" between the economy and environment a less bitter pill to swallow.

It may be most effective for the ethics treatment to follow the exercise. Since the "balance" method gives them a standard to shoot for, students should then have the opportunity to reconsider their answers.

Here is a closure to share with students after they have completed the activity.

Reality will be frustrating for the generation who has grown up learning to accept environmental responsibility. The following recount is simplified, but factual, and is a real life example of the middle road. It should not be discouraging but enlightening. Sometimes when it is impossible to kill the dragon, be satisfied with knocking a chink out of its armor.... progress is progress is progress!

[1] Josephson, Michael, *"Making Ethical Decisions in Environmental Practice,"* Environmental Manager, Vol. 1, July 1993.

CONCLUSION

There are many different options that Jay might choose. He always has the option of consulting with other professionals if he has run into an ethical snag. Generally, they will be objective and a good source for ideas.

In dealing with land development, companies have to comply with many regulations today and often have a representative or department that handles that aspect. Jay may opt to call a meeting with this individual or group of individuals and call attention to the aquifer's vulnerability. Accomplished in a non-accusing diplomatic way, he may be able to convince the developers to choose double-walled, lined, or anodized septic tanks in order to head off future liability. While the threat to the aquifer is still apparent, it can be greatly reduced. The state may even be able to buy back a portion of the land. However, it is doubtful that the company would relent their construction. In fact, Jay may have to recommend a compromise or advise the department that they will probably be sued.

Jay's uncle may have some help in dealing with his gasoline leaks. If he is in compliance with other state and federal regulations for underground storage tanks, he may be eligible to receive assistance from Florida's leaking UST trust fund. Available in most states, these funds allow small business owners of USTs to receive assistance in cleaning up leaks. The money for these funds usually comes from a tax on gasoline. The sites chosen to receive cleanup funds are based upon how large the risk is to human health or the environment. Since Jay's uncle's tank is located in an area above a drinking water aquifer, there is a good chance that his cleanup will be funded.

In Florida, as previously discussed, there is a tremendous need for wellhead protection. In 1980, the Florida Department of Environmental Protection (FDEP) began fighting for wellhead protection. FDEP was promptly sued by large industrial corporations that had almost unlimited legal resources. The suit was in court for almost 15 years. FDEP was forced to accept a compromise, a middle-of-the-road decision, by the judge. They achieved the stipulation of a circular buffer zone 500 feet in diameter.

Of course, this circular zone has no basis either geologically or hydrologically. Most aquifers are oddly shaped and miles in length or width. FDEP officials wanted to model individual aquifers and tailor the needed buffer zones. What good does it do to have a 500-foot circle of protective zone and a five-mile long cigar-shaped aquifer? It seems nonsensical, but the FDEP rejoiced. They now have buffer zones. Before May 1994, they had none. Perhaps they should have agreed to a compromise years earlier and started gathering data for the next fight.

Even state environmental agencies understand that they cannot unduly restrict the state's or nation's economy. An unhealthy economy often creates an inadequate tax base, which can ultimately result in underfunded state agencies.

HOW ARE DETECTION LIMITS SET FOR WATER POLLUTANTS?

9-12

OBJECTIVES

The student will do the following:

1. Explain the methods used to calculate detection limits.
2. Calculate detection limits on a set of data.
3. Demonstrate how reporting data close to detection limits must be qualified with an accuracy statistic.
4. Explain what happens to accuracy and precision as detection limits are set to increasingly lower levels.

SUBJECTS:
Math, Science (Environmental Science, Physics)

TIME:
1 class period

MATERIALS:
stop watch
small toy racing car
inclined surface
meter stick with cm divisions
metric ruler with mm divisions
scientific calculator (per class)

BACKGROUND INFORMATION

Government agencies, such as EPA, set water quality criteria for pollutant discharges and issue permits to facilities that discharge treated wastewater into receiving waters. Monitoring agencies and facilities run tests on discharges and must be able to document the amount of specific pollutants that are present in the discharges. Very specific tests are used to analyze water for pollutants, and each test has a limit of detection. Everyone's ideal would be that all discharges would contain zero pollutants. Advancements in technology have made it possible to measure smaller and smaller amounts of pollutants. The desire of the public in recent years for increased environmental protection has encouraged the trend toward requiring monitoring laboratories to measure and report these smaller amounts and to push down the amounts permitted to be discharged. There are several trade-offs involved in establishing more stringent regulations and requiring monitoring agencies to measure and report down to very low levels. In exchange for the greater protection of the environment that is provided, there is greater cost incurred by industries and taxpayers for the technology. Another trade-off that must be considered is greater uncertainty in the measurement. Statistical measures and expressions of the variance or random error may be used to express that uncertainty. The lower the level of detection and reporting, the more important it becomes to use some expression that qualifies the reported value with an accuracy statistic.

Terms

accuracy: the closeness of a measurement to the true or accepted value

Method Detection Limit (MDL): the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero

precision: the agreement among the numerical values of a set of measurements of the same quantity made in the same way

standard deviation: a statistical value that is equal to the square root of the arithmetic average of the squares of the deviations from the mean in a frequency distribution

uncertainty: lack of certainty; doubt

variance or random error: degree of change or difference; divergence; discrepancy

ADVANCE PREPARATION

A. Choose two objects to measure. One should be close to the length of a meter stick, with a length that is unambiguously close to a cm mark. The other object should be less than 1 cm; students will be estimating it to 0.1mm. This number inevitably will be ambiguous for students and is meant to be so.

B. Experiment and choose an incline and carefully mark a starting distance from the bottom that will allow a toy car to move to the endpoint in less than one second. Students will have trouble measuring this, but problem in measuring is the point.

C. Divide students into ten groups of 2-3 students, number the groups, and give them a sequence of measurements: large object, small object, timed car. You will assist with the car.

PROCEDURE

I. Setting the stage

A. Explain to students that they will be making measurements in their groups and writing these down without discussing them with other groups. This is to preserve their unbiased scientific openness to the true value of the measurement. Measurements will be compared and used.

B. Explain to students that they will be using a statistical method published by the EPA to be used by environmental laboratories to set detection limits. Instruct them to estimate and roundoff measurements as follows: large object - nearest cm; small object - nearest 0.1 mm; car time - nearest 0.1 or 0.01 second if possible.

II. Activity

A. Take measurements of objects and time.

B. List on board ten group measurements.

C. Use a scientific calculator to analyze the three sets of data for mean and standard deviation.

D. Utilize the following procedure to calculate the detection limits of the meter stick, the metric ruler, and the stop watch.

1. Method Detection Limit = standard deviation x t
(where t value is a statistical value used in the student's t test for testing the validity of data, a standard statistical method)

2. The t value to be used here is 2.821 for ten replicates at the 99% confidence level.

III. Follow-up

A. Ask students to explain what happened to the certainty of their data when they attempted to measure smaller things.

B. Ask students to suggest ways the certainty of their data could be improved. (Technology)

C. Involve students in a discussion about the factors involved in applications of new technology. One thing that may apply is the idea that because the technology exists, we have to use it to detect lower levels and require all monitoring facilities to report these. Whom do they think are the greatest advocates of this? (Often they are the companies that develop the technology.) Ask them to think about some analogies where the safety provided by a regulation may not be worth the cost of it. An example may be something like a broken stair in their home, on which people can trip and bump their knees, but which might cost several hundred dollars to be fixed properly by a good carpenter. People make those kinds of decisions every day about various aspects of their lives.

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Cunningham, William P. and Barbara Woodworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, IA, 1997.

Enger, Eldon D. and Bradley F. Smith, Environmental Science: A Study of Interrelationships, 5th Edition, Wm. C. Brown Publishers, Dubuque, IA, 1983.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

9-12

METALS POLLUTION REDUCTION

OBJECTIVES

The student will do the following:

1. Explain how metallic pollutants are removed from wastewater.

2. Determine the optimum pH level for different types of metal removal. Explain how to read the graph.

3. Describe problems that metallic pollutants cause.

4. Devise a method of disposal for metal-containing "sludge."

SUBJECT:
Science (Environmental Science, Biology, Earth Science, Chemistry), Math

TIME:
1 class period

MATERIALS:
(per lab station)
beaker
glass rod
pH paper or meter
water test kit for metal detection
sodium hydroxide (diluted in water)
metal salts
copies of student sheets

BACKGROUND INFORMATION

Metals in wastewater are harmful in excessive quantities to wastewater treatment plants, to receiving waters, and to those creatures living in or affected by the receiving waters. Most metal pollutants (Pb, Cu, Zn, Cd, and Fe) are present in household sewage in small amounts. When combined with metals from industrial operations (Cr, Ni, Ag, as well as those mentioned above), these metals have enhanced combined (synergistic) effects and may: (1) be toxic to treatment plant microorganisms; (2) bioaccumulate in the microorganisms (which eventually become sludge or biosolids); (3) pass through the treatment plant to the receiving waters and exhibit toxicity to stream biota; (4) accumulate in and contaminate sediments; and (5) bioaccumulate in the food chain to fish, other wildlife, and people.

Metals can be removed from wastewater using hydroxide precipitation at an optimum pH level, depending on the metal or mix of metals present. Industries may use either hydroxide precipitation or other means to remove high concentrations of metals in their wastewaters.

Terms

bioaccumulate: to accumulate larger and larger amounts of a toxin within the tissues of organisms at each successive trophic level

biota: the plant and animal life of a region

flocculant: a substance added to a mixture that will cause precipitates (flocs) to form; also called "coagulant"

hydroxide precipitation: using the hydroxide ion (OH^-) to cause a material to come out of solution

optimum pH: the pH condition that will produce the best results for a given purpose

ADVANCE PREPARATION

A. Prepare a solution of "polluted wastewater" using known quantities of metal salts of Fe, Pb, Ni, Zn, Cu, and Cd mixed in water (distilled water if available).

B. Measure the metal pollutant concentration using a water analysis kit from a Volunteer Monitoring Program (or see page F-69, Water Testing Fact Sheet) to determine a before-treatment pollutant content. (Note - it may simplify the procedure to introduce only one "pollutant" initially.)

C. Copy the Student Sheet.

PROCEDURE

A simulation of metal(s) removal will be done using a common technique of industry.

I. Setting the stage

This exercise requires a beaker, glass rod, pH paper or meter, and use of a monitoring kit equipped to test for the metal pollutant(s) of interest. A treatment solution of sodium hydroxide (diluted in water) is also necessary.

II. Activity

A. Into a beaker containing the polluted water, add a solution of sodium hydroxide (NaOH), controlling to the optimum pH in the figure on the student sheet and stir with a glass rod until a cloudy appearance occurs. This cloudiness is called floc and is the formation of metal hydroxides, which will eventually settle as a precipitate.

B. The majority of the "pollutants" have been removed; in a real-world application, the treated wastewater would be decanted or removed, leaving this precipitate, or sludge, behind.

C. Using an eyedropper, remove enough clear water and test again using the monitoring test kit. How do these results compare with the original ones?

III. Follow-up

A. Removal of the metal from wastewater is only an initial step. What happens to the "sludge"? Determine how it must be further treated and disposed of.

B. What must industry do to place these treatment steps (from A) into effect?

C. How do you determine (from the figure) the optimum pH to use if there is only Cd present and you want to remove to 1.0 mg/l? What if Cd, Ni, Cu, and Zn are present? Which metal is easiest to remove to 1.0 mg/l at a neutral pH? What must be done to pH before discharge if the optimum treatment pH is 10 to 11? How might this be done?

IV. Extensions

A. Contact a local wastewater treatment plant, consulting engineer, engineering professor, or state environmental agency and ask about experiences in metals treatment.

B. Why is there some amount of metal(s) left after treatment? What is the chemical basis for this?

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

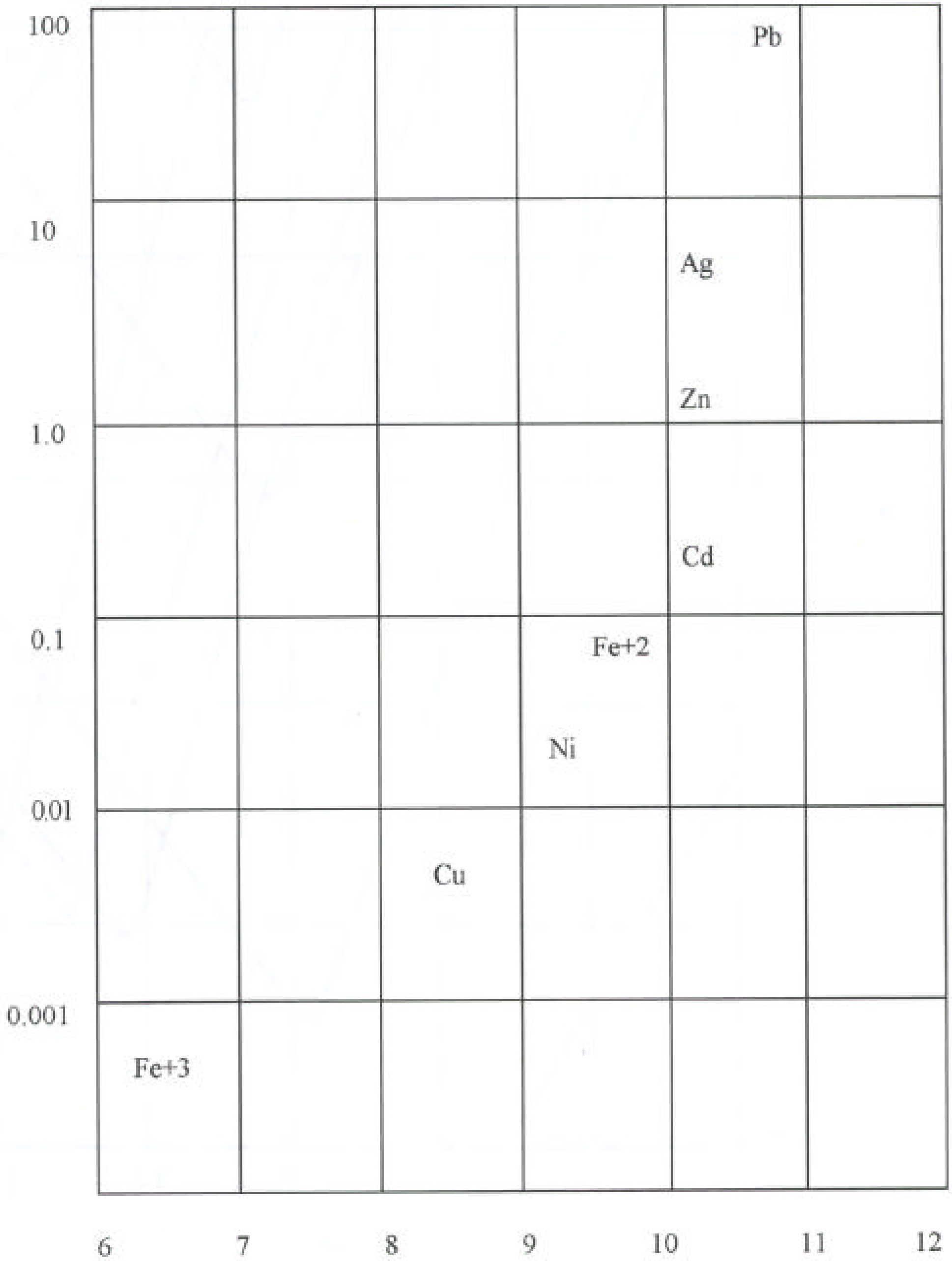
Cunningham, William P. and Barbara Woodworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, IA, 1997.

"Development Document for Effluent Limitation Guidelines and Standards for the Metal Finishing Industry ,"U.S. EPA, May 1980.

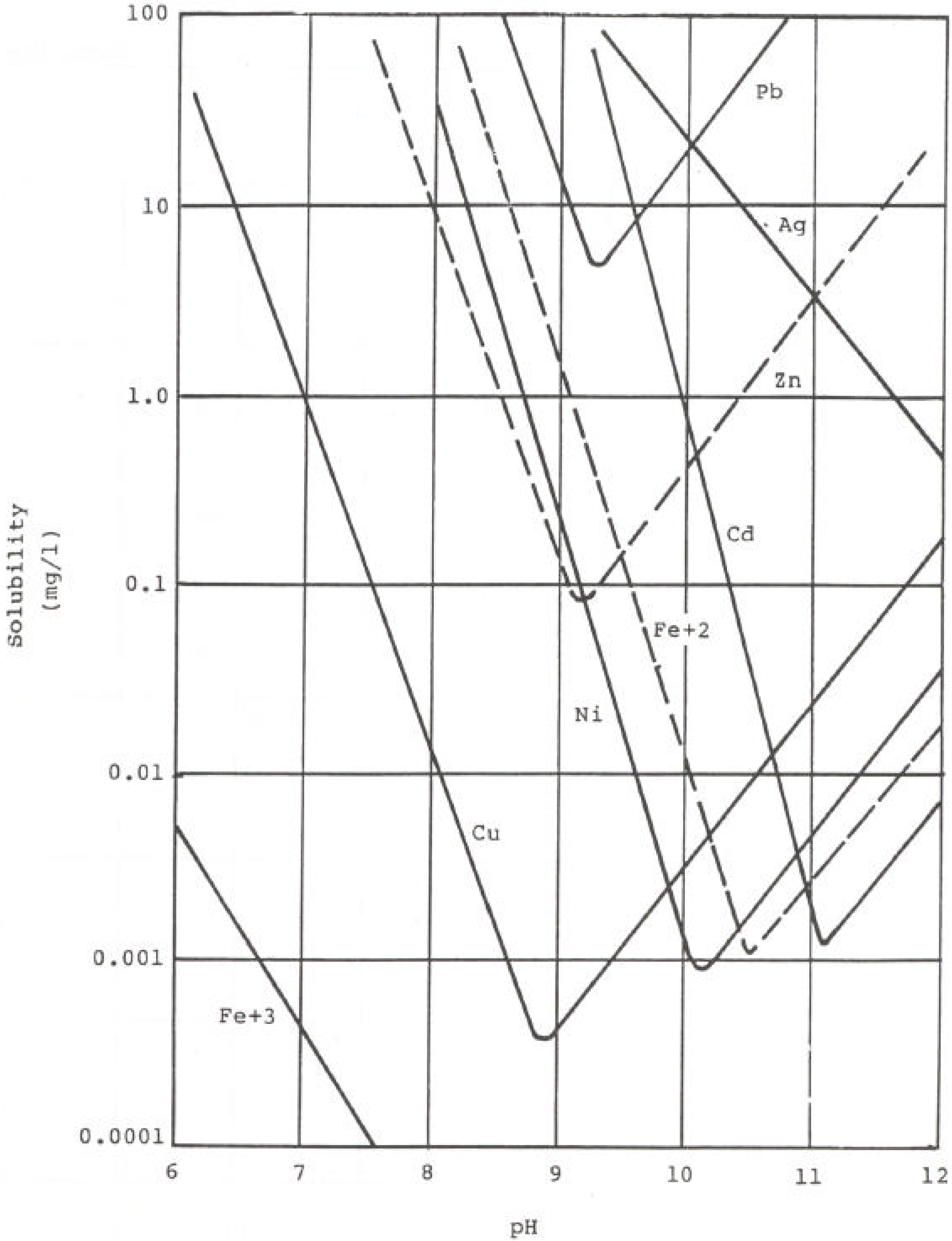
Enger, Eldon D. and Bradley F. Smith, Environmental Science: A Study of Interrelationships, 5th Edition, Wm. C. Brown Publishers, Dubuque, IA, 1983.

Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

Water Analysis Kit, page F-69, Water Testing Fact Sheet



SOLUBILITIES OF METAL HYDROXIDES AS A FUNCTION OF pH



SOLUBILITIES OF METAL HYDROXIDES AS A FUNCTION OF pH

WHAT IS IN SOURCE WATER?

9-12

OBJECTIVES

The student will do the following:

1. Observe pond and stream water samples for microorganisms and macroinvertebrates present in those aquatic ecosystems.

2. Categorize and compare the types of microorganisms in pond samples and stream samples (compare pond water samples with stream samples).

3. Distinguish between harmless macro- and micro-invertebrates and disease-causing organisms, if any.

4. Decide which pond appears to have better water samples.

SUBJECTS:
Science (Biology, Ecology)

TIME:
1 to 2 class periods
1 week extension

MATERIALS:
jars
sample of "pond water"
sample of "stream water"
labels
medicine dropper (per group)
microscope (per group)
slides with cover slips
kick nets or D-ring nets
distilled water
jars and labels
rice
book on aquatic microorganisms (if available)
wallpaper paste
paper & writing implements
student sheets

BACKGROUND INFORMATION

Freshwater biomes include lakes, ponds, wetlands, and rivers. Most aquatic organisms live near the surface where nutrients and oxygen are plentiful. Different types of communities of organisms dwell successfully in bodies of freshwater, depending on temperature, humidity, and amount of light. Some freshwater invertebrates are protists, green algae, and monerans (bacteria and blue-green algae). Other invertebrates, such as mayflies, stoneflies, snails, riffle beetles, crayfish, and caddisflies, may also be abundant.

Bioassessment is a technique used to monitor water quality. Groups of students can conduct bioassessments. This type of testing is a supplement to chemical testing. Usually different species are found in differing proportions and can be used as indicators of water quality. Some tolerant species can survive drastic changes in conditions. Other intolerant species are affected even by small amounts of pollution. Populations change when water quality changes.

<u>Terms</u>

algae: any various, primitive, chiefly aquatic, one-celled or multicellular plants that lack true stems, roots, and leaves, but usually contain chlorophyll. Algae are divided into three groups: chlorophyta (green), phaeophyta (brown), and rhodophyta (red), typically grow in sunlitwaters in proportion to the amount of nutrients available, and serve as food for fish and small aquatic animals.

bacteria: typically one-celled, non-photosynthetic microorganisms that multiply by simple division. They occur in three main forms; spherical (cocci), rod-shaped (bacilli), and spiral (spirilla).

bioassessment: an evaluation of the biological condition of a waterbody using biological surveys and other direct measurements of resident biota in surface waters

biomes: area or groups of ecosystems with similar climates, soils, and communities

community: assemblage of populations of species living together and interacting with each other within a certain area

population: group of organisms of a single species living in a certain area and interbreeding (or interacting)

tolerance: the natural or developed ability to endure or resist the harmful effects of a substance

ADVANCE PREPARATION

A. Collect samples of pond water in jars and label them with a unique name or location for each pond.

B. If possible, take students to the nearest stream and utilize kick nets or D-ring nets to collect macroinvertebrates. Place organism-containing water in sorting pans by group. Place organisms in jars with alcohol if preservation is desired, otherwise return organisms to stream.

C. Copy Student Sheets. (one set for each student)

D. If testing five-day-old pond water samples, add a few rice grains to each jar to feed organisms.

PROCEDURE

I. Setting the stage

A. Go over Microorganism and Macroinvertebrate Student Sheets.

B. Go over the different zones in a pond that support life.

C. Explain how to use wallpaper paste to slow down microorganisms (not needed for macroinvertebrates).

II. Activity Part 1- Observations

A. Prepare microscope slides of pond and stream water using medicine droppers and cover slips.

B. Ask students to make observations, draw, and identify the organisms present in the samples, using the Student Sheets as the key.

C. Let each student observe a variety of slides.

D. Compare and contrast the pond water organisms from different ponds.

Part 2 - Bioassessment

A. Have students identify the macroinvertebrates of the three groups according to their key for macroinvertebrate samples.

B. Have students record names and numbers of different macroinvertebrates found in each group for each stream macroinvertebrate sample.

C. Compare and contrast the results for different samples; determine the water quality.

III. Follow-up

A. Repeat the same procedure after 5-10 days. (Keep jars warm and in indirect sunlight.)

B. Record the changes in size, number, and species in the new samples and the 5-10 day samples.

C. Discuss possible reasons for any differences that are observed in the samples.

IV. Extensions

A. Is water quality different in the streams? Which is best? Why?

B. Collect more information about pond life and freshwater flora and fauna. (library research)

RESOURCES

Arms, Karen, Environmental Science, Holt, Rinehart, and Winston, Inc., Austin, TX, 1996.

Chiras, Daniel D., Environmental Science, High School Edition, Addison-Wesley, Menlo Park, CA, 1989.

Cunningham, William P. and Barbara Woodworth Saigo, Environmental Science: A Global Concern, Wm. C. Brown Publishers, Dubuque, IA, 1997.

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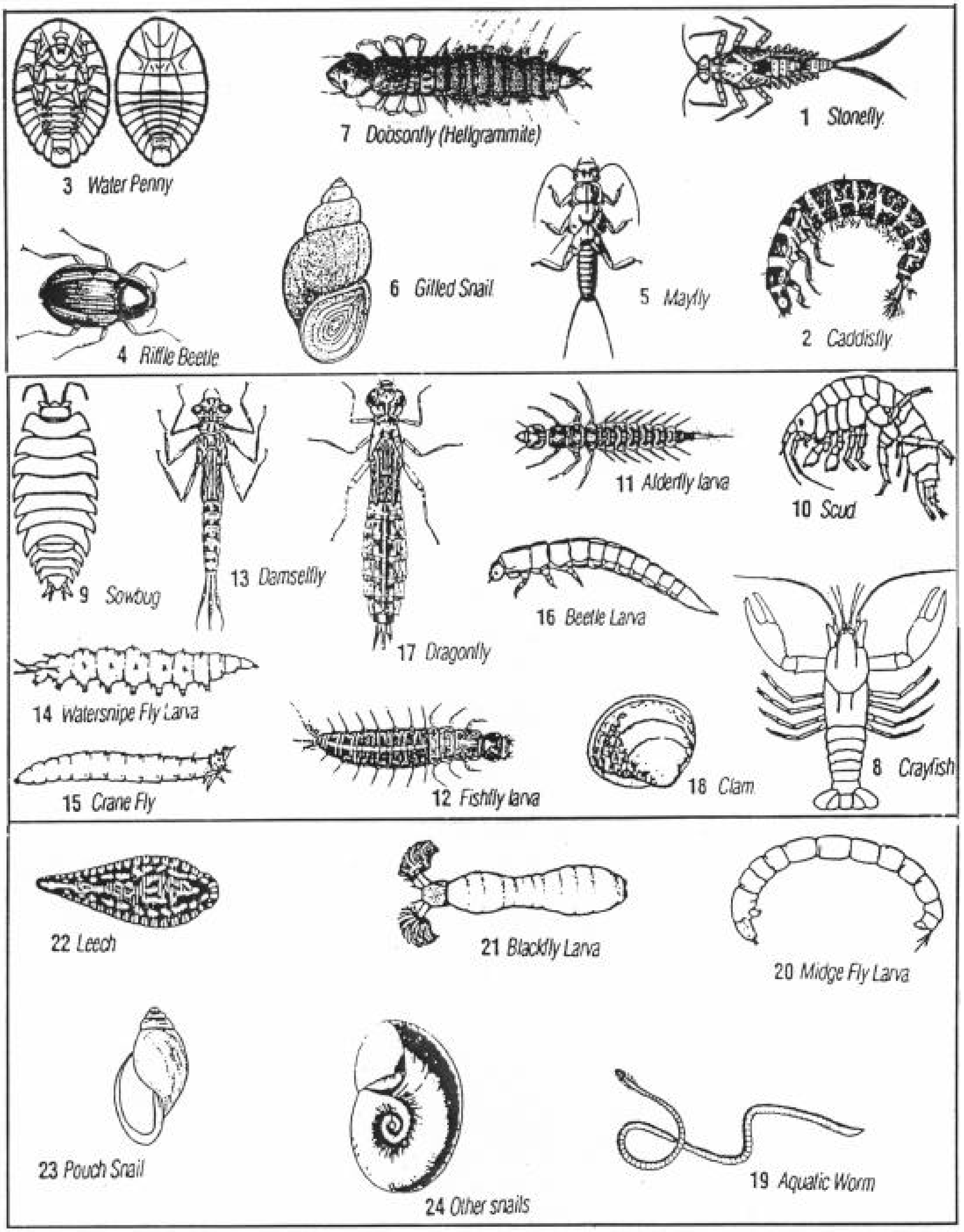
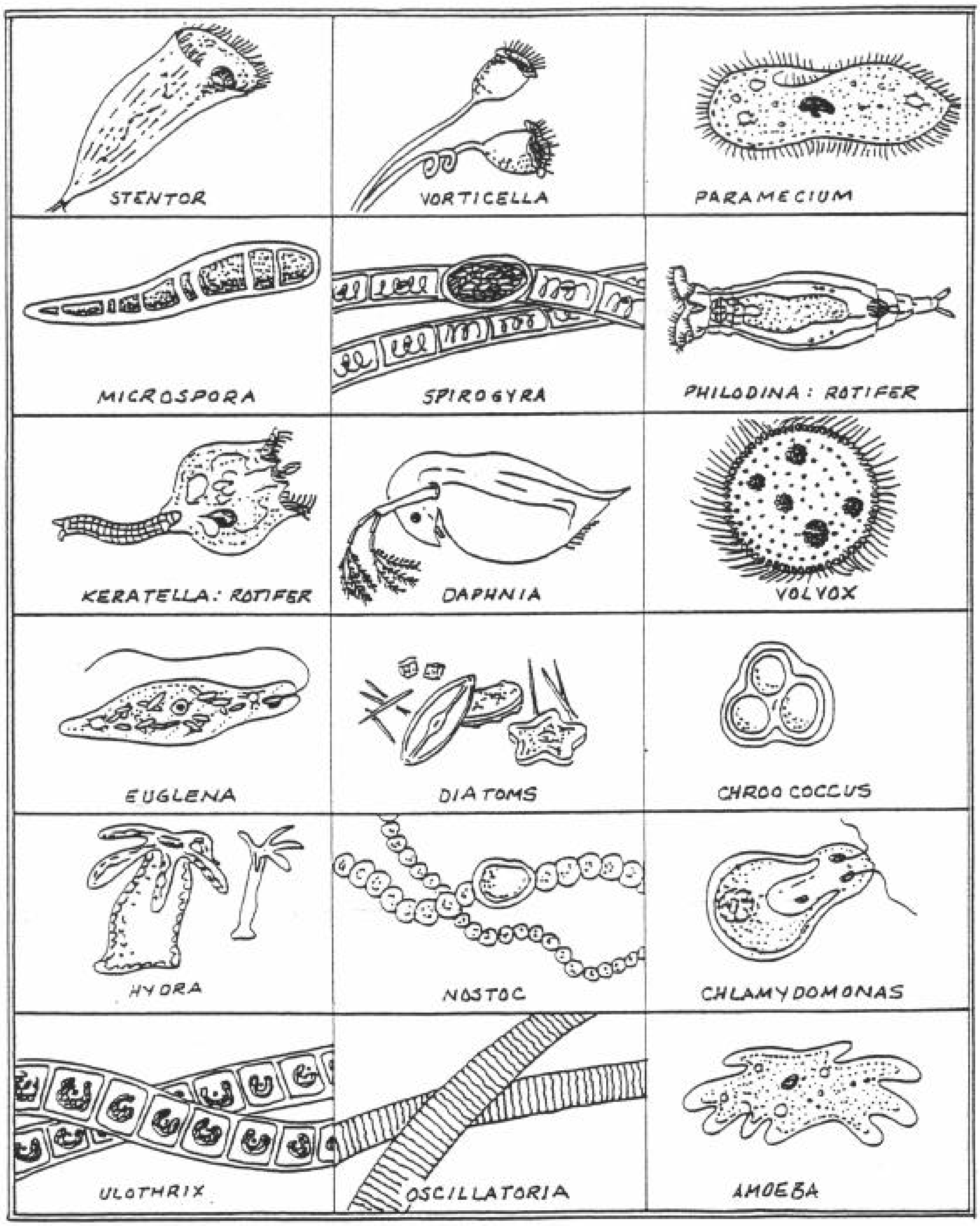
Nebel, Bernard J. and Richard T. Wright, Environmental Science: The Way The World Works, 4th Edition, Prentice-Hall, Englewood Cliffs, NJ, 1993.

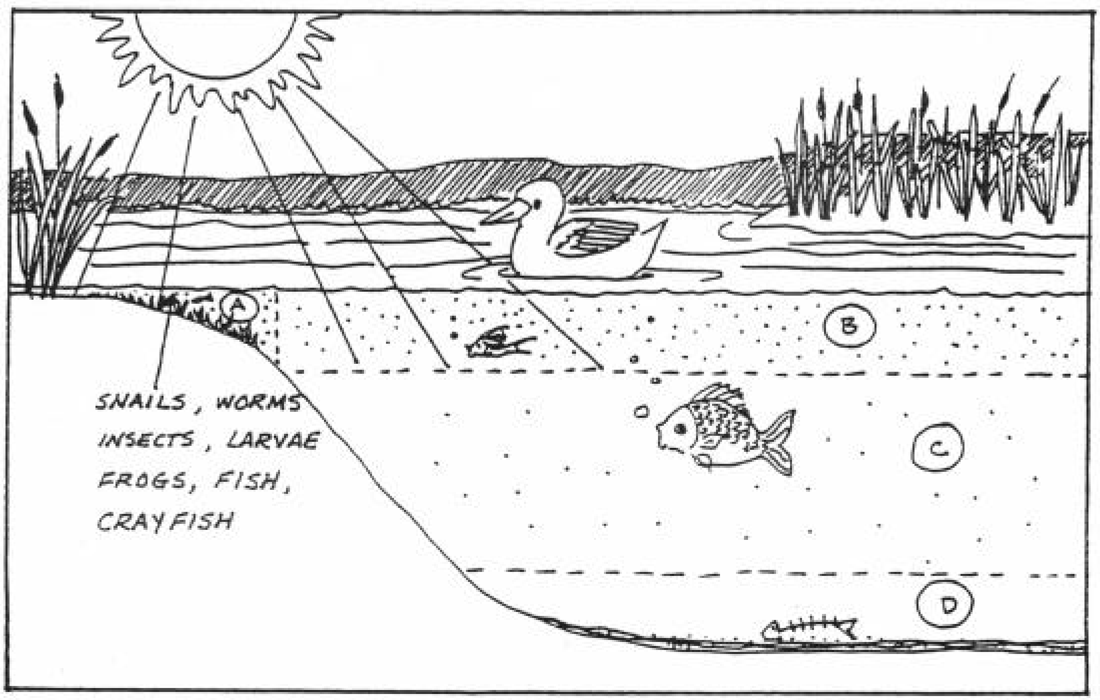
MACROINVERTEBRATE GROUPS
Beginner's Protocol PICTURE KEY

	GROUP 1		GROUP 2		GROUP 3
1.	STONEFLY	8.	CRAYFISH	19.	AQUATIC WORM
2.	CADDISFLY	9.	SOWBUG	20.	MIDGE FLY LARVA
3.	WATER PENNY	10.	SCUD	21.	BLACKFLY LARVA
4.	RIFFLE BEETLE	11.	ALDERFLY LARVA	22.	LEECH
5.	MAYFLY	12.	FISHFLY LARVA	23.	POUCH SNAIL
6.	GILLED SNAIL	13.	DAMSELFLY	24.	OTHER SNAILS
7.	DOBSONFLY	14.	WATERSNIPE FLY LARVA		
		15.	CRANE FLY		
		16.	BEETLE LARVA		
		17.	DRAGONFLY		
		18.	CLAM		


3 Water Penny
7 Dobsonfly (Hellgrammite)
1 Stonefly
4 Riffle Beetle
6 Gilled Snail
5 Mayfly
2 Caddisfly
9 Sowbug
13 Damselfly
17 Dragonfly
11 Alderfly larva
10 Scud
16 Beetle Larva
8 Crayfish
14 Watersnipe Fly Larva
15 Crane Fly
12 Fishfly larva
18 Clam
22 Leech
21 Blackfly Larva
20 Midge Fly Larva
23 Pouch Snail
24 Other snails
19 Aquatic Worm

COMMON FRESHWATER ORGANISMS





A pond or lake ecosystem is structured according to how much light is available.

A. Shallow water at shore line; sunlight reaches bottom; life abundant and varied.

B. Near surface; light penetrates for photosynthesis; phytoplankton, zooplankton abundant.

C. Cooler, darker; bacteria and fish that feed in Zone B.

D. Very dark and very cold, few bottom feeders, many decomposers.

WASTEWATER TREATMENT

OBJECTIVES

SUBJECT:
Science (Physical Science, Physics)

TIME:
2-3 class periods

MATERIALS:
student sheets
writing materials

The student will do the following:

1. Define wastewater and list components of wastewater.
2. Describe the function of a wastewater treatment plant.
3. Create a wastewater treatment model and use it to clean wastewater.
4. Describe some primary and secondary wastewater treatment methods.

BACKGROUND INFORMATION

Wastewater is not just sewage. All the water used in the home that goes down the drains or into the sewage collection system is wastewater. This includes water from baths, showers, sinks, dishwashers, washing machines, and toilets. Small businesses and industries often contribute large amounts of wastewater to sewage collection systems; others operate their own wastewater treatment systems. In combined municipal sewage systems, water from storm drains is also added to the municipal wastewater stream. The average American contributes 265-568 liters (66 to 192 gallons) of wastewater each day. Wastewater is about 99 percent water by weight and is generally referred to as influent as it enters the wastewater treatment facility. "Domestic wastewater" is wastewater that comes primarily from individuals, and does not generally include industrial or agricultural wastewater.

At wastewater treatment plants, this flow is treated before it is allowed to be returned to the environment, lakes, or streams. There are no holidays for wastewater treatment, and most plants operate 24 hours per day every day of the week. Wastewater treatment plants operate at a critical point of the water cycle, helping nature defend water from excessive pollution. Most treatment plants have primary treatment (physical removal of floatable and settleable solids) and secondary treatment (the biological removal of dissolved solids).

Primary treatment involves:

1. screening- to remove large objects, such as stones or sticks, that could plug lines or block tank inlets.

2. grit chamber- slows down the flow to allow grit to fall out

3. sedimentation tank (settling tank or clarifier)- settleable solids settle out and are pumped away, while oils float to the top and are skimmed off

Secondary treatment typically utilizes biological treatment processes, in which microorganisms convert nonsettleable solids to settleable solids. Sedimentation typically follows, allowing the settleable solids to settle out. Three options include:

1. Activated Sludge- The most common option uses microorganisms in the treatment process to break down organic material with aeration and agitation, then allows solids to settle out. Bacteria-containing "activated sludge" is continually recirculated back to the aeration basin to increase the rate of organic decomposition.

2. Trickling Filters- These are beds of coarse media (often stones or plastic) 3-10 ft. deep. Wastewater is sprayed into the air (aeration), then allowed to trickle through the media. Microorganisms, attached to and growing on the media, break down organic material in the wastewater. Trickling filters drain at the bottom; the wastewater is collected and then undergoes sedimentation.

3. Lagoons- These are slow, cheap, and relatively inefficient, but can be used for various types of wastewater.They rely on the interaction of sunlight, algae, microorganisms, and oxygen (sometimes aerated).

After primary and secondary treatment, municipal wastewater is usually disinfected using chlorine (or other disinfecting compounds, or occasionally ozone or ultraviolet light). An increasing number of wastewater facilities also employ tertiary treatment, often using advanced treatment methods. Tertiary treatment may include processes to remove nutrients such as nitrogen and phosphorus, and carbon adsorption to remove chemicals. These processes can be physical, biological, or chemical.

Settled solids (sludge) from primary treatment and secondary treatment settling tanks are given further treatment and undergo several options for disposal. (See Sludge Treatment and Disposal Methods on page 2-87 & 2-114 thru 2-115.)

Terms

activated sludge: sludge particles produced by the growth of microorganisms in aerated tanks as a part of the activated sludge process to treat wastewater

aeration: exposing to circulating air; adds oxygen to the wastewater and allows other gases trapped in the wastewater to escape (the first step in secondary treatment via activated sludge process)

biochemical oxygen demand (BOD): a laboratory measurement of wastewater that is one of the main indicators of the quantity of pollutants present; a parameter used to measure the amount of oxygen that will be consumed by microorganisms during the biological reaction of oxygen with organic material

biosolids: sludge that is intended for beneficial use. Biosolids must meet certain government-specified criteria depending on its use (e.g., fertilizer or soil amendment)**.**

decomposition: the process of breaking down into constituent parts or elements

domestic wastewater: wastewater that comes primarily from individuals, and does not generally include industrial or agricultural wastewater

effluent: treated wastewater, flowing from a lagoon, tank, treatment process, or treatment plant

grit chamber: a chamber or tank used in primary treatment where wastewater slows down and heavy, large solids (grit) settle out and are removed

influent: wastewater flowing into a treatment plant

lagoons (oxidation ponds or stabilization ponds): a wastewater treatment method that uses ponds to treat wastewater. Algae grow within the lagoons and utilize sunlight to produce oxygen, which is in turn used by microorganisms in the lagoon to break down organic material in the wastewater. Wastewater solids settle in the lagoon, resulting in effluent that is relatively well treated, although it does contain algae.

municipal: of or relating to a municipality (city, town, etc.). Municipal wastewater is primarily domestic wastewater**.**

primary treatment: the first stage of wastewater treatment that removes settleable or floating solids only; generally removes 40% of the suspended solids and 30-40% of the BOD in the wastewater

secondary treatment: a type of wastewater treatment used to convert dissolved and suspended pollutants into a form that can be removed, producing a relatively highly treated effluent. Secondary treatment normally utilizes biological treatment processes (activated sludge, trickling filters, etc.) followed by settling tanks and will remove approximately 85% of the BOD and TSS in wastewater. Secondary treatment for municipal wastewater is the minimum level of treatment required by the Clean Water Act.

sedimentation: the process used in both primary and secondary wastewater treatment, that takes place when gravity pulls particles to the bottom of a tank (also called settling).

settling tank (sedimentation tank or clarifier): a vessel in which solids settle out of water by gravity during wastewater or drinking water treatment processes.

sludge: any solid, semisolid, or liquid waste that settles to the bottom of sedimentation tanks (in wastewater treatment plants or drinking water treatment plants) or septic tanks

tertiary treatment: any level of treatment beyond secondary treatment, which could include filtration, nutrient removal (removal of nitrogen and phosphorus) and removal of toxic chemicals or metals; also called "advanced treatment" when nutrient removal is included

total suspended solids (TSS): a laboratory measurement of the quantity of suspended solids present in wastewater that is one of the main indicators of the quantity of pollutants present

trickling filter process: a biological treatment process that uses coarse media (usually rock or plastic) contained in a tank that serves as a surface on which microbiological growth occurs. Wastewater trickles over the media and microorganisms remove the pollutants (BOD and TSS. Trickling filters are followed by settling tanks to remove microorganisms that wash off or pass through the trickling filter media.

turbidity: the cloudy or muddy appearance of a naturally clear liquid caused by the suspension of particulate matter

wastewater: water that has been used for domestic or industrial purposes

PROCEDURE

I. Setting the Stage

A. Make transparencies of Teacher Sheets. Copy Student Sheets.

B. Discuss the processes involved at a typical municipal wastewater treatment facility.

C. Discuss typical municipal wastewater collection systems.

D. Relate discussion to any relevant local or national wastewater issues.

II. Activity

A. Have students complete Student Sheet.

B. (Optional): Have students research pertinent local or national wastewater issues and write a paper on their issue of choice.

III. Follow-up

A. Have students determine which types of treatment (primary, secondary, tertiary) and specific processes are used at the local municipal wastewater treatment facility.

B. Have students discuss the plant's efficiency (with respect to various contaminants) with a plant operator. Learn about any "pretreatment" operations conducted for industrial wastewater.

IV. Extensions

A. Visit the local municipal wastewater treatment plant, or invite a speaker from the plant to talk to the class.

B. View a video or slides of various types of wastewater treatment processes.

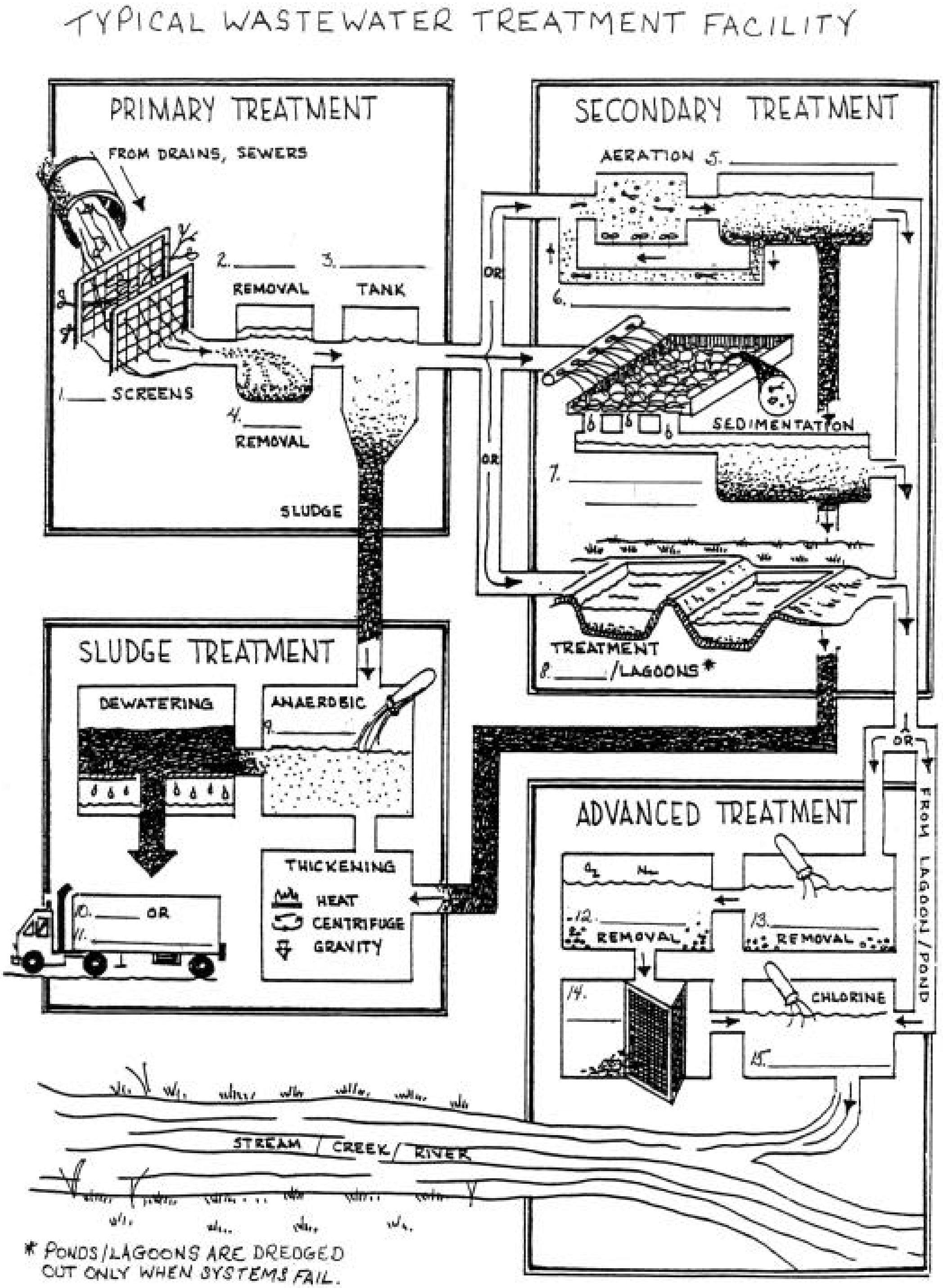
C. Determine which types of municipal treatment processes are used in industrial wastewater treatment processes. Discuss which processes are used for particular industries and why.

RESOURCES

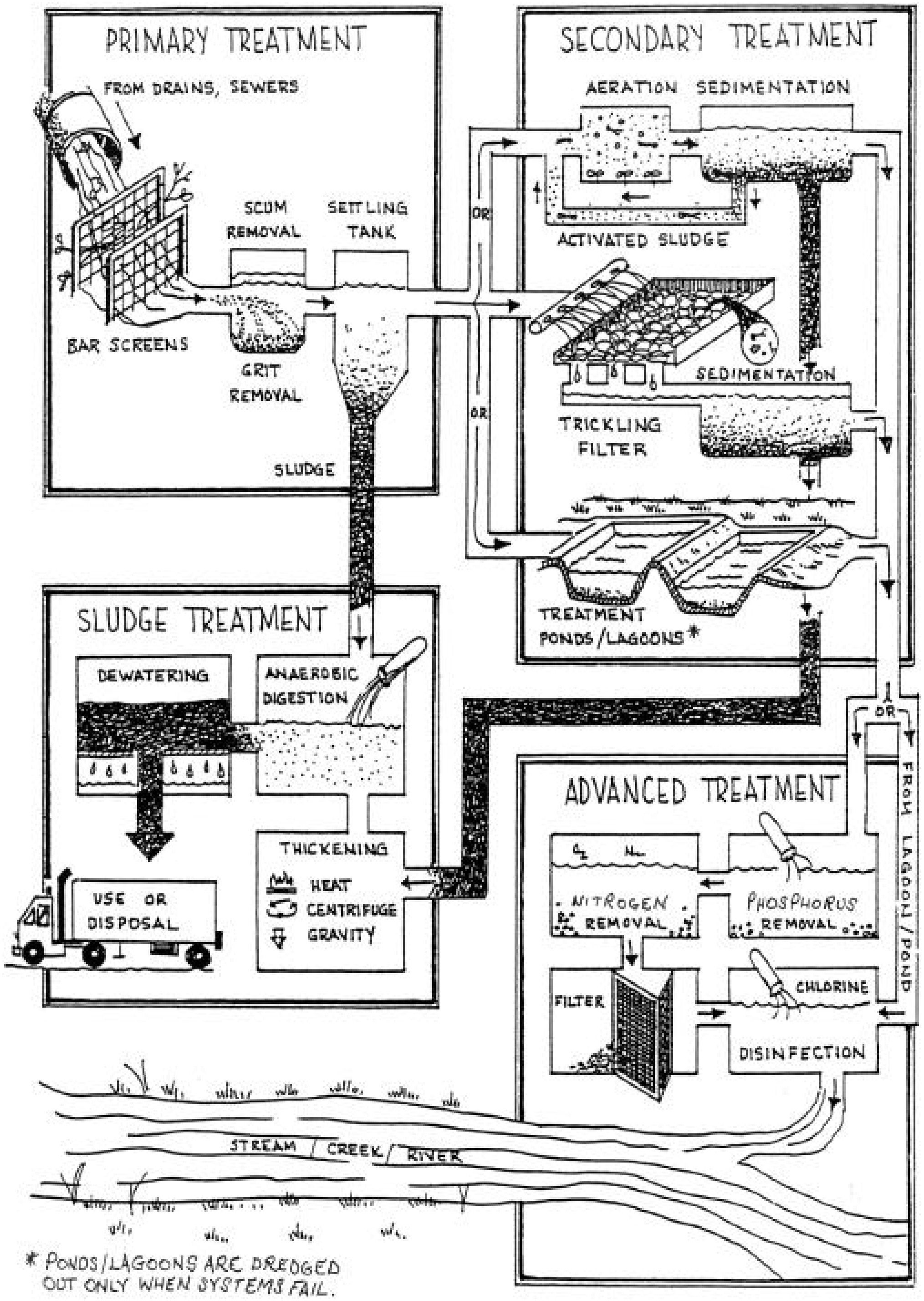
National Geographic Society Teachers Handbook, Geography: Reflections on Water", Nov. '92.

Nature Projects on File, "Cleaning Dirty Water," 6.008, The Diagram Group.

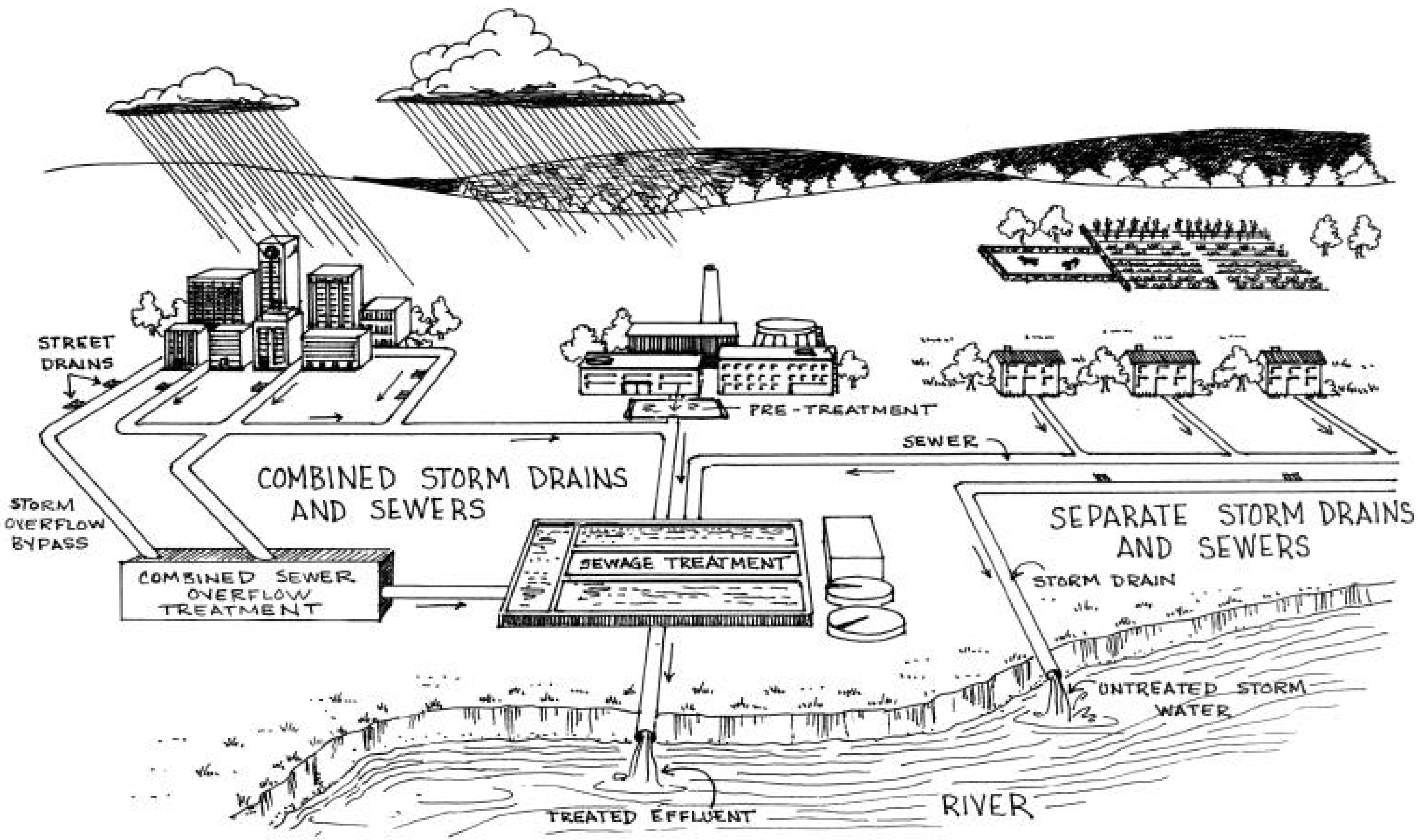
Water Environment Federation, “Clean Water for Today: What is Wastewater Treatment?” 1-800-444-2933 (Fax Reply Service)


TYPICAL WASTEWATER TREATMENT FACILITY
PRIMARY TREATMENT
FROM DRAINS, SEWERS
2. ____ REMOVAL
3. ____ TANK
1. ____ SCREENS
4. ____ REMOVAL
SLUDGE
SECONDARY TREATMENT
AERATION 5. ____
OR
6. ____
SEDIMENTATION
7. ____
TREATMENT
8. ____ /LAGOONS *
SLUDGE TREATMENT
DEWATERING
ANAEROBIC
9. ____
THICKENING
HEAT
CENTRIFUGE
GRAVITY
10. ____ OR
11. ____
ADVANCED TREATMENT
12. ____ REMOVAL
13. ____ REMOVAL
14. ____
CHLORINE
15. ____
FROM LAGOON / POND
STREAM / CREEK / RIVER
* PONDS/LAGOONS ARE DREDGED OUT ONLY WHEN SYSTEMS FAIL.

TYPICAL WASTEWATER TREATMENT FACILITY



MUNICIPAL SEWER SYSTEMS



2-89

THE WORLD OF BIOLOGICAL WASTEWATER TREATMENT

9-12

OBJECTIVES

The student will do the following:

1.Balance equations involving common household products found in domestic wastewater.

2.Describe different types of biological wastewater treatment and sludge treatment.

3.Identify microorganisms in wastewater and determine sludge quality.

SUBJECT:
Science (Chemistry, Biology, Physical Science). Social Studies (Economics). Language Arts

TIME:
2-3 class periods

MATERIALS:
students sheets

BACKGROUND INFORMATION

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 complete as summarized by:

Aerobic Microbes

Constituent + O_2 ÿ ÿ ÿ ÿ ÿ ÿ ÿ ÿ ÿ ÿ ÿ 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 municipal and industrial 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 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.

Biological organisms that provide treatment may be either suspended growth organisms (activated sludge, ponds, or lagoons) or attached growth organisms (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 Sheet 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 to keep these microorganisms under controlled conditions so that they can remove most of the solids from wastewater as it 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. The process thereby assists in protecting the receiving stream from organic loads that could lower dissolved oxygen enough to kill fish or otherwise adversely affect the receiving stream.

Terms

effluent: treated wastewater, flowing from a lagoon, tank, treatment process, or treatment plant

refractory wastewater: wastewater containing an organic or nutrient content that will not oxidize in normal treatment processes

variable wastewater: wastewater that comes from different sources (regular sewage, storm water, or industrial wastewater)

ADVANCE PREPARATION

A. Copy all Students Sheets.

B. Review or instruct students on how to balance equations.

C. Put students into work groups.

D. Copy sources of wastewater (from PROCEDURE, II. Activity. B), and cut the different ones into individual strips. Give 1 or 2 to each group.

E. Obtain from a treatment plant a sample of activated sludge or other material that would contain microorganisms. (Note: Students should not handle activated sludge, as it may contain pathogens. Teachers should receive handling instructions from a certified wastewater treatment operator.)

PROCEDURE

I. Setting the stage

A. Explain the purpose of organic constituent breakdown with oxygen in wastewater treatment.

B. Explain that there are many variations on the most commonly known biological treatment processes and sludge treatment processes.

II. Activity

A. Contact the local water and sewer authority, a consulting engineer, state or federal environmental agency, or another source and find out the most common wastewater treatment systems used in the area and why they are used. What are commonly used sludge treatment processes and what is typically done with the sludge.

B. Assuming joint treatment with domestic wastewater, use the Student Sheet information and contact one of the following external sources to find out its wastewater characteristics. Match the source with the treatment technique most applicable to that source. Be sure you can explain why you chose that method of treatment.

< domestic wastewater (small town)

< domestic wastewater (larger city)

< pulp and paper mill

< chemical plant

< textile dyeing operation

< poultry or meat processing

< petroleum refining

< fruit/vegetable processing

< bakery

< fertilizer manufacture

< soft drink bottling

< iron and steel manufacture

C. Visit the local municipal wastewater treatment plant (or talk to a plant operator) and determine its type. Why are those particular wastewater and sludge treatment processes used for your town or city?

D. Balance the equations on Biodegradable Balancing Student Sheet.

E. Look at a drop of activated sludge under a microscope. Each group should prepare 3 slides. Record the different types and numbers of organisms present on the Student Sheet for each slide. Draw pictures of what you see. Determine the sludge quality using the Student Sheet on quality.

III. Follow-up

A. Do you think your local municipal wastewater treatment plant is using the best treatment methods for your area and circumstances? Explain your answer.

B. What are some common organic constituents you would find in local wastewater. What is the source of most of them?

C. Do you think the treatment plant that the activated sludge was taken from is operating effectively? Explain your answer.

IV. Extensions

Have students research one household pollutant common in wastewater, searching for healthier environmental substitutes.

RESOURCES

Metcalf and Eddy, Wastewater Engineering: Collection and Pumping of Wastewater, McGraw-Hill, New York, 1981.

Water Environment Federation, "MOP for Treatment Plant Operation & Design," 1-800-444-2933.

Water Environment Federation, "Nature's Way" Video & Brochure, 1-800-444-2933.

METHODS OF WASTEWATER TREATMENT & DISPOSAL

1. EXTENDED-AERATION ACTIVATED SLUDGE

ADVANTAGES

Key advantages of the extended-aeration process include:

- Lowest solids production of any activated-sludge process
- High-quality effluent achievable
- Preengineered package plants quickly installed with minimal site preparation
- Favorable reliability with sufficient operator attention
- Nitrification likely at wastewater temperatures >15'C
- Relatively minimal land requirements
- Relatively low initial cost
- Can handle moderate-shock hydraulic loadings with minimal problems

DISADVANTAGES

Key disadvantages of this type of system include:

- High power consumption and energy cost compared to land-based or natural systems
- High O&M requirements compared to land-based or natural systems; skilled operator necessary
- Susceptible to excursions in effluent SS and associated BOD due to high flow variations and operator inattention
- Potential freezing problems in cold climates
- Possibility of poor settleability of mixed liquor suspended solids (MLSS) due to formation of "pinpoint" floc
- Potential for rising solids due to denitrification in final clarifier in warmer months
- Blower noise and odor potential
- Preengineered plants may require additional components or modification to meet specified effluent limitations

2. OXIDATION DITCH

ADVANTAGES

Key advantages of the oxidation ditch process include:

- Low solids production
- Excellent performance. High reliability
- Nitrogen removal likely
- Relatively low initial cost
- Can be designed for biological phosphorus and nitrogen removal

DISADVANTAGES

Key disadvantages to this process include:

- Protection from aerator freezing problems necessary in cold climates
- Relatively high maintenance requirements for aerators
- Potential for rising solids due to dentrification in final clarifier
- Requires good operator skills and routine monitoring

3. SEQUENCING BATCH REACTORS

ADVANTAGES

Key advantages of the SBR process include:

- Simple, reliable
- Ideally suited for wide flow variations

DISADVANTAGES

The disadvantages of this process include:

- Capable of very high and consistent effluent quality due to sequiescent batch shifting
- Requires less operator attention than most other mechanical systems
- High operational flexibility allowing capability for nutrient removal, filamentous growth control

- Some problems reported with decant systems
- Improvements to hardware continue to be made as the technology develops.
- Requires skilled operator and regulator inspection and maintenance

4. TRICKLING FILTRATION (TF) AND ROTATING BIOLOGICAL CONTACTORS (RBC)

ADVANTAGES

Key advantages of TF and RBC processes include:

- Simplicity of operation. Low energy requirements
- Dependability
- The relatively small amount of solids produced is more easily dewatered than activated sludge.

DISADVANTAGES

Key disadvantages of these processes include:

- High land requirements
- High capital cost
- Lower degree of process control
- The conventional TF process is limited with respect to performance.

5. TRICKLING FILTER SOLIDS CONTACT (TFSC) PROCESS

ADVANTAGES

Advantages of the TFSC process include:

- Applicable for new facilities or upgrading existing tricking filter plants
- Capable of consistently achieving very high-quality effluent (<20 mg/L BOD & SS)
- Relatively simple process
- Low cost and reliable upgrading technique for trickling filters
- Can be designed to provide nitrification

DISADVANTAGES

Key disadvantages of this process include:

- Primary clarification required
- Pumping required to douse trickling filter
- Potential for nuisance odors from primary clarifiers, trickling filter, solids handling
- Moderate O&M requirements; skilled operator necessary

6. CONSTRUCTED WETLANDS

ADVANTAGES

Constructed wetlands offer the following advantages for wastewater management:

- Low construction cost
- Passive system easily managed by small community with O&M personnel
- Excellent removal of biochemical oxygen demand (esp. BOD5) and suspended solids (SS) from primary or septic tank effluents
- Generally attractive systems with secondary ecological benefits in terms of wildlife habitat enhancement

DISADVANTAGES

The following disadvantages should be taken in account when considering a constructed wetland system:

- Lack of generally agreed-upon design factors, resulting in several unproven approaches to design of land-intensive systems, especially FWS types where up to 4 ha/Us (450 ac/mgd) have been required
- SF systems remain unproven for other than BOD5 and SS removal.

7. OVERLAND FLOW

ADVANTAGES

Overland flow is well suited for wastewater treatment by rural communities and seasonal industries with organic wastes. It provides secondary or advanced secondary treatment, yet is relatively simple and inexpensive to operate. If the vegetation cover can be harvested and sold (e.g., as forage), overland flow can provide an economic return from the reuse of water and nutrients. Of the land application methods of wastewater treatment, overland flow is the approach least restricted by soil characteristics; however, this method does require a relatively impermeable soil for conventional operation.

DISADVANTAGES

Overland flow is primarily limited by climate, crop water tolerances, and land slope. Application is restricted during wet weather and can be limited when temperatures remain below freezing. Application rates may be restricted by the type of crop grown. Steeply sloping or flat terrain is not well suited for this method of treatment. Disinfection is required in order to meet effluent permit requirements prior to discharge (unique to land application processes).

8. SLOW RATE LAND APPLICATION

ADVANTAGES

Slow rate land application is well suited for treatment of wastewater from rural communities and seasonal industries such as vegetable canning. It can provide an economic return from the reuse of water and nutrients for irrigation of landscaped areas or production of marketable, commercially processed crops. It also provides groundwater recharge. Of the various land treatment methods, slow rate land application is the least limited by surface slopes.

DISADVANTAGES

Because of the vegetation component, slow rate land application is limited by climate and nutrient requirements of the vegetation. Climate affects the growing season and will dictate the period of wastewater application and storage requirements. Crop water tolerances, nutrient requirements, and nitrogen removal capacity of the vegetation-soil complex limit the hydraulic loading rate. Application must be suspended during wet periods or frozen soil conditions. Because of the limits on the hydraulic loading rate, the area of land necessary is significantly larger than for other land application methods.

9. RAPID INFILTRATION

ADVANTAGES

Rapid infiltration is a method of land application providing very favorable removal of the conventional wastewater parameters-including ammonia-that is simple to operate and requires only a minimum of operator intervention. Moreover, it requires less land area than other land application methods and may be operated year round. It is a "zero discharge: method that provides groundwater recharge rather than requiring an outfall for direct discharge to surface water. Frequently, renovated wastewater is recovered via wells for reuse in irrigation.

DISADVANTAGES

Use of rapid infiltration is limited by site and soil characteristics that affect the capability of the soil to accept and treat the applied wastewater. Potential groundwater impacts from nitrate nitrogen are a serious concern and may also limit its application.

SLUDGE TREATMENT AND DISPOSAL METHODS

1. AEROBIC DIGESTION

ADVANTAGES

Key advantages of the aerobic digestion include:

- Minimal operator attention
- Low odor potential
- Simple process
- Resistant to upset
- No chemicals required

DISADVANTAGES

The disadvantages of this process include:

- Very high power consumption
- Aeration system requires high maintenance
- Larger volume tank required for cold climate application
- Foaming potential

2. ANAEROBIC DIGESTION

ADVANTAGES

The recovery and use of this gas (primarily methane) as well as the reduction in solids volume are considered the most attractive features of anaerobic digesters.

DISADVANTAGES

The complexity of the recovery and use process makes their feasibility marginal for wastewater systems with capacities in the range of 100,000 to 1 million gpd and unlikely in smaller systems.

3. LAND APPLICATION OF BIOSOLIDS

ADVANTAGES

Key advantages of land application include:

- Recycling as soil conditioner, source of organic matter and nutrients
- Simple
- Low cost

DISADVANTAGES

The disadvantages of this process include:

- Storage requirements may be considerable to accommodate generation during wet, frozen soil conditions
- Odor potential
- Local opposition possible
- Close monitoring required

Organic Constituents

Bacteria
(Constituent + O_2 ÿ 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

BIODEGRADABLE BALANCING

Name________________
Date ________________

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

1. Acetic Acid (vinegar)

   Microorganisms
   $CH_3COOH + 2O_2$! ! ! ! ! ! ! ! ! CO_2 + H_2O

2. Acetone (nail polish remover, will not stay in solution - very volatile)

   Microorganisms
   $CH_3COCH_3 + 4O_2$! ! ! ! ! ! ! ! ! CO_2 +
H_2O

3. Citric Acid (orange juice)

   Microorganisms
   $2C_6H_8O_7 + 9O_2$! ! ! ! ! ! ! ! ! CO_2 + H_2O

4. Sucrose (sugar)

   Microorganisms
   $C_{12}H_{22}O_{11} + 12O_2$! ! ! ! ! ! ! ! ! CO_2 +
H_2O

5. Benzene (a component of gasoline)

   Microorganisms
   $2C_6H_6 + 15O_2$! ! ! ! ! ! ! ! ! CO_2 +
H_2O

6. Phenol (present in mouthwash, toxic to microorganisms at low concentrations)

Microorganisms

$C_6H_5OH + 7O_2$! ! ! ! ! ! ! ! ! CO_2 + H_2O

BIODEGRADABLE BALANCING (cont.)

7. Naphthalene (mothballs, will sublime rather than dissolve)

Microorganisms

$C_{10}H_8 + 12O_2$! ! ! ! ! ! ! ! ! CO_2 + H_2O

8. Uric Acid

Microorganisms

$2C_5H_4N_4O_3 + 9O_2$! ! ! ! ! ! ! ! ! $CO_2 + H_2O + N_2$

Some of these compounds will <u>not</u> be effectively treated with biological stabilization.

9. Caffeine

Microorganisms

$2C_8H_{10}N_4O_2 + 19O_2$! ! ! ! ! ! ! ! $CO_2 + H_2O + N_2$

10. Acetylsalicylic Acid (aspirin)

Microorganisms

$CH_3COOC_6H_4COOH + 9O_2$! ! ! ! ! ! ! ! CO_2 + H_2O

11. Vitamin A

Microorganisms

$C_{20}H_{29}OH + 27O_2$! ! ! ! ! ! ! ! ! CO_2 + H_2O

12. Vitamin B_1 (thiamine)

Microorganisms

$2C_{12}H_{17}N_4SOC1 + 31O_2$! ! ! ! ! ! ! ! $CO_2 + H_2O + N_28 + S_2 + HCl$

13. Ascorbic Acid (Vitamin C)

Microorganisms

$C_6H_8O_6 + 5O_2$! ! ! ! ! ! ! ! ! CO_2 + H_2O

BIODEGRADABLE BALANCING (cont.)

14. Vitamin D_2

Microorganisms

$2C_{28}H_{43}OH + 77O_2$! ! ! ! ! ! ! ! ! CO_2 + H_2O

15. Tocopherol (Vitamin E)

Microorganisms

$2C_{29}H_{50}O_2 + 81O_2$! ! ! ! ! ! ! ! ! CO_2 + H_2O

16. Riboflavin (Vitamin B_2)

Microorganisms

$C_{17}H_{20}N_4O_6 + 19O_2$! ! ! ! ! ! ! ! ! $CO_2 + H_2O + N_2$

17. Alanine (a constituent of most proteins)

Microorganisms

$4C_3H_4NH_2O_2H + 15O_2$! ! ! ! ! ! ! ! ! $CO_2 + H_2O +$
N_2

18. Stearic Acid (soap)

Microorganisms

$C_{17}H_{35}COOH + 26O_2$! ! ! ! ! ! ! ! ! CO_2 + H_2O

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

Microorganisms
$C_2H_5OH + 3O_2$! ! ! ! ! ! ! ! ! CO_2 + H_2O

20. Starch

Microorganisms
$(C_6H_{10}O_5)n + 6O_2$! ! ! ! ! ! ! ! ! CO_2 +
H_2O

where n = 1

BIODEGRADABLE BALANCING
Teacher Answer Key

1. Acetic Acid (vinegar)

Microorganisms
$CH_3COOH + 2O_2$! ! ! ! ! ! ! ! ! $2CO_2 + 2H_2O$

2. Acetone (nail polish remover)

Microorganisms
$CH_3COCH_3 + 4O_2$! ! ! ! ! ! ! ! ! $3CO_2 + 3H_2O$

3. Citric Acid (orange juice)

Microorganisms
$2C_6H_8O_7 + 9O_2$! ! ! ! ! ! ! ! ! $12CO_2 + 8H_2O$

4. Sucrose (sugar)

Microorganisms
$C_{12}H_{22}O_{11} + 12O_2$! ! ! ! ! ! ! ! ! $12CO_2 + 11H_2O$

5. Benzene (a component of gasoline)

Microorganisms

$2C_6H_6$ + $15O_2$! ! ! ! ! ! ! ! ! $12CO_2$ + $6H_2O$

6. Phenol (present in mouthwash)

Microorganisms

C_6H_5OH + $7O_2$! ! ! ! ! ! ! ! ! $6CO_2$ + $3H_2O$

7. Naphthalene (mothballs)

Microorganisms

$C_{10}H_8$ + $12O_2$! ! ! ! ! ! ! ! ! $10CO_2$ + $4H_2O$

Teacher Sheet

BIODEGRADABLE BALANCING (cont.)
Teacher Answer Key

8. Uric Acid

Microorganisms

$2C_5H_4N_4O_3$ + $9O_2$! ! ! ! ! ! ! ! ! $10CO_2$ + $4H_2O$ + $4N_2$

9. Caffeine

Microorganisms

$2C_8H_{10}N_4O_2$ + $19O_2$! ! ! ! ! ! ! ! ! $16CO_2$ + $10H_2O$ + $4N_2$

10. Acetylsalicylic Acid (aspirin)

Microorganisms

$CH_3COOC_6H_4COOH$ + $9O_2$! ! ! ! ! ! ! ! ! $9CO_2$ + $4H_2O$

11. Vitamin A

Microorganisms

$C_{20}H_{29}OH + 27O_2$! ! ! ! ! ! ! ! ! $20CO_2 + 15H_2O$

12. Vitamin B_1 (thiamine)

Microorganisms

$2C_{12}H_{17}N_4SOC1 + 31O_2$! ! ! ! ! ! ! $24CO_2 + 16H_2O + 4N_2 + S_2 +$
$2HCl$

13. Ascorbic Acid (Vitamin C)

Microorganisms

$C_6H_8O_6 + 5O_2$! ! ! ! ! ! ! ! ! $6CO_2 + 4H_2O$

14. Vitamin D_2

Microorganisms

$2C_{28}H_{43}OH + 77O_2$! ! ! ! ! ! ! ! ! $56CO_2 + 44H_2O$

BIODEGRADABLE BALANCING (cont.)
Teacher Answer Key

15. Tocopherol (Vitamin E)

Microorganisms

$2C_{29}H_{50}O_2 + 81O_2$! ! ! ! ! ! ! ! ! $58CO_2 + 50H_2O$

16. Riboflavin (Vitamin B_2)

Microorganisms

$C_{17}H_{20}N_4O_6 + 19O_2$! ! ! ! ! ! ! ! ! $17CO_2 + 10H_2O + 2N_2$

17. Alanine (a constituent of most proteins)

Microorganisms

$4C_3H_4NH_2O_2H + 15O_2$! ! ! ! ! ! ! ! ! $12CO_2 + 14H_2O +$
$2N_2$

18. Stearic Acid (soap)

Microorganisms
$C_{17}H_{35}COOH + 26O_2$! ! ! ! ! ! ! ! ! $18CO_2 + 18H_2O$

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

Microorganisms
$C_2H_5OH + 3O_2$! ! ! ! ! ! ! ! ! $2CO_2 + 3H_2O$

20. Starch

Microorganisms
$(C_6H_{10}O_5)n + 6O_2$! ! ! ! ! ! ! ! ! $6CO_2 + 5H_2O$

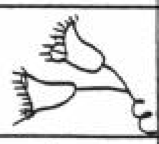
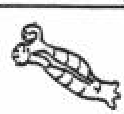
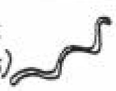
where n = 1

MICROBES IN ACTIVATED SLUDGE

DATE: ____________________ TIME: _______ AM PM

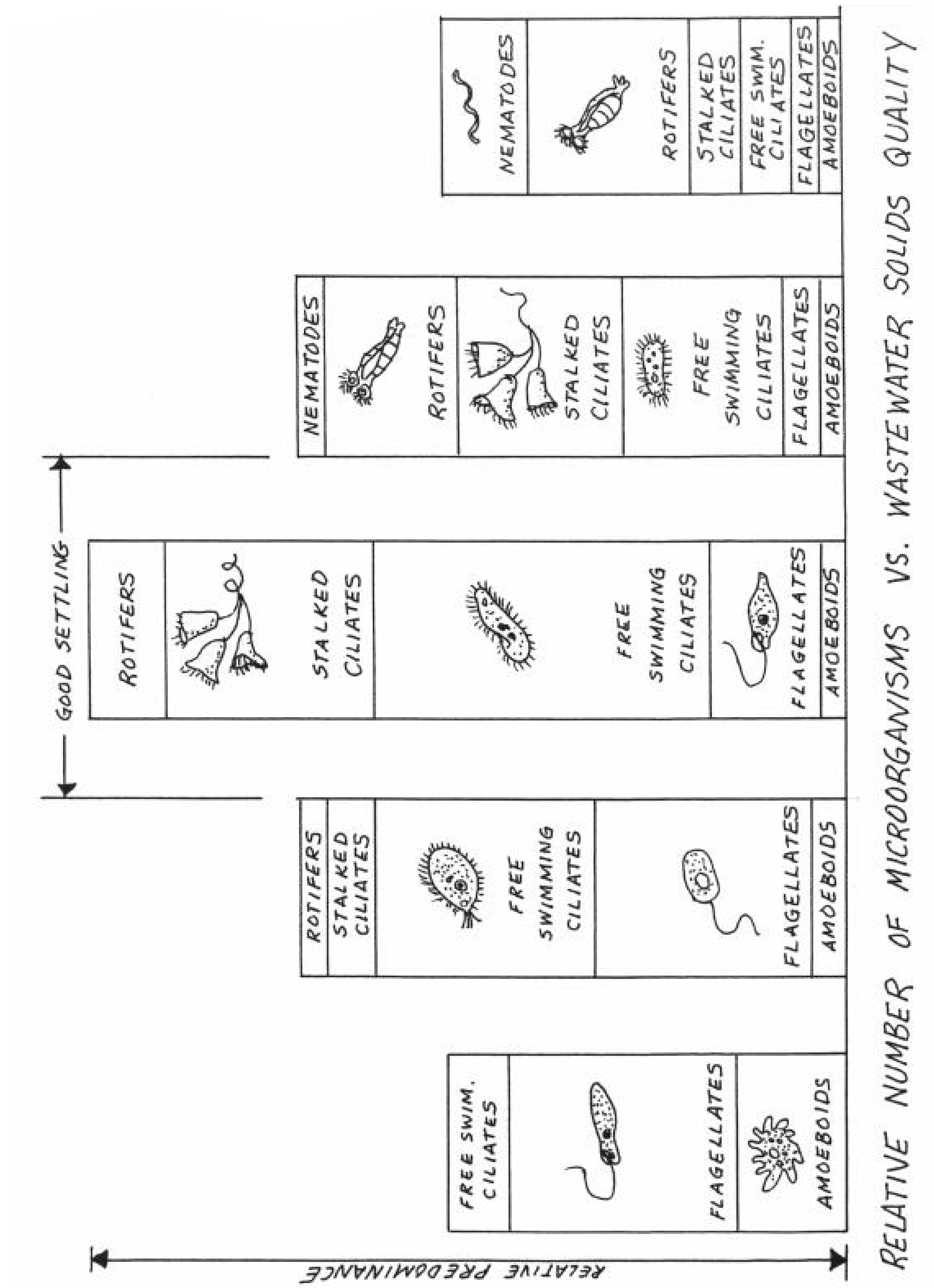
BY: ____________________

SAMPLE LOCATION: ____

MICROBE GROUP	SLIDE 1	SLIDE 2	SLIDE 3	TOTAL
AMOEBOIDS 				
FLAGELLATES 				
FREE SWIMMING CILIATES 				
STALKED CILIATES 				
ROTIFERS 				
NEMATODES (ROUND WORMS) 				

RELATIVE PREDOMINANCE:

1. ____________________
2. ____________________
3. ____________________


RELATIVE NUMBER OF MICROORGANISMS VS. WASTEWATER SOLIDS QUALITY
RELATIVE PREDOMINANCE
GOOD SETTLING
FREE SWIM. CILIATES
FLAGELLATES
AMOEBOIDS
ROTIFERS
STALKED CILIATES
FREE SWIMMING CILIATES
FLAGELLATES
AMOEBOIDS
ROTIFERS
STALKED CILIATES
FREE SWIMMING CILIATES
FLAGELLATES
AMOEBOIDS
NEMATODES
ROTIFERS
STALKED CILIATES
FREE SWIMMING CILIATES
FLAGELLATES
AMOEBOIDS
NEMATODES
ROTIFERS
STALKED CILIATES
FREE SWIM. CILIATES
FLAGELLATES
AMOEBOIDS

12 HOME RECYCLING OF GRAYWATER

OBJECTIVES

The student will do the following:

1. Design a home that recycles graywater.

2. Compute the cost effectiveness of reusing graywater.

SUBJECTS:
Science (Physics, Physical Science), Social Studies (Economics)

TIME:
2 class periods

MATERIALS:
large sheets of paper
drafting pencils
calculators
student sheets
water bills for 1 year
resource materials on basic plumbing

BACKGROUND INFORMATION

Home watering of plants and gardens accounts for 65 percent of domestic water use in the southwestern states. Only 35% is actually used inside the home. Of this amount, after the usage, approximately 60 percent ends up as graywater (water not in contact with sewage). A family of three can irrigate 100 square feet of lawn with two inches of graywater a week and not use fresh drinking water.

Sources of graywater are: wastewater from sinks, bathtubs, showers, and the clothes washer (though washer water may be pathogen-containing "blackwater" if laundry includes diapers). Graywater does not come from toilets, but may be used to supply toilets.

Most existing homes would be difficult (but not impossible) to retrofit for graywater reuse, but new homes could be designed to use graywater on the lawn, flowers, or a garden.

<u>Terms</u>

blackwater: domestic wastewater containing human or animal waste or other sources of pathogens

graywater: wastewater from households which does not come into contact with sewage

sewage: waste and wastewater produced by residential, commercial, and light industrial establishments; typically discharged into sewers and sometimes, into septic tanks

ADVANCE PREPARATION

A. Copy Student Sheets

B. Discuss Background Information with students.

PROCEDURE

I. Setting the stage

A. Hand out Student Sheet: Graywater Guidelines.

B. Discuss problems those guidelines may cause in designing a system for home re-cycling of graywater.

II. Activity

A. As a design project, divide the class into teams and have each team design an approach it would follow if building a new home with the intent to reuse all sources of graywater mentioned in the Background Information section. Include necessary collection, piping, and distribution of the water in the design plan, keeping in mind that long term storage of the water would not be desirable, oversaturation of a given use area must be avoided, materials of construction must be considered, nuisance conditions must not be created, and year-round disposal must be accommodated. Cost of the system should be estimated.

B. Students should determine the cost of watering lawns, house plants, and gardens at their homes before designing the graywater system. (The 65 percent figure could be used to do this, or a difference in July and January water bills could also add some insight.) If sewage treatment is also a cost to the residence, then the student should figure a 60 percent reduction in cost if the graywater is totally recycled or a percent of that if the design recycles less than 100 percent of the water. A total savings cost for one year by reusing graywater should be computed. How long will it take to pay for the cost of construction of a graywater reuse home?

Real cost-benefit analysis would consider how much money would be made assuming a certain % rate that the construction money would earn if invested instead and subtracting this figure to get the real benefit. Example of project cost $1,000, and earned $100 per year in water costs - pay back would not be 10 years. If we assumed a 6% interest rate, the benefit would be $100-($60 lost interest) or only $40 per year. Thus it would take 25 years to pay for the project.

III. Follow-up

A. Have student groups present their graywater recycling home plan to class.

1. How did they solve the problem of graywater storage, pumping, and overabundance?

2. Did they consider the winter months?

3. What was each student’s total cost savings in a year if his/her residence had the system designed for graywater use?

B. Give students copy of Student Sheet: A Graywater System. How do they think their design compared to this one?

C. Have students figure the average amount of water used each time someone showers or takes a tub bath, runs a dishwasher or washing machine, brushes teeth or washes hands. Figure this amount used for one week. Compare to how much of this amount would be needed for watering lawns, and flowers. (Make sure the design has the capability of sending water through the usual municipal water system when graywater is not needed so extensively - as in winter, long periods of rain, etc.)

IV. Extensions

A. Have a wastewater engineer speak to the class about graywater use.

B. Visit a residence or business that recycles graywater. Before the trip, have students make a list of questions about cost savings and problems to ask the owners.

RESOURCES

Kourik, R., Hill, A., Gray Water Use in the Landscape: How to Use Gray Water to Save Your Landscape During Droughts, Metamorphic Press, P. O. Box 1841, Santa Rosa, CA 95402, ed. 1988.

"Recycle Grey Water for Home Irrigation," Water and Wastes Engineering, September 1979, pp. 62-66.

GRAYWATER GUIDELINES

1. Use graywater promptly so that it doesn't accumulate in the storage tank.

2. Apply graywater below the soil surface, never with a sprinkler.

3. Plumb your graywater system with a valve to allow convenient switching back to the sewer or septic tank.

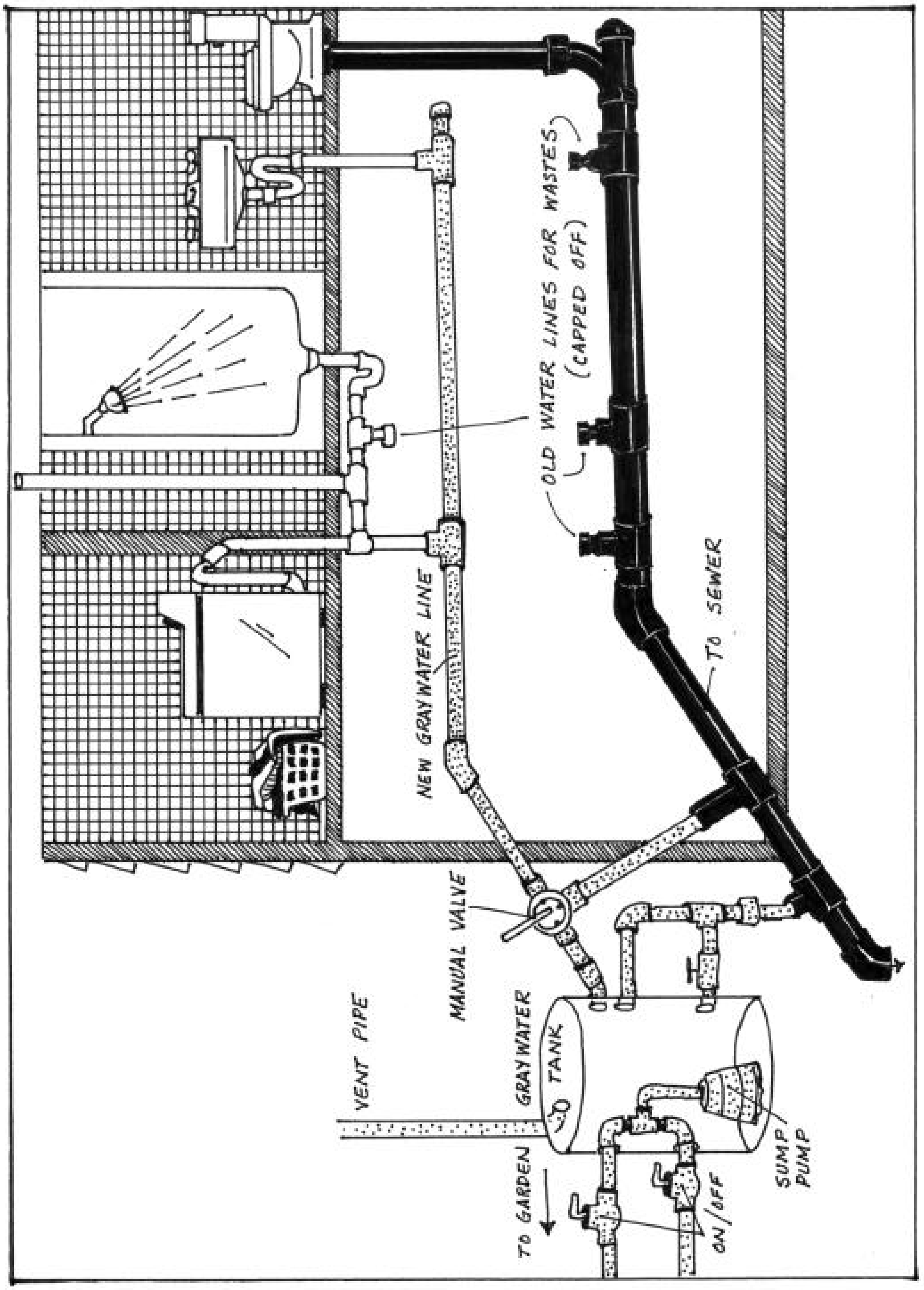
4. Avoid using graywater on acid-loving plants such as blueberry, heather, spruce, pin oak, crape myrtle, lily-of-the-valley, holly, mountain ash, and hemlock.

5. Use liquid detergents instead of powdered kinds because they have much less sodium. Avoid bleach and products that contain boron.

6. If you live where rainfall averages less than 12 inches a year, soak graywater-irrigated soil with six or more inches of clean water every three to five years to wash away accumulated solids.

Student Sheet

A GRAYWATER SYSTEM



9-12

DO SEPTIC TANKS DO THE JOB?

OBJECTIVES

The student will do the following:

1. Investigate a septic tank system and tell the functions of its two major components.

2. Explain how inefficient septic systems can cause contamination of surface waters located nearby.

3. Culture bacteria and practice sterile techniques in the lab.

4. Learn about percolation tests and percometers.

SUBJECTS:
Science (Biology, Ecology)

TIME:
3 days

MATERIALS:
student sheet - article
student sheet - septic tank system
Fecal Coliform Testing Kit
water samples in bottles copies of background information
plastic, sterile, disposable petri dishes
disposable gloves
alcohol for clean up

BACKGROUND INFORMATION

Almost 30 percent of the U.S. population dispose their sewage and wastewater through an on-site disposal system. Some 85 percent of the on-site disposal systems in the U.S. are septic tanks.

A septic tank system contains two major components: a holding tank (the septic tank itself) and the absorption field. See Student Sheet #1. The septic tank separates the solids from the liquids. The solids settle at the bottom of the tank. There is also a scum that collects on top of the water. Both of these will remain in the tank and must be pumped out periodically.

The wastewater is passed on to the absorption field through a connecting pipe. This field is also known as the soil drain field or the nitrification field. It consists of underground perforated pipes that commonly are in a closed loop system.

As the effluent flows through these perforated pipes, human waste (containing fecal coliform bacteria) is filtered out as it passes through the unsaturated soil, percolating downward to the groundwater. To avoid contamination, rural houses with both septic tanks and a private well typically must not have their well within 100 feet of the tank, and well casings must be sealed. This is intended to prevent the well water from being contaminated with fecal coliform bacteria and other harmful microorganisms from the septic system.

People with dwellings along lakes and rivers who have septic systems for their sewer and wastewater disposal must locate the absorption fields and pipelines no closer to the stream or lake than 50 feet, thus providing adequate filtration to remove microorganisms. However, if the ground is too wet or if the soil is too sandy, the distance may not be adequate; microorganisms may filter through to the lake or stream. Because this would contaminate lake or river waters, beaches in both public and private recreational areas should be closely monitored.

Prior to septic tank installation, percolation tests are run to determine how well the absorption field will work, and how quickly wastewater will move through it. A percometer is used to measure the infiltration rate of water through the soils where the septic tank is to be installed.

Terms

absorption field (drainfield): area where effluent from a septic tank is discharged

fecal coliform bacteria: a type of coliform bacteria found in the intestines of humans and warm-blooded animals that aids in the digestion process and is used as an indicator of fecal contamination and/or possible presence of pathogens

percolation: the downward movement through the subsurface soil layers to groundwater

percometer: an instrument to measure the rate of percolation

septic system: on-site equipment or system to treat wastewater, consisting of a septic tank and an absorption field

septic tank: a tank, commonly buried, to which all of the wastewaters from the home should flow and in which, primary digestion of the organic matter occurs by anaerobic bacteria; the main part of a septic system where scum and solids accumulate; derived from sepsis-meaning putrid decay or decay without oxygen.

ADVANCE PREPARATION

A. Order a Fecal Coliform Testing Kit.

B. Find sources of water (streams or lakes) that are close to homes using septic tank systems.

C. Have the students collect bottles of water from the designated areas. Be certain that the water is collected in clean bottles, and that it is then stored in the refrigerator until used as the source of bacteria-containing water. They should also collect some water from close to the shoreline but upstream from the possible contamination. This will let them know if the lake or stream already had a fecal coliform population independent of the suspected source.

D. Be certain that the students know the sterile procedures to be used when culturing bacteria.

PROCEDURE

I. Setting the stage

A. Explain the following to students.

1. Beaches may be closed if fecal coliform bacteria in sufficient numbers are found there.

2. A high fecal coliform count indicates that the water had been contaminated by human or animal wastes.

3. Basins of native plants may filter out the bacteria.

4. A high fecal coliform count may indicate human or other animal wastes. However, there is no reliable means known to determine the source of fecal coliform bacteria.

5. It would be safer, cheaper, and less trouble never to let the bacteria reach a high level in the stream or lake to begin with.

B. Explain to the students that whenever bacteria are cultured, there are sterile procedures that must be followed.

1. Work surfaces should always be washed down with a dilute bleach solution.

2. Hands should always be washed before and after working with the bacteria, and gloves should be worn during testing.

3. A minimum amount of talking and movement should be permitted in the room. No dust should be stirred up by talking or movement.

4. Petri dishes should be opened only when the agar or gel is to be poured and when the gel is swabbed with the water from the lake or stream.

5. The top of the petri dish should never be placed face-down on the counter.

C. Learn how to grow the indicator fecal coliform bacteria. Follow the instructions in the kit.

II. Activity

A. Explain to the students that inadequate septic tank systems along a stream or lake shoreline can contaminate the water with bacteria.

B. Ask for volunteers to bring in bottles of water from designated areas to be tested for fecal coliform bacteria.

C. Inoculate the gels with the water from the designated areas.

D. Incubate the cultures for the specified time; then look for fecal coliform growth on the gels.

E. Determine if the fecal coliform count reaches the action level. For swimming there should be no more than 200 fecal coliform/100 ml of water.

III. Follow-up

A. If the fecal coliform level is not within the safety level, inform the proper authorities.

B. Have the students label a diagram of a septic system and explain the functions of the two parts of the system. Tell them to write the functions under the labeled picture.

IV. Extensions

A. Collect a bottle of water from the water around the boats in a marina. Test this water for fecal coliform bacteria.

B. If any students have a septic system, have them bring in water samples from any wells or streams nearby (if applicable) for fecal coliform testing.

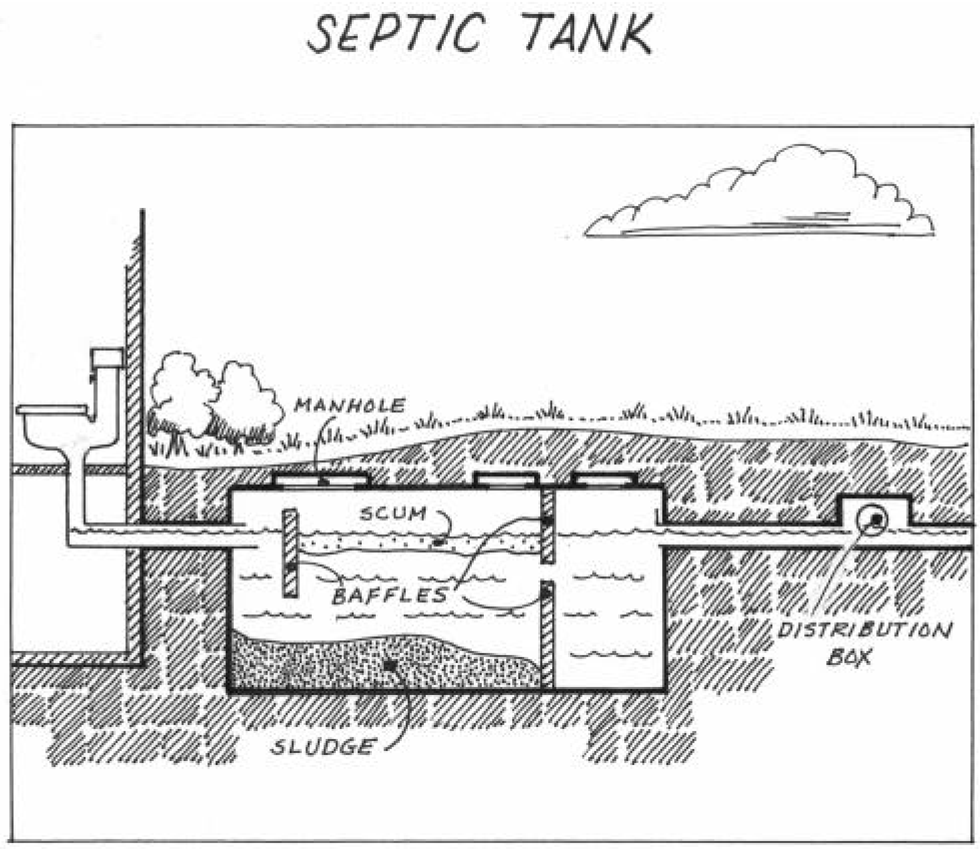
RESOURCES

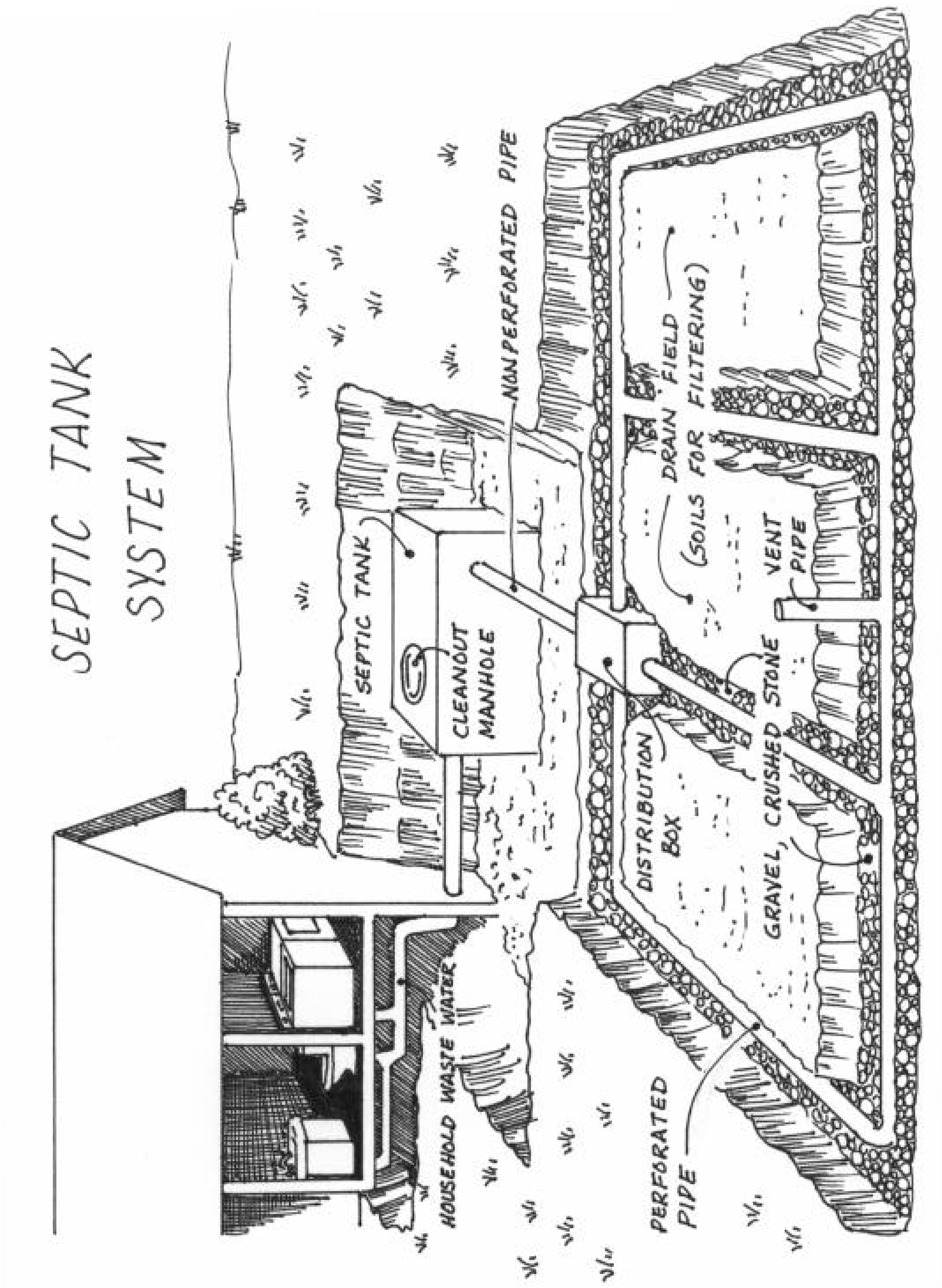
National Small Flows Clearinghouse, West Virginia University, Morgantown, WV 26506-6064, 800-624-8301.

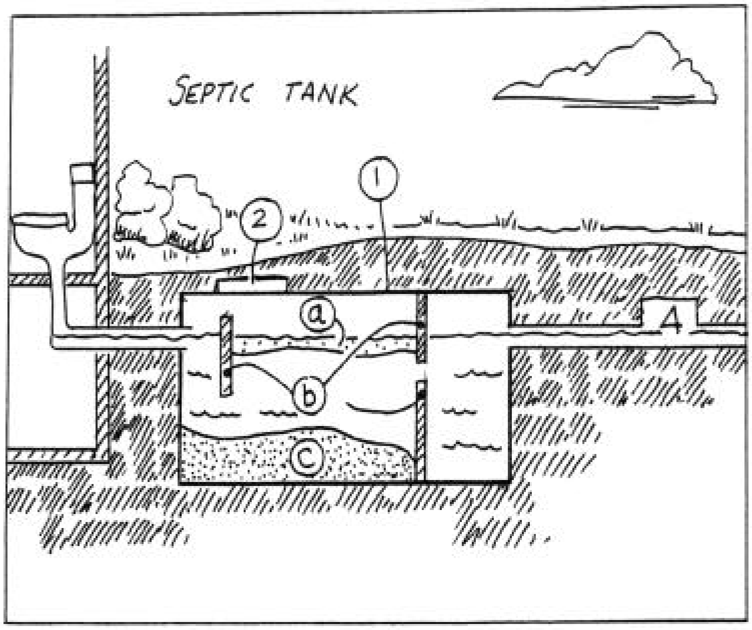
Refer to an article in the Los Angeles Times about beaches closed with health warnings.
Headline: Southland Leads U.S. in Beach Closings, Warnings.
Date: August 4, 1994, **Page:** A-3, **Edition:** Orange County Edition
Author: Marla Cone, Times Environmental Writer

Vesilind, Peirce, and Weiner, Environmental Pollution and Control, 3rd Edition, Butterworth-Heinemann, 1990.

Water Analysis Kit, page F-69, Water Testing Fact Sheet


SEPTIC TANK
MANHOLE
SCUM
BAFFLES
SLUDGE
DISTRIBUTION BOX


SEPTIC TANK SYSTEM
SEPTIC TANK
CLEANOUT MANHOLE
NONPERFORATED PIPE
DRAIN FIELD
(SOILS FOR FILTERING)
VENT PIPE
GRAVEL, CRUSHED STONE
DISTRIBUTION BOX
PERFORATED PIPE
HOUSEHOLD WASTE WATER



1. ______________________
   a. ______________________
   b. ______________________
   c. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
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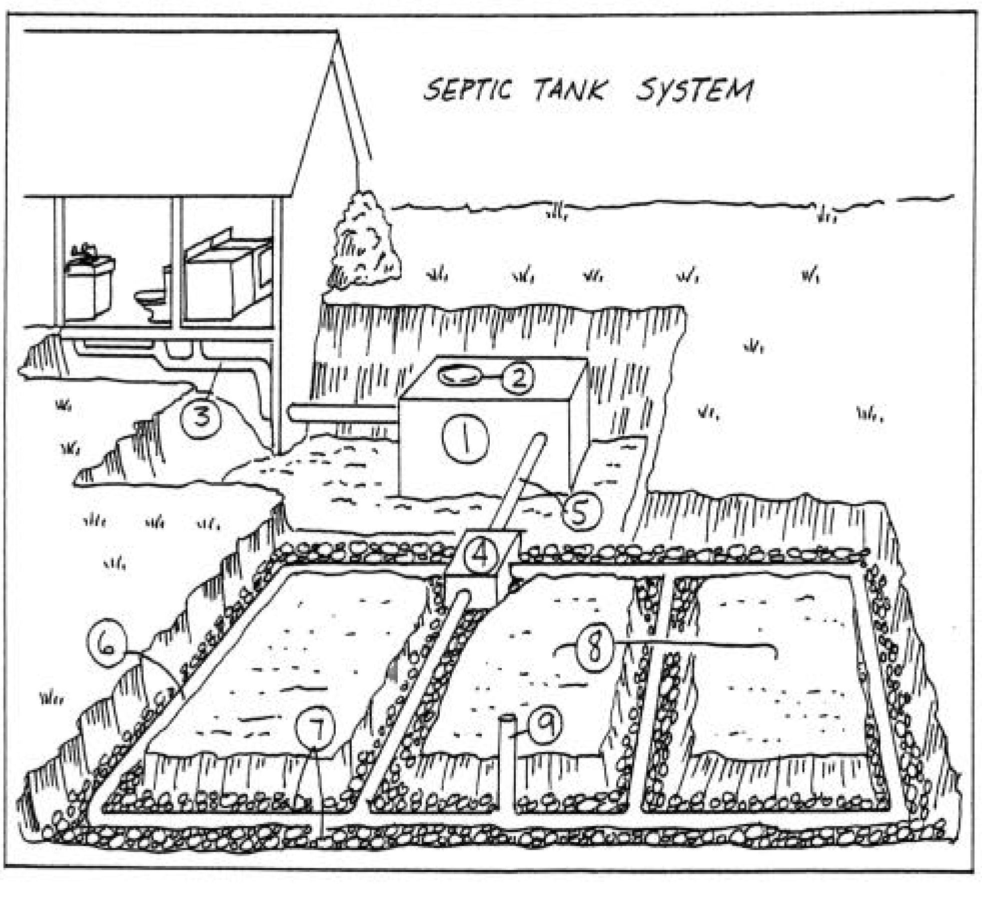
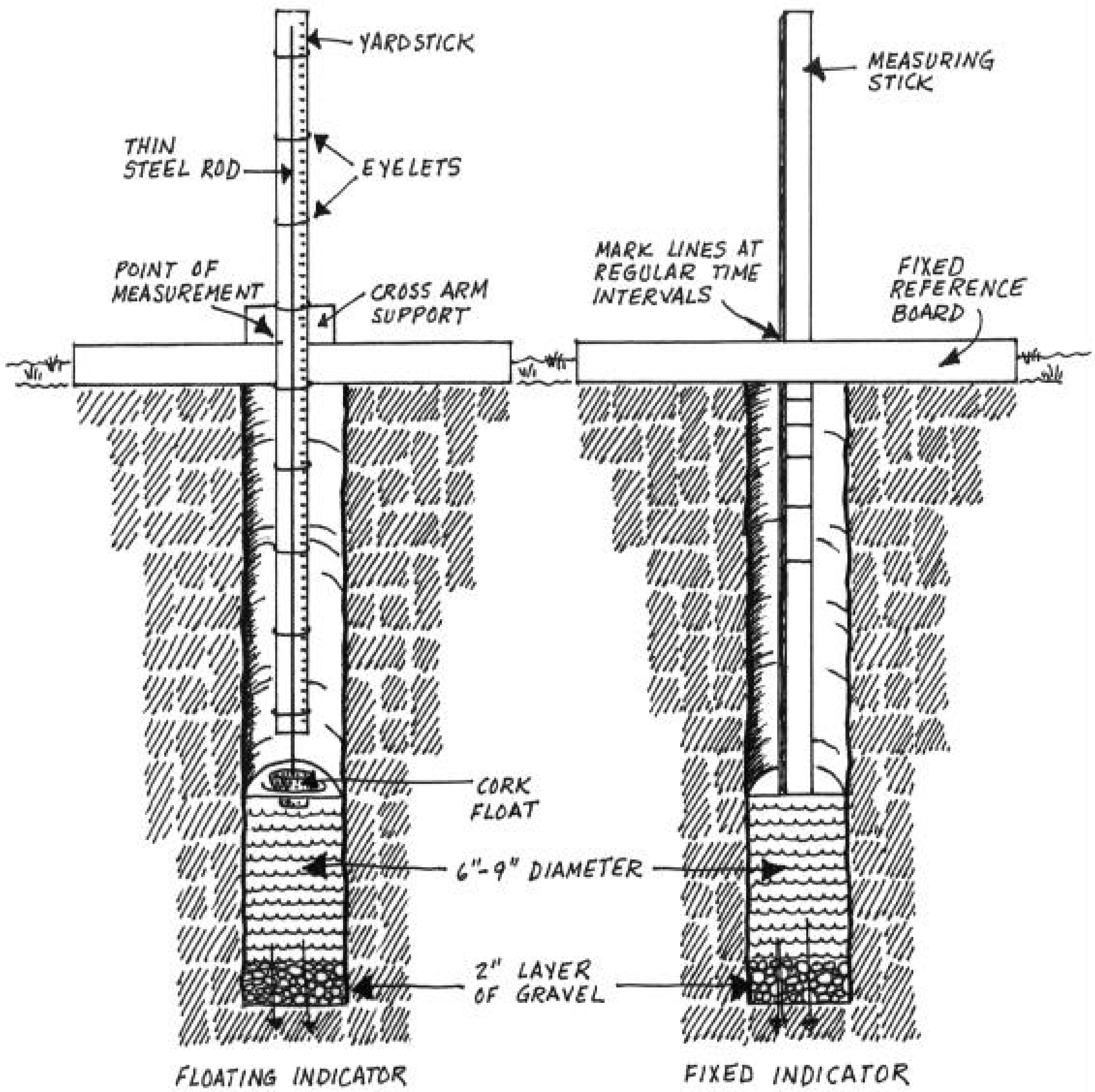
9. ______________________

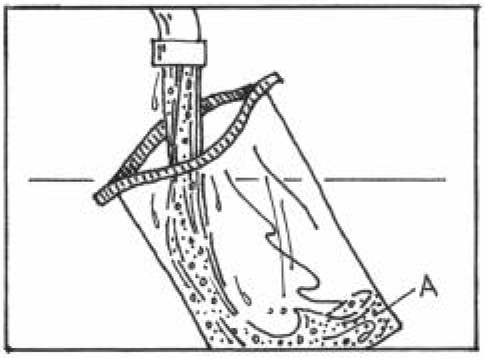


PERCOMETERS

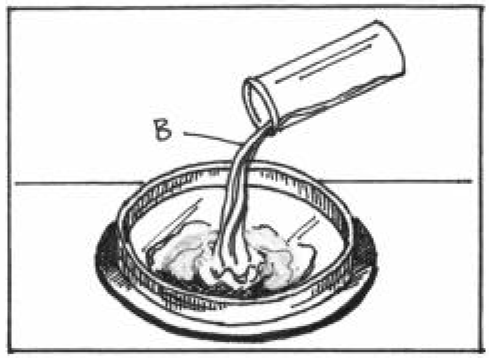


PREPARE HOLE AND PERCOMETER. FILL HOLE WITH WATER. MEASURE TO DETERMINE RATE AT WHICH WATER PERCOLATES OUT OF THE HOLE AS IT SEEPS THROUGH SOILS.

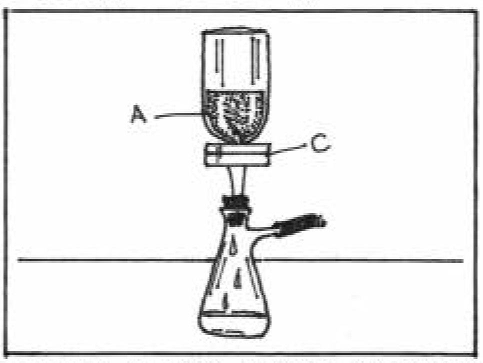
MEMBRANE FILTRATION TEST FOR BACTERIAL CONTAMINATION OF WATER



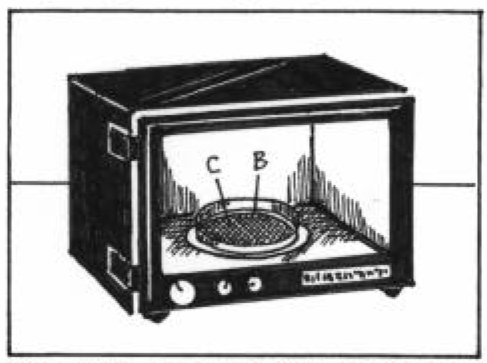
COLLECT SAMPLE (A).
DILUTE, IF NECESSARY, WITH WATER.



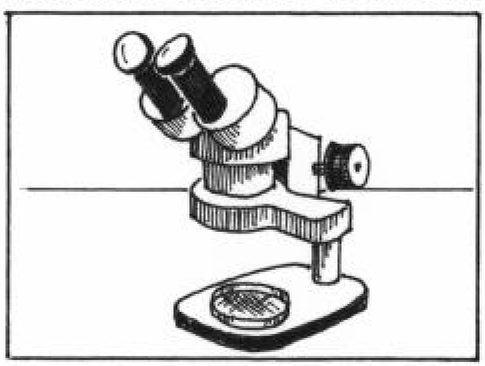
MIX MEDIUM (B).
ADD MEDIUM TO PETRI DISH.



VACUUM-FILTER SAMPLE (A) THROUGH MEMBRANE FILTER (C). RINSE FILTER.

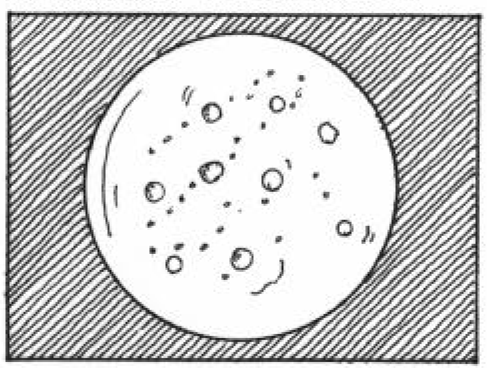


INCUBATE FILTER (C) ON MEDIUM (B) IN PETRI DISH AS INSTRUCTED.



COUNT TYPICAL COLONIES AT 10-15X MAGNIFICATION.

(OR)



CONFIRM COLONIES AND REPORT THE RESULTS.

LAND APPLICATION OF WASTEWATER SOLIDS

9-12

OBJECTIVES

The student will do the following:

1. Distinguish between raw/untreated and digested wastewater solids.

2. Determine if land application of wastewater solids is beneficial to increased plant productivity.

3. Describe problems with land application.

SUBJECTS:
Science (Biology, Ecology, Earth Science)

TIME:
Varies

MATERIALS:
different types of wastewater solids (as available)
bedding trays (approx. 10"x17")
local soil
fescue (grass) seed

BACKGROUND INFORMATION

Wastewater treatment processes generate several treatment by-products, some useful and some that must be landfilled or disposed of properly.

The recycling of wastewater solids (biosolids) by land application is becoming a widespread practice. Populated states are exporting municipal biosolids to less populated, agrarian states for incorporation into soil, usually on agricultural or pasture land.

At a municipal wastewater plant, collected solids originate from two main sources: the primary clarifier that removes easily settled solids and grit, and the secondary clarifier that removes biological microorganisms.

Solids from both sources generally are then directed to further treatment or to a "digestion" process that may be anaerobic or aerobic, depending on the treatment plant. From the digesters, the solid material is usually dewatered using either sand drying beds, a mechanical dewatering process, or other method for water removal. The finished product is then stabilized and ready for recycling or disposal.

Depending on the level of pathogen treatment reduction achieved: some cities and towns offer or sell composted wastewater solids to the public for yard and landscaping use, and some apply the solids on large tracts of land with site restrictions (e.g., public access).

Land application of wastewater solids may be accomplished in several ways: in liquid form on the ground surface, in liquid form by subsurface injection, or in spraying from fixed or portable irrigation nozzles. It also may be applied dry from a spreader vehicle followed by disk cultivation into soil.

Before wastewater solids can be recycled, they must comply with federal regulations governing quality and composition. Some states also require compliance with state, as well as federal regulations. Federal regulations require strict attention to pollutant limits, as well as the management and operational standards that safeguard health and the environment.

Crops preferred for land application are non-food chains such as cotton, grass, flower bed, or grain. Crops grown for animal feed or human consumption are regulated by strict federal regulations.

The nutrient "fertilizer" value of wastewater solids is not as high as chemical fertilizers. However, because of its high organic content (microorganisms) and low cost, biosolids have value as a soil amendment as well as a fertilizer. Primarily they improve soil moisture retention and are good for topsoil replacement. In this respect, they are much better than chemical fertilizers.

With growing populations, tighter management requirements, and higher wastewater treatment levels, wastewater solids production will only increase. It is important that ecologically sound, uniform, and practical management practices be used.

Terms

aerobic: with oxygen; needing oxygen for cellular respiration

anaerobic: in the absence of oxygen; able to live and grow where there is no air or free oxygen, as certain bacteria

biosolids: sludge that is intended for beneficial use. Biosolids must meet certain government-specified criteria depending on its use (e.g., fertilizer or soil amendment).

clarifier (settling tank or sedimentation tank): a vessel in which solids settle out of water by gravity during drinking water or wastewater treatment processes

digested solids: sewage solids that have been broken down by microorganisms

raw/untreated solids: settleable solids, grit, and other solid material removed by the primary clarifier (not treated by microorganisms)

ADVANCE PREPARATION

A. Obtain a water analysis kit that tests for minerals and nutrients. (See page F-69, Water Testing Fact Sheet).

B. Visit the local wastewater treatment plant and/or purchase from garden shops samples of well stabilized, digested wastewater solids. (**CAUTION: DO NOT** collect raw, partial, or undigested biosolids) Examples are:

1. well digested solids that have been dried on sand beds.

2. composted solids.

3. lime treated solids (dewatered).

4. chemically treated solids (dewatered from water or wastewater treatment plants).

C. Copy the Student Sheet. Copy the Teacher Sheet.

PROCEDURE

I. Setting the stage

A. Go over Background Information and terms with students.

B. Divide students into work groups to test the different solids and monitor fescue growth.

II. Activity

The purpose of this activity is to test for germination and growth rate of a grass (fescue) from seed in various well-stabilized dry solids.

A. Use the water analysis kit to test the different types of solids for the presence of these minerals and nutrients, nitrates (NO_3^-) or total nitrogen (N), phosphorus (P), potassium (K), silica (SiO_2), iron (Fe (I)), and for pH. If a test kit is not available, allow students to use the Teacher Sheet information to complete the data table.

B. Use bedding trays (approx. 10" x 17") as needed for types of solids available.

1. Make one tray (control) using local 100% soil.

2. Mix equal volumes of soil/solids in each tray. (Use protective wear and mix with garden tools.)

3. Plant equal amount of seeds in each tray, covering seed as specified by seed manufacturer.

4. Water routinely and monitor the day to germination time and follow growth rate for 4-6 weeks.

Note: If different types of solids are limited, do the experiment with various ratios of soil to solids along with the control.

III. Extensions

For centuries, the Chinese have returned their domestic wastewater and household wastes to the soil. What can the United States learn from this practice? How does the Chinese practice compare from an environmental perspective to U.S. practices of sludge incineration, ocean disposal, landfill disposal, and/or shipping to other states or countries for disposal?

RESOURCES

Davis, Barbara, Science in Motion - Chemistry, University of Alabama, Tuscaloosa, AL

Hairston, James E., Water Quality and Pollution Control Handbook, Alabama Cooperative Extension Service, Auburn University, Auburn, AL 36849-5612.

Metcalf and Eddy, Wastewater Engineering: Collection, Treatment, Disposal, McGraw Hill Inc., New York, NY, 1972, pp. 585-586, 627-628.

Viessman, Warren Jr. and Mark J. Hammer, Water Supply and Pollution Control, Harper Collins Publishers, New York, NY, 1985. pp. 645-647.

Water Analysis Kit, page F-69, Water Testing Fact Sheet

WHAT'S LEFT OVER

Minerals Tested For in Wastewater Solids	**Mineral Present** (yes/no)	**Its Usefulness or Not** (Explain Why)
Nitrate/Total Nitrogen		
Phosphorus		
Potassium (potash)		
Iron		
Silica		

pH = ____

1. Identify the useful materials present in the biosolids and discuss their uses.
2. What are some by-products of wastewater treatment that may not be useful as fertilizers?
3. What are some by-products of wastewater treatment that may not be useful as soil amendment ingredients?

TYPICAL PHYSICAL AND CHEMICAL COMPOSITION OF RAW AND DIGESTED WASTEWATER SOLIDS

Item	Raw/untreated solids		Digested solids	
	Range	Typical	Range	Typical
Total dry solids (TS), %	2.0-7.0	4.0	6.0-12.0	10.0
Volatile solids (% of TS)	60 - 80	65	30 - 60	40.0
Grease and fats (Ether soluble, % of TS)	6.0-30.0	.....	5.0-20.0	
Protein (% of TS)	20-30	25	15-20	18
Nitrogen (N, % of TS)	1.5-4.0	2.5	1.6-6.0	3.0
Phosphorus (P_2O_5, % of TS)	0.8-2.8	1.6	1.5-4.0	2.5
Potash (K_2O, % of TS)	0-1.0	0.4	0.0-3.0	1.0
Cellulose (% of TS)	8.0-15.0	10.0	8.0-15.0	10.0
Iron (not as sulfide)	2.0-4.0	2.5	3.0-8.0	4.0
Silica (SiO_2, % of TS)	15.0-20.0	.....	10.0-20.0	
pH	5.0-8.0	6.0	6.5-7.5	7.0
Alkalinity (mg/liter as $CaCO_3$)	500-1,500	600	2,500-3,500	3,000
Organic acids (mg/liter as Hac)	200-2,000	500	100-600	200
Thermal content (Btu/lb)	6,800-10,000	7,600*	2,700-6,800	4,000✞

* Based on 65 percent volatile matter.
✞Based on 40 percent volatile matter.

STORM WATER:
BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION

9-12

OBJECTIVES

The student will do the following:

1. Define storm water runoff.
2. Identify types of pollutants found in storm water.
3. Develop a plan on how to prevent the pollution of storm water at the school bus maintenance shop.
4. Develop a Best Management Practices plan for the maintenance shop.

SUBJECTS:
Science (Physical Science, Earth Science, Ecology)

TIME:
3-4 class periods

MATERIALS:
bus to travel to the school bus maintenance shop (see alternative activity)
notebook
copies of background information for each student

BACKGROUND INFORMATION

EPA has recognized that certain industries are significant polluters of storm water and has developed the storm water program to aid in reducing the pollutants being discharged into receiving streams via storm water. The main source of storm water is from rain or snow. Water travels from streets, parking lots, and building roofs to storm drains that discharge to nearby waterbodies. Communities are mainly responsible for maintaining or managing storm sewers. One way to manage storm runoff is to locate and permit each sewer and to develop a program to oversee and sample these regularly.

The focus of the storm water program is pollution prevention. Federal and state regulations require facilities to develop a pollution prevention plan or a Best Management Practices (BMP) plan. The BMP plan should be designed to reduce pollution at the source before it can cause environmental problems. The BMP plan is like a good housekeeping plan.

BMPs can include schedules of activities, prohibition of practices, maintenance procedures, and management practices to reduce or prevent the pollution of runoff from a site.

There are 5 major phases involved in developing a BMP plan for storm water runoff.

1. Planning & Organization

    a. Name a pollution prevention team.

    b. Review other BMP plans and build on other plans available such as a Spill Prevention Control and Countermeasures (SPCC) plan. The SPCC plan is a plan to help keep petroleum-related products from being discharged into the water.

2. Assessment

    a. Develop a site map.

    b. Inventory and describe exposed materials.

    c. List significant spills and leaks.

    d. Test for non-storm water discharges.

    e. Evaluate monitoring data.

    f. Summarize pollutant sources and risks.

3. BMP Identification Phase

    a. Baseline BMPs

        1. Good Housekeeping

        2. Preventive Maintenance

        3. Visual Inspections

        4. Spill Prevention and Response

        5. Sediment and Erosion Prevention

        6. Traditional Storm Water Management Practices (storm water detention ponds, collection of storm water)

7. Other appropriate BMPs

8. Employee Training

b. Select activity and site-specific BMPs

4. Implementation Phase

a. Implement BMPs.

b. Train employees.

5. Evaluation Monitoring

a. Conduct annual site inspection/BMP evaluation.

b. Conduct record keeping and reporting.

c. Review and revise plan.

<u>Terms</u>

best management practices (BMPs): techniques that are determined to be currently effective, practical means of preventing or reducing pollutants from point or nonpoint sources, in order to protect water quality. BMPs include, but are not limited to: structural and nonstructural controls, operation and maintenance procedures, and other practices. Usually, BMPs are applied as a system of practices rather than as a single practice.

pollutant (water): any substance suspended or dissolved in water which builds up in sufficient quantity to impair water quality

pollution prevention: preventing the creation of pollutants or reducing the amount created at the source of generation, as well as protecting natural resources through conservation or increased efficiency in the use of energy, water, or other materials

runoff: water (originating as precipitation) that flows across surfaces rather than soaking in; eventually enters a waterbody; may pick up and carry a variety of pollutants

secondary containment for above-ground fuel storage tanks: spill containment facility that will sufficiently contain 110 percent of the capacity of the largest tank located within the area of management

waters of the state: includes every natural or artificial watercourse, stream, river, wetland, pond, lake, coastal, ground or surface water wholly or partially in the state that is not entirely confined and retained on the property of a single landowner

ADVANCE PREPARATION

A. Reserve a school bus for the field trip.

B. Contact the school bus maintenance shop to set up a field trip and secure cooperation in allowing students to develop a BMP plan for the shop. If the shop already has a plan, secure cooperation for the field trip to evaluate existing plan and/or revise existing plan.

C. Copy Background Information and Student Sheets for each student.

D. Go over terms and define.

PROCEDURE

I. Setting the stage

A. Hand out Background Information and Student Sheets. Student sheets show important steps that can be taken in the community (Municipal Program) or by industries (Industrial Program) to prevent storm water pollution. Student sheets also depict common contributors to storm water pollution.

B. Discuss best management practices.

C. Lead a discussion on how storm water can increase pollution in water bodies.

D. Review the 5 major phases involved in developing a BMP plan.

E. Ask students why it would be important to name a pollution prevention coordinator or team. (Answers: 1. point of contact in an emergency and 2. clearly defines the BMP plan as a part of the coordinator/team job)

F. Explain that many sources of pollutants exist at automotive repair facilities. Some examples are these.

1. fuel

2. engine oil and other lubricants

3. antifreeze

4. refrigerants

5. batteries

6. wash water from the washing of the interior and exterior of buses and other equipment.

7. steam cleaning fluid from the cleaning of engines and other equipment

Explain to students that when it rains at the shop and these types of pollutants come into contact with the rain water, the runoff can become polluted. Ask students about other sources of pollution that might exist at an automobile (bus) repair facility.

II. Activity

A. Take a field trip to school bus maintenance shop.

1. At the shop, identify pollution sources.

2. Is fueling conducted on site? If so, are the fuel tanks above ground or below ground? If they are above ground, do they have secondary containment?

3. Where are used batteries kept?

4. How is used oil managed?

5. Is maintenance conducted on-site?

6. How are used tires managed?

7. If oil, fuel, antifreeze, or other fluids are spilled or leaked, are they cleaned up? If so, how? (Examples: oil dry, kitty litter, sawdust)

8. What types of activities are occurring on-site that might lead to non-storm water discharges? (Examples: washing of buses and the steam cleaning of engines)

9. After identifying pollution sources, ask students to identify methods that can be used to prevent the pollution of storm water runoff at the shop.

B. For homework, have students develop BMPs to use in developing a class BMP plan the following day.

C. On the following day, divide students into work groups to develop a BMP plan for the shop. Combine the work into a class BMP plan.

D. Present the class BMP plan to school bus maintenance shop.

III. Alternative activity

If a field trip is not possible, this activity can be used to show the cumulative pollution effects of storm water runoff.

A. The materials needed are these.

aquarium half filled with water
1 can of cola
1 can of orange soda
1 bag of hamburger buns
1 tube of crackers

B. Sort and distribute among the class members the "contaminants." Make sure no one class member has very much of any single contaminant. Do not let students know that the instructor is putting the same contaminants into the second aquarium.

C. Demonstrate the mess a single pollutant source can make by putting one contaminant into the aquarium. Have the students come one at a time and drop their "little bit" of contaminants into the first aquarium. Discuss how the resulting cumulative impacts of many small sources of pollution are often greater than single sources that are more easily regulated and controlled.

D. Discuss why "discrete" sources (industries and wastewater treatment plants) are more easily regulated and why it is easier for these discharges to be controlled and treated.

IV. Follow-up

A. Visit the maintenance shop in a month to evaluate the BMP plan.

B. Ask the shop manager to evaluate improvements in the BMP plan and to suggest revisions and/or additional improvements to the BMP plan.

V. Extensions

A. Develop other BMP plans for your school (chemistry class chemical disposal, erosion control on school grounds, art class paint disposal).

B. Have a speaker come from the city to explain the city's BMP plans for storm water management.

RESOURCES

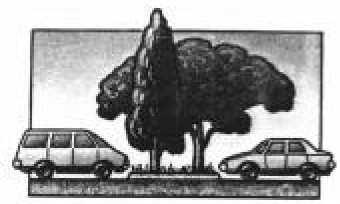
Developing Pollution Prevention Plans and Best Management Practices Plans, EPA Guidance Document 832-R-92-006

Developing Pollution Prevention Plans and Best Management Practices Plans Summary Guidance, EPA Guidance Document 832-R-92-002

When It Rains, It Drains: What Everyone Should Know About Storm Water, EPA Guidance Document 832-F-93-002

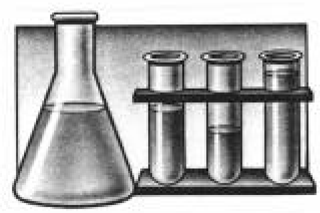
MUNICIPAL PROGRAM

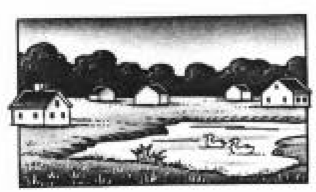
Prevent the release into the storm sewer system of hazardous substances such as used oil or household or yard chemicals.



Make sure new commercial and residential developments include storm water management controls, such as reducing areas of paved surfaces to allow storm water to seep into the ground.

Promote practices such as street sweeping, limiting use of road salt, picking up litter, and disposing of leaves and yard wastes quickly.





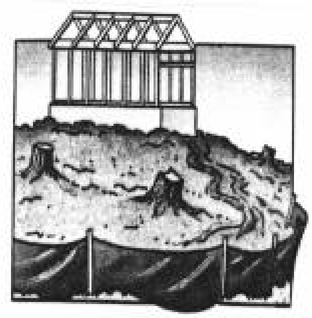
Collect samples of storm water from industrial sites to see whether pollutants are being released. If so, identify the type and quantity of pollutants being released.

Design and institute flood control projects in a way that does not impair water quality.

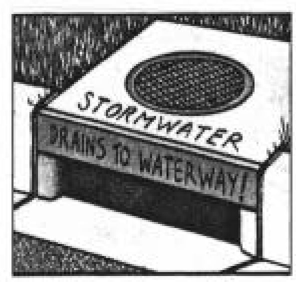
MUNICIPAL PROGRAM

Prevent runoff of excess pesticides, fertilizers, and herbicides by using them properly and efficiently. (Commercial, institutional, and residential landscapes can be designed to prevent pollution, conserve water, and look beautiful at the same time.)

Make sure that construction sites control the amount of soil that is washed off by rain into waterways.

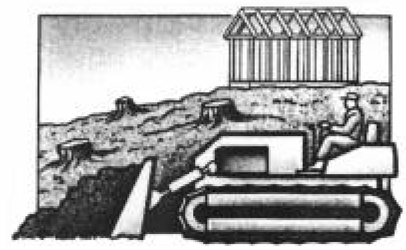


Promote citizen participation and public group activity to increase awareness and education at all levels. Encourage local collection pick-up days and recycling of household hazardous waste materials to prevent their disposal into storm water drains.

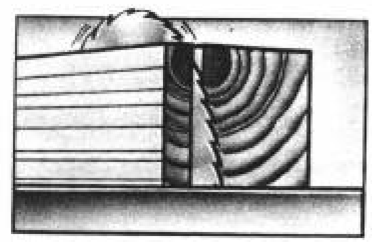


INDUSTRIAL PROGRAM

Owners of construction sites that disturb 5 or more acres must develop a plan before beginning construction. The plan must limit that area of disturbed soil and provide controls--like sediment basins--to keep sediment from running off.

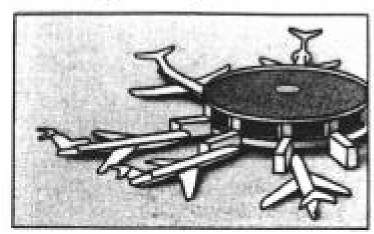


Operators of saw mills can reduce pollution by storing their materials and processing their products indoors; and removing any by-products from outdoor areas before these products come in contact
with storm water runoff.

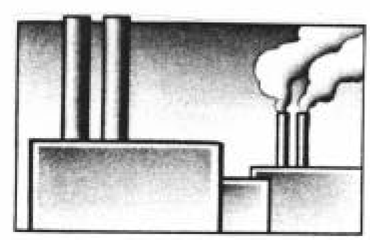


Operators of landfills should keep the storm water runoff from flowing over the pollutants and carrying them off the landfill sites.

Airport employees can reduce storm water runoff pollution by using deicing chemicals only in designated collection areas and by cleaning oil and grease spills from pavement immediately.



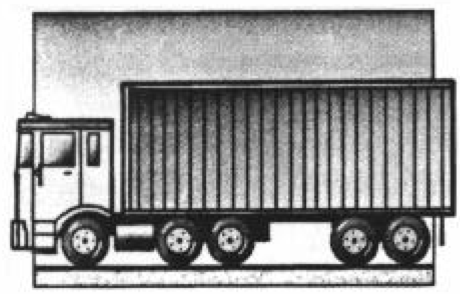
Chemical plant operators should develop spill prevention plans and use types of containers that do not rust or leak, eliminating exposure of materials to storm water runoff.



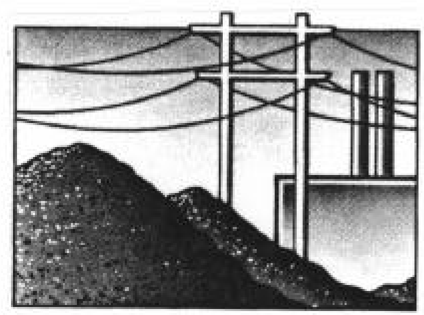
INDUSTRIAL PROGRAM

Owners of automobile junkyards should drain fluids from junked cars and properly dispose of hazardous chemicals.

Operators of trucking terminals should develop good housekeeping practices that clean up leaks and spills of oil and grease from the path of storm water runoff.

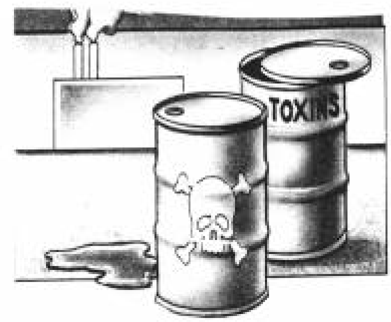


Power plant operators often store piles of coal and other fuels that have toxic components. Runoff from coal piles must be treated; other substances should be stored away from any possible contact with storm water runoff.

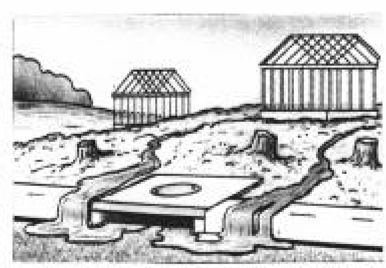


COMMON CONTRIBUTORS TO STORM WATER POLLUTION

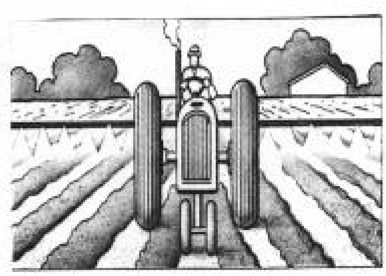
Industry - At industrial sites, chemicals spills that contain toxic substances, smoke stacks that spew emissions, and uncovered or unprotected outdoor storage or waste areas can contribute pollutants to storm water runoff.



Construction - Waste from chemicals and materials used in construction can wash into our waterways during wet weather. Soil that erodes from construction sites can contribute to environmental degradation as well.

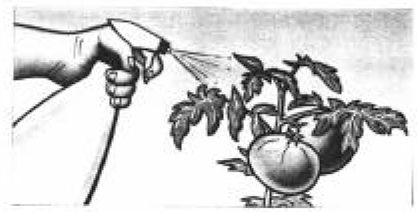


Agriculture - Pesticides, fertilizers, and herbicides used in crop production can be toxic to aquatic life and can contribute to over-enrichment of the water, causing excess algae growth, and oxygen depletion. Although storm water runoff from agriculture areas is not regulated under the EPA storm water permitting program, it is a nonpoint source of storm water pollution addressed by other EPA programs.

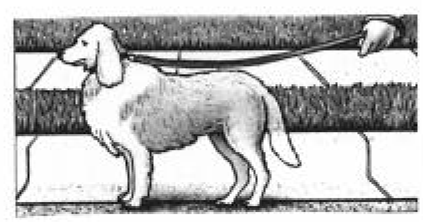


COMMON CONTRIBUTORS TO STORM WATER POLLUTION

Household - vehicles drip fluids (oil, grease, gasoline, antifreeze, brake fluids, etc.) onto paved areas where storm water runoff carries them through our storm drains and into our waterways.



Household - Chemicals used to grow and maintain beautiful lawns and gardens, if not used properly, can run off into the storm drains when it
rains or when we water our lawns and gardens.



Household - Pet wastes left on the ground get carried away by storm water, contributing harmful bacteria, parasites, and viruses to our waterways.