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WATER SCIENCE AND TECHNOLOGY IN THE MIDDLE EAST SINCE 1945

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My purpose is to trace some of the major developments in water science and technology, to note changes in attitude and achievement, and to suggest where some experiences of the past 30 years or so could usefully be used for the future. While the availability and use of water is my theme, some of the matters touched on may seem somewhat remote from it, but only rarely can water problems be considered in isolation. The time has arrived to integrate rather than to isolate the many problems involved in development.

A survey of scientific activities in the Middle East was conducted during 1943-45 for the Middle East Supply Centre, an Anglo-American organization based on GHQ Cairo, which, after the defeat of the Axis powers in Africa, turned its attentions to planning for peace as well as for the last years of war. The region was defined then to include much the same countries as the Arab Middle East today, but with some additions, notably the then Palestine, Abysinia, Eritrea, Turkey and Persia. The results of this survey were published in two volumes, one on agriculture by Keen (1946) the other on sciences other than agriculture by Worthington (1946). The survey included also rural education and welfare, published in a short report by Allen (1947) and a study of animal industry by Norman Wright who unfortunately was unable to bring it to the stage of publication.

The basic purpose of that survey was to encourage a regional approach to solving the problems of development of the Middle East, and this is likewise a purpose of the present Conference. At the back end of the war this purpose seemed in some respects easier of attainment than it appears today, for at that time many national aspirations were subjugated to an overall war effort. The colonial system of government still obtained in some countries and four ex-Italian colonies were under allied military administration. Accordingly, throughout the Middle East communication on practically any technical matter was rather easy using the military network. Diplomatic channels were reserved mainly for political questions.

In those days the whole educational system was a shaddow of what it has now become; and in the huge changes which have overcome the political, economic and social environment, the development of modern education and the technologies which follow from it must surely be one of the most important. In Arab areas the few Universities were then based mainly on traditional and religious foundations with not much science and technology, storage, has witnessed great advances, though perhaps less in the Arab countries than some others owing to the abundance of oil. It is well to remember that producing electricity involves dropping water to a lower level, whereas irrigation usually requires holding it up or even lifting it. In these days when the future of the civilized world appears to be bound up with the availability of energy, it is surprising that so little water energy, the use of which involves no consumption of the water resource, is yet mobilized. Figures presented at the UN World Water Conference of March 1977 showed that in South America and Africa only 6-8% of potential water power is yet used for hydro-electric purposes. Admittedly much of this unused energy is in countries where the demand is least, but it is well to remember that the resource exists.

The demands of industry on water supplies, though as yet small in most of our region as compared with industrialized countries, will surely grow. Here the question of water quality is of great importance, because, except for a few specialized industries, water of quality far below the standard required for domestic purposes is adequate. High quality water is currently consumed for industrial use on a very large scale, and one could well predict that, in the future application of appropriate technology, it will become a punishable offence to use water for industry of a quality above that which is essential for the purpose at issue. This goes particularly for cooling water, for which salinity is no serious disadvantage.

Finally the recreational uses of water, which were seldom brought into consideration 30 years ago, are now rapidly developing in most parts of the world. Sometimes these uses can be combined with the conservation of scientific or scenic interest, as in National Parks and nature reserves. In water sports such as various forms of boating, water-skiing, swimming, angling, there have been technical advances, and rising demands for facilities. Sometimes facilities can be combined with education and improvement of health: for example, as a prediction one could expect a swimming pool with treated water to be part of the planning of every village in future irrigation schemes. Coupled with the provision of latrines this would be the best way of preventing that worst of debilitating diseases - schistosomiasis.

Examples

It would be impossible, short of a large book, to cover the development of water science and technology in the Arab countries in any comprehensive way, so the rest of this paper consists of examples which appear to have relevance to what may be achieved in the future. Not all of these examples have been selected to show how problems in development have been solved successfully, for there have been mistakes as well as achievements, with lessons for the future to be derived from both. We may start with surface waters, because they are the most obvious and have lent themselves most readily to human use, and as such have been the subject of most application of water science and technology. It is well to remember, however, when looking to the future, that the quantity of surface water in the region is very greatly exceeded by the quantity of subterranean water.

Rivers

In terms of rivers, several low-lying countries in the region are remarkably well provided considering the aridity of their climate, the reason being that the largest rivers derive their water from highlands far away. The Nile, Tigris and Euphrates are the outstanding examples. The Nile, shared by no less than 8 countries, demands international cooperation of the highest order as well as science and technology. A description of the modifications to the natural hydrology of this river written 30 years ago reads very differently from now. For example the Owen Falls Dam, where the White Nile system originates from Lake Victoria, was constructed a few years after the War for hydro-electric production as part of the development plan for Uganda. The plan was worked out in full detail with the authorities in the Sudan and Egypt as the prime consumers of the Nile's water. From their point of view this project, by controlling the level of Lake Victoria, and thus converting it into the largest reservoir in the world, irons out fluctuations in flow, and this has eased the construction and management of all projects downstream. Other schemes for controlling the Upper White Nile were being considered about the same time, but were deferred more or less indefinitely when decision was taken to build the Aswan High Dam. Now the need for more water downstream has once again become so pressing that one of these schemes, the Jonglei canal in the upper Sudan, is even now starting. This is designed to bypass the Bahr-el-Jebel around the Sud region and thereby to reduce evapotranspiration losses in that area.

On the Blue Nile system, which produces far more water than the White Nile but most of it during a short period of the year owing to the seasonal rainfull in the highlands of Ethiopia, old ideas for controlling the flow at its origin from Lake Tsana, have been largely given up. Lower down, just after the Nile has crossed the border into the Sudan the recent Roseires Dam and reservoir has a big influence on the flow, particularly by diverting Blue Nile water for the expansion of perrenial irrigation in the Sudan. There have been other important works in that country, notably at Khashm-el-Girba which stores water in the Atbara, another flash-flood tributary of the Nile, but all these projects were put somewhat into the shade by the High Dam.

This great work, together with its hydroelectric installations and ancillary operations, including the removal and reconstruction of great archaeological monuments, has involved science and technology of a very high order, but mostly provided from outside the countries immediately effected. Inevitably this great interference with the natural regime has had ancillary effects, and certain journalists, underplaying the overall benefits of the High Dam and emphasizing the undesirable ancillary effects, stirred up controversy. Since some people, even scientists, believe what they read in the newspapers, some of the exaggerated information has even reached textbooks. A more balanced picture was presented by Kenawy (in Worthington, 1977, p. 371) and by an independent scientist, Rzoska (1976 a and b).

The primary purpose of the High Dam was of course to provide greatly increased water storage to meet the needs of Egypt and also of the Sudan, to establish a substantial area of new irrigation, to convert the remaining basin areas of Egypt to perrenial use, to avoid the threat of disasterous flooding, and to provide a very large quantity of electricity needed among other things for the manufacture of nitrate fertiliser. It was recognised in advance that there would be many ancillary effects and these were examined in advance, predicted as far as the then knowledge allowed, and weighed in the overall balance before the decision was made to proceed with the project. Among the undesirable effects were the deposition of Blue Nile and Atbara silt above the dam involving the need for greater consumption of chemical fertilisers, enhanced erosion of the river banks and certain coastal areas as a result of lack of silt in the Nile water, a big reduction in the sardine fishery off the Nile delta owing to the absence of nutrients formerly brought down by the river, the replacement of this fishery in part by a new one in Lake Nasser above the dam, and most important, an increase in the incidence of schistosomiasis, especially in Upper Egypt, following the expansion of perrenial irrigation.

It cannot, as yet, be claimed that the main purposes have been fully achieved or that the undesirable ancillary effects have been adequately mitigated. For example some of the converted basins and much of the newly irrigated desert is suffering seriously from salinization problems, mainly owing to inadequacy of the installed drainage. Moreover, it seems that the water losses from evaporation and seepage in Lake Nasser had been considerably under-estimated. However, it is quite untrue to say that these various environmental impacts came as a surprise, although all of them would have been easier to prevent or to mitigate had there been opportunity for longer and more intensive study in advance. One needs to remember that the High Dam came as a gift to Egypt. The offer was unlikely to be repeated, and one does not look a gift horse too closely in the mouth.

Upland gathering grounds

Quite a different form of technology, which applies to all countries whether developed or otherwise, concerns the protection of the upland gathering grounds in order to avoid rapid run-off of precipitation and the soil erosion which generally goes with it. Although the knowledge concerning this important topic derives from the sciences of hydrology, soil science and plant ecology, its application falls mainly in the fields of administration and politics; for what is generally needed is the protection of a substantial part of the upland gathering grounds from excessive use in agriculture or animal industry. They need to be left with a cover of vegetation. Protected uplands need not, however, be lost to economic use for many of them can be used for forestry, wild life, and National Parks to attract the tourist industry. Much progress in this subject has been made in the wetter countries of the tropics and sub-tropics, but where the protection of upland vegetation is most needed and most difficult is in arid or semi-arid country, where the attraction to cultivators of even a meagre rainfall in the uplands is difficult to resist.

Flash-flood wadis

Related to this is control of the flow in flash-flood rivers, including those which are dry wadis for most of the year. These are abundant in a number of Arab countries which in classical times formed part of the Greco-Roman Empire, and a study of the archaeological remains shows how well our classical forebears understood nature and worked with it rather than against it. I recall walking up the Wadi Cam in Libya which reaches the Mediterranean some 10 miles east of Leptis Magna. Even in the small tributaries the Romans had constructed stone dams at intervals of less than a mile. These are broken down now although some still hold flattish areas of silt used for growing a crop. In the old days no doubt the upper dams in the series were rapidly silted, but they served as settling tanks to protect the much larger reservoirs in the lower reaches of that wadi. The last of them took off by an aqueduct to supply the great city of Leptis Magna. Today water engineers are often tempted to construct a reservoir near the foot of a wadi, neglecting flood control and silt catching upstream.

Climatic change, natural and man-made

In cases such as the Wadi Cam, where the former system of water control no longer exists, as indeed in the much larger case of the disappearance of "the granary of ancient Rome", an argument has been going on for at least a century whether the changes in land and water use during the last couple of millenia have been caused by climate or by misuse. The argument has perhaps reached its climax and is causing the most intensive study and hypothication in the case of the recent Sahel drought. Although not all experts agree, the majority believe that, while the recorded short term variations in climate from one group of years to the next can be much greater in the tropical belts than in the temperate, and while the great climatic changes of the pleistocine associated with ice-ages and pluvial periods are undoubted, there is no reliable evidence to indicate an overall shift in the balance between precipitation, evaporation, run-off and percolation during the last two millenia. If we accept this we can be more optimistic about the future. If the Romans did it why cannot we? Although there may be some areas of man-made deserts where the processes of soil formation and subsequent growth of vegetation may have reached a point of no return, there are surely many other areas where destructive activities of the past millenium could be reversed and where land and water use could be combined to bring back something approaching the former prosperity.

At the same time however we should remember that leading authorities are much concerned with the effects on climatic change which might follow major interference with the earth's atmosphere. There are already signs that, if certain present tendencies continue unchecked, the ratio between precipitation and evaporation could be altered significantly. Less than 5% of the precipitation on Lake Victoria's 26,000 square miles of water and its catchment area flows out at the Owen Falls Dam. Thus a relatively small shift in the ratio could turn the upper reaches of the Nile into a dry wadi.

The changes in eco-climates and micro-climates which may be caused by large reservoirs, extensive irrigation or extensive drainage schemes, is another matter of much interest but as yet little knowledge. It is a matter of common observation that land close to large lakes and reservoirs generally grows dense vegetation, and that humidity is increased locally by evapotranspiration. Lake Victoria is large enough to create a local climate system with daily sea and nightly land-breezes, and these undoubtedly enhance precipitation in adjacent areas of high mountains. In the case of large areas of swamp and floating vegetation in hot dry climates, such as the Sud area of the Upper Sudan, it has been claimed that the loss of water through transpiration can be very much higher than that from a similar area of free water surface, and experiments with lysemeters have tended to confirm this. However, physisists maintain that the maximum increase could be no more than about 1.3 times the free water evaporation in any given set of climatic conditions, except where hot dry winds blow over the evaporating surfaces. In connection with the problem of enhanced evaporation caused by floating vegetation it is noteworthy that a new problem of water technology has developed during the past 20 years, namely the accidental introduction of the South American water hyacinth (Eichornia crassipes) which occurred first in the upper Congo, probably as an escape from ornamental ponds, has invaded most of the big river systems of Africa including the Nile, and also parts of the Middle and Far East. Away from its natural home, it has multiplied exceedingly and has presented problems in engineering and other measures of control.

Irrigation projects in arid areas obviously increase the amount of water entering the local atmosphere and it is often questioned whether this results in increased precipitation. However, the only really critical study on this, by Schickedanz and Ackermann (in Worthington, 1977, p. 185) on the phenomenal growth of irrigation in the great plains of North America, concludes that "at this early stage of the analysis, it is speculated that under very dry conditions in this climate, the addition of water vapour cannot be realised in the production of clouds and precipitation". Be this as it may, it is observable that sometimes a mist develops over an irrigated area which may cause occult precipitation in the form of dew. The above points illustrate that, in spite of much knowledge recently acquired, further research of a practical kind is still needed.

Irrigation and its problems

This paper is not concerned with agricultural production as such, but, as a means to it, irrigation is more important to the Arab countries than to any other comparable region. The water technology applied in irrigation today ranges from simple forms of hand-lift from a river, which have continued without interruption since the earliest civilisations of Egypt, through complex traditional systems of applying water power, such as the great "Noria" wheels constructed of timber which are still working efficiently in Syria, many forms of mechanical and electrical pump, some lifting water from deep-seated aquifers, to highly sophisticated forms of sprinkler and trickle irrigation. The culmination of irrigation technology is perhaps to be seen in the great circular irrigation schemes in the Libian desert, each covering a few hundred hectares, and looking from the air like huge green wheels laid on the ground, with water supplied from the hub as artificial rain from mobile spokes.

The water problems associated with the rapid development of irrigation, which scientists are still endeavouring to solve, present an equally wide range. They include the many different methods of applying water to crops in the right quantity, the quality of water, including means of reducing its salt content and sometimes increasing its nutrient content, the physics and chemistry of water in the soil typified by the salinisation problem, the best means of constructing drainage systems, the reduction of water loss through evaporation, the control of water-weeds, and of the aquatic fauna of which some kinds, such as mosquitoes and snails, transmit human and animal diseases. On top of these and many others, come the human problems: the provision of potable water, of sanitation, and of recreational facilities.

There are also problems of water polution which are sometimes acute in irrigated areas since the system of canals and drains offers an easy way of getting rid of waste. Sewage disposal sometimes has serious effects on the health of communities; waste from processing plants and excess use of fertilizers cause eutrophication, that is unduly high biological productivity which sometimes results in toxic products or de-oxygenation of water; irrigation water suffers increased salinity caused by recycling for irrigation perhaps several times in the course of a long river.

All these and other problems arising from irrigation were discussed at the International Symposium of February 1977 at Alexandria and are published in the volume edited by Worthington (1977). References to several of the contributions thereto have already been made, but it is worth indicating a few others which bear particularly on irrigation in Arab countries. The volume starts with a general assessment of the main effects and problems of irrigation in some 75 pages, which were the result of a joint working party convened by Professor Gilbert White of Boulder, Colorado, immediately after the symposium. Then come the individual papers and the discussions thereon. The influence of irrigation on hydrological processes was presented at length by G. Kovacs and T. Peczely of Hungary, and effects on water quality are described in a comprehensive paper by F.L. Hotes and E.A. Pearson of the USA. In the section on land use, soil and water, V.A. Kovda of USSR is concerned with soil fertility and the problems of salinity, alkalinity and compaction; he brings out differences of view on certain important soil problems between leading specialists in USSR and the USA. M.M. El Gabaly of Egypt has a comprehensive paper on the problems and effects of irrigation in the Near East region. A section on the effects of irrigation on biological balances was organised by M. Kassas of Egypt and includes papers on fisheries, mosquitoes, and on terrestrial biota. The section on the efficiency of irrigation schemes contains an overview by M. Holy, currently President of the International Commission on Irrigation and Drainage, another is on the influences of project management by M.G.Bos of the Netherlands, and a paper by I.Z. Kenawy on the efficiency of water use. Human problems are considered in two sections of the volume, one of them consisting of case studies. They include contributions from A. Coumbaras of France on the multidisciplinary approach to improved health which is derived especially from experience in southern Tunisia and the Ghab in Syria. Other papers are concerned with the social and economic consequences of large scale irrigation development, and with the two major irrigation diseases - schistosomiasis and malaria. Finally the international viewpoint is presented in several papers from the UN and the specialist agencies most closely concerned with irrigation. From these we learn, for example, that about 80% of the water consumed in the world by human activity is attributable to irrigation, that a very large proportion of irrigation schemes are operating at less than 50% efficiency in the use of water, and that a common by-product of irrigation, namely waterlogging and salinity of soil, is currently causing nearly as much irrigated land to go out of production as is being added by new projects. Statistics of this kind do not present a very encouraging picture of arid land irrigation, but an overall conclusion is that we know pretty well what to do about it from the scientific and technological standpoints. What the present and future demands is the application of this knowledge in the reorganization and recreation of many old projects even more, perhaps, than in the planning and designing of new ones. Above all a key factor for the future of irrigation is the daily activity of the individual irrigation farmer and his family on the land.

Underground water

Underground aquifers have been touched on but lightly in this paper but are becoming ever more important as knowledge on them is enhanced. Modern methods of geophysical prospecting provide an outstanding example of highly advanced technology applied from the industrial world to the Arab countries. Developed primarily in connection with the oil industry, they have also done much to reveal subterranean aquifers, indicating not only the quantity of water but also its quality. It is well to remember that the deep-seated aquifers, many of which are now being exploited, in most cases contain "fossil water", since they result from precipitation which has accumulated over many centuries. Thus their use, like that of oil, involves living on capital rather than income.

With all this modern technology it is salutary to recall that in some circles dousing continues to be used as a means of finding water. During the Second World War when the movement of troops in north Africa demanded water supplies where none existed previously, cases were not lacking where boreholes were sited by water deviners, although the method was not recognised officially. Certainly some experienced water deviners have an excellent eye for country and where water may be underground, but I recall the findings of a prominent water geologist who counted up the number of successful and unsuccessful boreholes made at that time by, a) dousers, b) sapper officers without advice, c) water geologists. The success of a) and b) was about equal, whereas that of c) was a great deal more.

The application of solar energy, which at long last seems to be developing quite effectively as a means of heating water is often thought of as a solution to the problem of lifting water for irrigation. Work is progressing at several laboratories on forms of low-lift solar pumps capable of one or two bullock power. If foolproof and needing no maintenance, these would obviously be of great benefit to countries like Egypt where a significant part of the crops is grown to feed animals, much of whose energy is expended in lifting water.

Desalination is another panacea hailed as a solution of water problems in arid coastal lands. The cost limits its use at present to domestic purposes; some projects which have been advanced for producing irrigation water by desalination seem to be out of scale. However, the cost of desalinating brackish water is very much less than of sea water. In some countries there are large supplies of water which is a little too saline for domestic or irrigation use. In such circumstances one could envisage the application of desalination techniques in the not too distant future.

Another approach to the use of brackish water for irrigation is from plant breeders producing resistant strains of certain crops and this has met with some success especially in Tunisia and Israel. Although communication of scientific results and methods of their application between the latter country and the Arab world is not yet easy, it should not be forgotten that scientists in the Negev Research Institutes have recently succeeded in devising means whereby cropping rates of certain plants can be doubled without using any more water.

Lastly, in this brief review of some water problems, I would enter a plea for integrated study, whether dealing with the development of a whole river basin, of an irrigation project, or of a village water supply. Many scientific disciplines are involved, for many questions cannot be left just to the hydrologist or the water engineer unless he is a person of very wide knowledge, interests and outlook. The working group which followed the symposium on arid land irrigation of February 1976, when it came to stating the current urgent research needs, concentrated almost entirely on integrated research: "To recommend integrated research is much easier than to carry it out, and there is no facile way of achieving it. The major difficulty often is to surmount the lack of communication among the different disciplines".

Conclusion

The past 30 years have seen tremendous developments in the world patters of science and technology, both in the governmental and non-governmental spheres. Much has been due to the great expansion of the United Nations family, at its centre, at the headquarters of its specialist agencies, and at the periphery with its regional organizations and its many establishments in individual countries. We have the first and second development decade, the indicative world plan for agriculture, the world plan of action for the application of science and technology to development, and in the subject of water the international hydrological decade followed now by the international hydrological programme. We have seen also the series of UN world conferences starting with the environment at Stockholm in 1972, followed by food 1973, population 1974, women 1975, habitat 1976, and those on water and desertification in 1977. The final UN world conference on science and technology for development of 1979 should benefit greatly from gatherings such as this one in the Arab region.

In the non-governmental sphere we have seen a similar expansion of international organizations working on many aspects of research and development. The largest and most comprehensive of these is the International Council of Scientific Unions which embraces 17 scientific unions and 9 committees, and has organised, among other major programmes, the international biological programme and, in cooperation with WMO, global atmospheric research programme. Outside ICSU in the water sphere, two large commissions of engineers, namely the international commission on irrigation and drainage and the international commission on large dams have also been active.

A great deal of the work of these many international bodies has been towards narrowing the technological gap between the developing and developed countries; but one frequently sees statements such as the following from the United Nations (1971): "The technological gap between the developing and developed countries, widened during the First United Nations Development Decade as new technologies kept on appearing at an accelerated pace in the developed countries. It is expected that this trend will continue also during the Second United Nations Development Decade. However, if new technologies are introduced judiciously, it is possible that developing countries may accelerate their technological advance."

The report goes on to illustrate economic and social gains which developing countries might obtain from the use of advanced sciences and technologies drawn from the industrial world. The illustrations are from three selected fields, namely nuclear, space and computer technologies.

While not for a moment questioning the judicious use of recent discoveries in these and other highly complex fields, I am constrained to state my view that the World Plan of Action, and also the Regional Plan of Action, pays insufficient attention to the people for whose benefit the plans are ultimately intended, in particular too little attention to their diversity and adaptability, and the constraints which these imply. It is too often assumed that men and women are equal in their individual potentialities and in their desires for progress. It is too often forgotten that one of the greatest attributes of Homo sapiens as a species is its diversity.

The tendency to diversity has been a primary force in the whole course of evolution; and it is this same force which has enabled man to colonize and adapt to conditions throughout the world, and throughout history. But in the application of science and technology to development, it seems to be assumed that the rural peasant in a warm climate has the same urges and desires as the industrial worker in a cold one. This implies a shortfall in understanding human ecology, and the reason for this is, I suppose, the rather backward and disorganised state which still obtains in "social" science compared with "natural" science. The former is striving to understand; the latter thinks it knows most of the answers.

30 years ago 'development' was looked at very largely in simple economic terms, such as gross national product and average income. A limited range of social services, mainly education and health, was thought necessary to achieve economic progress, but the achievements of local cultures, the wishes of the common people in so far as they were expressed, and the overall influence of new development projects on the environment and hence on the quality of life, were not considered of much account. There were a few people sounding warnings of where the world might be going as a result of rapidly expanding population and over-use of natural resources, and there was the beginning of a conservation movement interested especially in wild life and wild places. But not many of this avant guard, crying like pelicans in the wilderness, had influence on decision makers.

Meanwhile a series of events, such as the dustbowl in the North American prairies, the over-use of toxic chemicals in agriculture, great floods which caused disaster in over-populated countries, recognition that unique wild life was disappearing from the face of the earth, and the Sahel drought, stimulated more people, including scientists and politicians, to think of the future. The environmental revolution became established and ecology became a popular subject.

The environmental revolution is now certainly having an effect on science and technology in developing countries, including the whole Arab region. The World Bank will no longer finance development projects without an assessment of the environmental and social effects, and it seems likely that in future such impact assessments will be required for all development projects whether grant aided or not. I have even heard prominent engineers, accustomed to designing vast works in concrete and steel, speaking of "appropriate technology" and "intermediate technology".

In the light of these changes of attitude and of thought I would finish this paper with a question. In the improvement and elaboration of science and technology in developing countries should the narrowing and eventual closure of the technological gap between developing and developed be the overall aim? Or should a substantial part of the effort be guided by the diversity and adaptability, and the attitudes, of the indigenous people? In the latter case a technological gap may even be desirable in some branches of development. Technology would be built up from local roots, adapted to the local environment.

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