The Lincoln Library of Essential Information, The Frontier Press Co., Buffalo, 1966

WATER SUPPLY AND WATER POLLUTION CONTROL

Gilbert V. Levin

WATER SUPPLY

Water, (H_2O), is absolutely essential to all life as we know it. Furthermore, it is so difficult to imagine any kind of life not dependent on water that space biologists consider dry planets to be extremely poor hunting grounds in the search for extraterrestrial life.

The earth has water in abundance. Approximately three-fourths of its surface is covered by water. The water surface would be substantially greater in area if the polar ice caps were to melt. Practically all the water in or on the land surface of the earth cycles through the oceans. Evaporation produces clouds which drift over land and subsequently precipitate as rain or snow. Some of the fallen water percolates into the ground where it slowly flows through aquifers to the sea. The journey may take thousands of years. Most rainfall and melting snow, however, flow into rivers where this runoff from the land quickly finds its way back to the sea. In this process, the soluble salts already in the ocean water and those carried from the land in each new cycle remain and accumulate in the sea. The clouds consist of "fresh" water although the rainwater soon absorbs impurities from the air and the soil upon contact.

The role of water in supporting living matter may be considered as twofold. First, it is the necessary intracellular environment for all life forms. In all biochemical reactions, the participating chemicals must be in aqueous solution. Secondly, the vast majority of living things on earth also require water as their extracellular environment. These organisms range from algae to whales. Without the availability of water, life soon suffers. Living organisms, including man, can survive longer without food than without water. Droughts have rendered nearly barren large areas of the earth that once supported rich vegetation and animal populations.

For mankind, water has numerous uses other than the basic biological ones. Converted into steam, water carried directly the burden of the world's power requirements for over a century prior to the discovery of the electric motor. It continued to be basic to the development of electric power. From earliest times, its solvent properties made it the best cleansing agent and rendered it essential for countless industrial processes upon which the modern world depends. The teeming microorganisms in water assimilate and convert to harmless form sewage and other waste material deposited in it unless the quantity of the waste or its toxicity is overwhelming.

It is estimated that 92 to 98% of the earth's water is economically unusable by man, chiefly because of two reasons: (1) the salt concentration in the ocean and (2) much of the water is "locked up" in ice and snow. Until recently, however, the few percent available appeared sufficient for mankind's use for the near and distant future. But by the midpoint of the 20th century, signs multiplied pointing to a future problem. The world population was growing at an unprecedented rate. The amount of water used per person was increasing at an even greater rate. New industrial uses and increased agricultural uses for irrigation exceeded the rising domestic needs. To compound the problem, people moved to the cities in numbers that changed the entire land use and water use patterns. Now many people required tremendous quantities of water in small geographical areas. The demand was overtaking the supply in these areas. Meanwhile, mounting quantities of industrial waste and sewage discharged in surface waters diminished the supply of usable water. To avert this impending crisis, governments and scientists are turning their attention to four kinds of solutions.

First, research is being directed toward methods of increasing the available supply by converting salt water to fresh water. This might solve the problem for areas near sources of saline water.

Second, ways are being sought to make better use of the available supply of fresh water, chiefly by combatting pollution even to the point where the same water might be repeatedly used. Wastewater is already near the place where clean water is needed and hence transportation costs are minimum.

Third, fresh water wasting to the sea in areas where it is relatively plentiful is increasingly being stored and piped long distances to areas of need. In thirsty California, water obtained in this fashion is transported approximately 1000 miles.

Fourth, the "seeding" of clouds with tiny particles, such as silver iodide crystals, to cause the clouds to drop their load of moisture when it would not otherwise have rained is being attempted. To date, the results of this method are controversial, and it has not as yet produced major quantities of water in dependable fashion.

The best solution to the water shortage in a particular area depends on the relative costs of the four methods for that particular application. Thus no single solution is best for all cases.

At the present time, principal research efforts are being placed on the first two methods, saline water conversion and pollution control.

SALINE WATER CONVERSION

The Office of Saline Water was created by Congress in 1952 to focus attention and support research on this potential method for increasing the world's fresh water supply. Countries with desert areas near the sea, like Israel and Saudi Arabia, had already established desalination plants, of which some 200 small installations were in operation throughout the world by 1966. A dramatic example is the plant which the United States Navy set up in Guantanamo, Cuba, to make the naval base independent of the Cuban water supply.

The United States took the lead in research on saline water conversion chiefly because of the water needs of its highly developed industry. American industry requires many times as much water as the population uses for personal requirements. Moreover, the water thus used must frequently be purer than water tolerable for drinking.

With the aid of government subsidies, a dozen or more firms developed pilot plants for desalination with a view toward improving the economics of the various processes used. The following are the principal methods found to be feasible technically:

1. Distillation. This is the oldest method, described for shipboard use by Thomas Jefferson. A number of different distillation methods are in use and under development. Simplest is the solar still. Such an installation is now operating in Smyrna, Syria, where the sun's rays, passing through a plastic curtain covering a shallow basin, evaporate the water, which condenses on the under side of the curtain and runs into storage tanks.

In another distillation process, salt water is passed through evaporator units connected in series so that the condensed steam from each unit heats the water in the next. Another variation, known as flash distillation, heats saline water to a point just below boiling and then introduces it into a compartment at lower pressure. Part of the water immediately vaporizes; the rest runs into a chamber at still lower pressure and additional water is vaporized.

2. Freezing. This process makes use of refrigeration. The salt water is chilled until ice crystals are formed. As water freezes, it tends to exclude impurities. Thus, the ice is free of salt and, when collected and melted, produces fresh water.
3. Electrodialysis. In this process, salt water is placed in a vat divided into a number of compartments by special plastic membranes. An electric current is passed through the water, causing the positive and negative charged ions of the dissolved salts to move toward their respective opposite poles. Some of the membranes permit passage of positive ions only and others permit only negative ions to pass. The membranes are alternately spaced. In moving toward their respective poles, ions of both charges are trapped in alternate compartments. Thus, the water in every other compartment gradually becomes fresh, while that in the others becomes very salty. The fresh water is then collected.
4. Reverse Osmosis. If a membrane permeable to water, but not to dissolved salts, is placed between sea water and fresh water,

the latter will penetrate the membrane and diffuse into the sea water. The osmotic pressure exerted by the sea water is approximately 350 pounds per square inch and is the force driving the fresh water through the membrane. The exertion of a pressure on the sea water exceeding the osmotic pressure will cause the fresh water flow to reverse. That is, fresh water will be forced through the membrane from the sea water compartment into the fresh water compartment where it will accumulate. This is the basis of a relatively new and promising saline water conversion method.

Common to all the processes is a requirement for large amounts of energy. Conversion efficiencies remain many-fold less than that theoretically possible as calculated thermodynamically. Hence the economic feasibility of conversion in competition with other sources of fresh water, depends largely on the cost of power. One disadvantage of saline water conversion which places an additional power requirement on all conversion systems is that sea water, of course, occurs at sea level. Thus, the water must be pumped to its point of use. Stream water, on the other hand, is generally trapped in a reservoir at an altitude high enough to take considerable advantage of gravity for distribution.

WATER POLLUTION CONTROL

Despite the vast quantity of water on earth, nowhere does it occur as pure H_2O. It always contains dissolved substances. The definition of "pollution" is, therefore, difficult. However, for practical purposes, it is useful to think of polluted water as water containing substances in solution, or suspension, in quantities which make the water unfit for the use desired.

Pollution of fresh water comes chiefly from untreated or inadequately treated sewage and from industrial wastes. The pollution may be so intense that resultant biological and chemical reactions deplete the dissolved oxygen in the water to the point where aquatic life is killed in the vicinity of the discharge. Between the point of discharge and the zone of recovery, pollution exacts its esthetic and economic toll and imposes a threat to the public health. Recovery occurs as the result of dilution of the wastes, aeration of the water by stream flow or wind action and, primarily, through the assimilation of the wastes by microorganisms.

Almost all sewage treatment processes take advantage of this ability of microorganisms to convert wastes into relatively innocuous products. Thus, sewage treatment plants may be thought of as "condensed rivers" in which the microorganisms are cultured and given engineering and scientific support to exert a vigorous attack upon the wastes. In most such processes, large quantities of air must be pumped into the sewage to supply the dissolved oxygen required by the microorganisms. Excess quantities of the microorganisms and solid materials settled from the sewage are usually taken to a digester where anaerobic microorganisms convert them to inert, solid wastes for disposal as land fill. The treated liquid wastes are sometimes disinfected with chlorine prior to discharge to surface waters. A modern complete sewage treatment plant removes between 85% and 95% of the organic wastes present in domestic sewage.

As cities have grown in population, it has been necessary to increase the degree of sewage treatment provided in order to protect the surface waters. The improved treatment more completely reduces the sewage to inorganic minerals. Among these minerals are dissolved nitrate and phosphate, which are excellent nutrients or fertilizers. Additional, large quantities of phosphate are being added to sewage through the constantly increasing use of phosphate-rich detergents in homes and industry. These nutrients have created a new type of pollution. Because of the more intensive sewage treatment, the receiving waters are clearer. Sunlight more easily penetrates, and photosynthetic organisms, mostly algae, use the nutrients to proliferate. Undesirable, explosive growths of these organisms occur. They soon die, imposing a heavy oxygen demand on the stream and, except for the public health aspect, can create conditions just as objectionable as if the sewage had not been treated. Much research is now going into methods to remove the nutrients, principally the phosphate, from the sewage effluent. The problem has become acute in many of the world's famous lakes and rivers, including Lake Geneva, Lake Erie, Lake Tahoe and the Potomac River.

Industrial wastes constitute the other large source of contamination in bodies of fresh water. Oil, sulfite from paper mills, acid mine wastes, steel mill wastes, organic and inorganic compounds from chemical plants, slaughterhouse wastes, brewery wastes, and many other types of industrial wastes, including heat, are not easily removed or treated. Some of these wastes contain newly developed chemicals for which little or no information on treatment exists. Others, even after extensive research, defy treatment. Control of industrial wastes at the source, pretreatment before discharge to municipal sewers, and special, complete treatment at the industrial site are the three principal methods used in combatting this problem.

While scientific studies may discover successful waste treatment processes and practices, their effectiveness is dependent on governmental action restraining abuses by municipalities and industrial firms. Congress passed the Water Pollution Control Act in 1948 which authorized matching Federal grants for construction of municipal facilities for waste treatment by virtue of the Federal government's jurisdiction over interstate waterways. Subsequent acts of Congress, in 1956, 1961 and 1965, made the program permanent, expanded it in the enforcement, research and construction grant areas, and provided a mechanism for establishing water quality standards. As of the middle of 1966, 39 enforcement actions against municipalities and industries had been initiated. The moral effect was much wider, leading to policies adopted by numerous municipalities and industrial corporations to find feasible means of avoiding pollution of public waters. As a further intensification of the water pollution program, in 1966, at the specific request of the President, a new Federal Water Pollution Control Administration was established within the Department of the Interior. Water pollution control activities and personnel, previously centered within the Department of Health, Education and Welfare, were transferred to the new agency which was charged with instituting a program to clean up the Nation's rivers, lakes and estuaries.