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The oceans cover about 71 percent of the earth's surface, yet in many respects we know less about this "inner space" than we do about outer space. Our ever-expanding economy and exploding world population lends an increasing urgency to the development of the oceans as a source of minerals, fuels, and protein foods. A brief look at the ocean reveals that it is truly a storehouse, for dissolved in a cubic mile of sea water is an average of 165,000 short tons of chemicals in the form of salts, besides the many thousands of species of plants and animals that live and die within its bounds. And the strata under the seas contain an estimated 40 percent of the world's total oil reserves. The commercial application of scientific results will eventually lead to development of the sea's natural resources so that they will provide maximum benefit to mankind. Toward this end, the Navy plays a large role in the development of the marine sciences in the United States.

ONR AND THE SEA'S NATURAL RESOURCES

The Office of Naval Research has supported, and is currently supporting, systematic, scientific studies and surveys of the ocean floors and the collection, preparation, and dissemination of data concerning the chemistry, biology, physics, and geology of the seas. It is also stimulating oceanographic studies that both directly and indirectly enhance the development and utilization of marine resources. The long-range program for oceanographic research developed and projected by the Chief of Naval Research, Department of the Navy, and approved by the Chief of Naval Operations—known as Project TENOC (TEN years of OCeanography)—will advance oceanography on all scientific fronts and should lead to a doubling of research efforts in the study of the oceans during the next ten years.

Oceanographers will be greatly assisted in obtaining information in the fields of marine science by the establishment of the National Oceanographic Data Center in Washington, D. C., this past January (NavResRev, Feb. 1961). The Center is operated by the Navy Hydrographic Office and is jointly supported by the Office of Naval Research and several other government agencies interested in the subject. Until now, oceanographic data have been widely dispersed and could be assembled and used by oceanographers only after considerable effort and consumption of time. The Center will assemble, prepare, and disseminate scientific and technical oceanographic and closely related data.

The Office of Naval Research has also been a leader in sponsoring the development and acquisition of new and improved research instruments, devices, and techniques for oceanographic research. A spectacular result of this effort was the record-breaking dive of the bathyscaph TRIESTE, operated by the U.S. Navy Electronics Laboratory, to the bottom of the Challenger Deep in the Marianas Trench on 23 January 1960.

Today, exploitation of the sea is concentrated along the continental shelves, which constitute less than eight percent of the marine area of the earth. Bordering the continents, these shallow zones vary in width from a fraction of a mile to hundreds of miles. The widest shelf, occurring along the Arctic coast of Europe, is 750 miles in width; the average shelf width is 42 miles. A few coastlines—such as northern Chile, the north coast of South America, and most of the Pacific coast of the United States—lack shelves. The floor of the average shelf slopes seaward at about 10 feet per mile until it reaches a depth of about 600 feet (100 fathoms). At this point, known as the outer edge, the shelf usually starts to slope off much more rapidly, forming what is known as the continental slope. This slope then rapidly drops away to merge with the floors of the deep ocean basins, sometimes more than two miles below the surface of the sea.

MINERAL RESOURCES OF THE SEA FLOOR

As the continental shelves are more or less underwater extensions of the continents, the mineral resources of the shelf area are similar to those found on the enjoining land. Minerals recovered from the shelf include oil and gas, sulfur, iron, and coal. The problems involved in developing the mineral resources of the shelf are principally economic. The cost of continental-shelf petroleum operations, for example, ranges from two to ten times more than that for equivalent operations on land. Procedures are made difficult by the water cover, but rapidly advancing technology is overcoming most problems.

Oil and Gas

From the standpoint of economics, oil and gas are the most important minerals produced from the continental shelf. Today, the major production of oil and gas from the shelf areas of the Western Hemisphere is confined largely to the Gulf of Mexico and the Pacific Ocean off the California coast, although the continental-shelf areas of the Caribbean Sea, South America, and Alaska seem certain to become increasingly important in the world economy whenever improved technology decreases the cost of operation.

Sulfur

Sulfur ranks second to oil and gas as a potential mineral of the shelf area in the western part of the Gulf of Mexico. The sulfur, occurring in the cap rock of some of the salt domes underlying the shelf sediments off the Louisiana coast, is expected to be developed in the foreseeable future.

Iron Ore

Iron ore is already being mined from under the inner edge of the continental shelf off Bell Island, Newfoundland, where it is removed through shafts with entrances on the land. Reserves of ore available within a five-mile radius of Bell Island are estimated at three and one-half billion tons; other billions of tons are present but are not as readily available.

Coal

Coal that crops out along the coast and extends seaward occurs along the eastern side of Vancouver Island, British Columbia; in central and southern Chile; in the eastern and western parts of Cape Breton Island, Nova Scotia; and elsewhere. The Sydney coal field, in the eastern part of Cape Breton Island, contains estimated reserves totaling more than two billion tons—enough to support about 180 years of mining.

Phosphate

Phosphorite deposits occurring on bank tops, shelves, and other high areas off the California coast have been estimated at one billion tons—about 70 times the total yearly production of this material in the United States. Phosphate-bearing rocks on the shelf along the western coast of Florida and off the California coast, however, will assume importance only after depletion of the land reserves, for the phosphorus pentoxide (P_2O_5) content of marine deposits is generally much lower than deposits now being mined on land.

Manganese

The only mineral in the deep oceans that might prove to be economically recoverable in the foreseeable future is manganese, which occurs in nodules, some having diameters of 10 cm or more. These nodules, which also contain traces of copper, nickel, and cobalt, are widely distributed in the deep oceans, especially in the South Pacific and Indian Oceans. The high manganese dioxide content of the nodules (about 29 percent MnO_2) makes them a valuable potential manganese source.

MINERAL RESOURCES OF SEA WATER

The oceans of the world represent a storehouse of about 50 trillion tons of dissolved material. Ninety-nine percent of the dissolved material consists of eight elements: sodium, chlorine, sulfur, magnesium, calcium, potassium, carbon, and bromine. The remaining one percent is thought to include at least a trace of all other naturally occurring elements. Of the principal chemicals, common salt, magnesium, and bromine are currently being produced from sea water.

Salt

About 80 percent of the dissolved salts in sea water is composed of common salt (sodium chloride or NaCl). This, along with other less common salts—such as potassium chloride (KCl) and gypsum ($CaSO_4$)—is obtained by the solar evaporation of sea water from wide, shallow basins. More than one million tons of salt are produced annually by this method in certain parts of California which have the warm, dry climate necessary for the solar-evaporation method to be operable. Continental saline deposits, such as rock salt found in mines and the salt obtained from wells and salt lakes, is believed to represent the remnants of continental flooding by ancient seas.

Bromine

At present, undiluted sea water—which contains an average of 0.2 percent bromine—is the source of 80 percent of the bromine production in the United States. This means that, since 308,000 tons of bromine are contained in a cubic mile of sea water, nearly 20,000 tons of water must be processed in order to secure one ton of bromine (Figure 1). Brines and salt lakes serve as additional sources of bromine in the United States; in Europe, bromine is obtained from solid salt beds.

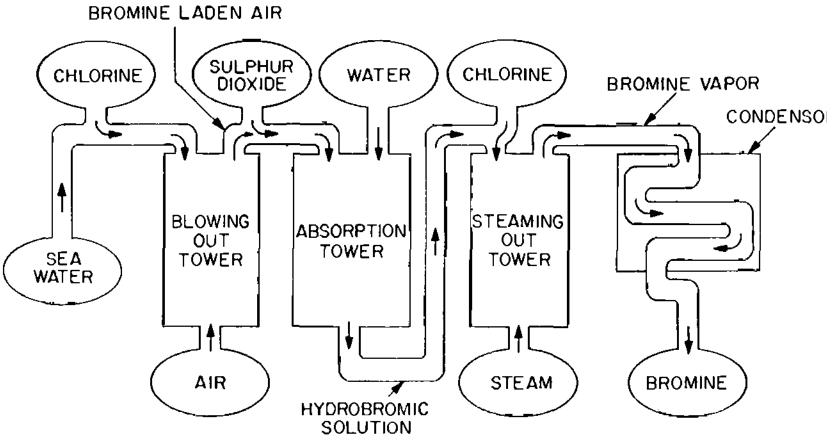

Figure 1 - The chemical process used by Dow Chemical Company to recover bromine from sea water. (Courtesy of Dow Chemical Co.)

Magnesium

The entire United States production of virgin magnesium is extracted from sea water, which contains an estimated six million tons per cubic mile. The recovery process now in use extracts 85 to 90 percent of the magnesium. By use of this method, the Dow Chemical Company plant at Freeport, Texas, is capable of producing 170 million pounds of magnesium per year (Figures 2 and 3). Smaller-scale extraction of magnesium is taking place at Moss Landing, Monterey Bay, California.

BIOLOGICAL RESOURCES

Fish

Fish are the most important of all the biological resources of the sea. Up to now ichthyologists have collected and named more than 25,000 species, which have been placed in three or four hundred families, but the great majority of commercial species are in less than

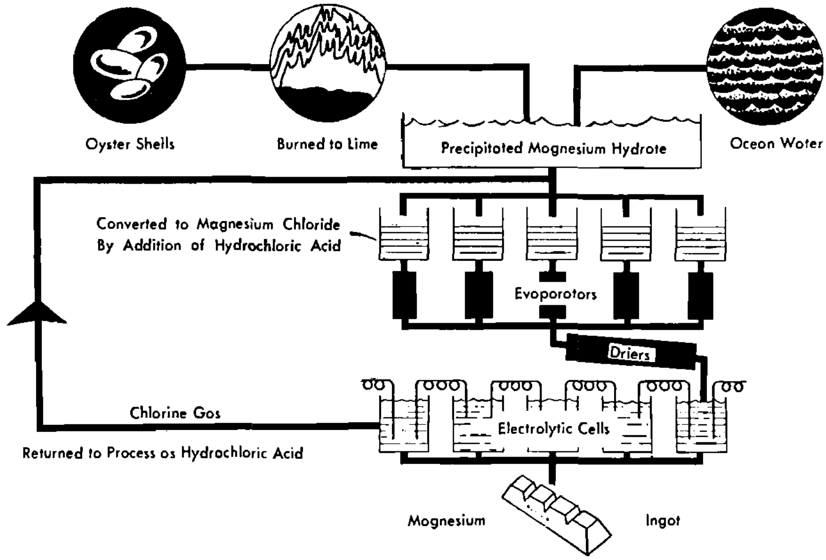

Figure 2 - The chemical process used by Dow Chemical Company to recover magnesium from sea water. (Courtesy of Dow Chemical Co.)

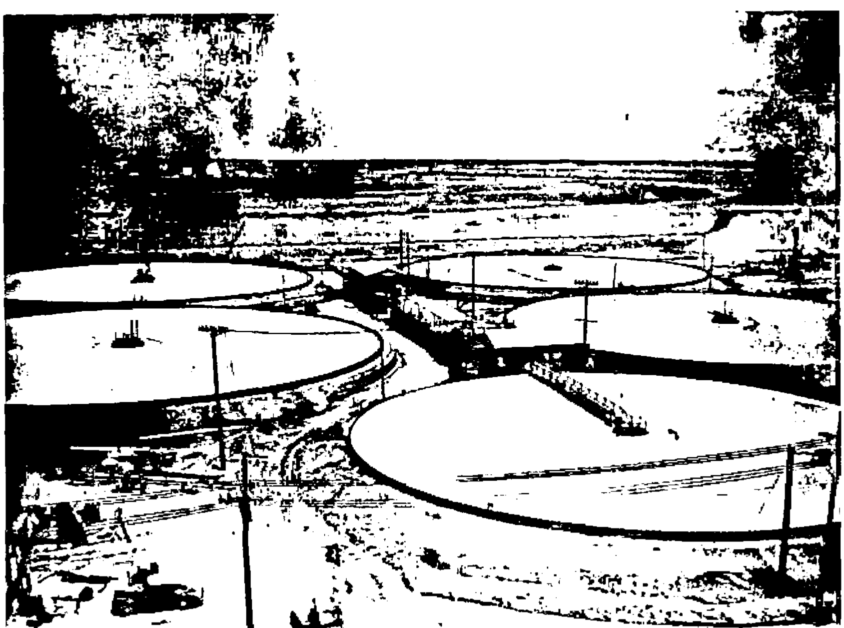

Figure 3 - Magnesium hydrate is precipitated in these tanks by the addition of lime or caustic to sea water in the Dow Chemical Company facilities in Freeport, Texas. (Courtesy of Dow Chemical Co.)

a dozen of these families. Although about two-thirds of all known species of marine fish—something like 17,000—live on the continental shelves in depths of less than 100 fathoms and usually within 20 miles of land, there are probably very few parts of the ocean entirely devoid of fish. Much research remains to be done, however, before any accurate estimate of the food-fish resources of the sea can be made.

In general, man makes poor use of the fish resources of the sea. In only a small part of the seas of the world—the coasts of western and northern Europe and the north temperate coasts of North America and Asia—are the sea fisheries exploited according to modern knowledge and practice (Figure 4). In these areas it has been necessary to form international commissions to impose and enforce catch limits in order to sustain the yield of many of the commercially important fish. Practically everywhere else only a small portion of the more easily caught fish are generally taken, the kinds depending principally on the types of primitive fishing methods available and on local tastes and prejudices.

Currently, new fishing methods, such as the use of screens of air bubbles to direct schools of fish into nets and the use of suction pumps

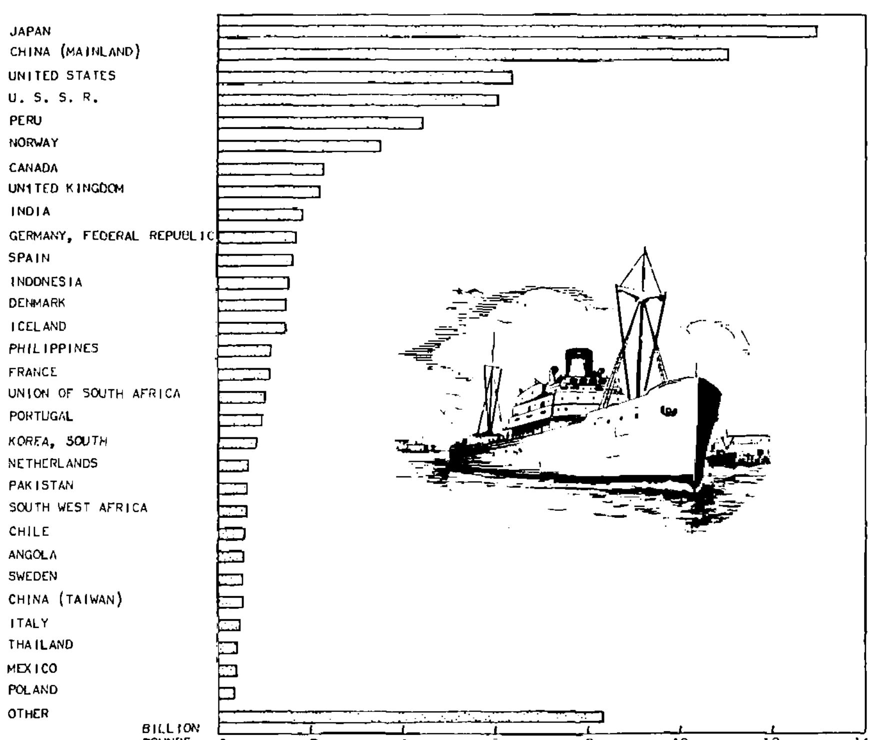

Figure 4 - World catch of fish, crustaceans, mollusks, and other marine life for 1959. (Courtesy of U. S. Fish and Wildlife Service).

in place of nets and hooks, are being devised and have proved successful in some regions. These new methods, along with innovations in boat design and equipment and the increase in exploration of new fishing grounds, will permit larger catches and economic fishing at ever-increasing distances from home.

Mollusks and Crustaceans

Although invertebrates—mollusks, crustaceans, etc.—make up more than 90 percent of the total animal population of the oceans, man uses only 16 percent of them for food. At the present time, most of the food invertebrates consist of oysters, clams, lobsters, shrimp, and squid. Oysters, clams, and mussels form valuable harvests in some regions and are underexploited in others. The most promising way to sustain the yields of these mollusks is to farm them, as is done now in some areas of the United States and in Japan, England, France, Italy, the Netherlands, Denmark, Australia, and the Philippines.

Squid are used extensively for food in countries of the Orient and southern Europe, but are not appreciated elsewhere. Of the 1,800,000 or so tons of mollusks harvested annually in the world, squid account for more than 25 percent of the total. Japan, with an annual catch of about 600,000 tons, is responsible for most of the world's squid harvest. Squid might become the most promising of the unutilized fishery resources, if not as a human food then perhaps as a good raw material for protein meal.

Shrimp are by far the most important of the edible crustaceans, with the annual catch in the South Atlantic and Gulf regions of the United States averaging about 250 million pounds. They are short-lived, fast-growing animals, a fact which gives them special value as a food resource, for it makes them less vulnerable than other species to intense fishing practices. Shrimp farming, although still in the experimental stage, may prove to be an important factor in meeting future shrimp requirements.

Lobsters, although probably not vastly abundant anywhere, are caught in Europe, North America, the West Indies, South America, Australia, and Japan. Increasing the lobster population through artificial propagation has been attempted by government agencies, but this method does not seem promising, and it is likely that, as human populations increase, lobsters will form an ever-decreasing part of the human diet. On the other hand, crabs—which have increased in popularity with the consumer in recent years—are probably not fully utilized, although it has already been necessary to regulate catches of some species in intensely fished areas.

Plankton

Marine plankton—the microscopic plants and animals that float on the high seas—has often been considered as a possible future source of food, for it is rich in protein and is extremely abundant. In the North Sea alone the estimated standing crop of zooplankton—only the animals—amounts to at least 10,080,000 tons, wet weight. Many fish feed almost exclusively on plankton, and at present it is more economical to fish for the plankton-eaters, such as the herring, sardine, menhadin, and whale, than it is to collect the plankton. With further knowledge of the distribution and composition of plankton will probably come a means of exploiting plankton resources directly. At any rate, the direct use of plankton may become absolutely necessary for feeding future world populations.

Seaweed

Seaweed (one form of algae) is currently being used for food and fertilizer and as a source of chemicals with unusual properties. Over a dozen factories—in the United States, Nova Scotia, Eire, Scotland, France, Denmark, the Netherlands, Norway, and South Africa—manufacture animal meal from seaweed. Farmers living near the seashore in Europe, North America, and the Orient gather seaweed for use as fertilizer. The use of seaweed as soil conditioners may, in the future, prove to be of great importance.

Another valuable potential use for seaweed is as a source of antibiotics, for the natural antibiotic effects of certain microscopic fresh-water algae (a relative of seaweed) have already been used effectively in sewage pools to make the effluent safe—from a public health standpoint—for discharge into local streams. Algin, a chemical derived from algae, is widely used in the food and chemical industries for its colloidal properties. Alginic acid, used to some extent in the manufacture of fibers, and agar, used in bacteriological laboratories as culture media, are further examples of useful algal products.

Although seaweed is of negligible importance as human food in the Western World, it constitutes an important food source in parts of the Orient and Oceania—in Japan alone, 310,000 tons were harvested in 1955. For man, unfortunately, seaweeds have very little nutritional value, for the protein content is low, and human enzymes are unable to digest much of their carbohydrate content. In view of its other uses, however, and with further research into the biology and distribution of these interesting plants, algae will assume increasing importance in the world economy.

FRESH WATER FROM THE SEA

It is estimated that by 1975 the need for fresh water will have increased to the point where we will need 32 percent more than will be available from natural fresh-water sources. Sea water will very likely be called upon to supply a part of man's future fresh-water needs. Several processes have been developed for the conversion of sea water to fresh water, and a few of these are already being used in areas where fresh water is unavailable. For example, on the Island of Aruba in the Caribbean, fresh water is produced from sea water for about $1.75 per thousand gallons.

The Office of Saline Water, U. S. Department of the Interior, has a number of fresh-water-conversion pilot plants throughout the country (Figure 5). It also has a program for the construction and operation of five demonstration plants, each using a different sea-water-conversion method. The Office now has built its first plant, at Freeport, Texas, and expects to begin operations in mid-June. At the end of 1961, a second plant, at San Diego, will begin operations. A third plant, to be located at Wrightsville Beach, North Carolina, is scheduled to open at a later date. The Gulf and West Coast plants will have a daily production capacity of about one million gallons of fresh water. The various conversion processes utilized at these demonstration plants are expected to produce fresh water for about one dollar per thousand gallons. One of the most important peaceful applications for atomic energy may be the production of low-cost fresh water from the sea for Navy as well as civilian use.

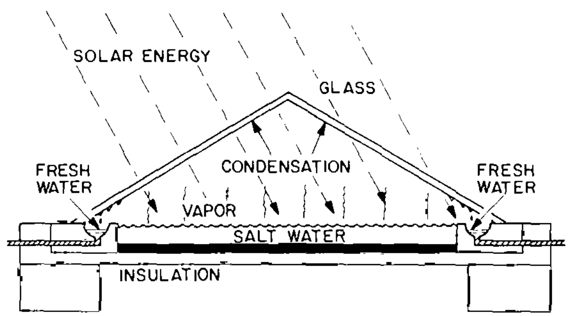

Figure 5 - A solar still of simple design for converting sea water into fresh water now undergoing tests at a Daytona Beach, Florida, research station of the U. S. Office of Saline Water. (Courtesy of the U. S. Office of Saline Water).