ENVIRONMENT AND WATER RESOURCES

ATEF HAMDY (*) - COSIMO LACIRIGNOLA (**)

ABSTRACT

Nowadays, water pollution is already a serious problem in the majority of developing countries: a large percentage of wastewater is untreated, and this is directly discharged into water courses, irrigation canals and drainage ditches.
Increased pollution from industrial and domestic sources, if allowed to grow unchecked, is likely to reduce the amount of water available for various purposes in future. Protection of water resources, if not receiving a priority consideration, will be a major cause for water scarcity in some regions, the total economic and health costs to the country due to unchecked pollution would be unbearable.
The present situation calls for strategies based on a new water awareness, founded on basic understanding of the particular role played by water for life and civilization. Those strategies have to adress the multi-cause environmental challenges emerging from water scarcity, water pollution and water — related — land fertility degradation respectively and have to be multi-sectorial in character with and integrated approach to land productivity and water resources.

RÉSUMÉ

Aujourd'hui, la pollution est déjà un problème sérieux dans la plupart des pays en développement: un grand pourcentage des eaux ne sont pas traitées et elles sont déchargées directement dans les cours d'eau, dans les canaux d'irrigation et les fossées de drainage.
Si l'on permet que la pollution des sources industrielles et ménagères augmente d'une manière incontrôlée, elle va probablement réduire la quantité d'eau disponible pour les différents objectifs à l'avenir. Faute d'une attention adéquate à la sauvegarde des ressources en eau, la pollution sera la cause primaire de la pénurie en eau, les coûts sanitaires et économiques pour le pays seraient insoutenables.
La situation actuelle requiert des stratégies basées sur la pollution incontrôlée, qui présuppose la compréhension de base du rôle joué par l'eau pour la vie et la civilisation. Ces stratégies doivent relever des défis environnmentaux d'origine multiple liés à la pénurie de l'eau, à la pollution et à la dégradation de la fertilité liée à l'eau et à la terre, respecitivement, et elles doivent être multi-sectoriels suivant une approche intégrée à la productivité des terres et des ressources en eau.

Water is the life-blood of the biosphere, constantly moving across borders between the atmosphere, the land, the ocean and back again.
Today the most easily accessible parts of renewable freshwater resources — in rivers, in lakes and in aquifers — have already been a subject of exploitation. The total amount of water available for human development and welfare and ecosystem functioning, is the same today as it has been throughout history - only much is now of poorer quality and differently distributed. The amount of water will basically remain the same also for future generations. In sharp contrast to the limited amount of available water, the rate of withdrawal has accelerated. Over this century the withdrawal has increased by a factor five whereas the population increase has been only a factor of three during the same period. The major reasons for this increased demand are industrial growth, increased urbanization and change in life-style and the population growth. The amount of water needed and demanded by ecosystems, where humans are an essential part, has reached such proportions that a serious water scarcity situation has arisen. Over one billion people lack access to an adequate supply of safe water for household consumption and 1.7 billion people do not have adequate sanitation. By 2025, more than 3 billion people will be living in countries suffering from water scarcity. Staggering as these figures are, the requirements of water for food and biomass security are even greater. Risks of increasing competition for the available water resources include: deteriorating public health; food and biomass insecurity; political conflicts; environmental degradation; further constraints on socio-economic development. To limit and cope with these risks we need to adopt new policies on a global scale. In the past, the relationship between population-environment-development was generally addressed in a manner constrained by one-dimensional approach. We must move beyond conventional water management and adopt a multi-disciplinary approach where the potential benefits and the responsibilities are shared between all the stakeholders.
Lessons from experience indicate that we must fundamentally change the way we think about and manage water. We must embrace new policies that are comprehensive, participatory and environmentally sound. This will require difficult decisions and actions on the part of all of us. But, one fundamental point is clear: we have no choice. At stake are our health, our economies and sustainable future.

SUSTAINABLE DEVELOPMENT

Before addressing the specific problems related to environmentally sound water development and management, it is useful to review briefly the concept of sustainability in development.
Interest in sustainable development has arisen as a con-

(*) Director of Research, CIHEAM/IAM-Bari, Italy.
(**) Director, CIHEAM/IAM-Bari, Italy.

sequence of national, regional and, subsequently, global concern about environment and in particular its natural heritage. It began to be articulated in Europe and North America in the 1960s and 1970s. Key events was the U.N. conference on Human Environment in Stockholm in 1972 and UNESCO's Man and the Biosphere Projects. The latter have a good claim to be forerunners of "sustainable development thinking" (Adams,1990).
In 1983, the U.N. General Assembly established the World Commission on Environment and Development and received from it its report, the so called "Our Common Future" (Brundtland Commission, 1987). Good development will protect and enhance the environment; attention paid to environmental concerns will strengthen developmental progress and projects.
The FAO definition adopted by its council in 1988, in the context of agriculture, forestry and fisheries is: "Sustainable development is the management and conservation of natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in the agriculture, forestry and fishery sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable".
In the run-up to the UNCED "The Earth Summit 92", the International Conference on Water and the Environment (ICWE), concluded with the Dublin statement on Water and Sustainable Development: "Scarcity and misuse of freshwater pose a serious and growing threat to sustainable development and protection of the environment; human health and welfare, food security, industrial development and the ecosystems on which they depend, are all at risk unless water and land resources are managed more effectively in the present decade and beyond they have been in the past".

THE WATER CRISIS

Most of the countries located in arid and semi-arid regions are already facing a water crisis, though the intensity and extent of that crisis could vary from one country to another, and with time. If the current trends continue, the water crisis will become widespread and more pervasive in nearly all arid and semi-arid countries by the early part of the 21st century.
It is now evident that within the present decade, water would undoubtedly become a most critical resource for the future development and survival of the arid and semi-arid countries, so much so that all the indicators point to increasing tensions between neighbouring countries over the use of international rivers, lakes and aquifers. Like the energy crisis of some two decades ago, a serious water crisis is now looming over the horizon. Unless every attempt is made simultaneously to make the existing water management processes significantly more efficient than they are at present, and the issue of utilization of various international water bodies is amicably and quickly resolved, the impending water crisis has the potential of becoming more pervasive and affecting adversely more lives than the energy crisis ever did at its peak.
There are many interrelated reasons which had contributed to this crisis and the major one will be discussed herein.

Population trends and explosive urban growth

The global population is continuing to increase steadily, with attendant implications for water quantity and quality. Estimates indicate that the current world population is likely to double to 10.64 billions by the year 2050. Developing countries, which are all in tropical and semi-tropical regions, will account for some 87% of this population, or 9.29 billions.
While there is no one-to-one relationship between population growth and higher water requirements, it is evident that with a substantial increase in world population, total water requirements for various uses will increase as well. This contributes to two contradictory trends which further complicate the water-management process. On one hand, a country's water requirements steadily increase with higher levels of human activities, on the other hand, per capita water available declines steadily since the total amount of freshwater available is limited (**table 1**).
The increase in per capita water requirements is an important consideration for estimating future water needs by the planners of developing countries, whose water demands are accelerating at a very rapid and alarming rate. So far this aspect has received very limited attention by the countries concerned as well as the international organizations.
Rapid population growth is always linked with fast urbanization and will substantially increase pressures on the supply and quality of water. Between 1950 and 1990, the number of cities with population of more than one million nearly quadrupled from 78 to 290. They are expected to more than double and exceed 600 by 2025 (**figure 1**). By 2025, 90 percent of population growth will have taken place in urban areas, increasing the demand for suitable quality for domestic, municipal and industrial use and for treatment of waste.

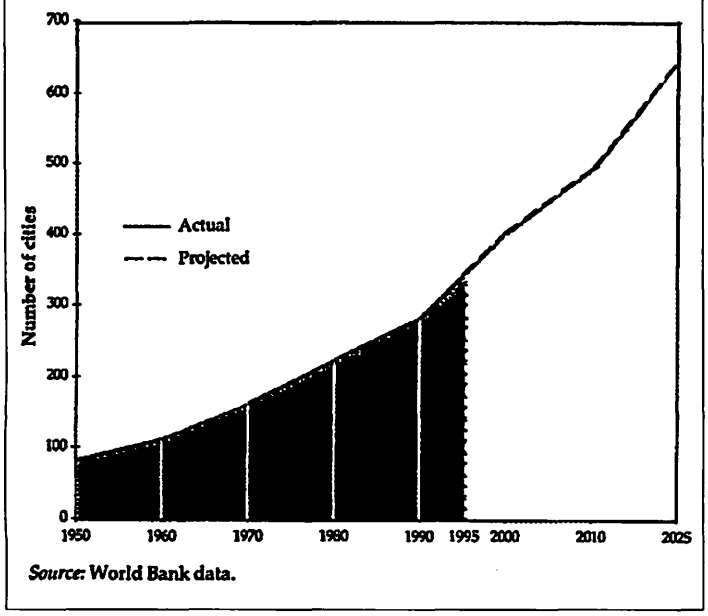
Water scarcity

The amount of fresh water available on an economic basis to any country on a long-term basis is limited. Since in arid and semi-arid countries nearly all the easily available sources of water have already been developed or are in the process of development, the unit costs of future projects in real terms can only be higher. For example, recent review of domestic water supply

Table 1 ***Population and per capita water availability for selected countries (*).***

	Population				Annual renewable freshwater available (km³)	Per capita freshwater availability (1000 m³)		
	Millions			Growth rate % per annum 1985-1994				
	1994	2025	2050			1994	2025	2050
Argentina	34.2	46.1	53.1	1.4	994	29.06	21.56	18.71
Bangladesh	117.8	196.1	238.5	2.0	2,357	20.00	12.02	9.88
Brazil	150.1	230.3	264.3	1.8	6,950	46.30	30.18	26.30
Canada	29.1	38.3	39.9	1.3	2,901	99.69	75.74	72.7
China	1190.9	1526.1	1606.0	1.4	2,800	2.35	1.83	1.74
Egypt	57.6	97.3	117.4	2.0	59	1.02	0.60	0.50
India	913.6	1392.1	1639.1	2.0	2,085	2.28	1.50	1.27
Indonesia	189.9	275.6	318.8	1.6	2,530	13.32	9.17	7.94
Japan	124.8	121.6	110.0	0.4	547	4.38	4.50	4.97
Mexico	91.9	136.6	161.4	2.2	357	3.88	2.61	2.21
Nigeria	107.9	238.4	338.5	2.9	308	2.87	1.29	0.91
Turkey	60.8	90.9	106.3	2.1	203	3.34	2.23	1.91
United Kingdom	58.1	61.5	61.6	0.3	120	2.07	1.95	1.95
United States	260.6	331.2	349.0	1.0	2,478	9.51	7.48	7.10

(*) The 1994 population estimated and population growth rates are from the World Bank Atlas (1996). Population projection (medium variant) for 2025 and 2050 are from the United Nations (1994).



Source: **World Bank data.**

Fig. 1 - Projected growth in the number of cities with more than 1 million inhabitants, 1950-2025 (Source: World bank data).

projects supported by the World Bank indicates that the cost per cubic meter of water for the next generation of projects is often two to three times higher than the present generation (Biswas, 1991a).

In many cases, water scarcity is the basic problem preventing a sustainable development of water resources. Water shortage can be the result of natural conditions related basically to low average amounts of available water resources, i.e. aridity, or related to extreme events, i.e. droughts, both creating difficulties to normal water supply and limiting the length of growing season. Future climate changes due to global warming can also become a cause for water scarcity in certain regions. Water scarcity can equally be induced by man, as a result of an increase in population and/or per capita consumption associated with social and economic development, or as a consequence of incorrect water use (over-exploitation of water resources, pollution, desertification, etc.). One relevant case is the excessive use of groundwater which tends to take place in some countries, leading to a decrease in water levels and consequently increasing the cost of pumping, and therefore the cost of the water supplied, to levels which are likely to generate non-competitive economic activity, particularly in the case of irrigated crops.

Nowadays issues of scarcity have put water at top political agenda. Agreement on access to water is an important part of the peace accords between Israel and its neighbors. A water treaty has also helped to maintain peace between India and Pakistan. But water policies are not confined to historical conflicted or dry areas. Today, nearly 40 percent of the world's people live in more than 200 river basins that are shared by more than two countries. Even within countries, conflicts over water are often bitter. As population and demand for limited supplies of water increase, interstate and international frictions over water can be expected to intensify.

Water quality

An assessment of water resources is incomplete without knowledge of the quality characteristics as assessed by their physical, chemical and biological constituents. These constituents may originate naturally from the environment (e.g. soils and geological formation) or from wastes discharged as a result of agriculture, human settlements and industrial activities. They are introduced either from point sources (mostly industrial and municipal), which are manageable, or from non-point sources (mainly agricultural), in which easy management is

more difficult.
The concentrations of the constituents simply express the status of the water in physical, chemical and biological terms, but quality can only be discussed meaningfully when it is related to a specific use. In such cases, guidelines must be given on the concentrations of various constituents which should not be exceeded in order to avoid impairing the water for any particular use.
Until 1987 no attempt had been made to assess globally the quality status of regional fresh waters. This was due to lack of data from most countries, particularly from the developing ones, where water data were not collected on a regular basis.
In the remainder of this century, water issues will become increasingly important. Monitoring and environmental management measures to preserve the quality of existing groundwater and surface water resources will take a prominent place on the agenda of global water resources use planning. Recently, different views have been expressed concerning the relative importance of water quantity versus water quality for health environment, and this on-going discussion will have to result in a balanced view on the issue, taking into account local epidemiology, ecology and economy.
New technologies will need to be applied to detect and monitor water resources in an integrated manner. Water quality is being checked through the Global Environmental Monitoring system by a network of national institutions. These data may be complemented by Remote Sensing (RS) observations of watersheds and river basins, and they will be increasingly analyzed with the use of Geographic Information Systems (GIS). It is of great importance to create intersectorial networks in which countries can apply these new technologies for a sound and integrated management of their natural resources. Ministries of health will have to set up their health monitoring and epidemiological assessment activities to provide such systems with adequate data so as to elucidate the linkage between environmental change and human health status.
In nearly all the developing countries, including the Mediterranean ones, water quality programs are either in their infancy or even non existent. A reasonable clear and detailed picture of environmental issues confronting the land and water sectors does not exist, nor any accurate estimates on the cost of land and water degradation to the national economy. The cost is already significant at present, and if no drastic actions are taken, the existing trends show that it is likely to become even higher during the 1990s. In addition, the status of water pollution and the extent to which water quality has been impaired for different potential uses simply are not available. On the basis of anecdotal and very limited information available, it can be said that the problem is already very serious near urban centers, especially for groundwater and lakes and for some rivers as well. It should be noticed that, once the groundwater is contaminated, it cannot be easily decontaminated.

Water degradation and water pollution

The annual world water withdrawal in 2000 is expected to be approximately 5,200 km³ which corresponds roughly to 13% of the natural runoff (39,000 km³) and 25% of the stable runoff foreseen for the same year (20,000 km³). If one considers effective water consumption instead of water withdrawal, these percentages will be reduced to approximately half of these values, i.e., 7% and 13%.
These figures, as presented, give no evidence of reason for special concern, but the situation changes drastically if pollution is taken into consideration. According to Lvovich 1979, the annual volume of wastewater rejected in water bodies in 2000 is expected to be approximately 6,000 km³, these wastewaters mobilizing approximately 38,000 km³ of river runoff to absorb the corresponding pollution. Considering that this last figure corresponds approximately to total natural runoff and is twice the stable runoff in 2000, and considering, furthermore, the marked differences in the world geographical distribution of water, this situation seems to be a reason for serious concern.
These estimates are of course only approximate, but they illustrate a very unfavorable trend and draw attention to what appears to be a potentially alarming situation threatening the sustainable development of water resources, unless the future evolution of water resources management and particularly of wastewater treatment technologies is very favorable and its application largely diffused.
Water pollution can be direct or indirect. *Direct pollution* is that resulting from rejecting pollutants directly in the water courses or the aquifers, and is usually the result of routine activities or accidental events. Pollution resulting from routine activities can be of two different types: *point source pollution*, which is generated mainly by municipal and industrial water use and can be controlled by adequate sewage treatment technologies which are well known but usually expensive (these technologies cover primary and secondary treatment and in some cases tertiary treatment, e.g., when eutrophication problems are important); *diffuse pollution* (or non-point-source pollution) which results from farming, forestry, urban discharges, transportation, construction-industry and sanitation landfills, its control being closely associated with good agricultural practices, and the implementation of adequate land-use policies.
Accidental pollution results from accidents which, in many cases, are likely to cause great damage. These accidents have recently increased and will probably tend to increase further in the future. Accidental pollution

has to be controlled by planning in advance adequate strategies for earlier detection and subsequent restriction of the region affected and minimization of impacts. Human activities increase and more and more waste products are contaminating available sources of water. Among the major contaminants are untreated or partially treated sewage, agricultural chemicals, and industrial effluents. These contaminants are seriously affecting the quality of water, especially for domestic use. Already many sources of water near the urban centers of developing countries have been severely contaminated, thus impairing their potential use.

The common contaminants were found to be heavy metals and organic micropollutants. The pollution problems were classified into those that were common to all fresh water bodies and those specific to rivers, lakes/reservoirs or groundwater. The classification is presented in **table 3**.

In developing countries, both fertilizers and pesticides are used in relatively huge quantities without the existence of a real control and regulations for use. Nitrate contamination of groundwater from agricultural activities has been a major environmental concern in many developing countries especially in those with extensive irrigated agriculture.

We continue to ignore the critical role of water in maintaining the quality of the environment and the link between a healthy environment and a healthy economy. Already half of our coastal wetlands have been drained for infra-structural or agricultural development, and in many places groundwater is seriously at risk from over exploitation and contamination by urban and rural pollutants and the intrusion of saltwater. Sewage and industrial waste pollute rivers on every continent. By some estimates, the amount of water made unusable by pollution is almost as great as the amount actually used in the human economy.

Nowadays, water pollution is already a serious problem in the majority of the developing countries: a large percentage of wastewater is untreated, and this is directly discharged into water courses, irrigation canals and drainage ditches. While one can question the actual percentage figures, there is no question that a very high proportion of domestic and industrial effluents are untreated at present. Increased pollution from industrial and domestic sources, if allowed to grow unchecked, is likely to reduce the amount of water available for various purposes in the future. At our present state of knowledge, we simply do not know the extent of contamination that has already occurred and which may render some water sources unusable in the future without expensive treatment. Protection of water resources, if not receiving a priority consideration, will be a major cause for water scarcity in certain regions. In addition, the total economic and health costs to the country due to unchecked pollution would be unbearable. Deterioration in the quality of this vital resource has very serious implications for health and the quality of life. Access to it becomes a right requiring equitable distribution to all society. Attempts have been made in most countries to ensure that even the poorest sections of the population have access to good quality drinking water, but much effort is still needed to attain this objective. Globally, water-related diseases account for 8 percent of all illness in developing countries, affecting some 2 billion people annually. It is estimated that 2 million children die for such diseases each year, death that could be averted if water supply and sanitation services were adequate. These diseases also play a significant role in adult mortality and sickness. Poor health caused by water-related diseases and unsanitary practices is very costly to the economy in terms of working days lost and reduced productivity. The pollution of water supplies may be aggravated if drinking water supply programs are not accompanied by appropriate sewage systems. Many developing countries have the operational means to assess their water quality. Without this information, they may be unaware of problems and perhaps endanger their population's health.

Table 2 ***Occurrence of major pollution problems in different types of water bodies.***

Type of water body	Water pollution problem	
	Specific of water body	Ubiquitous occurrence
River	Pathogens Organic matter Suspended matter Acidification	Heavy Metals
Lakes and reservoirs	Eutrophication Acidification	Organic
Groundwaters	Salinization Nitrates	Micropollutants
Source: WHO/UNEP, 1989.		

The structural imbalance and shrinking investments

The dominant fact which will be strongly evident over the next few decades is the structural imbalance between the constantly increasing demand for water to meet needs, and the naturally available water resources. Over the last few decades, the imbalance was limited to a few countries and requirements were met by the gradual additional harnessing of natural resources wrongly thought of as being infinite. This room for manoeuvre is progressively contracting and will be available less and less in the future.

Throughout the world, for the most part all easily exploitable sources of water have already been, or are currently being developed. For instance, in several Mediterranean countries, the imbalance will appear around the year 2000 and beyond. In the Middle East Region and the Southern Mediterranean countries, the

water demands will fast approach the limit of resources and the majority of countries in both regions could enter a period of chronic shortage during the 1990s. These countries will be facing several similar problems that may be outlined as follows (Hamdy et al, 1995):

- declining water resources per inhabitant both in terms of water availability and water withdrawals. It is expected that the available water per capita will be reduced by nearly 50% of the present level (**figure 2**);
- exploitation of water at a relatively high rate with the risk of water deterioration;
- excessive reduction in water withdrawals per capita, which will impose a significant effect on water sectorial use, creating notable competition and conflict among users in various sectors, and in the irrigation and domestic sectors in particular. Priorities will be given to satisfy drinking water demands to the expense of the available water allocated for the irrigation sector with the consequence of less irrigated surface and more land degradation;
- progressive degradation in the quality of available water resources because of increasing waste load discharged in water bodies and the atmosphere.

The other reason why expanding irrigation water supply in real terms is unlikely to effect dramatic increase in water demands, is the cost of developing new water sources.

It is expected that such costs for the next generation of projects to be often two to three times higher than that of the present generation (World Bank, 1992).

In addition, the very noticeable decline in the donor's interest in providing investment funds for major water development projects in developing countries and the high capital requirements for new projects, mean that there may be significant delay in the implementation timetable of future projects and that additional new sources of water would not be available in the future as expected at present. This complacency, in all likelihood, would make the future water crises even more serious than what they are expected to be at present.

Inefficient water use

Water resources problems are often associated with lack of efficiency in water use in agriculture, industrial and domestic supply.

Agriculture is by far the most important water use activity (**table 3**); it is also probably the sector least efficient in water use (**figure 3**). Worldwide the efficiency of irrigation system is estimated at only 40%. But given sufficient incentives, water withdrawals for irrigation could be cut by 10 to 40% without reducing crop production.

Low irrigation efficiencies can be primarily attributed to water mismanagement (**figure 3**), in addition to technical problems of conveyance, distribution and on-farm application as well as to poor maintenance of irrigation structures, often caused by inadequate investments for operation and maintenance. In almost all developing countries where major rehabilitation or modernization of water supply systems are needed, financing is a

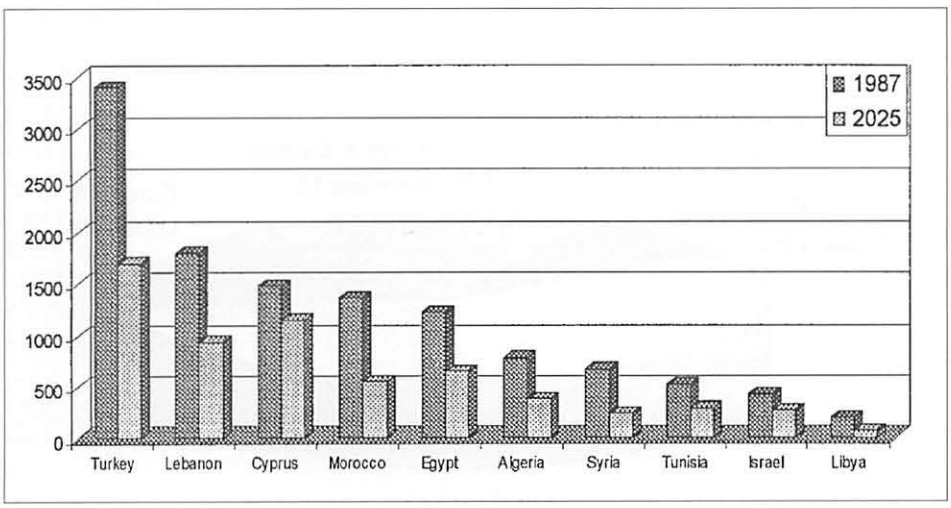


Fig. 2 - Water availability per capita in the southern Mediterranean countries.

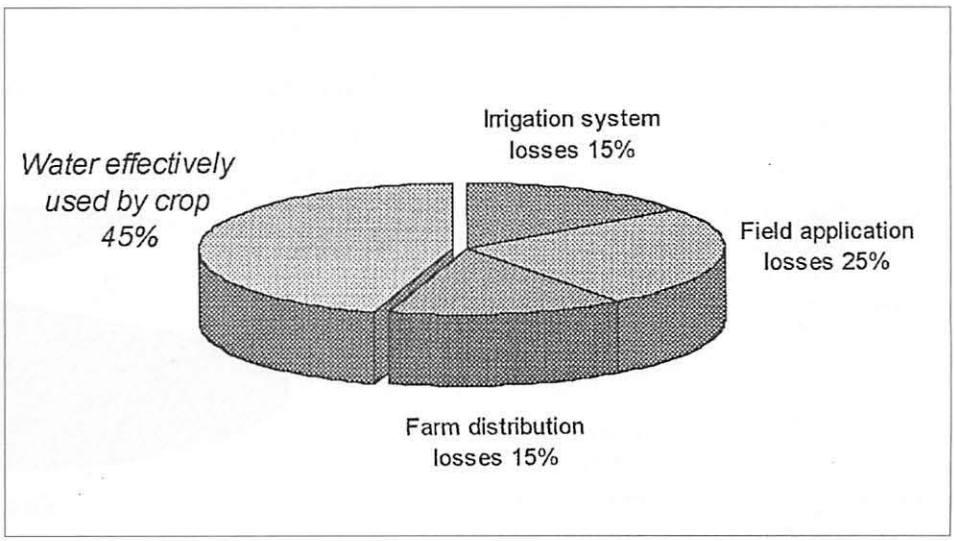


Fig. 3 - Average losses of irrigation water (Source: FAO, 1994).

Table 3 *Evolution of distribution of water use by types of use.*

	Water withdrawal (%)			Effective consumption (%)		
	1940	1980	2000	1940	1980	2000
Agriculture	84	72	65	96	95	94
Industry	12	22	26	2	3	4
Municipal	4	6	9	2	2	2

principal constraint.

Equally, several countries are still considering water as a free commodity with prices always lower than real cost, and in particular irrigation water that is often heavily subsidized. The failure to recognize the economic value of water has led to wasteful and environmentally damaging uses of the resource. Managing water as an economic commodity is an important way of achieving efficient and equitable use and of encouraging conservation and protection of water sources. It should be realized that, if we want to have enough water of sufficiently good quality, we have to pay for its true value. There is much room for increased efficiency in water sources use. In this respect, irrigation is a major concern; as water is often supplied to farmers at a cost well below the cost of supply, this being a particularly important issue in developing countries, the food production of these countries would greatly benefit. Achieving such goals is primarily a subject of a proper and environmentally sound water management of the available water resources in each country.

In order to raise irrigation efficiencies, it is necessary to improve system water management and on-farm water management, where the farmer must be a prerequisite for the latter. In order to improve operational efficiency, it needs to be recognized that irrigation development is now primarily a management task rather than a design and construction one.

Poor performance of irrigation and drainage systems

Over the last 40 years, the area of irrigated land in the world has expanded rapidly at an overall rate of 2.7% a year and it has reached 253 million hectares in 1986 (**figure 4**); of the total gross irrigated area 73% was in developing countries. In contrast to irrigation, two thirds of the drained and flood protected area of the world are in developing countries. (**figure 5**).

In spite of this rapid expansion in gross irrigated areas, irrigation and drainage have undergone little technological change over this period. Principally as a result of inadequate technologies, management practices and policies, most irrigation systems around the world in both developing and developed countries, are performing far below their potential. This is true in virtually every dimension of performance, efficiency, productivity, equity, sustainability and impact on rural livelihood. In developing countries, irrigated agriculture is globally characterized by the following features:

- the overall performance of many irrigated projects is much less than expected. Inadequate operation and maintenance and inefficient management of an increasingly scarce water resource contribute to problems;
- the priority is always given to the water quantity with

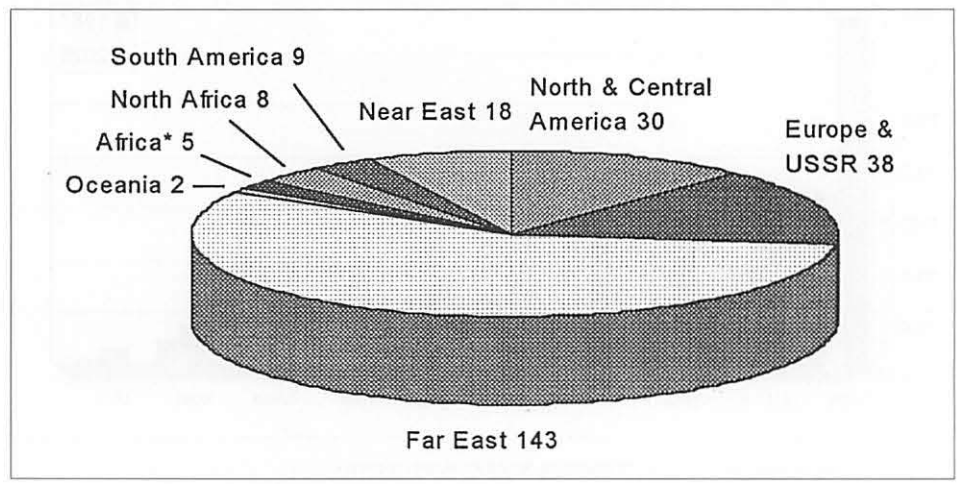


Fig. 4 - World irrigated area, 1986 by region (million hectares).

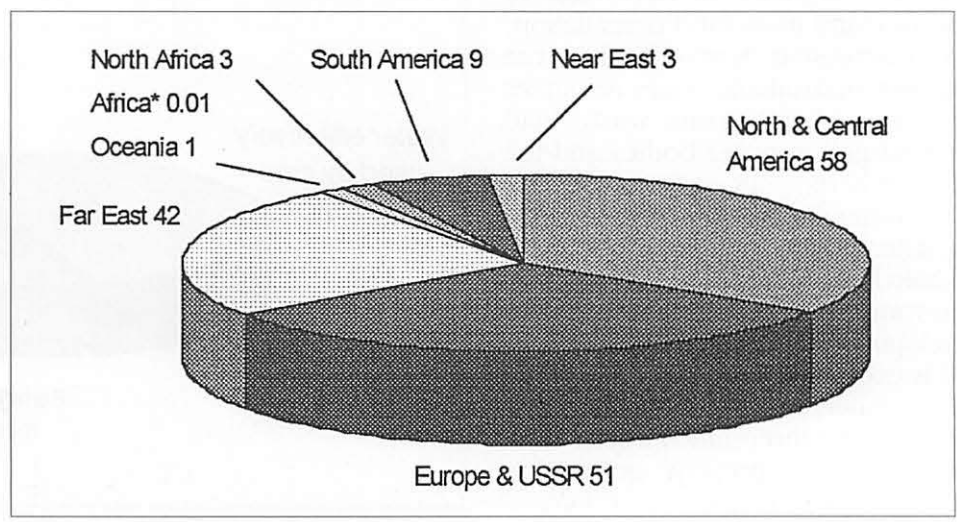


Fig. 5 - Area protected by drainage and flood control by region (million hectares).

minimum consideration to its quality; the quantity and quality are not interlinked;
• large irrigation projects have been given high priority, while small-scale water programs for agriculture have received inadequate attention.
Poor management practices, inefficient water use, failure to place a high economic value on water have undoubtedly had a profound impact on the earth's physical environment.
Water-logged and salted lands, declining and contaminated aquifers, shrinking lakes and destruction of aquatic habitats combine to hang onto irrigation a high environmental price.
Biswas (1991) estimates that the share of irrigated land damaged by salinization amounts to 27% of the total irrigated area around the world. Szabolcs (1989) estimates that some 10 million hectares are abandoned yearly as a consequence of salinization, sodification and waterlogging.
Figure 6 gives an idea of the problem worldwide (Postel, 1989).

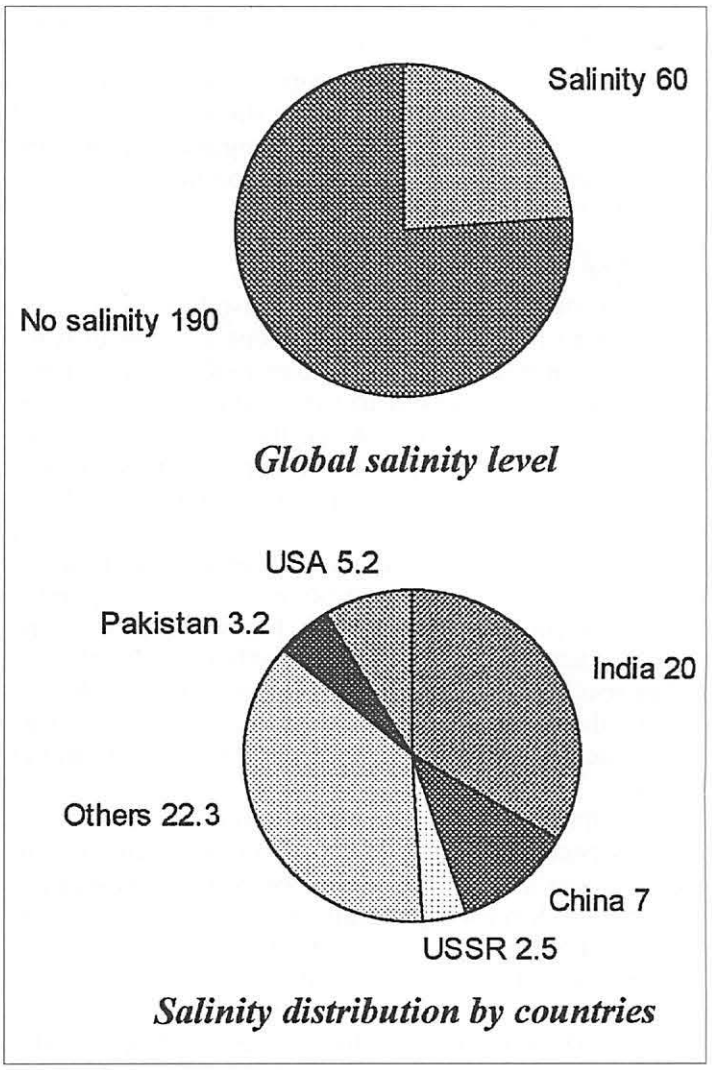


Fig. 6 - Irrigated land damaged by salinization (areas in million hectares).

THE ENVIRONMENT AND WATER MANAGEMENT

Environmentally-sound water management implies that:
1. development be controlled in such a way to insure that the resource itself is maintained and that the adverse effects on other resources are considered and where possible ameliorated;
2. options for future development are not foreclosed; and
3. efficiency in water use and in the use of capital are key criteria in strategy selection.
Recognizing these ideas is one thing, translating them into action is another. More specifically, what is required to foster the adoption of the three elements noted above in planning and policy making are: the recognition of concepts of environmentally-sound development and resilience, the incorporation of a more comprehensive perspective and the pursuit of higher levels of efficiency.
Preparation of water management requires planning, design and implementation of water control systems, including operation and maintenance, regulatory oversight and coordination. The management of water shortage integrates all facets of water resources management, including water supply, water quality management, irrigation and farm drainage, energy generation, fisheries enhancement, recreation and general aesthetics, as well as flood control.
In such a complex task, there is a confusion about who should do what in order to be ready to handle the problem.

Constraints to environmentally-sound management

A comprehensive and critical analysis of existing literature on environmental aspects of water development in the Mediterranean region indicates that there are many constraints which limit the potential application of available knowledge by water professional and decision-makers in developing countries. On the basis of this analysis, the following five major constraints can be identified:
1. incomplete framework for analysis;
2. lack of appropriate methodology;
3. inadequacy of knowledge;
4. institutional constraints;
5. absence of integrative approach.
It should be noted that the four major constraints identified are not independent. On the contrary, they are often closely interrelated.

1. Incomplete framework for the analysis

The framework currently used for analysis and considering various environmental impacts associated with water development projects is overwhelmingly biased towards assessing only the negative impacts.

What is thus needed is a balanced framework for analysis which will identify both positive and negative impacts. The next step should then be how to maximize the positive impacts and minimize the negative ones. A framework that considers only the negative impacts and ignores the positive ones is both incomplete and counterproductive.

2. Lack of methodology

A review of the process currently used by developing countries to incorporate environmental issues in water management indicates that the methodologies available at present do not appear to satisfy the special requirements of those countries. While the environmental impact assessment (EIA) process was made mandatory in several industrialized countries, its actual use so far in developing countries has been somewhat slow. The reason for this slow acceptance is the lack of an operational methodology that can be successfully applied in the developing countries with limited expertise, resources, data and time. The EIA methodologies that are being used in industrialized countries are not directly transferable to developing countries for various socio-economic and institutional reasons (Biswas and Kindler, 1989).

The complex, lengthy, expensive and time-consuming EIAs as practiced in developed countries, are not the right tool to assess the impact of water development projects in developing countries. It is also important that in addition to being appropriate to local circumstances, they should be affordable in terms of cost and maintenance. Many hydrological services in the developing Mediterranean countries have not been guided on these latter aspects. It is not uncommon to find that equipment has been acquired without ensuring that it can be operated and maintained properly. Hence, the life span of equipment is unduly shortened, thereby wasting scarce resources. Also, it is necessary to develop guidelines which can actually be used by professionals for water management in planning and managing projects.

3. Lack of adequate knowledge

The results presented so far show that there is some working knowledge about the Mediterranean countries water. However, as it can be seen from a comparison of the various estimates, differences exist with regard to the water balance components and the water resources at the various levels.

Those scientists who have made contributions to this knowledge, pointed to the lack of adequate data on the hydrological cycle, the lack of sufficient areal coverage of the data and their representativeness, the gaps in data, the quality of data, and in some cases problems of access to data even if they are available. In addition, there are questions raised about the adequacy of the

scientific basis, methods and techniques used in making the assessments.

There are many areas where adequate technical knowledge may not exist for getting reliable answers. Equally, there are areas where "conventional" knowledge can at best be dubious and at worst totally erroneous.

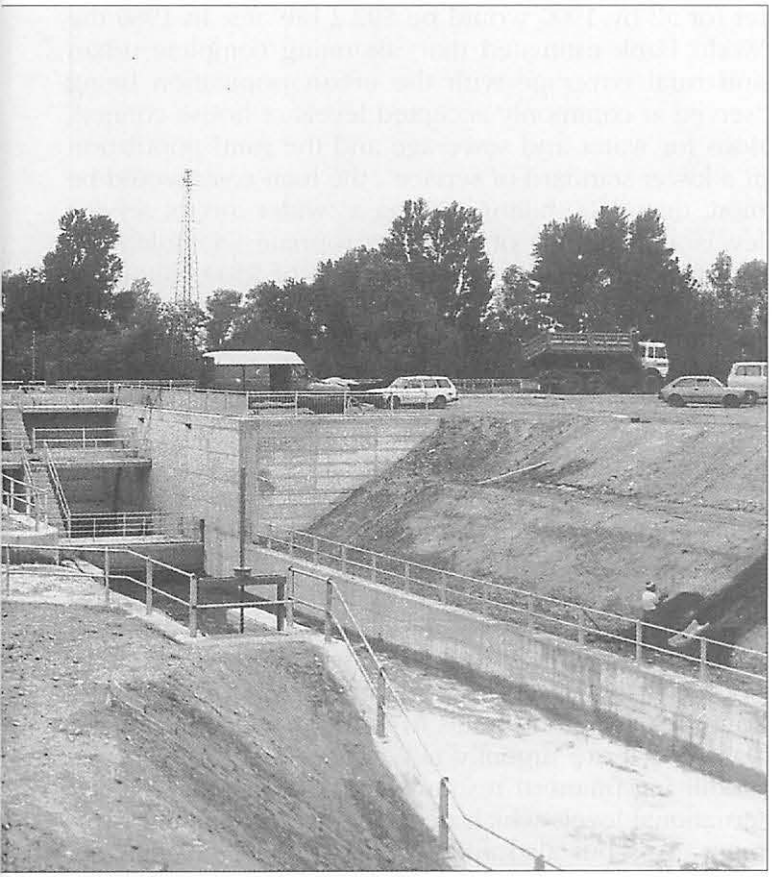
4. Institutional constraints

A sectorial approach to water development is a major institutional constraint in all developed and developing countries, and this has an important bearing on the sustainability of projects.

There are many reasons for this situation, but one of the most important is the division of responsibilities between the various water-related issues. Because of long-standing rivalries, the coordination and cooperation between the various ministers leave much to be desired and yet in any large scale water development project all these issues must be integrated within the project area. While it is easy to point out this necessity, how this integration can be really effected in the field is a very complex and daunting task.

5. Absence of integrated approach

The "Integrated" approach is not really new. It was already recommended at the 1977 United Nations Conference in Mar del Plata that led to the declaration of the



1980s as the Water and Sanitation Decade with the objective of providing drinking water and sanitation for all by 1990.

This was analyzed at length during numerous regional and international conferences most notably at New Delhi in 1990, Delft in 1991, Dublin in January 1992 and Rio in June 1992. All of these conferences stressed again the importance of an integrated approach to water resources planning and management. For example, the Dublin conference Report states: "... The effective management of water resources demands a *holistic approach* linking social and economic development with protection of natural ecosystems including land and water linkages across catchment areas or groundwater acquifers...".

The Rio Earth Summit's recommendation given in its Agenda 21, chapter 18 entitled "Protection of the quality and supply of Freshwater Resources: Application of *Integrated Approaches* to the Development, Management and Use of Water resources" states: "As population and economic activities grow, many countries are rapidly reaching conditions of water scarcity or are facing limits to economic development. This scarcity, accompanied by aggravated pollution of freshwater resources..., demands the integration of sectorial water plans and programs within the framework of national economic and social policies... This integration should be carried out at the level of the catchment or sub-basin...".

The Rio conference further clarified that, integrated water resources management was based on the perception of water as a natural resource, a social and economic commodity whose quantity and quality determine the nature of its utilization.

The analysis of the aforementioned statements starting from the U.N. Mar del Plata (1977) and ending with the Rio Earth Summit (1992), recommended the integrated approach for an effective management of water resources as its objectives are to achieve the social goals of equity, efficiency and environmental quality. However, in spite of the investments and the efforts made during that decade, these objectives were not met and today more than one billion people do not enjoy access to clean water and almost two billions are without adequate sanitation. This is the general situation, the question is what should be done to improve it and be ready to overcome future shortage of water.

It is very difficult to speak generally, but some improvement can be done using past-experience and accumulated knowledge.

To alleviate the problem of water shortage, the following is needed:

• Improve information activities, generally the most neglected ones, including:

— data collection and management;
— analysis and planning;
— coordination and technical assistance;
— research, training and public information education.

Data management is a critical information activity in a situation of shortage of water. To be successful, data management must be integrated with regulation, water supply assurance, water allocation, planning for development and comprehensive water management.

— The management of water resources scarcity should be a continuous process and not a project which starts when a drought occurs and finishes when water supplies are back to normal.

— Improve water supply by the improvement of existing water resources through: efficient uses, construction of surface reservoirs, conjunctive use of surface and groundwater, conservation and protection of water resources and rain harvesting.

— The reuse of unconventional water resources on a relatively large scale in the agricultural sector through the set-up of new management strategies which are, technically, environmentally and economically applicable.

Fundamental environmental challenges

Three fundamental environmental challenges will have to be addressed in the new strategies needed for the 21st century.

1. *multi-cause water scarcity* due to:

— population growth *per se* producing an ever increasing population pressure on a finite water availability;
— urban growth resulting in ever-increasing point demands for water;
— desiccation of the landscape due to degradation of soil permeability and leading to drought-like conditions even in high rainfall areas.
2. *multi-cause water pollution* due to:
— airborne emissions;
— pollution from agricultural land-use, industrial activities, and human waste;
— wastewater outlets.
Pollution from most of these sources gets caught and carried by the water cycle and ends up, often with detrimental impact, in land and water ecosystems.
3. *multi-cause water-related fertility degradation* due to:
— salinization/water logging from poor irrigation management
— effects of acid rain originating from air emissions;
— reduced water holding capacity due to reduced use of organic fertilizers, and removal of organic matter from the soil;
— land permeability degradation due to mismanagement of land.
To these challenges one should add the *financial challenge*. The widening gap between financial resources available and the escalating needs of funds for water resources development and management for the socio-economic development of the Third World region requires urgent attention. This situation forces us to find ways to get more out of less. Funds needed for investments, operation and maintenance in the traditional water sector are estimated at up to 20% of public expenditures in many countries. The debt burden in developing countries constraints their ability to invest in water projects with long gestation periods. Many countries also provide large subsidies to particular water users, which can distort water use and interfere with sustainable use of the resource.

Areas requiring improved efficiency in water management

For environmentally sound water management to be satisfactorily implemented still much has to be done in several important areas as illustrated in the following:

Mobilization of financial resources

Developing countries must mobilize adequate financial resources for water management. The amounts of investment required for water management, both capital costs and subsequent operation and management costs are significant. In a paper prepared for the Water Conference, the WHO, with initial assistance from the world Bank, estimated that the investment necessary to meet the target set for community water supply of clean water for all by 1990 would be $92.2 billions. In 1980 the World Bank estimated that, assuming complete urban and rural coverage with the urban population being "served at commonly accepted levels of house connections for water and sewerage and the rural population at a lower standard of service", the total costs would be more than $600 billions. Using a "wider mix of service levels and the use of more appropriate technologies", the Bank provided a second option of $300 billions or less.
Assuming that such estimates are correct, it means an investment of $82.2 millions every day of the decade for new drinking water installations alone; other aspects of water management are not included.
The above figures are given primarily to show that the financial resources necessary for efficient water resources management and development are substantial. There is no point in making the rhetorical statement that if only 1% of global expenditures on armaments could be channeled to water management, financial problems would be resolved.
Poor cost recovery in water projects in developing countries also contributes to additional funding limitations. What are urgently needed are realistic plans for mobilizing financial resources at both national and international levels which not only include capital investment costs but also adequate operation and management costs of all the water projects constructed.

Development and training of human resources

The lack of adequately trained human resources is a serious constraint to efficient management of water resources in most developing countries.
On a long-term basis, training is probably one of the most important requirements for efficient water management. Current evidence indicates that the lack of trained and experienced personnel has tended to increase the cost of water projects and at the same time reduce their efficiency. For example, if irrigation projects are considered, the lack of trained management personnel and the absence of farmers experienced in irrigated agriculture have not only tended to increase the irrigation costs but have also reduced the benefits expected from the schemes. In addition, the lack of technicians and other similar trained personnel at lower levels of expertise is creating serious management bottlenecks.
An important aspect of the development and mobilization of human resources that has not received adequate attention thus far is the underemployment and ineffective use of trained manpower in several developing countries. In these countries, generally speaking, an adequate pool of trained manpower exists, but because of lack of incentives, the inability of management to motivate staff, excessive institutional red tape and other related reasons, staff members often do not develop, or

seldom work at their full potential. While multilateral and bilateral organizations have now mostly started to give increasing attention to training requirements, commensurate interest in improving overall managerial skills is generally lacking. If managerial skills can be improved —and the scope for such improvement is substantial —there is no doubt that more can be achieved in most countries with the currently available financial and human resources. The strengthening of managerial skills requires the urgent attention of all parties concerned.

Development and application of appropriate technology

Efficient water management depends not only on people, but also on the resources and technology they have access to, and the socio-cultural-institutional framework within which these are utilized (Biswas and Biswas, 1985; Fano, 1981). By itself, technology employed in pursuit of rational water management is neutral, but how it is used can determine the success or failure of projects. The choice of technology depends on many factors, and often what may be considered the most appropriate technology in one country turns out to be most inappropriate for solving almost identical problems in another.

Developing countries are not all the same: they are at different stages of development and may have different social, cultural and institutional backgrounds.

Many instances can be cited where inappropriate technology is being imported to developing countries from industrialized countries, through either bilateral or multilateral aid programs, without critical appraisal by either the donors or the recipients. Accordingly, more attention needs to be given to developing and using appropriate technology for efficient and environmentally sound water management under site-specific conditions.

Conservation and enhancement of water quality

As a general rule, nearly all developing countries have better expertise, databases and institutional capacity for the management of water quantity than water quality, even though water quantity and quality aspects are closely interrelated. While there are some signs that interest in water quality management is increasing, much progress remains to be made.

Many developing countries have still not formulated water quality standards to control the discharge of effluents to both surface and groundwater. Even in those countries where standards exist, the monitoring and enforcement of standards leave much to be desired. The use of policy alternatives such as accelerated depreciation and tax incentives to encourage investment in pollution control facilities requires further attention. Similarly, acceptance of the "polluter pays" principle, and ensuring that polluters do actually pay, will go a long way towards controlling water pollution.

In some developing countries, considerable debate is now taking place on the tradeoffs between the benefits occurring from pollution control and the increased costs of economic activities. A rational analysis of any such tradeoff is somewhat complex since the health and environmental costs of water pollution are neither easy to quantify nor are they necessarily paid by the polluters and their immediate customers.

Mitigation of natural hazards: droughts and floods

Two of the important objectives of any water development project are flood control and reducing the impacts of droughts. The untold human suffering caused by the recent droughts in many sub-Saharan countries is well known. Similarly devastation due to periodic floods can be witnessed in all developing countries. Efficient water management can alleviate many of these problems.

For better flood and drought management, a better and broader vision is necessary. Water management by itself is unlikely to be enough. We need to look at land and water as an interacting unit if the adverse impacts of floods and droughts are worsened due to human activities, which means that better planning and control mechanisms need to be used. Watershed management, patterns of land use, a working warning system, and the existence of adequate relief measures are normally essential for the management of natural hazards like floods and drought.

Concluding recommendations

It is becoming clearer and clearer that, continued rapid growth in population together with socio-economic changes are exerting increasing pressure on policymakers and on the public to find viable and realistic water

management strategies that can deal with the following four issues:
1. How to safeguard water to meet basic needs for difficult uses;
2. How to minimize water losses;
3. How to allocate scarce water for desired socio-economic development;
4. How to protect the environment from degradation and loss of productive capacity.

The common requirements in all practical responses to the solutions of all these major issues must include greater investments, better institutions, more technology and expertise, and intensified cooperation.

The water crisis, coupled with the many existing environmental stresses (including, for example, land and water pollution, erosion and sedimentation, natural and man-caused hazards) emphasize the need for continued development of human potentials, education and public understanding as an essential element in a major international effort.

Particular weight has to be given to capacity building within national research institutions in order to increase the capability within individual countries to address issues of sustainable development with adequate attention to environmental constraints.

Here, international cooperation can play a very important role. Combining international experience of countries with different levels of development may also be mutually beneficial as the developing countries can learn from the experience of the more developed ones, taking the lessons of their successes and failures, and the more developed countries have the opportunity to use their skills to help sustainable water resources development in developing countries.

Concerning the interdisciplinary and intersectorial character of water resources problems, it is essential for the achievement of a sustainable development of water resources that adequate institutional framework for water resources management, be established in each region and each country. Water management can be rational only if the institutions responsible for such management are efficient. The present situation calls for strategies based on a new water awareness, founded on basic understanding of the particular role played by 'wafer for life and civilization. Those strategies have to address the multicause environmental challenges emerging from water scarcity, water pollution and water related-land fertility degradation respectively and have to be multi-sectorial in character. In addition, those strategies should take an integrated approach to land productivity and water resources in order to strive for sustainable land productivity. ●

REFERENCES

Adams W.M. (1990) - Green Development Routlage. London.

Arnell N. (1992) - The potential effects of climatic changes on water resources management in the U.K. + Climatic fluctuation and water management". Eds. M. Abu-Zeid and A.K. Biswas, Buterworth-Heinemann. pp. 107-116.

Boswas A.K. (1991a) - Inauguration Address. Seventh World Congress on Water Resources. INRA-Rabat, Morocco, May 1991.

Boswas A.K. (1991b) - Water for sustainable development in the 21st Century: a global perspective. Water International, 16, 219-224.

Biswas A.K. (1994) - Considerations for sustainable irrigation development in Asia. Intern. Jour. Water resources development, 10 (4), 445-455.

Biswas A.K. (1996) - Water development and Environment. In: Water Resources Environmental Planning, Management and Development. Ed. by A.K. Biswas. pp. 1-37.

Biswas A.K. and Kindler J. (1989) - Sustainable water development and management: A synthesis U.N.E.P., pp 26.

Boswas R.M. and Biswas A.K. (1985) - The Global Environment: past, present and future. Resources Policy, Vol. 11, No 1, 25-42.

Brundtland H. (1987) - Our common future. Oxford University Press.

Da Cunhan L.V. (1989) - Sustainable development of water resources. Proceedings of the International Symposium (SISIPPA), Lisbon, Portugal, 19-23 June, 1989.

Falkenmark M., and Biswas A.K. (1995) - Further moment to water issues: comprehesive water problem assessment. Ambio 22(8), 556-600.

Fano E. (1981) - The role of International Community in the drinking water supply and sanitation decade. Natural resources Forum, Vol. 8, 261-269.

Fao (1988) - World Agriculture Towards 2000". A FAO Study, N. Alexandratoss eds. Bellhaven Press, London.

Fao (1994) - An international action programme for sustainable agricultural development. Water for life.

Gleick P.H. (1993) - Water in a crisis: Guide to the fresh water resources. Oxford University Press.

Hamdy A., Abu-Zeid M. and Lacirignola C. (1995) - Water crisis in the Mediterranean: Agricultural water demand management. Water Intern. Jour. Vol. 4. 515-526.

Ihe/Undp (1991) - A strategy for water sector capacity building. Proc. of the UNDP Symposium. Delft, The Netherlands. 3-5 June, 1991. IHE Report Series, n. 24.

International Conference on Water and Environment, ICWE (1992) - Development Issues for the 21st Century. The Dublin Statement and Report on the Conference, 26-31 January, 1992, Dublin, Ireland.

Mar del Plata Action Plan (1977) - United Nations Water Conference Mar del Plata. Argentina, 14-15 March, 1997.

Postel S. (1989) - Water for agriculture: Facing the limits. World Watch paper 93, The World Watch Institute, Washington D.C.

Shiklomanov I.A. (1996) - Assessment of water resources and water availability in the world. State Hydrologic Institute, Russian Federation.

Szabolcz I. (1989) - Salt affected soils. CRP press. Boca Raton, FI.

United Nations (1992) - Agenda 21. United Nations, New York.

United Nations (1994) - World population prospects. The 1994 revision. The United Nations, New York.

United Nations Development Program, UNDP (1990) - Report on the Global Consultation of safe water and sanitation for the 1990s. United Nations Development Program, New York.

Who/Unep (1989) - Global fresh water quality. A first assessment. Blackwell Reference.

World Bank (1992) - World Bank development report. Oxford Press, New York.