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INTEGRATED WATER MANAGEMENT: SOME INTERNATIONAL DIMENSIONS

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ABSTRACT

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With the continuing increase in world population, and rising standard of living, more and more water will be necessary to satisfy basic human needs. The global picture with regard to water use and availability is very uneven, and the policy options for major sectoral uses — rural and urban water supply, agricultural requirements and hydro-electric power generation are explored. The social and environmental implications of water development are briefly discussed. Finally, the question of the availability of adequate water to sustain future world population and development to the year 2000 is analysed. It is concluded that the major problem in the area of water-resources development is not one of the Malthusian spectre of impending scarcity, but one of instituting rational management practices.

INTRODUCTION

Water, said the Greek philosopher Pindar, as early as the fifth century B.C., is the best of all things. It may perhaps be an overstatement, but it certainly is not surprising, especially when it is considered that it has been one of the most precious commodities throughout man's recorded history. Water makes human, animal and plant life possible, and without it, life and civilization, at least the way it is known today, cannot develop or survive.

During the late Stone Age, man started growing food by raising livestock and farming. Agricultural communities gradually developed on flat and fertile land adjacent to the river valleys. Since the population was small and water was plentiful, people simply migrated during prolonged droughts until better locations were found. Thus, from the very beginning, water has been treated as a "free" resource, a gift from God, that can be used as desired or squandered on whims. This freewheeling concept, until recent times, did not pose serious large-scale management problems.

The situation started changing with the advent of the Industrial Revolution. Centres of dense population started to develop as workers left agricultural sectors to man burgeoning industry. As the industrial cities developed, they attracted more migrants from the rural sectors, which, in turn, attracted more industry, and thus created a vicious circle. Unfortunately, it was a common practice to establish industry near to large water courses because of the ease with which the waste products could be discharged. In addition to the industrial effluents, cities often discharged their wastes into the rivers without much treatment, and thus compounded the pollution problem. The result of such developments was gross water pollution near and around centres of population. In Medieval Paris, streets were often like open sewers, but the River Seine was clean and one could see fish swimming. Times have changed. Today, the streets of Paris are clean, but the Seine is murky and grey, and one would indeed be fortunate to see any fish.

POLICY OPTIONS FOR SECTORAL USES

Water is used for many purposes, chief among which are, domestic, irrigation, hydropower, industrial, navigation, recreation, wildlife habitat and waste disposal. In addition, water resources management plans often consider flood control and low-flow augmentation requirements. The quality and quantity of water required to satisfy each of these demands vary considerably, depending on types of demands, geographical locations, cultural traditions, standards of living, climatic characteristics and other individual factors.

Policy options for major sectoral uses of water on a global and regional scale will be briefly discussed herein.

Rural and urban water supply

From a global perspective, the problem can be viewed within two extremes. At one extreme are the highly urbanised cities of advanced industrialised countries, where the vast majority of the population have in-house water connections and sewerage services, backed by adequate infrastructure and institutional arrangements, having access to adequate financing, high-level technology and necessary service personnel. At the other extreme is the rural sector of developing countries having no service of any kind for either potable water or excreta disposal. In between these two extremes are the majority of cases, where certain percentage of the population have access to water supply and/or sewerage services.

The World Health Organisation (W.H.O.) carried out a survey in 1976 on the extent of water supply and sewerage facilities available, at the end of 1975, to developing countries. Based on the survey questionnaire that was returned by 67 developing countries, following scenario emerges. In urban communities, 57% of the population have house connections and another 18% have access to stand-pipes, making a total of 75% (390 million people) that have access to potable water. The situation, of course, is far worse for the rural sector, where only 20% (248 million) have reasonable access to safe water. Considering both rural and urban populations together, only 35% (638 million) are adequately served.

These, of course, are average figures, and hide the tremendous disparity that exists even within the developing countries. The range of this disparity can be easily seen by considering community water supply situation in Africa. At the upper range are several countries where more than 90% of the urban population are served by potable water. These are Botswana, Lesotho, Liberia (all 100%); Mauritius, Senegal (98%); Gambia, Guinea, Ivory Coast, Kenya, Togo, Zambia (97%); Benin, Egypt (94%); Morocco and Tunisia (91%). At the bottom end of the scale are the rural populations of many countries, where even 5% do not have access to safe water. These are Burundi, Gabon, Madagascar, Sierra Leone (1% or less); Kenya (2%); Gambia (3%); Togo and Zaire (5%). In addition, there are several other countries where data on rural sectors are not available, but they are virtually certain to be less than 5%. These are Central African Republic, Ethiopia, Guinea and Lesotho (U.N., 1976).

The goal of the Second Development Decade (DD2) of the United Nations is to extend water availability by 1980 to 100% of urban populations (60% through house connections and 40% through stand-pipes), and 25% of rural population. The investment required to reach this goal for Africa has been estimated at US$ 3,479 million, $ 2,576 for urban and $ 903 for rural populations (World Bank, 1976).

Unless a concerted effort is made to meet the DD2 targets, these will continue to remain targets. This is especially true in view of the latest unencouraging picture of Africa that has emerged from the W.H.O. (1976) survey:

> "The percentage of the urban population served by house connections in Africa increased only marginally from 33% to 36% from 1970 to 1975. Therefore, a more realistic target of 45% to be achieved by 1980 is now proposed for this region, instead of the global target of 60% already adopted. The percentage of the urban population served by public standposts has actually decreased from 34% to 29%. The proposed new target is 35%, giving a total 1980 urban target of 80%, including both house connections and public standposts."

and

> "In the rural sector, the percentage of the population having reasonable access to safe water increased from 13% in 1970 to 21% in 1975. In view of the progress made, a new target of 35% is proposed for attainment by 1980."

If the DD2 targets are met for Africa by 1980, and this target is continued to the year 2000, the number of people without safe water will continue to increase with time. As shown in Table I, during the period 1970 to 2000, populations seved with safe water will increase from 92 to 433.5 million, but during the same period, the number of people not served will increase from 188.6 to 379.5 million. This means that unless the countries and the international community revise the DD2 targets upwards after 1980, all the popu-

TABLE I

Water supply situation in Africa, 1970—2000 (population is in millions, and does not include Angola, Equatorial Guinea, Malawi, Mozambique, South West Africa/Namibia, Rwanda, Republic of South Africa, Zimbabwe, Swaziland and island countries and territorries)

Population	1970			1980			2000		
	total	served	not served	total	served	not served	total	served	not served
Urban	70.0	51.2	18.8	108.0	108.0	0.0	307.0	307.0	0.0
Rural	210.6	40.8	169.8	289.0	72.3	216.7	506.0	126.5	379.5
Total	280.6	92.0	188.6	397.0	180.3	216.7	813.0	433.5	379.5

lation of Africa will not have access to safe water even by the year 2000 (U.N., 1976).

The quality of water available is of prime importance to human health. Use of potable water will undoubtedly reduce health hazards like cholera, typhoid, infectious hepatitus and bacillary dysentery. It would further reduce human contacts with vectors of water-borne diseases like schistosomiasis, trypanosomiasis or Guinea worm (*Dracunculus medinensis*). For example, with regard to trypanosomiasis, some have estimated that the Gambian sleeping sickness, trypanosoma gambiense, can be reduced by 80% by good water supply schemes (Bradley, 1974). While this figure may be somewhat optimistic, there is no doubt that the provision of potable water will reduce the incidence of the dreaded sleeping sickness disease by reducing the exposure of human beings to tsetse flies during the water collection journey. Similarly, Guinea worm infection, which currently affects some 48 million people, chiefly in India and West Africa, can also be reduced (Muller, 1971). Maximum infection occurs during dry periods, when people rely on ponds and other shallow sources. Infection rates of over 50% have been observed in India and Nigeria, and incidences of around 20—30% are commonly reported. The health and economic costs to the communities can be substantially reduced by rational water resources development and management. It would further reduce the water collection journey, mainly of women and children who currently spend up to five hours every day collecting the family water requirements. The time, thus freed, can be used for learning or productive work.

Water for agriculture

Water is essential for agriculture, and if the world food crisis is to be solved, there is no alternative but to increase the total area under irrigation. The potential benefits to crop production under various degrees of water control, combined with additional material inputs and consistent with cultural practices, are shown in Table II (average output increases, with increases in the degree of overall control).

Cropping intensity is a key-element in determining the value of irrigation and benefits to be accrued from such developments. These indices are especially important where arable land is scarce, and thus limits to agricultural production will be determined by crop yield and intensity of cropping. Table III shows irrigated areas and cropping intensities for developing market economy countries for 1965 and 1975 and projected values for 1990 (F.A.O., 1977). The cropping intensity for 1975 ranged from 89 in Latin America to 129 for Asia, and the 1975 values for all four regions are higher than the corresponding figures for 1965.

Agriculture is the largest user of water, and accounts for some 80% of global consumption (comparable figure for the U.S.A. is slightly over 40%). In 1975, the total area irrigated in the world amounted to $223 \cdot 10^6$ ha of which $92 \cdot 10^6$ ha were in developing countries. By 1990 it is estimated that these figures will have risen to $273 \cdot 10^6$ and $119 \cdot 10^6$ ha, respectively (F.A.O., 1977).

It is, however, not enough to increase irrigated areas. Effectiveness and efficiency of the supply and distribution system must be maintained. Current estimates indicate that some $86 \cdot 10^6$ ha throughout the world are now in need of improvement. Similar improvement will be necessary on $45 \cdot 10^6$ ha of the developing market economy countries mentioned in Table III, out of a total of $92 \cdot 10^6$ ha, by 1990. The estimated cost for such improvement, at 1975 prices, will be more than US $22,500 million. In addition, adequate drainage improvement work has to be carried out on $52.4 \cdot 10^6$ ha (much of it within the $45 \cdot 10^6$ ha of irrigation improvement) at an additional cost of $12,400 million for the proper control of water and salt balance in the soil. Thus, the total cost of irrigation improvement schemes for the developing market economy countries, up to the year 1990, is expected to be $34,900 million.

As more difficult and expensive land and water resources have to be developed in the future than in the past, the cost for new irrigated land (22,200 hectares) for the same countries mentioned earlier is expected to be over $ 61,000 million, at 1975 prices, giving an approximate average price of $2800 per hectare. Provision of adequate drainage is included in the estimate, ranging from $200 to $1000 per hectare. The recent experience of escalating costs by the World Bank, however, does not bode well for the world. Costs of the magnitude of $5000 to $6000 per hectare, for exclusively gravity irrigation systems, are now not exactly uncommon. Thus, if anything, the latest estimates may be somewhat on the conservative side.

The enormity of the task of expanding and maintaining irrigated areas in the developing market economy countries up to the year 1990 is, in itself, staggering, the magnitude of which can be seen from the following summary:

$22.2 \cdot 10^6$ ha new irrigation
$45 \cdot 10^6$ ha irrigation improvement

TABLE II

Yields of paddy rice with different degrees of water control (F.A.C., 1977)

Degrees of water control	Material inputs	Location	Average yield for 1971—1974 ($t\,ha^{-1}$)
No water control (rainfed, 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 Republic; Sri Lanka; west Malaysia	3.0
(d) sophisticated management practices (mid-season drying)	high fertilizer use + improved seeds and pest control	Republic of Korea	5.0
	and + diversification, mechanization	Japan	6.0
Experimental conditions			10.0

$78 \cdot 10^6$ ha drainage improvement, including $52.4 \cdot 10^6$ ha on irrigated land
$438 \cdot 10^9$ m^3 additional water
$97.8 billion of investment at 1975 prices

These investment costs, it must be realised, do not include costs of new irrigation or improvement of existing irrigation systems outside developing market economy countries. It is estimated that, by 1990, for the rest of the world, new irrigation will have been provided for $23.1 \cdot 10^6$ ha, $41.3 \cdot 10^6$ ha existing irrigation will have been improved, and all these developments will require an additional $528.4 \cdot 10^9$ m^3 of water. The investment cost for this additional part is not available at present.

TABLE III

Irrigated land (IL, in thousands hectares) and cropping intensities (CI, in percentage utilisation of cultivated area) for developing countries, 1965—1990

Region	1965		1975		1980	
	IL	CI	IL	CI	IL	CI
Africa	1,882	104	2,610	107	3,570	121
Latin America	9,623	77	11,749	89	14,850	95
Near East	13,329	80	17,105	95	21,400	106
Asia	45,691	119	60,552	129	74,370	142

Water for industry

Industry requires a large amount of water. In the U.S.A. industrial demand accounts for nearly 40% of the total water requirement, and five major industrial groups — food and kindred products, pulp and paper, chemicals, petroleum, coal products and primary metals — account for slightly more than 85% of total withdrawals. Nearly 60—80% of water required for industrial processing is for cooling, and need not be of high quality. However, such an enormous discharge of heated water has intensified the problem of thermal pollution, and some studies indicate that the quantity of heat to be dissipated to the aquatic environment will increase ten-fold in the U.S.A. during the last three decades of this century (Biswas, 1974). The possibility of using thermal discharges for beneficial purposes is not very significant at the present time (Biswas and Cook, 1974).

There are basically two sets of policy issues with regard to industrial use of water: use of river systems to dispose of industrial wastes and the striking difference between the gross amount of water needed for various industrial processes to manufacture the same product. Besides discharging heated water, industry is responsible for the disposal of a whole variety of waste products depending on the stringency of local pollution control measures. Thus, discharges of mercury to the aquatic environment have created serious problems in Japan and Canada, with the resulting development of the "Minimata

TABLE IV

Water requirements and waste loads for selected industries

Industry	Range of water requirements per unit of product	Pounds of BOD_5^{*1} per 1000 gal. of process water*2
Steel (10^3 t)	8 — 61	—
Soap (10^3 t)	0.96— 37	16.70
Gasoline (10^6 l)	7 — 34	2.50
Paperboard (10^3 t)	62 —376	2.21
Sugar beets (10^3 t)	1.8 — 20	9.16

*1 5-day biological oxygen demand.
*2 1 lb. $gal.^{-1}$ = 0.119826 kg l^{-1}.

Bay" disease. Similar problems have been observed with cadmium, arsenic and polychlorobiphenyls (PCB's) as a result of which new rules and regulations are being drafted and updated in different parts of the world.

The second set of policy issues is on the actual use of water by industry. The amount of water required depends on the type of industry, processes being used, availability of water and legal requirements. The cost of water is rarely a major issue, since it represents 0.005—2.58% of total manufacturing costs for the five most intensive water-using industries mentioned earlier. Seldom does this cost exceed 1%. Within these limits water requirements vary tremendously for the same industrial group, as shown in Table IV. It is quite common to find some industrial plants requiring 5—40 times more water than other plants manufacturing the same product. The example of soap, given in Table IV, indicates the higher range to be 38 times that of the lower. Such drastic differences in net amounts of water required are due to the use of extensive in-plant recirculation and treatment technologies, as compared to simple once-through flow processes. While water requirement for industrial purposes is high, a small fraction of the water used is actually "consumed", that is, incorporated into the product, or lost through evaporation or seepage.

According to DD2 targets, industry in developing countries is expected to grow at an annual average of 8%. The Lima Declaration and Plan of Action envisages that their total share of manufacturing output will increase to 25% by the year 2000. If these targets are to be met, industrial water requirements for developing countries will increase substantially. Effects of such manifold increases of industrial activities on water will depend on availability of supply and, what is more important, the standards set by the various administrative bodies on the quality of receiving waters.

Hydro-electric power

Hydro-electric power is an important product of water development, and currently accounts for 70—90% of all electricity generated in Brazil, Canada,

TABLE V

Potential and current hydropower developments of different continents

Continent	Potential available 95% of time (MW) (1)	Potential output 95% of time (GW yr.$^{-1}$) (2)	Present installed capacity (MW) (3)	Current annual production (GW yr.$^{-1}$) (4)	[(4)/(2)] × 100 (5)
Africa	145,218	1,161,741	8,154	30,168	2.6
Asia	139,288	1,114,305	47,118	198,433	17.8
Europe (including U.S.S.R.)	102,961	827,676	135,498	505,317	61.0
North America	72,135	577,086	90,210	453,334	78.5
Latin America	82,221	649,763	18,773	91,415	14.1
Oceania	553,810	4,434,468	307,362	1,307,564	29.5

Morocco and Norway. With the current energy situation, hydro-electric power makes a great deal of sense in many countries, especially in terms of achieving self-reliance and reducing balance of payments problems due to the import of energy-producing materials. While capital costs for hydropower developments are quite high the running costs are minimal. In addition, such developments, if properly planned, could be highly labour-intensive and thus reduce unemployment problems in developing countries.

The potential for hydropower has been exploited to a great extent in North America and Europe, including the U.S.S.R., as shown in Table V (U.N. Water Conference, 1977). However, there is a vast potential that can be exploited in Africa, Asia and Latin America. Africa is the most underdeveloped, the current annual production being only 2.6% of the potential output. In sharp contrast to North America, where the share of hydropower in total electricity generated has been steadily declining, and is expected to continue to decline in the future, the situation in Africa — even with the current very low level of development — has been quite the opposite. Thus, the share of hydropower has increased from 22.9% in 1962 to 28.4% in 1974. This trend towards increased emphasis on hydropower generation, in preference to other forms of energy development, is expected to continue in the foreseeable future.

There is a major misconception with regard to hydropower. Many people tend to think that because of economics of scale, all recent developments must be large-scale, like the Aswan in Egypt, Volta in Ghana, or James Bay in Canada. The global situation is somewhat opposite. It is the small- and medium-sized potentials that offer the greatest promise in the future.

SOCIAL AND ENVIRONMENTAL IMPACTS OF WATER DEVELOPMENT

The social and environmental implications of water development are many, and the resulting effects often extend much further than the river basin unit itself. The interactions of diverse forces are often so complex that ecologists and environmentalists are hard-pressed to predict overall effects with any degree of certainty. At the present stage of the art, ecologists often find it impossible to convince engineers, economists and politicians that certain developments are unwise, or of the necessity to spend scarce resources on appropriate remedial measures because of the lack of hard facts or solid scientific evidence. In addition, water-resources development has been traditionally within the domain of engineers and, consequently, social and environmental considerations have often been neglected during the planning

TABLE VI

Environmental implications of water development

PHYSICAL SUBSYSTEM	
Hydrologic system:	*Atmospheric system:*
Water quantity	Evaporation
level	Micro-climate
discharge	
velocity	*Crustal system:*
groundwater	Geology (soil, mineral content, structure)
losses	Earthquake
Water quality	
sediments	
nutrients	
turbidity	
salinity and alkalinity	
temperature stratification	
BIOLOGICAL SUBSYSTEM	
Aquatic ecosystem:	*Terrestrial ecosystem:*
Benthos	Submerged land and vegetation
Aufwuchs	Drawdown zone
Zooplankton	Zone above high water level
Phytoplankton	Failure impacts
Fish and aquatic vertebrates	Loss of animal habitat
Plants	Food chain repercussions
Disease vectors	
HUMAN SUBSYSTEM	
Production system:	*Sociocultural system:*
Agriculture	Social costs
Fishing and hunting	Political implications
Wildlife	Anthropological effects
Recreation	
Energy	
Transportation	
Manufacturing	

process. A typical example is the near disaster in the Peace—Athabasca delta in Canada, due to the construction of the Bennett dam. Consistent reduction of the level of the lake played havoc with the local flora and fauna, which seriously affected the life-style of the local Treaty Indians and Metis. The social dislocation was quite serious, and the situation was finally rectified at significant economic cost.

The social and environmental impacts of water development can best be discussed by dividing the effects on three categories of sub-systems — physical, biological and human — as shown in Table VI. Since these effects have been discussed in detail elsewhere by the author (Biswas, 1971, 1977; Biswas and Biswas, 1975, 1976), these would not be considered here.