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Water Development in Developing Countries: Problems and Prospects

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Abstract: Important as water is to man's manifold acitivities, a significant percentage of mankind still do not have access to clean water for drinking and personal hygiene. According to a WHO survey of facilities available in developing countries to the end of 1975, 75 % of urban population and 20 % of rural population have access to potable water. Studies carried out by the UN system estimate that investment necessary to provide clean water and sanitation by 1990 to both rural and urban areas is on the order of $ 132,940 million in constant 1977 dollars. Furthermore, provision of clean water alone is unlikely to eliminate all water-borne diseases, since it is only one of several complex factors affecting human health.

The situation in developing countries on water requirements for agriculture, industry and generation of hydroelectric power also requires attention because of large amounts of water involved. Effectiveness and efficiency of the supply and distribution systems must be given top priority. There is a considerable potential for improving the efficiency of water use in virtually every developing country and in every sector.

Introduction

In the sixteenth century, Akbar the Great, the celebrated Mogul emperor of India, decided to establish a new capital for his vast empire. The best architects available in the country were asked to design a magnificent palace in Fatehpur Sikri, not far from Agra, on the dry plains of Northern India. The cream of Indian artisans worked for several years to complete the capital, and vast amounts of resources were spent on the realization of the emperor's dream. As any modern traveller to Fatehpur Sikri will attest, it still is an excellent testimonial to the Indian architecture. The completed palaces still remain intact, virtually untouched by the centuries in between, a noteworthy achievement by itself.

The history of the new capital, however, was not so auspicious. Akbar used it only for fifteen years, and then had to abandon it rather ignominiously to return to his old capital. The reason for his retreat was water: his architects and planners had grossly underestimated the availability of water in such an arid region. Thus, when the available meager water supply was exhausted, Akbar had no choice but to abandon his new capital.

Fatehpur Sikri is a beautiful monument to bad planning on the grand scale, but unfortunately in the area of water resources development it is not the only such example. Starting with the earliest dam ever built, Sadd el-Kafara (Dam of the Pagans), sometime between 2950 BC and 2750 BC, on Wadi el-Garawi about eigtheen miles south of Cairo (Biswas, 1970), which had no spillway for passage of water downstream, human history is replete with such examples from both developing and developed countries.

Water is used for many purposes such as municipal, 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 location, cultural traditions, standards of living, climatic characteristics and a variety of other individual and site-specific factors.

In this paper we shall review the present status of water development and use in developing countries.

Water for Domestic Consumption

Present Situation

Important as water is to man's manifold activities, a significant percentage of mankind still does not have access to clean water for one of the most fundamental requirements for human survial: water for drinking and personal hygiene. The sources of water in many developing countries still continue to be shallow communal ponds or uncovered wells, from which the water is used for all domestic purposes like drinking, bathing, or cleaning clothes. Domestic animals often share the same source of water, and it is used to clean them as well. All these diverse activities often contribute to severe water pollution, and the continued use of the resulting contaminated water pose a definite health hazard for both humans and animals.

From a global perspective, the problem of rural and urban water supply can be viewed within two extremes. At one extreme are the highly urbanized cities of advanced industrialized 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, sophisticated technology and necessary service personnel. At the other extreme is the rural sector of developing countries, having no service of any kind whatsoever, either for potable water or for 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 actual percentage of the world's population that have currently access to clean water is unknown. In spite of the work done by the individual countries, various United Nations agencies, and other international and bilateral aid organizations, representative data in this area are scarce, and accordingly a rough picture of the magnitude of the global problem is only available.

Of all the studies carried out so far, the one that provides the best picture is by the World Health Organization (WHO), who attempted to survey the extent of water supply and sewerage facilities available in developing countries to the end of 1975. The survey was done by a questionnaire, which was returned by 67 developing countries. According to the WHO survey (1976), 57 % of the population in urban communities have house connections, and another 18 % have access to standpipes, making a total of 75 % (390 million people) that have access to potable water. The situation, as to be expected, is significantly worse in the rural areas, where only 20 % (248 million people) have reasonable access to safe water. If both the rural and the urban sectors are considered together, only 35 % (638 million people) are adequately served (WHO, 1976).

These, of course, are average figures, which obscure the tremendous disparity that exists even within the individual developing countries. The range of this disparity can be easily seen by considering the information on the community water-supply situation in Africa which was prepared for the United Nations Water Conference held at Mar del Plata, Argentina, in March, 1977 (United Nations, 1978). It indicated that 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%); Marocco and Tunisia (91%). At the bottom end of the scale are the rural populations of many countries, where even 5 % of the population do not have access to safe water. Among these are Burundi, Gabon, Madagascar, Sierra Leone (1% or less); Kenya (2%); Gambia (3%); Togo and Zaire (5%).

The information provided above are the best available at present, but these should be used with some caution. In the development literature, the percentage figures obtained by WHO seem now to be solidly enshrined and are taken to be representative of the global situation so far as **all** the developing countries are concerned. This, of course, is incorrect for several reasons. Firstly, it should be noted that the WHO questionnaire was returned by only 67 countries, and hence cannot be considered representative of **all** developing countries. Secondly, the figures analysed by WHO were as provided by the countries concerned. As anyone who has worked in this area knows, detailed information for most countries are not available, and accordingly the information provided to WHO, at least for several countries, are pure guessworks on their parts, and undoubtedly contain significant margins of errors. Thridly, it is not uncommon for some countries to provide wrong information deliberately. This situation stems from two concerns. Some countries, at least in the past, have provided over-optimistic statistics for prestige reasons, and others have used diametrically opposite strategy, and have provided pessimistic information, hoping such status would increase the flow of aid. Accordingly a realistic assessment of community water supply situation in developing countries has yet to be made.

Planned Availability

Whatever be the real global situation in the area of urban and rural water supply, the "good" intentions of the international community has never been in doubt. For example, one of the important targets of the Second Development Decade (DD2) of the United Nations in 1970 was to extend water availability by 1980 to 100 percent of urban populations, 60 % through house connections and 40 percent through standpipes; and to 25 % of rural populations. But now, only one more year to go to the end of the decade, it is highly unlikely that the DD2 targets can be met. Let us consider the situation

Tab 1 Water supply situation in Africa, 1970–2000 (population is in millions, and does not include Angola, Equatorial Guinea, Malawi, Mozambique, Namibia, Rhodesia, Rwanda, South Africa, Swaziland and island countries and territories).

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	307	307	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

only in one continent – Africa. According to the WHO survey mentioned earlier (WHO, 1976):

> 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.
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> 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.

Even for the unlikely case of the DD2 for Africa being met by 1980, and if this target is continued to the year 2000, the number of people without safe water will still continue to increase with time. As shown in Tab 1, during the period 1970 – 2000, population served 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 population of Africa will not have access to safe water even by the year 2000 (UN, 1976).

There have been more changes in the target since the WHO survey (Biswas, 1977a, 1977b). The United Nations Conference on Human Settlements (1976), commonly known as HABITAT, held at Vancouver in June 1976, passed a resolution which stated that in most countries urgent action was necessary to "adopt programmes with realistic standards for quality and quantity to provide water for urban and rural areas by 1990, if possible." This target was subsequently reendorsed by the UN Water Conference (Biswas, 1978a).

The financial implications of the HABITAT target was analysed by WHO and the World Bank for the UN Water Conference (WHO 1976). According to this analysis, investments required to meet the targets by 1990 are the following (figures in constant 1977 dollars):

Urban water supply	–	$ 51,400 million
Rural water supply	–	$ 40,800 million
Urban sanitation	–	$ 32,340 million
Rural sanitation	–	$ 8,400 million
Total	–	$ 132,940 million

High as though this total figure is, it must be considered to be an underestimate, since the analysis carried out was somewhat simplistic, and did not include many of the ancillary costs. Thus, the real costs are bound to be much higher.

A point should be made here about the need of tackling the water supply and the sanitation problems simultaneously. Lack of appropriate sanitation means that both surface and ground water, especially close to centres of population, can easily get contaminated. This would undoubtedly pose health hazards, and the situation can worsen during the rainy season when much of the wastes could be washed into the unprotected sources of drinking water.

No one will argue with the statement that access to safe drinking water and hygienic disposal of wastes is an important social goal in every developing country. After the UN Conferences on Human Settlements and on Water, community water supply is very much an "in" topic at the present time in the international fora. In fact, the United Nations has proclaimed the decade 1980–1990 as the **International Water Supply and Sanitation Decade.**

Improvement of Domestic Water Supplies

One must, however, ask some penetrating questions so that the international community does not get disappointed with the results obtained a decade or so from now, after having invested billions of dollars to improve the water supply and sanitation conditions all over the world. Important though water supply is, it is only one component of the socioeconomic infrastructure of human settlements which include other broad and diverse elements like housing, health services, availability of nutritious food and energy, transportation, education, and a variety of other factors. Massive investments are necessary to improve the deplorable situation in all of these areas. Our productive capacity is limited, and thus even the most optimistic man in the world cannot realistically expect that adequate resources can be generated to solve all these global problems simultaneously within such a short time.

Thus the question must be asked: what benefits can be rationally expected from such a massive investment in water supply and sanitation? Two major benefits are traditionally mentioned in all the international discussions: reduction (or in certain cases elimination) of water-borne and water-related diseases, and elimination of water-collection journey of women and children. Both these benefits will be reviewed herein.

Water Quality

The report prepared by WHO and the World Bank for the UN Water Conference (White 1978) categorically states: "The importance of safe community water supply and sanitation in the control of diseases such as diarrheas, typhoid and paratyphoid fevers, shigelloses, salmonellas, cholera, infectious hepatitis, amoebiasis and giardiasis is well established."

However, at the present state of knowledge, any objective attempt to determine the precise relationships between quantity and quality of water and public health is bound to produce inconclusive results. While no one can dispute the fact that clean water will improve public health, the problem arises when attempts are made to determine the direct health benefits of improving the quality of water supply. This is because water is only **one** of the several complex factors affecting human health, and all these factors-including environmental, economic, educational and cultural conditions-are closely interconnected. Any multivariate analysis of these factors will not provide definitive answers. Thus, only the provision of clean water will not eliminate a water-borne disease like cholera. On the contrary, it should be noted that under many conditions scientists have failed to demonstrate any distinct correlation between quality of water supply and diarrheal diseases (Feachem 1978). An examination of certain case studies from different parts of the world will make this clear.

A study of the diarrheal diseases in Costa Rica concluded that water pollution could not be shown to have a direct effect on diarrhea morbidity. A recent study on the tubewells in Bangladesh failed to establish any relationship between their use and the incidence of cholera and other diarrheas. Similarly, studies in Lesotho have failed to show an association between improved quality of water supplies and incidence of diarrheal disease or typhoid (Feachem 1978). The reasons for such findings are complex, and will only be discussed briefly herein.

First, water is not the only means through which fecal-oral diseases like cholera, typhoid, diarrheas, dysentries or hepatitis are transmitted. Hence, even though the quality of water supplies is improved, these diseases could still continue to be transmitted by other routes. In other words, unless it is clearly known that diarrheal disease is almost exclusively water-borne in a specific community, improvement of water quality alone is unlikely to change the incidence of the disease significantly. This point has mostly escaped the attention of donor agencies and countries.

Second, improving water quality via standpipes does not automatically improve personal hygiene practices which have developed over centuries. People may have clean water to drink at home, but bathing and laundry facilities remain as before, and contaminated water used for such purposes continues to remain a major source of infection. Thus, in the absence of house connections, communal washing and laundry facilities must be provided before any marked decrease in water-related disease may be expected.

Third, it is important to educate the public about good hygiency practices. Let us consider our experiences in India, where now standpipes have been provided in several rural areas. What is happening is as follows:

(1) People have no information on how to store water safely. Accordingly, some contamination is taking place at home where water is stored.

(2) People have safe water to drink at home. But when they are thirsty and are away from home, they think nothing of going to the nearest water source, irrespective of its quality, and having a drink.

(3) Small children, who normally have the highest incidence of diarrheal diseases, are not using the improved water supply in the same way as the adults do. This possibly is a major reason which could explain the tubewell example in Bangladesh quoted earlier.

(4) In most cases, no attempt has been made to provide drainage for spilled water at the standpipes. Thus, a pool of stagnant water around standpipes is a common sight in most developing countries. Our observations in Balasore, India, my home town, clearly indicates that these stagnant pools are providing good breeding grounds for mosquitoes, which means that the present practices are falling far short of good housekeeping. In other words, we are trading water-borne diseases for mosquito-borne diseases like malaria. In Balasore, incidence of malaria has significantly increased since the introduction of standpipes.

(5) Availability of water in many places has been intermittent (Fig 1). This is because the standpipes often break down due to heavy use rates, and maintenance procedures are not very good. In certain parts of South India and Bangladesh, as much as 80 percent of the tubewells established with foreign aid are currently out of service. In many cases the problem is due to the good-intentioned ideas of foreign experts who have very little understanding of the social, economic and technological conditions in the developing countries. In fact, a cynic might be tempted to say that a new multinational industry, having a very high growth rate, has developed: the proliferation

of institutes in the developed countries offering instant advice on and solution to the Third World problems. They come equipped with the latest "buzz-words" like appropriate technology or basic human needs, stay in the Hiltons, and profess to understand the real problems of the developing countries.

What happened in Bangladesh is that the experts decided to "naturalize" the technology. Thus, the tubewells were manufactured at the local workshops. As any person from a developing country knows, quality control in such village workshops leaves much to be desired. Hence, the results were predictable. The community tubewells, which have very high use rates, broke down very quickly. While some donor countries provided funds for installing tubewells, resources were scarce for maintaining the facilities. Lack of maintenance, misguided priorities, and poor management have contributed to keep the water supply system idle. Accordingly, inhabitants of the area have no choice but to use contaminated water, which they used earlier.

(6) Finally, our studies indicate that provision of public taps in a community does not necessarily increase the volume of water used per capita or change water-use patterns. It is now quite evident that the quantity of water used has an important bearing on human health.

Adequacy of Water Supplies

We have discussed earlier why improvement of water quality alone is unlikely to bring all the benefits to mankind that the international community is expecting. Emphasis so far on all international discussions has been on water quality; very little consideration has been given to the quantity of water used. And yet, this is an important dimension of the relation between water and health.

How much water do we need per person per day? There are no hard and fast answers. Even for the simpler case of basic survival, the needs depend on body size, climate, type of work being performed, etc. Normally, it is of the order of 5 litres per capita per day (lcd). But survival needs are very different from health needs, which are significantly higher. Information on the lower limit of water consumption to maintain adequate health is scarce, but some indication of this limit can be obtained from a 10-year study carried out in Singapore during 1960 to 1970 (Special Issue, 1976). The study attempted to correlate domestic water use in relation to water borne diseases reported in Singapore hospitals. It indicated that as domestic water use goes up, disease goes down. However, there did not seem to be any improvement beyond daily per capita water consumption of around 90 litres of high quality water. Any improvement beyond 90 lcd seems to be more of an aesthetic nature. Thus, one could conclude that 90 lcd of water can be considered to be the "social minimum" for that area.

Unfortunately other studies of this nature are not available to draw some firm conclusions. For example, we do know that as our standard of living increases, so does our consumption of water. Hence, for the Singapore study, it is highly likely that some socioeconomic indicators changed as well when per capita water use increased, which means increase in water use cannot be an exclusive cause of reduction in incidence of disease.

Fig 1 Wait for Water (photo: P. Almasy; courtesy of WHO). Three times a week, drinking water comes to this Peruvian surburb of 25 000 inhabitants. At variable pressure, it flows for about three hours in the morning from 3 small pipes. The queue forms early; first come, first served. The order is the order of cans. When the trickle of water ceases and not every can has been filled, a silent queue awaits the next day that the water will start flowing again.

If, however, 90 lcd is an indicative figure of the lower limit of water consumption to maintain adequate health, we are in big trouble! Most people tend to arbitarily fix this limit around 15 to 25 lcd, and a recent World Bank (1977) publication confirms this. Naturally, if the target for water use is 90 lcd, and present design practice is to aim for only 17 to 28 % of this figure, we are unlikely to make much headway in significantly improving health conditions in the developing countries by providing only good quality of water, without giving much thought to the quantity of water used. Thus, what is urgently necessary is some work to get a better understanding

Fig 2 Women carrying water in India (photo: A.S. Kochar; courtesy of WHO). Women of the developing world spend considerable time in collecting the family water requirements, carrying their heavy pitchers for miles at a stretch.

of the relation between water quantity and health. Such work should not need either much money or time, but would undoubtedly improve the benefits to be accrued from the investment of billions of dollars to improve water supply for health considerations.

Socioeconomic Impact of Improved Water Supplies

The second major benefit attributed currently to the provision of potable water is that it would significantly reduce, and even possibly eliminate, the time now spent in collecting water. The time thus freed, could be used for learning and productive work.

There is no doubt that the major beneficiaries of the availability of safe water are going to be the women of the developing world, who currently spend considerable time in carrying water and collecting firewood. According to the Economic Commission for Africa of the United Nations (1975), 90 % of all water and fuel in Africa is collected by the women: men only contribute to 10 % of this task. Thus, the improvement of water supplies will reduce the water-collection journey, made mainly by women and children, who currently spend up to 5 hours every day collecting the family water requirements (Fig 2). Naturally, time spent in carrying water is a function of the distance of the source from the consumer; and depending on the distance, it could seriously affect the total daily working time of water carriers. For example, if the water source is about 1 km away, a woman would spend at least 3 hours a day carrying water, and it would account for nearly 50% of her daily working time.

It should not, however, be assumed (as it seems to be done at present) that by simply freeing women from this chore, they would automatically find productive work. In fact, unless this additional labour availability is specifically considered within the framework of national planning, and special efforts are made to use women productively, it is highly unlikely that they would find something productive to do during the time thus saved. We must remember that already unemployment and underemployment are serious problems in developing countries. According to the International Labour Organization (ILO, 1976), one billion new jobs must be created in the developing countries by the year 2000, a most difficult task under the best of circumstances. The ILO target does not include the need for job creation for the additional labour force that would be created by reduction of time spent on water-carrying journeys.

There are two additional benefits which will accrue if the water-collection journey is eliminated. These are nutrition and health implications, seldom mentioned in any development literature.

It has been estimated that the efforts to fetch water take up to 12% of daytime calorie needs of most water carriers in non-dry areas. In drier areas and in mountainous regions, energy spent in collecting water and firewood may take up to 25% or more of the daytime calories. Women are not traditionally the most well-nourished member of the family; the most nutritious food being normally reserved for the men, the breadwinners of the family. Thus, elimination of the water-collection journey for women, by providing potable water closer to home, has important implications in terms of **nutrition,** a fact often overlooked by planners and politicians.

There are also **health implications** for the water-collection journey, during which some infection takes place. Many vectors of water-borne or water-related diseases tend to concentrate around water sources. The water-collection journeys thus considerably extend the periods of human contacts with vectors like mosquitoes (malaria, filariasis, etc.), snails (schistosomiasis) and flies (trypanosomiasis). Bradley (1974) has estimated that the Gambian sleeping sickness, **Trypanosoma Gambiense**, can be reduced by 80 % by good water-supply schemes. While the author feels that this figure is 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 setse flies during the water-collection journey.

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 Tab 2. Tab 2 shows

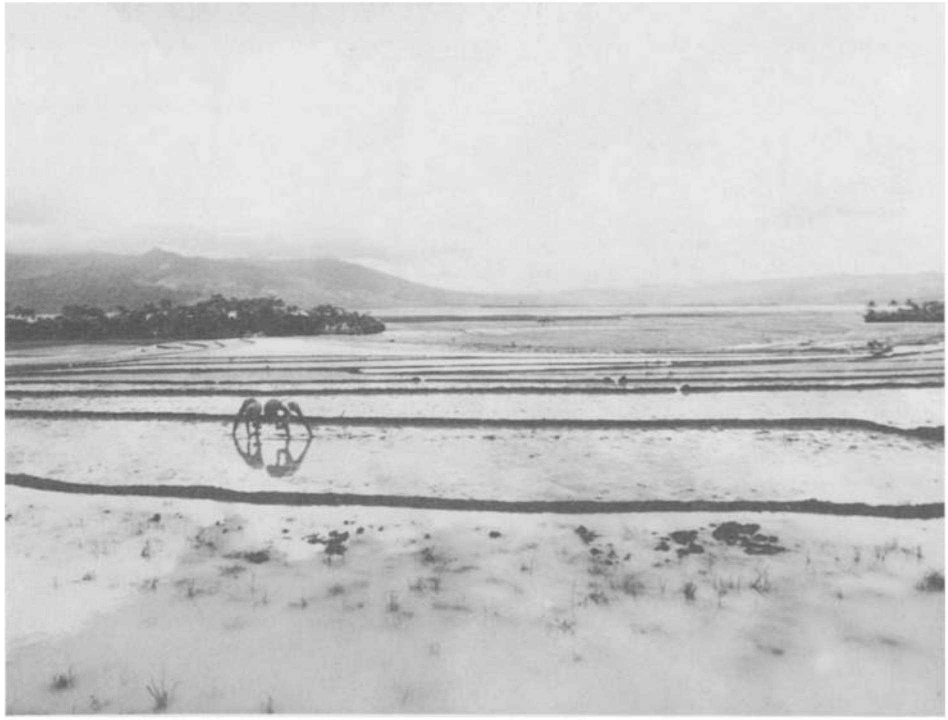

Fig 3 Rice fields in Indonesia (photo: B. Wolff; courtesy of UN). Watering the land is an ancient skill, but supplies are sometimes misused. Improvements are needed to use water more efficiently for growing more food.

Tab 2 Yields of paddy rice with different degrees of water control (FAO, 1978)

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 seed and pest control	South Korea	5.0
	+ diversitifi-cation, mechanization	Japan	6.0
Experimental conditions			10.0

that average yield increases with increases in the degree of overall water documented by the case of paddy vice production.

Cropping intensity is a key element in determining the value of irrigation and benefits to be gained from such developments. These indices are especially important

Region	1965		1975		1990	
	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

Tab 3 Irrigated land (IL in thousands ha) and cropping intensities. (CI in percentage utilization of cultivated area) for developing countries, 1965–90 (FAO, 1978)

where arable land is scarce, and where limits to agricultural production will be determined by crop yield and intensity of cropping. Tab 3 shows irrigated areas and cropping intensities for developing market economy countries for 1965 and 1975 and projected values for 1990 Food and Agri. Org., 1978). 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 United States is approximately 34 percent). In 1975, the total area irrigated in the world amounted to some 223 million ha, of which 92 million ha were in developing countries. By 1990, it is estimated that these figures will have risen to 273 million and 119 million ha, respectively (FAO, 1978).

It is, however, not enough to increase irrigated areas. Effectiveness and efficiency of the supply and distribution system must also be maintained. Current estimates indicate that some 86 million ha throughout the world are now in need of improvement. Similar improvement will be necessary on 45 million ha of the developing market economy countries out of a total of 92 million, 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 million ha (much of it within the 45 million ha of irrigation improvement) at an additional cost of 12 400 million dollars 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 US $ 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 ha) for the same countries mentioned earlier is expected to be over $ 61 000 million, at 1975 prices, giving an approximate average of $ 2 800 ha. Provision of adequate drainage is included in the estimate, ranging form $ 200 to $ 1 000 per ha. The recent experiences of the World Bank indicate that the costs are increasing. Costs of the magnitude of $ 5 000 to $ 6 000 per ha, for exclusively gravity irrigation systems, are now not exactly uncommon. Thus, if anything, the estimates mentioned are likely to be 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 this task can be seen from the following summary:

22.2 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 thousand million m^3 of additional water; and
97.8 thousand million dollars investment cost at 1975 prices.

These investment costs 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 million ha, 41.3 million ha of existing irrigation will have been improved, and all these developments will require an additional 528.4 x 10^9 m^3 of water. The investment cost for this additional part is currently not available.

Water for Industry

Industry requires a large amount of water. In the United States industrial demand accounts for nearly 60 percent of the total water requirement, and five major industrial groups--food and related products, pulp and paper, chemicals, petroleum, coal products and primary metals--account for slightly more than 85 % of total withdrawals. Nearly 60 to 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 United States during the last three decades of this century (Biswas, 1974).

Tab 4. Water requirements and waste loads for selected industries

Industry	Unit	Range of water requirements per unit of product	5 day BOD in lbs/1000 gal of process water discharge	5 day BOD in kg/1000 l of process water discharge
Steel	Ton	8,000 – 61,000	–	–
Soap	Ton	960 – 37,000	16.70	2.00
Gasoline	Kilolitre	7,000 – 34,000	2.50	.29
Paperboard	Ton	62,000 – 376,000	2.21	.26
Sugar beets	Ton	1,800 – 20,000	9.16	1.10

(BOD = Biochemical Oxygen Demand)

The possibility of using thermal discharges for beneficial purposes is not very significant at the present time (Biswas, 1978b; 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 identical 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 disease. Similar problems have been observed with cadmium, arsenic and PCB (polychlorinated biphenyls), as a result of which new rules and regulations are being formulated and/or old ones being 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 the legal requirements. The cost of water is rarely a major issue, since it represents 0.005 to 2.58 % of total manufacturing costs for the five most intensive water-using industries mentioned earlier. Seldom does this cost exceed 1 percent. Within these limits, water requirements vary tremendously for the same industrial group, as shown in Tab 4. It is quite common to find some industrial plants requiring 5 to 40 times more water than other plants manufacturing the same products. The examples of soap, given in Tab 4, indicates that the higher value is 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 requirements 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 the 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, on the standards set by the various administrative bodies on the quality of receiving waters.

Hydroelectric Power

Hydroelectric power is an important product of water development, and currently accounts for 70 to nearly 100 % of all electricity generated in Brazil, Canada, Morocco, Norway and Sri Lanka. With the current energy situation, hydroelectric 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 USSR: 60 to 80 %. In other regions of the world, generally less than 20 percent is being exploited (Tab 5).

Efficiency of Water use in Developing Countries

There is considerable potential for improving the efficiency of water use in virtually every country and in every sector. The agricultural sector, which accounts for nearly 80 % of the global water consumption, is probably the most inefficient sector where most improvements could be

Region	Potential avaiblable 95% of time (10³ kW) (1)	Potential output 95% of time (10⁶ kWh/y) (2)	Present installed capacity (10³ kW) (3)	Current annual production (10⁶ kWh/y) (4)	Percent of developed potential (4)/(2) x 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 USSR)	102 961	827 676	135 498	505 317	61.0
North America	72 135	577 086	90 210	453 334	78.5
Latin America	81 221	649 763	18 773	91 415	14.1
Oceania	12 987	103 897	7 609	28 897	27.8
World Total	553 810	4 434 468	307 362	1 307 564	29.5

Tab 5 Potential and current hydropower developments of different continents (after UN Water Conference Secretariat, 1978).

made. Existing efficiencies of irrigation systems are often so low that they do not by any means reflect the real water requirements for crop production. In fact, in many instances present water consumption patterns are not only wasteful but are also definitely harmful. From some of our recent studies of several developing countries, it is quite common to find that 80 to 85 % of water delivered to the head gate of the main canal never reaches the crop. Thus, projection of future global water requirements based on present-day "demands" is highly misleading, and the time has come to ask whether such analyses have any fundamental technical value. Water consumption per unit agricultural area has been decreasing slowly during the recent past, but it must be admitted that it is nowhere even close to the real value.

In spite of this sad situation, there is a considerable reluctance in many countries to allocate resources to improve the situation drastically. The emphasis is much more on construction of new dams and new systems than on improving the efficiency of the existing irrigation systems. However, such policies do not make sense for several reasons. Firstly, the efficiency of new schemes deteriorate very fast without appropriate maintenance measures. Secondly, it is cheapter to rehabilitate existing schemes than to construct new ones. As a rule more water is available per unit cost from the improved existing systems than from new projects. Finally, the time required to plan and build new schemes is significantly longer than that for improvement.

In view of these advantages, one may legitimately ask why has the renovation of existing schemes not received the priority it deserves? The answer is complex but, at the risk of simplification, the following explanation is offered. An analysis of past priorities and the actions taken in many countries indicate that agriculture (and thus irrigation) has not received priority in national development plans. Many large new dams have been built with the main objective of providing cheap power for rapid industrialization of the country. Irrigation development, and especially improvement, often took a back seat. Also, several developing countries, at least in the past, opted for prestigious projects like large dams, football stadia, nuclear power plants, or airports, rather than putting through critically necessary land reforms or irrigation improvement. The reason for such a course or action is not difficult to discern. A brand new prestigious structure has "sex appeal"; politicians can make political hay out of it. Such projects have also served the donor countries well, both in terms of propaganda value and opportunistic motives. They seem to be often more interested in financing large and visible structural projects, irrespective of their immediate relevance to the recipient country's national needs. Such attitudes seem to be changing, but it has to be admitted that the progress is slow.

Efficiency of water use can also be significantly improved in industrial and domestic sectors. In some countries like Canada, where industry claims nearly 84 % of total withdrawal (comparative figure for India is 1 percent), extensive recycling and process changes, especially for new industry, will bring water requirements towards the lower range of the values shown in Tab 4. Use of existing knowledge, supported by more rational water pricing structures, can reduce these values even further.

There is considerable potential for water conservation in the domestic water-supply sector as well. In developed countries, the original principal uses of domestic water supplies, drinking and washing, have long been relegated to secondary roles in terms of the quantity of water used. The major uses are now lawn watering (it may account for 50 % of water used in middle and upper income neighbourhoods), washing clothes and dishes, and car washing. Extremely high levels of loss in the distribution systems (caused by leakes from the water mains and faucets), especially in the developing countries, is also a major problem. In certain urban areas such leakage losses could account: for one-half of the total water pumped. For a city like Calcutta, that has an acute water shortage problem, no one really knows how much potable water is lost due to such leakages. Further problems are created by the lack of service personnel and proper maintenance practices. Thus, seventy percent of hand pumps installed are out of order in many parts of the world, and constantly running standpipes are now quite common sights in many rural and urban centres of the developing world.

Concluding Remarks

I have reviewed the water development situation in developing countries briefly. The social and environmental implications of water development have not been discussed, since I have recently analyzed them comprehensively elsewhere (Biswas, 1978c, 1978d).

Many engineers and economists associated with water development projects make a fundametal error: they consider water development as an end by itself. While benefits of water development, especially in developing countries, are many, we must realize that it is only one of the means to an end. The ultimate end we are striving for is how to improve the socioeconomic environment of man everywhere in this planet. This is by no means an easy task, but we must in our own ways make a small contribution to the realization of this overwhelming goal. As an old Chinese proverb proclaims "A journey of a thousand miles begins with a single step."

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