GROUNDWATER: CLEANING UP

9-12

SUBJECTS:	
	Science (Environmental Science, Physical Science, Earth Science), Social Studies (Political Science, Government)
TIME:	
	2-8 class periods
MATERIALS:	
	Box (cardboard or other) Various colors of paint Poster board Thin strips of paper Glue Pencil Narrative material

OBJECTIVES

The student will do the following:

1. Create a model and display board that informs other students and/or the public about different aspects of groundwater contamination that pose a threat to health and human safety.

2. Illustrate some remediation activities that aid in correcting these problems.

BACKGROUND INFORMATION

Groundwater is one of the Earth's most valuable resources. During the late 1970s, the realization of the threats to the nation's groundwater supplies and the implications of those threats became evident to natural resource managers and society as a whole. Publicity about situations such as that encountered at Love Canal triggered both concern and demands for action. Enactments followed, such as the Resource Conservation and Recovery Act (RCRA); Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); and Safe Drinking Water Act (SDWA); forming the major thrust of the federal government's groundwater protection policy.

In July 1991, a new "Groundwater Protection Strategy" was outlined in the final report of the Environmental Protection Agency's Groundwater Task Force. The Task Force was established in 1990 by EPA's Administrator to develop a comprehensive, national approach to addressing groundwater protection concerns. EPA selected a "pilot state" for each region to help outline and refine the process for developing a core groundwater protection program.

Some possible sources of groundwater contamination are listed below.

1. Leaking underground storage tanks (examples: gasoline tanks at service stations)

2. Septic tanks (domestic or commercial wastewater on-site disposal systems)

3. Leaking above-ground storage tanks (ASTs) (examples: bulk fuel terminals, ASTs containing heating fuel)

4. Spills and leaks of solvents, fuels, and other chemicals being transported by rail, truck, or pipeline (example: train derailment)

5. The improper disposal of hazardous chemical wastes into septic tanks, unpermitted injection wells, and unpermitted dumping areas

6. Unpermitted dumps and landfills where solid and hazardous wastes have been disposed without proper engineering and geologic considerations

Once polluted, groundwater must be cleaned up or remediated, if possible. There are several methods of remediation with pluses and minuses described in the following paragraphs.

AIR SPARGING

Engineers have used air sparging since about 1985 to clean contaminated aquifers. In air sparging, wells are used to inject a gas, usually air, beneath contaminated soils or aquifers. The air causes turbulence and groundwater mixing, which increase the rate of soil and water contaminant desorption. Contaminants move into the air phase, and extraction or vacuum wells pull these vapors through the vadose zone to the surface. Air sparging and soil vapor extraction technologies rely on contaminant mass transport and biodegradation. Experienced engineers can design a system to enhance either process. In both cases, oxygen transport is essential for the technology to work. The air sparging system will usually consist of air sparging wells, a soil venting system, vapor monitor probes, groundwater recovery control, and air emissions control. (See Student Sheet Figure 1 for illustration.)

CHEMICAL OXIDATION TECHNOLOGY

Chemical oxidation technology was developed to destroy dissolved organic contaminants (fuels and solvents) in water. The technology uses ultraviolet (UV) radiation and hydrogen peroxide to oxidize organic compounds present in water at parts per million (ppm) levels. This treatment technology produces no air emissions and generates almost no residue, sludge, or spent media that require further processing, handling, or disposal. Ideally, end products are water, carbon dioxide, halides (for example, chloride), and, in some cases, organic acids. The technology uses medium pressure mercury vapor lamps to generate UV radiation. The principal oxidants in the system, hydroxyl radicals, are produced by direct photolysis of hydrogen peroxide at UV wavelengths.

In Figure 2 on the Student Sheet, contaminated water enters the oxidation unit through a section of pipe containing a temperature gauge, a flow meter, an influent sample port, and hydrogen peroxide and acid injection points. Contaminated water is dosed with hydrogen peroxide before the water enters the first reactor. After chemical injections, the contaminated water flows through a static mixer

and enters the oxidation unit. Water then flows through the six UV reactors, which are separated by baffles to direct water flow. Treated water exits the oxidation unit through a pipe equipped with a temperature gauge, an effluent sample port, and a base injection point. Base may be added to the treated water to adjust the pH to meet discharge requirements.

This system is used to treat landfill leachate, groundwater, and industrial wastewater all containing a variety of organic contaminants including chlorinated solvents, pesticides, polynuclear aromatic hydrocarbons, and petroleum hydrocarbons.

IN-SITU BIOREMEDIATION

Advancing technology is allowing scientists to isolate different microbes capable of performing many beneficial functions. Several thousand different kinds of microbes are found naturally in soil; however, only a small percentage of them are capable of breaking down contaminants. Furthermore, not all of these pollution-consuming microbes are capable of quick and effective biodegradation.

Engineers and microbiologists have spent a number of years experimenting with and developing several of the most effective strains of synergistic microorganisms with metabolic pathways capable of degrading a variety of hydrocarbon-based contaminants under either aerobic or anaerobic conditions.

These microbes are naturally occurring and are not genetically engineered. Microbial formulas are made up of a number of different strains of microorganisms that work symbiotically to remove a large variety of contaminants from the surrounding environment. Cultures are resilient to fluctuations in pH, salinity, and temperatures that frequently occur in the field. Microbes have successfully remediated contaminants in temperatures as low as 40 degrees Fahrenheit. Microbes have remediated a variety of contaminants ranging from PCPs, PCBs, DDT, and BTEX chemicals to paint thinners, municipal sewage, chlorinated solvents, and creosote.

Once all of the contaminants have been removed from the site, the microbes become self-consuming, leaving behind organic material that acts as a fertilizer.

Terms

above-ground storage tanks (ASTs): any type of container used above the surface to store products. Regulated ASTs include those containing 660 or more gallons (in one container) or 1320 gallons (in more than one container) of oil of any kind and which pose a potential discharge to surface waters.

air sparging:
injecting air into groundwater to help remove contaminants

bedrock:
the solid rock that underlies all soil, sand, clay, gravel, and loose material on the Earth's surface; the bottom layer

biodegradation:
the breakdown of materials by living things into simpler chemicals

chemical oxidation:
a means of destroying dissolved organic contaminants in water using ultraviolet (UV) radiation, hydrogen peroxide, or other processes

hazardous waste:
waste materials that are dangerous to human health and/or the environment

in-situ bioremediation:
a means of degrading hydrocarbon-based contaminants at the site of contamination

injection well:
a well in which fluids, such as wastewater, saltwater, natural gas, or used chemicals, are injected in the ground for the purpose of disposal or to force

adjacent fluids like oil into the vicinity of oil-producing wells

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.

plume:

an area where a contaminant has spread out

soil venting:

vacuum extraction or soil vapor extraction; a means of reducing concentrations of volatile chemicals in petroleum products absorbed into soils in the unsaturated zone. A vacuum is applied to the soil to create a negative pressure gradient that causes movement of vapors toward extraction wells. The volatile chemicals are then removed through the wells, treated, and discharged into the atmosphere or reinjected to the subsurface.

synergistic:

more than one agent working together to produce enhanced combined effects (i.e., a greater total effect than the sum of the individual effects)

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 (expect heating oil tanks and some motor fuel tanks used for farming or residential purposes)

vadose zone:

the zone of aeration between the Earth's surface and the water table; area of the soil that contains both air and water; same as unsaturated zone--zones between land surface and the water table

ADVANCE PREPARATION

A. Collect or have students bring in all the materials for construction of a groundwater model.

B. Copy and review Background Information.

C. Put terms and definitions on the board.

D. Some organizations loan out working groundwater models. Check with your local extension agency, department of environmental management, or water resources research institute to see if these are available. (See Teacher Sheet.)

PROCEDURE

I. Setting the stage

A. Hand out Background Information and Student Sheets. Discuss with students.

B. Plan a time and place to display the final product of this activity. It may be used for school and/or community display.

C. If a groundwater model can be obtained, use it along with the activities packet provided with the model to demonstrate the hydrogeologic cycle and how the effect of (remediation) pumping and treating a groundwater contaminant plume removes the contaminant that is a threat to health and human safety.

II. Activity

Construct a three-dimensional (box) model of the surface and subsurface of the Earth, showing surface features, soil, bedrock, and groundwater with various sources of contamination present from man-made materials. Label each area on the model with a flag for reference to a written explanation of the area on the display board. (See Student Sheet Figure 3 for drawings.)

<u>Construction of Groundwater Model</u>

1. Draw on sides of box. Trace in soil/bedrock contact and successive geologic beds going downward toward the bottom of the model.

2. Draw line through soil parallel to top of bedrock with a sloping downhill or downgradient slant to represent the water table and its direction of flow.

3. Paint the soil and bedrock earthy colors, and paint the area in the soil below the water table line a blue water color to the top of bedrock.

4. After placing possible sources of contamination on top of the model, paint contamination moving straight down below the source on the side of the model toward the water table.

5. Show contamination entering the water table and flowing in the direction of groundwater flow.

6. Cut and glue thin strips of white paper around areas of the “plume” of contamination to represent monitoring of the vertical and horizontal extent of the plume. To represent remediation of the plume, glue more strips into the plume and show contaminant extraction or destruction through the appropriate technology.

7. On the top of the model representing the ground surface, use toothpicks or pins to locate flags with letters that cross reference the area of concern to a reference letter on the display board so that the area and activity can be described.

III. Extensions

A. Have students research state and federal laws and any local ordinances that protect groundwater.

B. Assemble a display board that informs people in the local community how their groundwater resource is invaluable for human needs and how it is protected.

C. Present material on the display board that informs people in the local community how their groundwater resource is invaluable for human needs and how it is protected.

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.

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

Figure 1

Figure 2

Figure 3

This groundwater model is a very effective tool for demonstrating the hydrogeologic cycle, for showing the effects of well pumping, and for showing how human activities can contaminate groundwater.