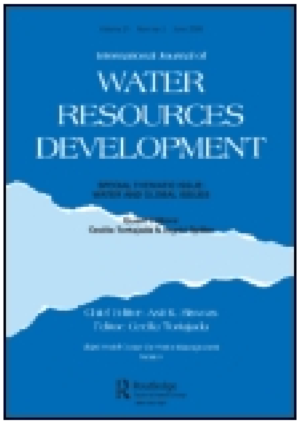

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Major water problems facing the world

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Major Water Problems facing the world

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Abstract

Water has become an increasingly important ingredient in the development process of all countries. Not only is safe drinking water essential for our well-being, but water is also a primary requisite for further agricultural, industrial and energy-related developments. Based on existing studies, four major water problems facing the world today are identified. These are the provision of safe drinking water; water requirements for further agricultural, hydroelectric and industrial developments; sustainability of water development projects; and development of water resources shared by two or more states. Both the magnitude and nature of the problem areas are discussed. Four major strategic considerations, as they relate to the priority areas identified, are outlined. These include consideration of the multidimensionality of the problem; promotion of the efficient use of water; encouragement of better management of water resources systems; and application of research results to solve real-world problems.

THE ROLE of water in the overall development process of countries has become an increasingly important issue during the last decade due to several events, some natural and others man-made. Firstly, severe droughts and floods in many parts of the world during the early 1970s contributed to a major food crisis. During the World Food Conference (Rome, 1974), convened to propose solutions to such a major global crisis (Biswas and Biswas, 1975), it became evident during the deliberations that proper control and management of water is absolutely essential not only for further horizontal expansion of agriculture, but also for increasing the overall yield from existing cultivated land.

Secondly, the steadily increasing prices of fossil fuels, especially oil, focussed international attention on the development of hydroelectric power (a renewable

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resource) as a viable source of additional electric power generation. This was a departure from the practices of the 1950s and '60s, when many countries preferred to construct power plants with a fossil fuel base because of the economic advantages they offered and their easy availability.

Thirdly, the Lima Declaration of the United Nations Industrial Development Organization recommended that, by the year 2000, 25 per cent of global industrial production should take place in developing countries. If this is to be achieved, more water will be required for further industrial development. Fourthly, the UN Conference on Human Settlements (Biswas, M.R., 1978) and on Water (Biswas, M.R., 1977) emphasized the plight of people in developing countries, especially in rural areas, who do not have access to safe drinking water. On the recommendation of the 1977 Water Conference, the decade 1981-1990 was officially declared the International Drinking Water Supply and Sanitation Decade, by the General Assembly of the United Nations (Biswas, 1981a).

Finally, pollution of inland and coastal water bodies and of the oceans has attracted increasing national and international concern, partly through the work of the United Nations Environment Programme (UNEP), which itself was created in the early 1970s at the UN Conference on the Human Environment (Stockholm, 1972). All these events, individually and collectively, clearly indicated the urgent necessity of sustainable water development to ensure optimal utilization of available water, as well as maintenance of its quality.

Major Water Problems facing the world

The author has carried out a number of water resources development studies for the United Nations Water Conference (Biswas, 1978), held at Mar del Plata, Argentina, in 1977; for various United Nations agencies and international organizations, such as the Organization of Economic Co-operation and Development in Paris, the North Atlantic Treaty Organization in Brussels, the International Institute of Applied Systems Analysis in Laxenburg and the International Federation of Institutes of Advanced Studies in Stockholm; scientific organizations, such as the International Water Resources Association and the International Commission on Irrigation and Drainage; and individual governments of numerous developed and developing countries. Based on these studies, the major water problems facing the world are:

(1) Provision of safe drinking water.
(2) Water requirements for further agricultural, hydroelectric and industrial developments.
(3) Sustainability of water development projects.
(4) Development of water resources shared by two or more states.

These priority areas have been selected on the basis of three major criteria:

(1) Global interest and thus, affecting a large number of people.
(2) Immediate nature of the problem.
(3) Availability of adequate information on the magnitude and extent of the problems, as well as knowledge of the steps to be taken for their solution.

It should be noted that the problems identified have not been listed in any specific order of priority. This is because some of the problem areas listed are site-specific. For example, the provision of safe drinking water is primarily relevant to developing countries and is not a problem among advanced industrialized nations. Similarly, development of shared water resources is a major problem for many countries but not applicable to countries like Australia or Sri Lanka. In contrast, all four problems are important for many countries like Argentina, Bangladesh, Brazil, Egypt, India or

Kenya. For these countries, the four areas need immediate emphasis and simultaneous attention.

Provision of Safe Drinking Water

A large number of people in developing countries do not have access to clean water. Reliable figures on the exact number do not exist. But an aggregate of selected 'raw' estimates of varying degrees of accuracy from many developing countries is provided by their governments and compiled by the World Health Organization (WHO) of the United Nations. Its most comprehensive recent survey, as of the end of 1975, rested on questionnaires returned by 71 developing countries, which unfortunately did not include the most populous country in the world — the People's Republic of China.

According to this survey, 77 per cent of the urban population had access to piped water supply through house connections or standpipes. The situation, as to be expected, was significantly worse for rural communities, where 78 per cent did not have access to safe water (WHO, 1976). The report further indicated that the number of people with access to public water supply schemes in developing countries increased from about 400 million to some 750 million during the period 1970 to 1975. Despite this dramatic increase, however, the number of people *not* receiving clean water remained almost the same, due to rapid population growth.

A later WHO estimate for 1980 (even more unreliable than the 1975 survey) indicated that the percentage of urban and rural populations having access to clean water had increased to 75 and 29 per cent respectively (WHO, 1981). Since rural populations predominate in developing countries, the percentage of the total population having such access increased from 38 per cent to 43 per cent during the five-year period.

Two important issues emerge from a review of the limited information available. Firstly, access to safe drinking water is, at present, essentially a rural rather than an urban problem. This situation has developed over the years not only because of distinct urban bias on the part of national planners, but also due to existing political and institutional pressures. The elite who hold power are urban-based and their policies, in spite of the rhetoric, clearly favour the urban areas, where their power centres normally lie. The fact that rural people tend to be poor, illiterate and malnourished, and thus have very little political power, does not help. The direct beneficiaries of national policies are often the educated urban elite who are in power. In addition, inadequate planning, insufficient budget, incomplete execution of plans, limited appreciation of the problems of rural people and a lack of understanding and emphasis by donor countries and agencies — all these factors have not helped the cause of water supply in rural areas.

Secondly, from the existing scattered data available, it must be concluded that, while major advances have been made during the past 20 years in increasing the percentage of people having access to clean water in most developing countries, there have also been declines in some regions. WHO carried out three surveys in 1962, 1970 and 1975. The data obtained are not strictly intercomparable, since the numbers of countries surveyed have changed with time: 75 countries in 1962, 91 in 1970 and 71 in 1975. Furthermore, an examination of 1970 and 1975 data indicates that even the individual national estimates of many countries differ significantly from one period to another due to major differences in enumeration, presumably because of different people involved and/or different techniques used.

In spite of these constraints, when changes in percentages of urban population served during the 1962 to 1970 period are considered, the situation in the South-East

Asian and East Asian regions improved remarkably, both by more than 20 per cent. In contrast, the situation was much different in the Latin American and Caribbean region, where a ten per cent decline was registered. Similarly, in the 1970 to 1975 period, South-East Asia, East Asia and the Western Pacific showed most improvement (15 per cent or more) but, unfortunately, in Africa, south of the Sahara, the situation deteriorated and showed a two per cent decline.

As this deplorable situation of water availability became more clearly recognized, a series of goals and objectives were approved at intergovernmental level during the last decade (Biswas, 1981a). Among these was the United Nations Conference on Human Settlements, commonly known as Habitat (Vancouver, 1976), which approved a sweeping goal of safe water for all by 1990, if possible. The following year, the United Nations Water Conference approved that 'all peoples have the right of access to drinking water in quantities and of a quality equal to their basic needs.' It recommended that 'priority attention' should be given to 'the segments of the population in greatest need'. It re-endorsed the Habitat target of clean water for all by 1990 and urged countries to develop suitable national plans and programmes to meet the targets by 1980. It further recommended that the decade 1981-1990 should be designated the International Drinking Water Supply and Sanitation Decade (Biswas, 1978).

A realistic estimate of the chances of success in achieving the goals of the Decade has to be that they are not very great for a variety of reasons which have been discussed elsewhere (Biswas, 1981a). Goals and targets are easy to design and resolutions are easy to pass. But resounding and pious declarations are not enough by themselves: they must be implemented. The Decade's objective, of clean water for all by 1990, should at best be considered as the target to be aimed at (and preferably achieved) by as many countries as possible. It should be considered as the beginning of more intensified programmes and activities, with the first stage being the provision of even intermittent water supply in urban areas and standpipes in rural areas. The final phase could be the provision of running water in all homes.

Based on current trends, clean water and sanitation for all by 1990 may appear like the impossible dream sought by Don Quixote, the Man from La Mancha. But, for many citizens of the world, this dream could become a reality with intensified efforts and that alone is worthwhile. This is no doubt an important priority area.

Water Requirements for further Agricultural, Hydroelectric and Industrial Developments

While availability of safe drinking water is very important, the agricultural and industrial sectors, on a quantitative basis, are the major users of water, significantly more than domestic water use. On a global basis, agriculture is the largest user of water, accounting for approximately 80 per cent of global consumption (Biswas, 1978, 1979). Industrial water use is a major consideration in certain countries like Canada, where it accounts for nearly 84 per cent of total withdrawal. The corresponding figure for the United States is about 40 per cent. However, for a developing country like India, industrial water use accounts for only about one per cent of total withdrawal (Biswas, 1979).

Without appropriate water control, it will not be possible to solve the world's food crisis. The potential benefits to rice production under various degrees of water control, combined with additional material inputs and consistent with cultural practices, are shown in Table 1, in which average output increases when the degree of overall control is increased (FAO, 1978).

TABLE 1
YIELDS OF PADDY RICE WITH DIFFERENT DEGREES OF WATER CONTROL

Degrees of water control	Material inputs	Location	Average yield for 1971-74 in tons/hectare
No water control (rainfall, uncontrolled flooding)	nil	Laos	1.3
Successive introduction of water control			
(a) elimination of floods	nil	Kampuchea	1.5
(b) elimination of drought	low fertilizer application	Burma India Thailand	2.0
(c) improved water control (irrigation and drainage)	low to medium fertilizer application	Pakistan Vietnam Sri Lanka Malaysia (West)	3.0
(d) sophisticated management practices (mid-season drying)	high fertilizer use + improved seeds and pest control	South Korea	5.0
	+ diversification, mechanization	Japan	6.0
Experimental conditions			10.0

Source: FAO (1978).

In 1975, the total area irrigated in the world amounted to 223 million hectares (ha), of which 92 million ha were in developing countries (FAO, 1978). The amount of water used by irrigated crops is nearly 1,300,000 million m³ but because of losses, the amount used increases to almost 3,000,000 million m³. (This aspect will be discussed later.) Only some 15 per cent of the world's croplands are irrigated, yet they contribute 30-40 per cent of all agricultural production.

By 1990, it is estimated that the total area irrigated in the world will increase to 273 million ha, of which 119 million ha would be in developing countries (FAO, 1978). Expanding and maintaining irrigated areas is going to be a challenging task for the future; its magnitude can be judged by the following requirements for the developing market-economy countries only (FAO, 1978):

- 22.5 million ha of new irrigation
- 45.0 million ha of irrigation improvement
- 78.2 million ha of drainage improvement, including 52.4 million ha on irrigated land
- 438,000 million m³ of additional water
- US$97,800 million of investment at 1975 prices

Industrial developments will also require more water in the future. According to the targets set for the Second Development Decade of the United Nations, industry in developing countries was expected to grow at an annual average rate of 8 per cent. The Lima Declaration and Plan of Action recommends that the total share of manufacturing output of developing countries should increase to 25 per cent by the year 2000. If the Lima target is to be met, industrial water requirements for developing countries will increase substantially. This would have major impacts not only on the quantity of water used, but also on the quality of water due to the discharge of effluents. Much of the water required by the industrial sector (nearly 60 to 80 per cent) need not be of a high quality since it is used primarily for cooling. However, such enormous discharges of heated water could aggravate thermal pollution problems.

Hydroelectric power is a major objective of water developments. Currently, it accounts for 70 to nearly 100 per cent of all electricity generated in countries as diverse as Brazil, Canada, Morocco, Norway and Sri Lanka. Hydropower has recently become attractive for many countries, especially in terms of increasing self-reliance and reducing the national balance-of-payments problem caused by importing energy-producing materials. While the capital costs for hydro developments are high, running costs are minimal. Furthermore, generation of electricity does not consume water, which can then be used for agricultural, industrial and other purposes.

The potential for hydropower has been realized to a great extent in North America and Europe (including the USSR). But there is a vast potential waiting to be developed in Africa, Asia and Latin America as shown in Table 2 (El-Hinnawi, 1981). Africa's hydro potential is the least developed, its current annual production being only 4.3 per cent of the potential output. Thus, in Africa, the trend towards increasing emphasis on hydropower generation, in preference to other forms of energy development, is likely to continue for the foreseeable future.

Sustainability of Water Development Projects

Water development, like any other type of development, must be sustainable over the long term and the social and environmental costs from such developments should be kept to a minimum. Currently, over-irrigation is endemic and not exactly an uncommon practice in both developed and developing countries. Much water brought to the fields, after major capital expenditure, is thus wasted; this practice contributes to the development of adverse environmental problems, such as an increase in groundwater tables and salinity levels. Ultimately, it reduces the yield of agricultural

TABLE 2
WORLD HYDROPOWER POTENTIAL

	Potential available 95% of time (10^3kW)	Potential output 95% of time (10^6kWh/y)	Present installed capacity (10^3kW)	Current annual production (10^6kWh/y)	Per cent of developed potential (4)/(2) x 100
Africa	145,218	1,161,741	11,437	49,663	4.3
Asia	139,288	1,114,305	59,773	245,096	22.0
Europe (incl. USSR)	102,961	827,676	177,797	620,676	75.0
N. America	72,135	577,086	111,402	434,035	75.2
Latin America	81,221	649,763	38,582	176,845	27.2
Oceania	12,987	103,897	9,578	31,669	30.5
World Total	553,810	4,434,468	408,569	1,557,984	35.1

Source: El-Hinnawi (1981).

products, thus undermining the very objective for which the initial development was undertaken.

There are many cases where water development projects, designed to increase irrigated agriculture, have contributed to problems that eventually reduced the total food production. Among such problems are the deterioration of soil fertility and eventual loss of good arable land due to the progressive development of salinity, alkalinity or waterlogging. For example, at one time Pakistan alone was losing 24,280 ha of fertile cropland every year; currently, nearly 10 per cent of the total Peruvian agricultural area is affected by land degradation due to salinization. Other major areas affected by salinization are the Helmud Valley in Afghanistan; the Punjab and Indus Valleys in the Indian sub-continent; Mexcali Valley in Mexico; and the Euphrates and Tigris Basins in Syria and Iraq (Biswas, M.R., 1979a, 1979b).

Groundwater resources have been extensively developed in many countries in recent years, primarily for irrigation. If such developments are based on the fundamental hydrological principle that the rate of abstraction should be equal to or less than the rate of recharge, then they are sustainable. Unfortunately, in many instances, the rate of abstraction of groundwater far exceeds the rate of recharge, thus contributing to serious over-exploitation. Such practices result in not only a continual lowering of the watertable, but also often contribute to decreased pressure in aquifers, changes in rate and direction of flow, salt water intrusion and land subsidence. Continued over-exploitation, coupled with high energy costs, could mean that the watertable is lowered to such an extent that it is no longer economic to pump the water for irrigation. Agricultural developments in such instances can only be treated as temporary phenomena, since production declines significantly once water availability is reduced. This situation has already occurred in many parts of the world. For example, recent data from groundwater monitoring in the province of Tamil Nadu in India indicate that at least 37 observation wells had a net fall of more than 6 metres during a mere six-year period, between January 1973 and January 1979. One well recorded a net fall of as high as 16.40 metres, which means an average lowering of 22.77 cm per month — a very high figure viewed from any direction (Srinivasan, 1979). With increasing emphasis on the use of groundwater for the further horizontal and vertical expansion of agriculture, it is imperative that the developments planned are sustainable.

Development of Water Resources shared by two or more States

With increasing demands on water for different purposes, conflicts between nations sharing the same river and lake basins or aquifers are likely to intensify in the future (Zaman, 1983). The magnitude of the problems of developing shared water resources has not yet been fully realized. National boundaries frequently divide drainage basins and conflicts between nations often arise due to competing demands over limited supplies of available water and/or deterioration of water quality through waste discharges. On a global basis, there are 214 river or lake basins that are shared by two or more countries (Biswas, 1981b). These are distributed as follows:

Africa	57
Asia	40
Europe	48
North and Central America	33
South America	36
Total	*214*

There are nine river and lake basins which are shared by six or more countries. Arranged in descending order according to the number of countries involved, these are:

Danube	**12 countries** — Romania, Yugoslavia, Hungary, Austria, Czechoslovakia, Federal Republic of Germany, Bulgaria, USSR, Switzerland, Italy, Poland, Albania.
Niger	**10 countries** — Mali, Nigeria, Niger, Algeria, Guinea, Cameroon, Upper Volta, Benin, Ivory Coast, Chad.
Nile	**9 countries** — Sudan, Ethiopia, Egypt, Uganda, Tanzania, Kenya, Zaire, Rwanda, Burundi.
Zaire	**9 countries** — Zaire, Central African Republic, Angola, Congo, Zambia, Tanzania, Cameroon, Burundi, Rwanda.
Rhine	**8 countries** — Federal Republic of Germany, Switzerland, France, Netherlands, Austria, Luxembourg, Belgium, Liechtenstein.
Zambezi	**8 countries** — Zambia, Angola, Zimbabwe, Mozambique, Malawi, Botswana, Tanzania, Namibia.
Amazon	**7 countries** — Brazil, Peru, Bolivia, Colombia, Ecuador, Venezuela, Guyana.
Lake Chad	**6 countries** — Chad, Niger, Central African Republic, Nigeria, Sudan, Cameroon.
Mekong	**6 countries** — Laos, Thailand, China, Kampuchea, Vietnam, Burma.

It should be noted that the countries listed are arranged on the basis of their share of the total basin area per country. For example, the Mekong River Basin has a total area of 786,000 km^2; the area and percentage share by the six countries is shown in Table 3.

Viewed from a different perspective, there are at least 40 countries where a minimum of 80 per cent of the total area of the country falls within an international river basin (Table 4).

During the past decade, several long-standing conflicts have emerged over the development of international rivers, such as the Colorado (United States and Mexico), Euphrates (Syria and Iraq), Ganges (India and Bangladesh), Indus (India and Pakistan), Jordan (Israel and Jordan) and La Plata (Brazil and Argentina). With

TABLE 3
COUNTRIES SHARING THE MEKONG RIVER BASIN

Country	km^2	Percentage
Laos	199,500	25.4
Thailand	180,000	22.9
China	174,000	22.2
Kampuchea	149,000	18.9
Vietnam	60,500	7.7
Burma	22,500	2.9

TABLE 4
COUNTRIES WHERE AT LEAST 80 PER CENT OF TOTAL AREA FALLS WITHIN INTERNATIONAL RIVER BASINS

Countries	Total Area (km²)	Area within International Basin (km²)	Percentage of country within International Basins
AFRICA			
Benin	112,620	104,800	93
Burundi	27,830	27,830	100
Central African Republic	622,980	622,980	100
Congo	342,000	283,500	83
Equatorial Guinea	28,050	28,050	100
Ethiopia	1,221,900	972,100	80
Gabon	267,670	229,700	86
Gambia	10,260	9,500	91
Guinea	245,590	198,200	81
Lesotho	30,360	30,360	100
Malawi	118,480	113,500	96
Nigeria	923,768	805,000	87
Rwanda	26,390	26,390	100
Sudan	2,505,813	2,035,900	81
Swaziland	17,360	17,360	100
Uganda	236,040	236,040	100
Upper Volta	274,200	274,200	100
Zaire	2,345,410	2,339,800	99
Zambia	752,610	752,610	100
Zimbabwe	390,580	389,360	100
ASIA			
Afghanistan	647,500	587,000	91
Bangladesh	142,780	123,300	86
Bhutan	47,000	47,000	100
Iraq	434,920	362,500	83
Kampuchea	181,040	158,000	87
Laos	236,800	222,900	94
Nepal	140,800	140,800	100
EUROPE			
Andorra	470	470	100
Austria	83,850	83,850	100
Belgium	30,510	29,300	96
Bulgaria	110,910	88,000	80
Czechoslovakia	127,870	127,870	100
German Democratic Republic	108,180	100,300	93
Hungary	93,030	93,030	100
Liechtenstein	160	160	100
Luxembourg	2,590	2,590	100
Poland	312,680	298,570	95
Romania	237,500	233,000	98
Switzerland	41,290	41,290	100
Yugoslavia	255,800	211,850	83
LATIN AMERICA			
Bolivia	1,098,580	1,018,200	93
Paraguay	406,750	406,750	100
Uruguay	177,510	172,610	97
Venezuela	912,050	734,210	80

increasing population and the need for further economic development, pressures for development of a country's resources will become even more critical. For example, the Ganges Basin alone may have to support some 500 million people by the year 2000. With such pressures, the potential for conflicts between nations will, in all probability, increase dramatically.

There is thus an urgent need to identify existing and emerging conflicts and to develop guidelines and processes for resolving them. International organizations like the United Nations have not made any serious attempts or studies for the resolution of such conflicts.

Strategies

In order to ensure sustainable development in the four priority areas mentioned, several strategies have to be adopted. Only the more important strategic considerations will be discussed here due to limited space.

Multidimensional problems

Many of the current strategies for water resources are based on the primary objective of solving a specific narrow problem on the principle of reductionism. Strategies are generally developed by those professions that tend to dominate the problem. This approach has contributed to more problems since nature is not organized in the same way as are professions. For example, one hears of engineering problems, biological problems, social problems, chemical problems, medical problems and so on. In a real world, of course, nothing can be further from the truth. A problem is a problem and the addition of the professional adjective only indicates our way of viewing and analysing that problem. The method of analysis depends on the analyst's education, training and background, all of which can introduce significant biases in the resulting analyses on which strategies for solutions are based.

Let us consider the first priority area discussed — community water supply. It has been mostly argued that if the quality of water supply is improved, there would be tremendous health benefits. This is not surprising since public health workers dominate this field. Contrary to all the pious statements made in various international fora, it is not possible at present to define precisely the relationship between quality of water and public health. Other broad and diverse elements are also important, such as housing, comprehensive health services, availability of nutritious food, energy, education and transportation. Many health and other related benefits that most people now expect from the provision of clean water are unlikely to accrue unless a broader view of the problem is taken.

Current studies in Bangladesh, Guatemala, Lesotho and the United States have failed to demonstrate that improvements in water quality have a marked impact on the incidence of diarrhoeal disease. The reasons for such findings are complex and are discussed in detail elsewhere (Biswas, 1981a). Suffice it to say that water is not the only means through which faecal-oral diseases (like cholera, typhoid, diarrhoeas, dysenteries or hepatitis) are transmitted. Furthermore, from the empirical studies available so far, it is becoming increasingly evident that the quantity of water used has an important impact on health. And yet the current practice of providing standpipes does not appear to increase water use patterns in rural areas.

Improving water quality via standpipes does not automatically improve personal hygiene practices that have developed over centuries. Only in a few instances, where potable rural water supply schemes have been developed, have bathing and laundry facilities also been provided. People thus continue to use contaminated sources for these purposes and infection continues. The importance of educating the public about good hygienic practices cannot be overemphasized. At present, such services in rural areas are mostly non-existent, even for those households looking for information. Unfortunately, this simple lesson has still not been fully grasped by most national and international agencies active in this area.

It should also be pointed out that, in most cases, there is no provision for drainage of spilled water at the standpipes, with the result that pools of stagnant water — a common sight in most developing countries — have become breeding grounds for mosquitoes and other insects. This in effect means trading water-borne for mosquito-borne diseases!

Encouraging the efficient use of water

With increasing water requirements, it is essential that strategies encourage the efficient use of water. Such strategies are especially relevant for the agricultural and industrial sectors, where there is enormous potential for saving water.

There is no doubt that, at present, water use in the largest sector — agriculture — is inefficient. As previously stated, 1.3×10^{12} m^3 of water is used globally for irrigating crops, for which 3×10^{12} m^3 of water has to be withdrawn. In other words, 57 per cent of the total water withdrawn is lost. And this is likely to be a conservative estimate! The actual losses are probably much higher.

One of the most inefficient aspects of existing irrigation systems is often the section where water is transferred from canal outlets to farms. It has almost become a 'no-man's land' due to undefined responsibility, which in turn contributes to improper design at first and, later, to unsatisfactory operation and maintenance. While much research has been carried out on losses from canals, very little has been done on losses from such sections of the irrigation system. Studies carried out on 40 such sections in the Indus Basin during 1975 and 1976 indicated losses ranging from 33 to 65 per cent, with an average of 47 per cent. Another investigation on 60 sections, carried out in 1977 and 1978 by the Water and Power Development Authority of Pakistan, indicated similar losses (Biswas, 1981b). The magnitude of this problem can best be realized by considering the case of well-lined canals, which are expensive to construct but have operating efficiencies of 70 to 80 per cent. When the efficiency of the total system is considered (that is, lined canals in conjunction with the inefficient section from canal outlets to farms), the total efficiency is of the order of 20 to 50 per cent. This means that even for expensive, lined and well-maintained canal systems, less than one-quarter of the water released from a reservoir reaches the crops being irrigated. The Central Board of Irrigation and Power of India recommend that channels above 1,000 cusecs (304.9 m^3/sec) should be lined (CBIP, 1975).

A major consequence of this sad state of affairs is that engineers have accepted this inefficient system, at least implicitly. During the planning of irrigation projects, total water requirements are generally calculated by multiplying the extent of the total area to be irrigated by the water required per hectare. The water requirement per hectare is generally estimated on the basis of existing systems where, as we have seen, major amounts of water released from reservoirs are lost. Accordingly, overall estimates of the water requirements for irrigation are invariably high — certainly significantly higher than necessary — and this inefficient system is condoned and perpetuated. In other words, most irrigation systems designed so far are generally inefficient and use far more water than is needed. Unfortunately, instead of attempting to make irrigation systems more efficient and then maintain them at such high levels, engineers are constantly looking for new sources of water instead.

Costly alternatives are often considered, such as interbasin water transfer, when such major and expensive projects are not essential (Biswas, 1981c). Cheaper alternatives are available and can be implemented within a significantly shorter time frame with the indigenous labour force and expertise, by simply improving the existing systems. Furthermore, when new projects are developed, unless special efforts are made to maintain their efficiencies at high levels, their effectiveness will decline with time and the vicious circle continues. Viewed from a different standpoint, present irrigation systems are highly efficient in recharging groundwater!

While the potential for saving irrigation water is extremely high, water can be used more efficiently in other sectors as well. For example, nearly 60 to 80 per cent of the water required for industrial processing is for cooling; by extensive recirculation, the total water requirements can be drastically reduced. Thus, water requirements per ton of soap manufacturing vary from 960 to 37,000 tons, the lower figure being only 2.5 per cent of the former. Similar savings in water can be achieved with other industrial processes. Accordingly, strategies promoting water conservation will become increasingly important in the future.

Better Management of Water Resources Systems*

Much emphasis in the past has been placed on the planning and construction of water resources systems: management aspects have not received adequate attention. There are many reasons for this neglect but only two will be mentioned here. Firstly, the engineering profession tends to dominate the water field and seem to be more interested in the design and construction of new projects rather than actually managing them. Design and construction aspects are considered to be a challenge, whereas maintenance and management do not appear to be considered so.

Secondly, aid agencies prefer construction of major projects like dams. Such projects are more appealing to donor countries since much of the aid can be used for consultancies, construction contracts, purchase of equipment and so on. This means that a major percentage of the funds expended on the projects ultimately return to the donor country. For example, current estimates indicate that 70 per cent of aid funds in Great Britain return to that country. Furthermore, politicians of both donor and recipient countries can get more political mileage out of large projects compared to those that deal with management only.

The return from improved management practices can be demonstrated from two recent well-documented experiments. The first was at the International Rice Research Institute in the Philippines, where modest changes were made in the water-distribution procedures for a distributory commanding 5,700 ha (Valera and Wickham, 1978). Some minor technical improvements were also made. These had the effect of increasing rice production by 94 per cent over a two-year period. The production significantly increased by 149 per cent in the tail section. Similarly in Sri Lanka, Shanmugarajah and Atkukorale (1978) report a 50 per cent increase in rice production for an area of 5,000 ha irrigated by a tank. This was achieved by better management

*For further details on management aspects, see *Water Supply and Management*, Volume 5, Number 1, 1981.

practices alone. In contrast, Carruthers (1981) reports that more than half of the irrigated land in Madagascar is currently not producing at all because of poor maintenance and operating difficulties.

For community water supply, management is also a very important consideration. There simply is no point in installing new services if they cannot be maintained. Past studies indicate that 40 to 80 per cent of all hand pumps break down within three years of installation. In 1976, as many as 80 per cent of the tubewells, established with foreign aid, in South India and Bangladesh were out of service (Biswas, 1981a). Currently, 30 to 40 per cent of the tubewells in Bangladesh are inoperative at any given time and some have not been used for the last 2 or 3 years.

Application of Research Results to real-world problems

Currently, much emphasis is placed on research but not enough on its application. This is giving rise to two main problems. Firstly, there are too many research projects going on whose real values are somewhat dubious. Secondly, even for good research projects, the investigators do not appear to have the motivation to use their results to solve actual problems. While the author has no objection to researchers living in ivory towers, these should not be their only place of residence!

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