Troubled Water

Many people take for granted that a clean, plentiful water supply will always be available. Unfortunately, overconsumption and pollution pose dire threats to this critical life support system. As the world’s population escalates, so does the demand for water. Population growth and economic expansion have caused global withdrawals of fresh water to more than quadruple between 1940 and 1990. Residents of rapidly expanding U.S. states like Florida, Arizona, and California, as well as citizens of other countries, are dealing with the dilemma of strained water resources on a daily basis.

Because many people live in arid regions, we have developed the ability to transport water and satisfy demands for water in many different ways. However, we have not developed adequate methods of ensuring the best and most efficient use of this limited resource. Twenty countries already suffer water shortages extreme enough to impede development and harm human health, and by 2050, the number of people living in water-scarce countries is projected to be between 1 and 2.5 billion people—equal to 13 to 20 percent of the world population. According to the 1996 United Nations Human Development Report, nearly 1.3 billion people in the developing world still lack access to safe water, and efforts to supply it are falling behind population growth rates.

Americans get water from two main sources: the surface water of rivers, lakes, streams and reservoirs, and underground water supplies contained in aquifers. An aquifer is a permeable layer of sand, gravel, or rock where water collects. This groundwater provides drinking water for half the nation. As our demand for water depletes surface water resources, groundwater sources must supply more of the water we use. One example of a strained surface water resource in the United States is the Colorado River. The amount of river water allotted to each state or city by law actually adds up to more water than flows in the river. In China, unsustainable use of groundwater for domestic, industrial and agricultural needs has lowered the water table under Beijing from 5 meters below ground level to around 50 meters.

According to David Seckler, Director General of the International Irrigation Management Institute, slowing down the rate at which the amount of water available per person is decreasing may depend more on stabilizing population than anything else that policymakers can do.

An Unquenchable Thirst

Irrigation and other agricultural practices are responsible for about 69 percent of all water withdrawals on a global scale. In fact, the irrigation of land solely for livestock feed accounts for a major portion of the United States water consumption.

Aside from irrigation, water is used for manufacturing and food processing. Hydroelectric power plants use water to generate electricity. Nuclear power plants and other industries use water for cooling purposes. Water is used countless times each day by individuals for bathing, drinking, washing clothes and dishes, and flushing toilets.

As a nation, we withdraw about 400 billion gallons of water each day for residential, industrial and agricultural purposes. This figure translates into approximately 1,500 gallons per person; only about 150 gallons of this is what we use directly in our households every day. Although per capita water use has stabilized with improved technology and water conservation in recent years, Americans still use more water, both in total and in per capita terms, than any other industrialized country in the world. An average resident of Germany or France, for example, uses about one-third the water of a typical American.

**Muddying the Waters**

Pollution further compounds water shortages. Various human activities and water uses have degraded the nature and quality of the world’s water supply. The health of two-thirds of the world’s population is endangered by the water they drink and use to cook and bathe. Polluted and poisoned by sewage, agricultural runoff and industrial wastes, water flows back into our streams, rivers, lakes and oceans.

In cities of the developing world, some 90 percent of sewage is released untreated into surface water. Frequently these wastes pollute waters used for drinking and irrigation. As urbanization in developing countries increases, more people may be exposed to unsafe drinking water.

There are three main areas of water pollution: Ocean pollution, groundwater contamination and surface water contamination. Comprising 71 percent of the Earth’s surface, the oceans receive most of the world’s wastes. In recent years, unmanaged urban growth, coastal construction, intensive agriculture, offshore oil drilling, mineral extraction, deforestation, boating, overfishing and acid rain have increasingly fouled the seas around us. The industrialized countries of the world now put more tons of trash into the ocean each year than they take out in tons of fish. More than 1,300 major industrial facilities in the United States have federal permits to dump their waste directly into coastal waterways. This waste includes hundreds of chemicals, as well as many persistent toxins.

Another source of ocean pollution is spilled oil. Great attention was brought to this phenomenon when the Exxon Valdez went aground in Alaska’s Prince William Sound in 1989, spilling nearly 11 million gallons of crude oil, soiling more than 700 miles of beach, and killing thousands of birds and marine wildlife. During the 1991 Persian Gulf War, Iraq’s leader, Saddam Hussein, ordered oil spills as a military tactic. The destruction caused by these spills was estimated to be more than a dozen times greater than the Valdez disaster. The United Nations has tried to control the pollution and overexploitation of the oceans through international conferences and global initiatives, but there is still much to be done in cleaning up global waters.

**A Deadly Drink**

Groundwater and surface water contamination is also a grave concern throughout the world. In developing countries, water-borne biological hazards (bacteria, viruses, parasites, etc.) are responsible for high infant mortality rates. Parasites, resulting from water pollution...
or poor sanitation practices, are found in surface waters of many semi-arid countries. Microbiological agents and parasites can be contracted from swimming in polluted waters or from eating contaminated shellfish. This problem is not only found in less developed countries. Popular tourist beaches around the world are dealing with this pollution in varying degrees of intensity.

While water-borne germs are found mostly in less developed countries, developed nations suffer chemical pollution, which has emerged as a serious threat to all countries which have introduced industrialization and chemically-supported agriculture. The most immediate stress on human health is the consumption of contaminated water. Thus far, 800 different organic and inorganic chemicals have been found in drinking water. Some organic contaminants occur naturally, but inorganic constituents of drinking water are usually the result of various industrial solvents discharged from manufacturing plants, small trade sources, and households.

In Milwaukee, Wisconsin, in April of 1993, almost 400,000 people were victims of cryptosporidiosis, a water-borne disease outbreak, as a result of poor water treatment methods. According to the U.S. Environmental Protection Agency (EPA), 80 large water systems throughout the United States have failed to meet regulations for basic filtration.11

When human wastes and pesticide and herbicide runoff wash into surface water sources or oceans, they alter the nutrient and chemical composition of the water, making it more suitable for various kinds of algae. The algae blocks light and, when it decays, uses oxygen needed by fish and other aquatic species to survive. This process, called eutrophication, is very hazardous to aquatic habitats. Although substantial global research has been done on this phenomenon, it is still considered one of the most serious water quality problems and continues to increase in many parts of the world.

Just over half of all Americans are dependent on groundwater, at least in part, as a source of drinking water.12 Any pollutant that comes in contact with the ground may contaminate groundwater. Underground toxic storage tanks, pesticides, toxic waste dumps and septic tanks, and industrial chemicals infiltrate the water supplies. The area of the United States affected by ground water pollution is growing at an accelerating rate.

Though the earth contains vast water resources, only a small part of the water in the hydrosphere is available at any one time for use by people. This figure indicates the world's distribution of water, treating the whole supply as if it were 55 gallons. The primary sources of water for human use are from groundwater, freshwater lakes, and rivers.
Troubled Water

Student Reading

tanks all pose serious threats to groundwater quality. For example, a single gallon of used motor oil which comes into contact with a source of fresh water can render one million gallons of that fresh water undrinkable. More than 65 percent of all water pollutants originate in our homes: the sinks and toilets in American households often become the conduits for caustics and household cleaning products. The oil that drips from our cars and the chemicals washed from our lawns can also enter drains and reach groundwater supplies. These practices comprise a huge source of often unmonitored hazardous wastes.

Staying Above Water

In 1972, deciding that something needed to be done on a federal level concerning contamination of waters, the U.S. Congress passed the Clean Water Act. This was the most comprehensive and expensive environmental legislation in the nation's history. The bill commenced a major change in the country's approach to water pollution control by limiting the contaminated discharges and setting water quality standards. Although great strides have been made in cleaning up the nation's waters, significant levels of water pollution still persist.

Very little has been done on the federal level to address water shortages in much of the western United States. Although water withdrawals are lower than they were in 1980, parts of the country are suffering from a decreasing fresh water supply. For example, the amount of irrigated land in four Great Plains states has decreased due to a drawing down of the Ogallala aquifer.\(^1\) Water crises extend around the globe, especially in areas experiencing growth and increased urbanization, where supplies of clean water are rapidly diminishing.

Every effort should be made to preserve the precious two percent of Earth's waters that we depend on to sustain life. Individuals can aid this effort by using water judiciously and disposing of toxins safely. National governments can encourage cleaner, more plentiful water supplies by strictly regulating industry and agriculture's water use. Because the vast oceans belong to all the world's people, international cooperation is essential for ensuring water quality for present and future generations.

Endnotes


\(^2\) Ibid., p. 302.


\(^4\) Ibid., p. 31.


\(^12\) \textit{National Water Quality Inventory: 1994 Report to Congress}. U.S. Environmental Protection Agency.

Water, Water Everywhere

Student Activity 10

Introduction:
Although 75% of the Earth’s surface is covered with water, only a very small fraction is available for human use. Of the water that is available to us, some becomes contaminated from human actions, such as toxic run-off from agriculture, factories or pollutants that we dump in the water supply from our sinks at home. Population growth over the past 30 years has caused demand for water to double in about half the countries in the world. Residents of states with rapidly growing populations, as well as citizens of other countries, often experience water shortages. In the following activity, students will gain an appreciation for the ways we use water and the need to conserve it.

Procedure:

Part 1:

Set-up:
1. Gather all materials.
2. Fill one small container with sand.
3. Fill a one-liter container with water, add 4 drops of blue food coloring and stir.
4. Label the other 5 containers as follows: a one-liter container “oceans”; a small plastic container “polar ice”; a small container “deep groundwater”; a small container “fresh water.”
5. Make a transparency of the adjacent diagram.
6. Measure and set aside 34 grams of salt.

Facilitating the Activity:

Perform the following class demonstration to help students visualize the distribution of the Earth’s water resources:
1. Display the seven containers prepared for this activity.
2. Display a transparency of the figure on the right. Use a graduated cylinder to distribute the one liter of water into the five empty containers according to the percentages indicated in the figure. (For example, 97.1 percent of the water on the Earth is found in the oceans. Because one liter contains 1000 milliliters, 97.1 percent of one liter is 971 milliliters. Therefore, pour 971 milliliters into the container marked “oceans.”)
3. After you have filled the empty containers with the appropriate amounts of water, continue with the demonstration as follows:
   a) Add 34 grams of salt to “ocean” container; this will match the salinity of the water sample with the salinity of the earth’s oceans (3.5 percent)
   b) Place the plastic “polar ice” container in the freezer.
   c) Set the “other” container aside. We do not have access to this water.
   d) Pour the “deep ground water” into the container of sand.
   e) Ask the students which of the containers represents fresh water that is readily available for human use. (They should easily see that only the jar marked “freshwater” has the readily available supply.) Initiate a discussion on the limits of fresh water supplies, the problems of population growth and distribution, and the contamination of existing supplies. Only a small part of this fresh water (.003 percent of the Earth’s total water supply) is accessible. The rest is too remote (found in Amazon or Siberian rivers) to locate, too expensive to retrieve or too polluted to use. Hold a plate in front of the class and dramatically drop the usable portion of fresh water onto it. (Represent this portion as one drop of water from an eye dropper.)

Concept:
Although water covers three-quarters of the Earth’s surface, only a small fraction is available for human consumption. As the population grows, water efficiency and conservation become more important.

Objectives:
Students will be able to:
• Understand aspects of a shared natural resource, such as availability and distribution.
• Estimate the amount of resources they use and compare that figure to actual use.
• Design a graph to show current resource use and use after conservation measures have been taken.

Subjects:
Biology, environmental science, math, family life

Skills:
Estimation, graphing, mathematical calculation, observation, research, writing

Method:
Students observe a brief demonstration on the distribution of the world’s water and then calculate how much water they use on a daily basis, both directly and indirectly.

Materials:
7 clear containers (2 one-liter containers, 5 smaller containers, one of which is plastic)
1 plate
Overhead projector
Masking tape
Marking pen
One liter of water
Salt (34 grams)
Sand (approximately 250 ml)
Blue food coloring
1000 ml graduated cylinder
One eye dropper
Graph paper
Calculators (optional)
Copies of Student Worksheet
Freezer

Adapted by permission from the National Science Foundation. The original activity appears in the National Science and Technology Week Activity Guide, 1988, by the National Science Foundation, Washington, DC.
Part 2:
1. Have students record how many gallons of water they think they use individually in an average day. Later, they will compare this estimated daily water use with their calculated daily water use.
2. As a group, have them list all the ways members of their class use water on a day-to-day basis.
3. Using the data in the table, “Domestic Uses of Water,” have them determine their individual water use per day for each activity that the class listed in step 2. They should include their share of general family uses such as dishwasher and clothes washer. Then they can determine their individual total water use per day.
4. Students should compare the individual water use calculated in step 3 with the water use estimated in step 1. Are their calculated figures higher or lower than their estimated figures? Ask students whether they consider themselves typical water users. Have them explain their answers.
5. Students should now draw a bar graph to illustrate how much water is used by their class for each activity. Which activities require the most water? Using the class average, students should also calculate the average use of their town and/or state.

Suggested Answers to Student Worksheet Questions:
1. Water is needed to grow the food and grasses the calf would consume.
2. Student answers will vary.
3. Student answers will vary.
4. Possible answers: purchasing and eating foods which require less water to cultivate (eating lower on the food chain); recycling items to prevent excessive use of water in manufacturing; driving less.
5. Possible answers: take showers instead of baths; don’t let water run while brushing teeth or shaving; fix leaky faucets; install watersaving devices for toilet and shower; water lawn less frequently; run dishwasher and washing machine only when you have full loads.

Follow-up Activities:
1. Have students investigate new household products which conserve water (such as low-flush toilets, new shower heads, timed sprinklers, etc.) Each student or group of students could be responsible for writing up a brief synopsis of the costs and benefits of one or two of these products.

(Note: Free catalogs listing water conservation devices are available from: Eco Source, 610 Wendell Court, Atlanta, GA 30336, 800/864-2737; and Gaia Inc., 1 Mill St., Suite A26, Burlington, VT 05401, 800/456-1177.)

2. Have students read their home water meters daily for a week, at the same time each day, and report back to the class. They can then compare these readings to their estimates of daily water use. They can then read the meter for a second week, in which they implement many of the conservation measures suggested above.

Adapted by permission from Biological Science Curriculum Study. The original activity appears in Biological Science: An Ecological Approach (Kendall/Hunt Publishing Company, 1987, 1992, 1999).
## Domestic Uses of Water

<table>
<thead>
<tr>
<th>Activity</th>
<th>Gallons Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brushing teeth</td>
<td>2-10</td>
</tr>
<tr>
<td>Washing hands</td>
<td>2</td>
</tr>
<tr>
<td>Shaving</td>
<td>20 (2/min.)</td>
</tr>
<tr>
<td>Showering</td>
<td>20-25 (5/min.)</td>
</tr>
<tr>
<td>Tub bathing</td>
<td>25-35</td>
</tr>
<tr>
<td>Flushing toilet</td>
<td>3.5 - 8</td>
</tr>
<tr>
<td>Getting a drink</td>
<td>0.25</td>
</tr>
<tr>
<td>Cooking a meal</td>
<td>5-7</td>
</tr>
<tr>
<td>Washing dishes</td>
<td>30 (8-10/meal)</td>
</tr>
<tr>
<td>Automatic dishwasher</td>
<td>15</td>
</tr>
<tr>
<td>House cleaning</td>
<td>7</td>
</tr>
<tr>
<td>Washing machine</td>
<td>24-50</td>
</tr>
<tr>
<td>Watering lawn</td>
<td>10/min. (102/1000 m³)</td>
</tr>
<tr>
<td>Leaking faucet</td>
<td>25-50/day</td>
</tr>
</tbody>
</table>

(Faucet and toilet leaks in New York City = 757 million gallons/day)

## Indirect Uses of Water

### Agricultural

<table>
<thead>
<tr>
<th>Item</th>
<th>Gallons Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kg corn</td>
<td>374</td>
</tr>
<tr>
<td>1 loaf of bread</td>
<td>150</td>
</tr>
<tr>
<td>1 kg rice</td>
<td>1,232</td>
</tr>
<tr>
<td>1 kg grain-fed beef</td>
<td>1,760</td>
</tr>
<tr>
<td>1 kg cotton</td>
<td>4,400</td>
</tr>
</tbody>
</table>

### Industrial

<table>
<thead>
<tr>
<th>Item</th>
<th>Gallons Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 gallon gasoline</td>
<td>10</td>
</tr>
<tr>
<td>1 kg steel</td>
<td>25</td>
</tr>
<tr>
<td>1 kw electricity</td>
<td>80</td>
</tr>
<tr>
<td>1 kg paper</td>
<td>220</td>
</tr>
<tr>
<td>1 kg synthetic rubber</td>
<td>660</td>
</tr>
<tr>
<td>1 kg aluminum</td>
<td>2,200</td>
</tr>
<tr>
<td>1 car</td>
<td>100,000</td>
</tr>
</tbody>
</table>
1. There are many water uses that are not obvious to most people. Consider, for example, that 1.2 million gallons of water are needed to raise one calf until it is fully grown. Why do you think so much water is needed to raise a calf?

2. Make a list of the ways you use water indirectly, for example, in the production of food you eat or materials you use.

3. Compare your list with the table above, “Indirect Uses of Water.” How many of these uses did you list?

4. How could you reduce your indirect use of water?

5. What could you do to reduce your direct use of water?

6. Is there any evidence that the water supply you use daily is decreasing in size or is being contaminated by pollutants? How could you go about obtaining this information?
**Roll on Mighty River**

**Student Activity 11**

**Introduction:**

The Colorado River runs like a lifeline through some of the most arid regions in the United States and Mexico. This mighty river carries between five and 24 million acre feet of water per year, with an average of 15 million acre feet. (An acre-foot is the amount of water that it would take to submerge an acre of land, which is about the size of a football field, to a depth of one foot.) It touches seven states before reaching Mexico, and its watershed covers one twelfth of the continental United States.

For several centuries, people have used water from the Colorado to transform the landscape of the American West. Water grows not only crops, but also cities in the desert; the Colorado irrigates 3.5 million acres of agricultural land and provides 25 million people, including residents of Denver, Salt Lake City, Las Vegas, Phoenix and Los Angeles. The river runs through six national parks and recreation areas, and both free-flowing and dammed areas provide a variety of opportunities for outdoor recreation. The 11 federal hydroelectric plants on the river use dams to provide power to about three million people.

But these benefits come at a price: all of the states, Mexico and several Native American reservations are allowed to use a portion of the river, and except in the wettest of years, the Colorado dries up about 10 to 20 miles before it reaches its historic mouth at the Gulf of California. Because of dams, native species of fish can’t swim upstream to spawn, and they are crowded out by species introduced because of their appeal to anglers. Reservations may soon be able to lease any excess water they save through conservation measures, which may make water a considerably more expensive commodity for the cities and farms downstream.

**Procedure:**

1. Divide the class into groups of seven to ten students. Some students in each group will form a panel of judges assigned to arbitrate conflicting demands on the Colorado River. (Groups may have two to five judges if numbers are uneven.) Up to five students will represent the various groups competing for water. Have students make nametags to identify their roles. These students are the parties in the arbitration, and their positions are described below:

   a) **Sugar beet farmer in Colorado.** You need water for irrigation to grow your sugar beets. Producing sugar in Colorado is an important farm industry and supports many jobs. Without water for irrigation your farm would be worthless and you would have to move to the city to find work.

   b) **Planner for the Southern Nevada Water Authority (SWNA).** This is the agency that regulates water for southern Nevada, including Las Vegas. You must provide water for a large tourist industry as well as a booming population. At current growth rates, you can meet the water needs of your region until 2015.

   c) **Biologist for the Recovery Implementation Program for endangered native fish.** In 1994, the U.S. Fish and Wildlife Service designated 1,980 miles of the Colorado River as critical habitat for four species of fish under the Endangered Species Act. Your job is to make sure the flow of water through the dams is regulated to sustain fish stocks, which is not the most efficient flow for operating hydroelectric plants and may affect recreation on some sections of the river.

   d) **President of an electric utility company in Los Angeles.** Most of the power you supply to your customers comes from the hydroelectric plants on the Colorado River. With new restrictions on the amount of water that can be used to generate electricity, you may have to purchase power from a more expensive or environmentally damaging source and pass along the new costs to your customers.

   e) **Representative of a Native American tribal government.** You use 80-90% of the water allocated to your reservation, but a new federal government policy may allow you to lease to other users any water you save through new conservation measures. This could bring much-needed income and jobs

**Concept:**

Increasing demands on U.S. water supply and diminishing amounts of unpolluted water cause groups to compete for their “share” of the available supply.

**Objectives:**

- Students will be able to:
  - Research and understand the position of a stakeholder in competition for a natural resource.
  - Present a position on an issue to a panel of peer judges.
  - Design a plan to equitably distribute a resource among several competitors.

**Subjects:**

- Environmental science, social studies

**Skills:**

- Public speaking, debate, library research, decision making, problem solving

**Method:**

By investigating water use along the Colorado River, students get a first-hand look at the complexity and frustration surrounding water use problems in arid and semi-arid regions.

**Materials:**

- Note cards for arguments and questions (optional)
- Poster board for charts and evidence (optional)
Roll on Mighty River

Student Activity 11

to the reservation. Currently, water savings such as this are available for free use by others downstream.

2. Allow the parties time to research their positions in the library and on the Internet. This should take one or two class periods. Advise them of the points they should cover and encourage them to use charts and posters to summarize their positions. The judges will also need to spend time in the library in order to prepare for the trial. They should make a list of questions to ask the different sides during the arbitration, based on their own research. Some good sites to start with are the Water Education Foundation at http://www.water-ed.org and the Southern Nevada Water Authority at http://www.lhwwd.com/snwa.html.

3. When everyone is ready, hold the arbitrations. To avoid distraction, separate the groups as much as possible, ideally in different rooms. During each arbitration, the parties present their cases, using visual aids and note cards when needed, and then answer questions by their panel of judges.

4. After the presentations, the judges need to make decisions and design a plan of action. Each plan should then be presented in front of the class by one of the judges. The plan may include a specific course of action, such as giving more or less water to one of the parties. It could require that the parties conserve water. Or it could recommend technological solutions such as better irrigation equipment or fish elevators. The plan should clearly set priorities for water use in the area, justify these priorities, and indicate how conflicting demands might be met in the future.

Follow-up Activities:

1. As this activity illustrates, short of impractical or extremely expensive methods, it is almost impossible to create more water. The only way to make more water available is to conserve it. There are many ways to save water in students’ everyday lives. For example, they can:
   - take short showers instead of baths;
   - turn the water off when brushing their teeth;
   - wash the car from a bucket rather than letting a hose run;
   - collect rain water to water house plants;
   - replace old showerheads with low flow models;
   - and place plastic bottles of water and rocks in toilet tanks.

Have students come up with their own list of the many possible ways to conserve water. Make a poster listing all of the conservation ideas and hang it in the classroom.

One systematic way to save water is to conduct a water audit of the school or individual homes. Have students work through the water audit in Student Activity 10: Water, Water Everywhere.

2. Find out where the water for your school comes from, and trace its path from the original body of water to its end location after wastewater treatment. Discover other uses of the same water source and identify any scarcity or pollution problems for your water source.
