Water as a Resource

Water Quality

As noted earlier, most of the water in the hydrosphere is in the very salty oceans, and almost all of the remainder is tied up in ice. That leaves relatively little surface or subsurface water for potential freshwater sources. Moreover, much of the water on and in the continents is not strictly fresh. Even rainwater, long the standard for “pure” water, contains dissolved chemicals of various kinds, especially in industrialized areas with substantial air pollution. Once precipitation reaches the ground, it reacts with soil, rock, and organic debris, dissolving still more chemicals naturally, aside from any pollution generated by human activities. Water quality thus must be a consideration when evaluating water supplies.

Measures of Water Quality

Water quality may be described in a variety of ways. A common approach is to express the amount of a dissolved chemical substance present as a concentration in parts per million (ppm) or, for very dilute substances, parts per billion (ppb). For example, if water contains 1 weight percent salt, it contains one gram of salt per hundred grams of water, or one ton of salt per hundred tons of water, or whatever unit one wants to use. Likewise, if the water contains only 1 ppm salt, it contains one gram of salt per million grams of water and so on. For comparison, the most abundant dissolved constituents in seawater can be measured in parts per thousand (magnesium, sulfate) or even percent (sodium, chloride).

Another way to express overall water quality is in terms of *total dissolved solids* (TDS), the sum of the concentrations of all dissolved solid chemicals in the water. How low a level of TDS is required or acceptable varies with the application. Standards might specify a maximum of 500 or 1000 ppm TDS for drinking water; 2000 ppm TDS might be acceptable for watering livestock; industrial applications where water chemistry is important (in pharmaceuticals or textiles, for instance) might need water even purer than normal drinking water.

Yet describing water in terms of total content of dissolved solids does not present the whole picture: At least as important as the quantities of impurities present is *what* those impurities are. If the main dissolved component is calcite (calcium carbonate) from a limestone aquifer, the water may taste fine and be perfectly wholesome with well over 1000 ppm TDS in it. If iron or sulfur is the dissolved substance, even a few parts per million may be enough to make the water taste bad, though it may not be actually unhealthful. Many synthetic chemicals that have leaked into water through improper waste disposal are toxic even at concentrations of 1 ppb or less.

Other parameters also may be relevant in describing water quality. One is pH, which is a measure of the acidity or alkalinity of the water. The pH of water is inversely related to acidity: the lower the pH, the more acid the water. Water that is neither acid nor alkaline has a pH of 7.

For health reasons, concentrations of certain bacteria may also be monitored in drinking-water supplies.

A water-quality concern recently close attention is the presence of naturally occurring radioactive elements that may present a radiation hazard to the water consumer. Uranium, which can be found in most rocks, including those serving commonly as aquifers, decays through a series of steps. Several of the intermediate decay products pose special hazards. One—radium—behaves chemically much like calcium and therefore tends to be concentrated in the body in bones and teeth. Another—radon—is a chemically inert gas but is radioactive itself and decays to other radioactive elements in turn. Radon leaking into indoor air from water supplies contributes to indoor air pollution. High concentrations of radium and/or radon in ground water may result from decay of uranium in the aquifer itself or, in the case of radon, from seepage out of adjacent uranium-rich aquifers, especially shales.

Hard Water

Aside from the issue of health, water quality may be of concern because of the particular ways certain dissolved substances alter water properties. In areas where water supplies have passed through soluble carbonate rocks, like limestone, the water may be described as “hard.” **Hard water** simply contains substantial amounts of dissolved calcium and magnesium. When calcium and magnesium concentrations reach or exceed the range of 80 to 100 ppm, the hardness may become objectionable.

Water Use, Water Supply

Inspection of the U.S. water budget overall would suggest that ample water is available for use. Some 4200 billion gallons of precipitation fall on this country each day; subtracting 2750 billion gallons per day lost to evapotranspiration still leaves a net of 1450 billion gallons per day for stream flow and groundwater recharge. Water-supply problems arise, in part, because the areas of greatest water availability do not always coincide with the areas of concentrated population or greatest demand, and also because a portion of the added fresh water quickly becomes polluted by mixing with impure or contaminated water. People in the United States use a large amount of water. Biologically, humans require about a gallon of water a day per person, or, in the United States, about 300 million gallons per day for the country. Yet, Americans divert, or "withdraw," about 400 *billion* gallons of water each day—about 1350 gallons per person—for cooking, washing, and other household uses, for industrial processes and power generation, and for livestock and irrigation, a wide range of *"offstream"* water uses. Another several trillion gallons of water are used each day to power hydroelectric plants *"instream"* use. Of the total water withdrawn, more than 100 billion gallons per day are *consumed*, meaning that the water is not returned as wastewater. Most of the consumed water is lost to evaporation; some is lost in transport (for example, through piping systems).

Extending the Water Supply

Conservation

The most basic approach to improving the U.S. water-supply situation is conservation. Water is wasted in home use every day—by long showers; inefficient plumbing; insistence on lush, green lawns even in the heat of summer; and in dozens of other ways. Raising livestock for meat requires far more water per pound of protein than growing vegetables for protein.

Still, municipal and rural water uses (excluding irrigation) together account for only about 10% of total U.S. water consumption. The big water drain is irrigation, and that use must be moderated if the depletion rate of water supplies is to be reduced appreciably. For example, the raising of crops that require a great deal of water could be shifted, in some cases at least, to areas where natural rainfall is adequate to support them. Irrigation methods can also be made more efficient so that far less water is lost by evaporation. This can be done, for instance, by drip irrigation. Instead of running irrigation water in open ditches from which evaporation loss is high, the water can be distributed via pipes with tiny holes from which water seeps slowly into the ground at a rate more closely approaching that at which plants use it. The more efficient methods are often considerably more expensive, too. However, they have become more attractive as water prices have been driven up by shortages. As noted in the changes in government water policy could provide incentives to conserve, especially with respect to ground water.

Domestic use can be reduced in a variety of ways. For example, lawns can be watered morning or evening when evaporation is less rapid than at midday; or one can for go traditional lawns altogether in favor of ground covers that don't need watering.

Storm water can be directed into recharge basins rather than dumped into sewer systems. Increasingly, municipalities in dry areas are looking to recycle their wastewater.

Interbasin Water Transfer

In the short term, conservation alone will not resolve the imbalance between demand and supply. New sources of supply are needed. Part of the supply problem, of course, is local. For example, people persist in settling and farming in areas that may not be especially well supplied with fresh water, while other areas with abundant water go undeveloped. If the people cannot be persuaded to be more practical, perhaps the water can be redirected. This is the idea behind interbasin transfers—moving surface waters from one stream system's drainage basin to another's where demand is higher.

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California pioneered the idea with the Los Angeles Aqueduct. The aqueduct was completed in 1913 and carried nearly 150 million gallons of water per day from the eastern slopes of the Sierra Nevada to Los Angeles. In 1958, the system was expanded to bring water from northern California to the southern part of the state. More and larger projects have been undertaken since. Bringing water from the Colorado River to southern coastal California, for example, required the construction of over 300 kilometers (200 miles) of tunnels and canals. Other water projects have transported water over whole mountain ranges. It should be emphasized, too, that such projects are not confined to the drier west: for example, New York City draws on several reservoirs in upstate New York. If population density or other sources of water demand are high, a local supply shortfall can occur even in an area thought of as quite moist. Dozens of inter basin transfers of surface water have been proposed. Political problems are common even when the transfer involves diverting water from one part of a single state to another. In 1982, it was proposed to expand the aqueduct system to carry water from northern California to the south; 60% of the voters in the southern part of the state were in favor, but 90% of those in the north were opposed, and the proposition lost. The opposition often increases when transfers among several states are considered. In the 1990s, officials in states around the Great Lakes objected to a suggestion to divert some lake water to states in the southern and southwestern United States. The problems may be far greater when transfers between nations are involved. Various proposals have been made to transfer water from little-developed areas of Canada to high-demand areas in the United States and Mexico. Such proposals, which could involve transporting water over distances of thousands of kilometers, are not only expensive (one such scheme, the North American Water and Power Alliance, had a projected price of $100 billion), they also presume a continued willingness on the part of other nations to share their water. Sometimes, too, the diversion, in turn, causes problems in the region from which the water is drawn.

Desalination

Another alternative for extending the water supply is to improve the quality of waters not now used, purifying them sufficiently to make them usable. Desalination of seawater, in particular, would allow parched coastal regions to tap the vast ocean reservoirs. Also, some ground waters are not presently used for water supplies because they contain excessive concentrations of dissolved materials. There are two basic methods used to purify water of dissolved minerals: filtration and distillation. In a filtration system, the water is passed through fine filters or membranes to screen out dissolved impurities. An advantage of this method is that it can rapidly filter great quantities of water. A large municipal filtration operation may produce several billion gallons of purified water per day. A disadvantage is that the method works best on water not containing very high levels of dissolved minerals. Pumping anything as salty as seawater through the system quickly clogs the filters. This method, then, is most useful for cleaning up only moderately saline ground waters or lake or stream water.

Distillation involves heating or boiling water full of dissolved minerals. The water vapor driven off is pure water, while the minerals stay behind in what remains of the liquid. Because this is true regardless of how concentrated the dissolved minerals are, the method works fine on seawater as well as on less saline waters.

A difficulty, however, is the nature of the necessary heat source. Furnaces fired by coal, gas, or other fuels can be used, but any fuel may be costly in large quantity, and many conventional fuels are becoming scarce. The sun is an alternative possible heat source. Sunlight is free and inexhaustible, and some solar desalination facilities already exist. Their efficiency is limited by the fact that solar heat is low-intensity heat. If a large quantity of desalinated water is required rapidly, the water to be heated must be spread out shallowly over a large area, or the rate of water output will be slow. A large city might need a solar desalination facility covering thousands of square kilometers to provide adequate water, and construction on such a scale would be expensive even if the space were available. Desalinated water may be five to ten times more costly to deliver than water pumped straight from a stream or aquifer. For most homeowners, the water bill is a relatively minor expense, so a jump in water costs, if necessitated by the use of desalinated water, would not be a great hardship. Water for irrigation, however, must be both plentiful and cheap if the farmer is to compete with others here and abroad who need not irrigate and if the cost of food production is to be held down. Desalinated water in most areas is prohibitively expensive for irrigation use. Unless ways can be found to reduce drastically the cost of desalinated water.

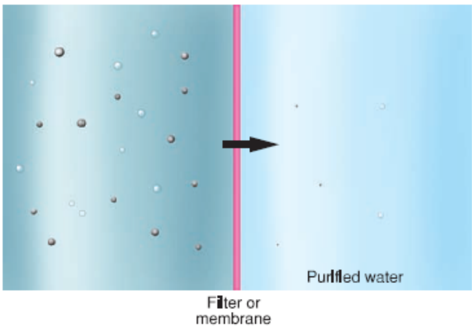

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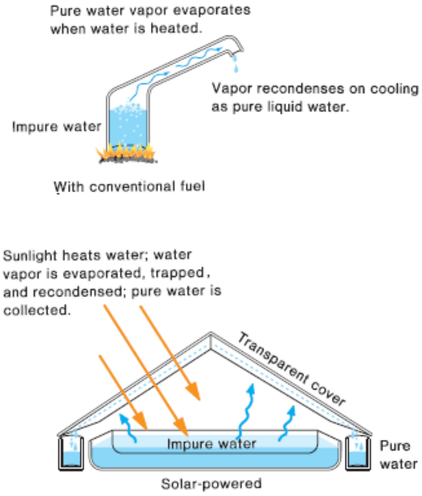
Figure 11.33

Methods of desalination. (A) Filtration (simplified schematic): Dissolved and suspended material (represented by dots at left) is screened out by very fine filters. (B) Distillation: As water is heated, pure water is evaporated, then recondensed for use. Dissolved and suspended materials stay behind.



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Questions for Review

1. Explain three characteristics used to describe water quality.
2. What is *hard water*, and why is it often considered undesirable?
3. Industry is the big water *user*, but agriculture is the big water *consumer*. Explain.
4. Compare and contrast filtration and distillation as desalination methods, noting advantages and drawbacks of each.