INTERNATIONAL HYDROLOGICAL DECADE

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INTRODUCTION

OUT of the total surface area of the globe (510,101,000 km.^{2}), about 29·2% (148,892,000 km.^{2}) consists of land above sea-level. The land is very unevenly distributed, there being twice as much land in the northern hemisphere as in the southern. Within the northern hemisphere again, the greatest stretch is found between latitudes 15° and 65°. More than half of the land (about 56%) lies below an altitude of 500 m., about half of this being between sea-level and 200 m. It is in these areas that the greatest concentration of the world's population occurs.

The precipitation of water, as snow and rain, on the earth's surface, is also quite irregular. This depends on the configuration and morphology of the land and of the atmospheric circulation. Only a few coastal tracts and certain other restricted areas lying in the path of moisture-laden winds receive more than 40 inches of rain per year. The arid regions are those which get less than 10 inches of rain per year while those which get between 10 and 20 inches are classed as semi-arid. The arid lands form about 25% of the total land area and lie mostly between 15° and 35° latitudes on either side of the equator, though this distribution is not regular. In North Africa, the aridity in certain areas is caused by descending air currents which become compressed and heated and thereby the air abstracts moisture leaving the ground drier than before. In Central Asia, the interior is intensely heated in the summer, but receives so little moisture that it is dry all through the year.

Parts of the Sahara, Central Arabia and Central Asia contain the most forbidding deserts of the world. The deserts occupy some 14% the land surface while the semi-desert steppes occupy another 14%, making up a total of 16 million sq. miles (41 million km.^{2}). The area of the Sahara is 3·5 million sq. miles, most of it stone-covered, with extremely low rainfall. The Australian desert covers nearly 1·3 million sq. miles. The Arabian desert covers 1 million sq. miles, a third of it being sand-covered; its interior is called, quite appropriately, 'the empty quarter'. The Turkestan desert occupies 0·75 million sq. miles, abutting against the Caspian Sea on its west. The Persian desert is 150,000 sq. miles while the Takla Makan in the Centre of Asia covers 200,000 sq. miles, merging into the semi-arid areas of Mongolia and Kazakhstan. The Atacama desert of Chile-Peru occupies some 140,000 sq. miles of the S. American Pacific Coast, the coastal area being often foggy. The Patagonian desert further south, to the east of the Andes, has an area of 260,000 sq. miles. South-Western U.S.A. is another area of desert and semi-desert covering half a million sq. miles. The Kalahari in South Africa contains some 220,000 sq. miles of desert surrounded by a large semi-desert. It will thus be seen that a very large area of the globe is unsuitable for human activity. Out of the remaining area of land, the ice-covered Arctic and Antarctic regions as well as the mountainous regions are also unsuitable, leaving only the rain-receiving plains and plateux and parts of the mountainous regions for human settlements.

For some years past, the UNESCO has taken great interest in the study of the problems of the arid and semi-arid tracts and an expert Committee, consisting of eminent hydrologists, meteorologists and geologists, has been directing the work of research teams. Arid zone research institutes or units have been functioning in the Sahara, South Africa, Western U.S.A. and other places. One has been set up recently at Jodhpur to study the problems of the Rajasthan region and it is already engaged in questions relating to re-forestation, ground water, fixation of sand-dunes, etc. Water-supply is one of the major problems of the arid and semi-arid regions and has been receiving much attention.

WATER-SUPPLY—A WORLD PROBLEM

Next to air, water is indispensable for living beings. Human settlements have been established from the very earliest times near sources of freshwater such as large rivers and fresh-water lakes. Until recently, when the need for large quantities of water for industrial purposes has necessitated the scientific study of water resources, their development and conservation, there has not been much difficulty in securing the requirements of water from the usual sources of supply. During recent decades, monetary and engineering resources have been untilised for constructing reservoirs to ensure large supplies of water, but this has now to give way to systematic studies of the sources of water-supply. Such investigations require full data on meteorological, geological and hydrological factors in order that the principles of storage of water, its distribution, its movement, etc., can be properly understood, before the sources can be developed and used to the best advantage. At present, only a few advanced countries have given serious thought to the various problems relating to surface and ground water. The necessity for carrying out similar studies in other countries is now felt in an acute manner; hence the question of the scientific study of hydrology in all its aspects has become a world problem to be tackled as a well-co-ordinated international project.

The distribution of water resources lends itself to study on a large scale both regionally and at a continental level. Very often, the problems involve more than one nation in any particular region. It becomes then necessary for several nations to come to an agreement about the utilisation of their common resources in an equitable manner. Some rivers and lakes are common to two or three countries and this makes it incumbent on these countries to share their experience and pool their resources for properly developing and utilising the water available in the tract to the best advantage of all.

Need for Collection of Data

Water-supplies are controlled by rainfall, climate, local geography and geology and are liable to vary from time to time. The proper understanding of these factors in their local relationship and interdependence will take a fairly long period. This fact as well as the great magnitude of the problem have suggested that hydrological studies should be undertaken over a period of at least a decade in order that the data collected are reliable. During this period it would be possible to delineate the chief lines of investigations, but these will have to be extended further in future. Such studies will require trained personnel for investigations both in the field and in the laboratory. It is only a few countries which already have the resources for investigation at present. Most other countries will require either finance or trained personnel and facilities, or both. Only when proper organisations are set up in each country and the necessary finance secured for continuous studies, will it be possible to make good progress.

In these investigations the range of data to be collected is quite large and expensive. These will include rainfall and its variations over a long period, the influence of local climatic factors, the amount of surface water available, the distribution of ground water in relation to the local geology and structures, and other relevant information. This will be followed by a systematic study of hydrological factors and the making of water inventories. Local factors will always have to be given special attention as they may not conform to any general pattern. The development of the resources will require the use of advanced engineering techniques which will be available only in industrially advanced nations. After the water is used it will have to be disposed of in such a way that much of it can be utilised again whenever possible.

In the initial stages many countries which are technically backward will have to apply their resources to the collection of basic data and the training of personnel for undertaking the tasks in a systematic manner. The making of water inventories will have to be in two or more stages, firstly for immediate and pressing needs of the local population and for agricultural uses. Then come the requirements of such industries as can be profitably set up in the region. Other aspects of study can follow later after the personnel gains experience. Thus, all countries will, in the first instance, have to set up training schools and hydrological services which will have to fit into an international pattern; numerous observation stations must be established for collection of rainfall and other data such as the distribution of surface water, evaporation absorption by the gound, flow in rivers, etc. Later on ground water will have to be examined from the point of view of both the ultimate and actually recoverable resources. Tests will have to be made to determine what part of the ground water can be brought to the surface and utilised without overpumping and otherwise spoiling the reservoirs. Permanent research organisations and laboratories will have to deal with all questions coming under the purview of research development and utilisation. Liaison will have to be established with other countries not only for standardisation of data but also for discussion and solution of common problems.

Hydrological Studies in the U.S.A.

In this connection it would be instructive to examine a few facts relating to advanced countries. It has been calculated that, if the amount of water evaporated from the sea surface can be precipiated entirely over the surface of land uniformly, it will form a layer 100 inches thick. This amount is approximately three times the potential annual evaporation from all the land surface. For continental U.S.A., excluding Alaska, the average annual rainfall is 30″ (including snowfall). The amount of water precipitated on this area (about 2,000 million acres) is about 5,000 million acre-feet per year. Probably about 10 times this amount is stored as underground water, though unevenly in different areas. About 70% of this water is evaporated or transpired by plants into the air, leaving only 30% to flow on the surface and to sink into the ground. Only 7% of the annual precipitation (about 345 million acre-feet) or about one-fourth of the stream flow is utilised for agriculture, irrigation and all other purposes. Less than half of this is used for agriculture while a similar quantity is used for industrial cooling, washing, etc. Only a comparatively small quantity is used for domestic and municipal purposes. The amount of water actually consumed comes ultimately to 2% of the total precipitation as the rest of the amount withdrawn is returned to the ground and to the streams (Revelle, 1963).

The average daily use of water in the United States is at present said to be about 570 million $m.^3$ for major industries, 510 million $m.^3$ for irrigation and 100 million $m.^3$ for household and other purposes. This gives a total of 1,180 million $m.^3$ which when divided by the population (180 million) gives the *per capita* consumption of 6·6 $m.^3$ per day (Spiegler, 1962). The average daily use of water by individuals and by families varies considerably in different areas because those in the dry areas naturally use less water than those who live in the humid areas.

The consumption of water is steadily increasing not only because of increase in population but also because of the expansion in the variety of human activities and industries.

A Senate Committee on Water Resources in the U.S.A. has estimated that the actual consumption of water (year 1960 ?) was about 110 billion gallons per day and that the existing storage capacity is 278 million acre-feet. According to them, by 1980 the US will consume about 190 billion gallons per day and an *additional* storage capacity of 315 million acre-feet will be required, *i.e.,* more than double the present capacity. (1 acre-foot = 1233·5 $m.^3$ = 325,850 US gallons). It is stated that, in spite of the great progress already made in hydrology in that country, the available information is still inadequate and that a major effort is needed in research for a comprehensive study of ground water. We can therefore envisage the inadequacy of our position.

Treatment of Saline Water

Every country which has embarked upon industrialisation is now finding that the usual sources of water relied upon till now are not sufficient and that extra supply will have to be obtained either from large distances or from the conversion of sea or lake water. The consumption of water for drinking purposes alone is of the order of 2 to 8 litres per day per person according to the season, the environment, the nature of work on which the person is engaged, etc. But drinking water is not the most serious problem. The requirements for other purposes such as for agriculture and industries are much heavier.

Drinking water should not ordinarily contain more than 500 parts of dissolved salts per million parts of water, though some variation may be allowed. It is known that in some parts of Africa the local tribes use water having as much as 2,500 parts of dissolved salts per million without serious effects, but this is a very extreme case. This latter concentration should be considered too high even for several of the food crops.

Certain countries which have had to face acute shortage of water are already turning to the ocean for obtaining their supplies. Sea-water is quite unsuitable for most purposes as it is; but it has been converted into potable water on board ships for some decades. In recent years, particularly after the second world war, the conversion of sea-water into fresh-water has been taken up for careful study. There are at present several industrial plants working on desalination of sea-water, for example in Kuwait, Israel, Libya, South Africa and Virgin Island. Most of these are still working on an experimental basis. A few plants are also experimenting with various methods in the USA, so that the basic data as well as the advantages and disadvantages of each may be evaluated for long-term adoption.

The simplest is the distillation of water by evaporation which may be done through the help of hot steam. Evaporation by the sun's heat has also been tried but it does not seem to be very attractive compared to other methods. Multi-stage evaporation is found to be more economical than single-stage because of the saving of heat. Another method is that of flash distillation in which heated water is allowed to evaporate suddenly when it enters a space where the pressure is low. This produces a flash of steam. This method is used in Kuwait and Virgin Island. Another process employs freezing; water when freezing rejects the dissolved salts and is therefore more or less free of salts. A more recent process uses electrodialysis; in this there is a series of cells separated by membranes which are alternately permeable to positive and negative ions when electric current is passed through the unit. In one set of cells the salts become concentrated while in the alternate set depletion of salts takes place; thus the latter cells will produce practically fresh water. Ion exchange resins are also used for purifying saline water. Raw water is passed through a column of active cation exchanger containing resins with hydrogen ion which are exchanged with positive ions in the water. The water which thus becomes acidic then passes through an anion exchange column where another type of resin exchanges all negative ions with OH. Thus the original ions are exchanged with H and OH, finally giving practically fresh water (H_2O). The ion exchange process is perhaps the most costly of all and therefore cannot be used on a large scale, unless there are special reasons for adopting it.

Cost of Desalination of Sea-Water

Regarding the cost of making potable water from salt-water some data have been released in the USA. There are five experimental plants in that country where approximate costs have been worked out. The plant at Freeport (Texas) which uses multi-effect vertical distillation tubes with a capacity of one million gallons per day (m.g.d.) cost 1·25 million dollars to erect. The plant at Webster (S. Dakota) uses electrodialysis method, and it costs 0·25 million dollars; one at San Diego (California) with a capacity of 1 m.g.d. uses multi-stage flash distillation; its cost was 1·6 million dollars. Another plant at Roswell (New Mexico) uses the vapour compression process; it has a capacity of 1 m.g.d. and cost 1·8 million dollars. The fifth plant at Wrightville (N. Carolina) uses the freezing processes and has a capacity of 1 m.g.d. and it was put up at a cost of 1·25 million dollars. Initially the average cost of the water produced by these plants was around 4 dollars per 1,000 gallons, but it has since been reduced to 1 to 1·5 dollars per 1,000 gallons. The cost was worked out on the basis of a period of 20 years amortisation of capital, and 4% interest. It is expected that when larger plants could be put up, the cost can further be reduced perhaps to 0·5 dollar per 1,000 gallons in the most favourable conditions. On the other hand, the cost of water from ordinary wells and reservoirs is now of the order of 15 to 25 cents per 1,000 gallons in general, but it is gradually going up. Estimates by people experienced in the processes mentioned above go to show that a plant having a capacity of 30 m.g.d. would be able to produce water at 50 to 60 cents per 1,000 gallons in the near future; this of course depends to some extent on fuel cost which, if obtained cheaply, may bring down the water cost further. In any case, it is not expected that the cost of water can be reduced below 30 cents per 1,000 gallons even under the most favourable conditions. It is also gathered that the combination of a plant to produce both power and water may reduce the cost further. With a power plant of the capacity of 70,000 KW, and fuel available at 10 cents per million BTU, the cost is approximately 5 millions per KWH. If such a plant is combined with one for producing 14 or 15 m.g.d. the cost would be around 27 to 30 cents per 1,000 gallons, making allowance for capital, fuel operation maintenance of other charges. If the capacity is increased to 25 to 30 m.g.d. the cost may be lowered to 25 cents per 1,000 gallons. There are, however, other factors to be taken into consideration in these estimates.

Need for Worldwide Studies

For many years past there has been an International Association of Scientific Hydrology (IASH) which is now a member association of the International Union of Geodesy and Geophysics (IUGG). Several advanced countries have also Societies of Hydrologists who are studying the scientific as well as technical aspcets of water utilisation. The idea of studying the water resources on a worldwide scale has been exercising the minds of many specialists. In 1961 the National Academy of Sciences of USA appointed a Committee to go into the question of the study of water resources in a manner similar to some of the geophysical studies undertaken during the International Geophysical Year (IGY). This led, in October 1961, to a discussion of the broader aspects of hydrology at a meeting of the IASH in Athens. The Executive Committee of this Association approved of the idea of taking up hydrological studies on a worldwide scale and circulated the information to the National Committees of some 45 countries who were members of the International Council of Scientific Union (ICSU) for their comments. By the middle of 1962 some 27 countries responded, most of them being enthusiastic in their support to an international programme. In the meanwhile the proposal was brought to the notice of the UNESCO whose support had to be secured as the programme had to be given official status. The Executive Board of the UNESCO at its Session in

November 1961 recommended to the Director-General to make provision for an International Conference to explore the ways of undertaking a programme of research and training in hydrology. It also proposed a meeting to be held in collaboration with the international organisations affiliated to the United Nations such as WMO, FAO, WHO, etc. The WMO fully supported the programme at its meeting held in May 1962 and promised active participation. The Advisory Committee on Arid Zones, of the UNESCO, also supported the proposition at its meeting in August 1962. In May 1963, the UNESCO arranged for an International Meeting for considering the whole programme and the various problems connected with it. A working document was prepared and distributed to all the Member-States of the UNESCO. The meeting was attended by 48 countries in addition to representatives of the International and Scientific Organisations. The result of these discussions was circulated by the UNESCO which invited each country to indicate what action it proposed to take, with such modifications as were considered necessary. The UNESCO agreed to provide a central secretariat for the international programme which was proposed to be called the "International Hydrological Decade" as it was thought that a period of at least 10 years would be required for gathering worthwhile data and achieving some useful results. The UNESCO document of June 1964 gave reality to the programme which was initiated by the U.S. Academy of Sciences and by the IASH. It was decided to set up a council for the International Hydrological Decade to enable a detailed programme of planning and research to be drawn up by the various National Committees and other Organisations. It was also agreed that the IASH, which is a body of hydrologists, would be the consultants and advisers for the scientific aspects of the programme, particularly for establishing training institutions for the personnel that would be required to carry out the programme. By the middle of 1964 several countries have already begum to organise and plan for the collection of data and training of personnel.

THE PROGRAMME

The lines of investigation to be undertaken during the International Hydrological Decade will be quite comprehensive and will consist of the following :

Organization.—The setting up of hydrological units and training of technical personnel in hydrology and engineering aspects ; liaison between technical and administrative sections ; liaison between different countries through the UNESCO ; arrangement of programmes and documentation of results and distribution of informations to all countries.

Field-Work.—Measurement of precipitation, percolation, evaporation and run off ; chemical studies on the nature of water ; preparation of maps and charts.

Surface Water Flow.—Water and sediment in river flow ; erosion ; transport and sedimentation ; occurrence of floods and the local causes ; soil moisture and loss of water ; study of the best methods of using water for agriculture.

Ground Water.—Geological, geophysical and geochemical studies of wells and boreholes ; fluctuation of ground water level ; discharge and recharge of aquifers ; coastal water and its relation to sea-water ; salinity ; drainage, irrigation and water-logging.

Influence of Man.—Destruction of forests, effects of roads and railways, water pollution, etc.

Engineering Aspects.—Construction of dams, canals, irrigation works and industrial plants ; improved methods of planning and development of water resources and their utilisation, and waste disposal.

Legal.—Uniform water laws in all countries as far as possible.

Conservation.—Best methods of using water for various purposes ; purification of used water ; return of water and recharge of aquifers ; standardisation of quality.

These various problems will now be systematised for study and implementation by the different countries so that the water resources in the various regions can be utilised in a scientific and systematic manner. Though the project is planned for a decade, it will only be the beginning of the scientific study and rational use of the water resources by the whole world.

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1. *Report on National Water Resources*, U.S. Senate Select Committee. Vols. 1 to 3, U.S. Senate, Washington, D.C., 1960.
2. *An Outline of International Programme in Hydrology*, Publication 131 of the National Academy of Sciences, National Research Council, Washington, D.C., 1963.
3. Mc Guinness, C. L., *U.S.G.S. Water Supply Paper No.* 1800, 1963.
4. Nace, R. L., "A plan for International Co operation in hydrology," *IUGG Chronicle*. January 1962.
5. Revelle, Roger, "Water resources research in the Federal Government," *Science*, November 1963, 142 (3595), 1027.
6. Spiegler, K. S., *Saline Water Purification*, John Wiley & Sons, New York, 1962.
7. Sverdrup, H. U., Johnson, M. W. and Fleming, R. H., *The Oceans*, Prentice Hall, New York, 1946.
8. Thomas, H. E. and Leopold, L. B., "Ground water in N. America," *Science*, March 1964, 143 (3610), 1000.
9. White, G. E., *Science and the Future of Arid Lands*, UNESCO, Paris, 1960.