EARTHWATCH

Global Environment Monitoring System

WHO/UNEP Report on

WATER QUALITY

Progress in the Implementation of the Mar del Plata Action Plan and a Strategy for the 1990s

First published 1991

NOTE

CONTENTS

Acknowledgements

For the preparation of regional assessments, a series of consultant missions were conducted within a relatively short time-span. The consultants' findings provided the basis for estimating the progress achieved in the area of water quality since Mar del Plata and for the development of a strategy for the 1990s.

The co-sponsoring organizations gratefully acknowledge the contributions of:

Drs M. Dray, H. El-Ghobary and M. Meybeck for their dedicated work in Africa;
Dr A. Demayo for expert missions in the Americas;
Mr S. Ramadan for the extensive review of the West Asia region;
Dr K. Khan and Professor P. J. Peterson for their comprehensive country reviews of Asia and the Pacific; and
J. Jackson for the in-depth analysis of the European situation.

Based upon these reports, Drs M. Meybeck and R. Helmer prepared the global synopsis and strategy respectively.

Thanks are due to Drs V. Vandeweerd and E. Ongley for constructive comments on the report.

The UNEP/WHO/UNESCO/WMO Global Freshwater Quality Monitoring Programme (GEMS/WATER) provided the framework for this activity. The report was edited by J. Jackson and typeset by I. Stewart at the GEMS Monitoring and Assessment Research Centre (MARC) at King's College London, University of London.

1

Introduction

Fresh water is a finite resource, essential for agriculture, industry and for human existence itself. Without fresh water of adequate quantity and quality, sustainable development is not possible. Water pollution and wasteful use of fresh water threaten socio-economic development and make costly water treatment essential to satisfy increasing needs for drinking water. Human impacts on the environment have increased dramatically during past decades and they continue to grow in natural ecosystems, freshwater and marine environments and the atmosphere. Socio-economic development – including urbanization, industrial production, agricultural activities and their associated pollution – has reached a level where water quality becomes a limiting factor for further development in many river basins.

1.1 Global Problems

Water quality is a term which expresses the suitability of water to sustain various uses or processes. These uses may be human or ecological – any particular use will have certain requirements for the physical or chemical characteristics of water; for example, limits on the concentrations of toxic substances for drinking-water use or restrictions on temperature and pH ranges for water supporting invertebrate communities. Water quality is therefore defined by a range of variables which limit water use; many uses have some common requirements for certain quality variables but each use will have its own demands and its own influences on water quality. Quantity and quality demands of different users will not always be compatible and the activities of one user may restrict the activities of another, either by demanding water of a quality outside the range required by the other user or by lowering quality in the course of using the water. Efforts to improve or maintain a certain water quality often aim at a compromise between the quality and quantity demands of different users. There is an increasing recognition that natural ecosystems have a legitimate place in the consideration of options for water quality management. This is both for their intrinsic value and because ecosystems are sensitive indicators of changes or deterioration in overall water quality, providing a useful addition to physical and chemical information.

Water quality is influenced by a wide range of natural and human processes. It is important to recognize the mutual influence of quantity and quality in assessing the availability of water of suitable quality. Natural problems are of most significance when the quantity of water is limited and the greatest use must be made of a scarce resource. High salinity is a widespread problem in arid areas – where money is available, desalination can take place but in many countries saline water cannot be used. In this case, suitable quantities of water may be available but are of unsuitable quality, imposing restrictions on human activity. Naturally occurring water quality problems are not of concern for ecosystems but human attempts to treat natural conditions may be disruptive.

Human influence on water quality is widespread, attributable to various activities and uneven in the degree to which it causes ecosystem disruption or restricts use. A problem such as faecal pollution is attributable to one source – human populations – but the reasons for occurrence, combative measures and water quality problems are varied. Faecal pollution may occur because of a complete lack of waste disposal facilities or because of inadequate or underfunded collection and treatment facilities. The effects of faecal pollution vary – in developing countries, disease is the primary problem, while in developed countries, organic load and eutrophication are of greater concern, both in the rivers into which sewage or effluent is discharged and in the sea into which the rivers flow or sewage sludge is dumped. A single source may therefore contribute to a number of water quality problems, just as each problem may have a variety of contributing factors. Eutrophication arises not only from faecal pollution and high organic loads but from agricultural fertilizers and livestock. The control of pollution from diffuse sources is especially difficult – among others, this is true of faecal pollution, heavy metals and pesticides.

There is now a fundamental need for scientific assessments of water quality on a world-wide basis. Such assessments must raise awareness of the magnitude of the problems and emphasize the urgent need for action, in addition to establishing a rational basis for

Mar del Plata Action Plan on Water Quality

The United Nations Water Conference was held in Mar del Plata, Argentina, in March 1977. The meeting was convened upon the principle that the accelerated development and orderly management of water resources are prerequisites in improving the economic and social conditions of humanity, especially in developing countries. The recommendations of the conference, known as the Mar del Plata Action Plan, addressed the following: assessment of water resources; water use and efficiency; environment, health and pollution control; policy, planning and management; natural hazards; public information, education, training and research; regional and international co-operation. Assessment of water resources included quality aspects as follows:

> *"To improve the management of water resources, greater knowledge about their quantity and quality is needed. Regular and systematic collection of hydrometeorological, hydrological and hydrogeological data needs to be promoted and be accompanied by a system for processing quantitative and qualitative information for various types of water bodies ... Mechanisms for data collection, processing and publication and arrangement for monitoring water quality should be reinforced."*

The conference was also concerned that large-scale water development projects have important environmental repercussions of a physical, chemical, biological, social and economic nature. It was concluded, therefore, that environmental health should be integrated into water resources development as follows:

> *"It is necessary to evaluate the consequences which the various uses of water have on the environment, to support measures aimed at controlling water-related diseases, and to protect ecosystems."*

Water pollution from sewage and industrial effluents and the use of chemical fertilizers and pesticides in agriculture were recognized as major water quality issues. The conference concluded therefore that:

> *"Concerted and planned action is necessary to avoid and combat the effects of pollution in order to protect and improve where necessary the quality of water resources."*

To this end, a series of measures were recommended:

- conduct surveys of levels of pollution in surface and ground waters;
- harmonize methods for assessing and monitoring water quality;
- establish quality standards for the various uses of water;
- regulate the discharge of industrial, urban and mining wastes;
- adopt in general the Polluter Pays Principle;
- use of substances which minimize environmental health hazards; and
- gradually eliminate the discharge of hazardous waste substances.

water pollution control. As early as the United Nations (UN) Conference on the Human Environment in Stockholm in 1972, and later at the UN Water Conference in Mar del Plata in 1977, the member states of the UN system recommended a variety of measures. Proposals for action ranged from control of disease vectors associated with irrigation and restrictions in the use of agrochemicals, to the monitoring and control of sewage and industrial effluents. The years of the United Nations International Drinking Water Supply and Sanitation Decade (IDWSSD or "The Water Decade", running from 1981 until 1990) were marked by a general deterioration in quality of vital water resources, particularly those of developing countries. Action programmes on water quality began to emerge during the latter part of the decade and these are described below.

1.2 Water Quality and the United Nations

The UN Water Conference in 1977 was the first meeting on water to involve policy making at the highest levels. The Action Plan agreed at the Conference was approved and its implementation recommended by all member states of the United Nations.

The Administrative Committee on Co-ordination – Intersecretariat Group on Water Resources (ACC-ISGWR) was set up to monitor implementation of the Mar del Plata Action Plan. At its 8th Session in 1987, it was agreed that further efforts should be made to develop a comprehensive strategy for action at national, regional and global levels for the implementation of the Action Plan in the 1990s.

Following the 10th Session of the Committee on Natural Resources (CNR), the Economic and Social Council (ECOSOC), through Resolution 1987/7, agreed with this view and requested the Secretary-General to undertake the following:

> *"In consultation with the Regional Commissions and Organizations of the United Nations Systems, to report to the committee on Natural Resources at its 11th Session on progress in formulating proposals for a comprehensive strategy to implement the Mar del Plata Action Plan during the decade 1991–2000, and to include an assessment of these proposals as they relate to the action of the United Nations System."*

International organizations and other support agencies were requested to give active assistance to developing countries in coping with problems caused by water pollution.

It was therefore decided at the 9th Session of the ACC Intersecretariat Group on Water Resources in October 1988 that a meeting of a Panel of Experts be convened to advise on the design of a strategy for the implementation of the Mar del Plata Action Plan in the 1990s. This meeting was held at Challes-les-Eaux, France, in March 1989 and the group endorsed the proposal to carry out detailed assessments (on a regional scale) of progress and problems in the implementation of the Mar del Plata plan. The recommendations of the expert group were reported to the 11th Session of CNR and to ECOSOC, which in Resolution 1989/7 reiterated the need for a strategy for the 1990s, and requested that the strategy be submitted to CNR at its 12th Session in 1991.

Following these developments, regional assessments of the progress made in implementing the Mar del Plata Action Plan since 1977 were carried out. These assessments looked specifically at five aspects:

- water resources assessment;
- water for sustainable agricultural development;
- water quality issues;
- water resources management; and
- human resources development.

The regional assessments in the third category provided the basis for identifying the main elements of the Global Strategy for Water Quality Management presented in this document.

In May 1989, the Committee on Development Planning (CDP) stressed the importance of water in sustainable development and requested concerted action by the United Nations organizations. Problems of water scarcity resulting from poor co-ordination and planning in land and water development were emphasized, together with water quality degradation due to agricultural, industrial and municipal water pollution. CDP recommended that the UN Conference on Environment and Development scheduled for June 1992 should include in its agenda a separate item on sustainable development of the use of water resources, and take into account the strategy for the implementation of the Mar del Plata Action Plan in the 1990s to be formulated by CNR.

1.3 Global Strategy Development

In response to a resolution of the Stockholm Conference, four UN agencies (United Nations Environment Programme (UNEP), World Health Organization (WHO), United Nations Educational, Scientific and Cultural Organization (UNESCO) and the World Meteorological Organization (WMO)) jointly launched the first global programme to monitor surface- and ground-water quality, which was named GEMS/WATER. Since 1979 water pollution has been monitored and long-term trends examined, with developing countries having taken part actively in practical implementation. The data accumulated were used in the production of a first assessment of water pollution issues on a global scale (*Global Freshwater Quality: A First Assessment*, published by Basil Blackwell, Oxford, on behalf of WHO and UNEP, 1989).

During the latter years of the Water Decade several regional expert groups studied water quality issues for various parts of the world. Their findings were also used in the regional assessment studies and their recommendations considered for the global strategy. The most important ones are:

- ECLAC (1989). The Water Resources of Latin America and the Caribbean: Water Pollutión. Report prepared by the Economic Commission for Latin America and the Caribbean;
- UN/ECA & DTCD (1989). Interregional Meeting on River and Lake Basin Development, with Em-

phasis on the African Region, Addis Ababa, October 1988;

- IBRD/EDI & WHO/CEHA (1988). Regional Seminar on Water Resources and Water Quality Management, Amman, May/June 1988;
- UN/ECE (1989). Water Use and Water Pollution Control: Trends, Policies, Prospects. Report prepared by the Economic Commission for Europe; and
- ESCAP (1989). Seminar on Water Quality Monitoring in the Asia and Pacific Region, Beijing, September 1989.

At the global level, a group of technical specialists was gathered in Poland by the United Nations Department of Technical Co-operation and Development (UN/DTCD) in September 1989 to draw up recommendations on water quality issues. They prepared the *Warsaw ('89) Guidelines for Water Quality Management in*

Events leading from the Mar del Plata Action Plan to the Global Water Quality Strategy

March 1977

Adoption of the Mar del Plata Action Plan by the UN Water Conference.

January 1981

Beginning of the UN International Drinking Water Supply and Sanitation Decade (The Water Decade).

January 1987

Interregional seminar convened on 10th anniversary of the UN Water Conference, which included a detailed review of the progress made in implementing the Mar del Plata Action Plan.

May 1987

ECOSOC, agreeing with the ACC-ISGWR recommendation for a comprehensive strategy for implementing the Mar del Plata Action Plan in the 1990s, requested the Secretary General to report to the 11th Session of the CNR on the measures necessary for such a strategy.

March 1989

ACC-ISGWR convened a Panel of Experts which formulated a strategy covering water resources assessment, sustainable agricultural development, mobilization of financial resources, human resources development, institutional strengthening and promotion of appropriate technology. The panel recommended that regional assessments of progress achieved in the implementation of the Mar del Plata Action Plan be undertaken to determine the main issues for action in the 1990s.

February–May 1990

Regional consultant missions to evaluate current water quality problems and to identify necessary actions were carried out through a UNDP-funded project, executed jointly by UN/DTCD and WHO.

June 1990

Regional consultant meeting convened by WHO at GEMS MARC in London to finalize the regional assessments and to prepare a global strategy on water quality issues for the 1990s.

August 1990

UNEP/WHO expert consultation in Leningrad on global freshwater quality monitoring and assessment reviewed the global strategy document.

October 1990

Final draft of the global strategy on water quality issues for the 1990s submitted to the ACC-ISGWR at its 11th session in Geneva.

Developing Countries, covering technical actions required, economic considerations and institutional and legal aspects.

As part of the assessment of progress of the Mar del Plata Action Plan, a joint project funded by the United Nations Development Programme (UNDP) and executed by the UN/DTCD and WHO was launched in late 1989 to assess regional water quality issues. The objectives of this study were:

- to assess freshwater quality on a region-by-region basis, identifying gaps in knowledge and needs for future monitoring and assessment;
- to prepare regional summaries of key water quality issues, their present status and their likely future development; and
- to make recommendations for coping with water quality degradation and pollution in support of sustainable development.

As part of the project, regional experts were each assigned one of the UN Regions. The experts each prepared a comprehensive report covering the regional situation and giving region-specific proposals for action. The short time available for these assignments meant that the studies were largely based upon the exploitation of existing data bases and information sources at regional and international centres. The UN Economic Commissions, WHO Regional Offices and other regional organizations were consulted in this respect. Additional support was provided through GEMS/WATER project offices.

The regional reports were then harmonized and summarized at a meeting of the regional consultants (London, June 1990). At this meeting, a global synthesis of important water quality issues and a global strategy for water quality management were also prepared.

The consultants' findings and recommended actions were then circulated for comment to experts convened to discuss the monitoring and assessment of water pollution within a global framework (Leningrad, August 1990). This GEMS/WATER review meeting on global water quality issues not only dealt with the assessment of water pollution problems but was also invited to consider resulting policy options for water quality management.

This report is structured in accordance with the above objectives of the UN/WHO assessment study. The introduction and an overview of the issues are followed by a series of self-contained regional chapters each summarizing the current situation and making concrete proposals for specific action required. Regions for this purpose were defined as the groups of member states of the respective UN economic commissions. North America was treated as a part of the American continent (although Canada and the USA are members of the Economic Commission for Europe).

A global synopsis of water quality issues follows, joining the regional reports together to give a comprehensive world-wide view. The last chapter presents a global strategy for the 1990s which aims to control water pollution problems and to protect aquatic ecosystems, particularly those in developing countries.

2

Africa

Africa is a continent where water availability is highly variable – rainfall ranges from less than 100 mm a^{-1} in some areas to more than 2,000 mm a^{-1} in others. Economic development, population density and water use are very heterogeneous. In combination with human factors, the natural conditions of climate and geology greatly influence water quality. For these reasons, water quality problems vary markedly from one part of the continent to another. In this report we have divided Africa into six sub-regions for which common major issues could be identified. However, this assessment is limited by the lack of available data because Africa as a whole has the lowest level of water quality monitoring. The six sub-regions are: the Maghreb, the Sahel, the Nile Basin, the Zaire Basin, the Gulf of Guinea, and East Africa. In addition, a special section on the African Great Lakes is presented.

2.1 Present Situation and Major Issues

Surface waters are relatively abundant in the Gulf of Guinea and the Zaire Basin. In most other African regions perennial rivers are found primarily in the highlands (e.g., the Maghreb, Ethiopia, and the Rift Valley). Close to the equator (e.g., Oubangui and Kasai rivers) the seasonal water discharge is evenly distributed, whereas in the tropics, the rivers are subject to large seasonal discharge variations and may be completely dry in the Sahel and in Southern Africa at certain times. Certain regions are also subject to large annual variations in rainfall. Africa has only one of the 10 largest rivers in the world in terms of discharge – the Zaire river (second only to the Amazon). On a global scale the Zambezi, Niger and Nile are of medium size and other rivers are mostly of regional importance – Senegal, Bandama, Volta, Ogooue Ruzizi (see Table 2.1). Africa has some of the world's biggest freshwater lakes, for example Tanganyika, Malawi and Victoria – the area of Lake Victoria is the second largest in the world, after Lake Superior (see Table 2.2).

In about two-thirds of the populated part of the continent the major source of water is ground water. Seven main types of aquifers can be identified:

1. Local sedimentary aquifers in folded areas such as in the Mitidja plain (Algeria); restricted to the Maghreb;
2. Coastal sedimentary aquifers in Senegambia, the Gulf of Guinea, Congo, Somalia and Mozambique;
3. Large sedimentary aquifers in Niger, Mali, Chad, the Zaire Basin, the Kalahari and Southern Africa (Karroo);
4. Precambrian crystalline aquifers, usually patchy and surficial in most parts of the old African shield;
5. Ethiopian and Rift Valley volcanic aquifers;
6. East African limestone aquifers in Somalia;
7. In the Sahara the Nubian sandstone and "continental intercalaire" aquifers are important water sources (although not renewable – they are not recharged by rainfall or surface water and the age of water is therefore 20,000 years) where water is found at depths ranging from 50 to 500 m.

   The type of aquifer may have significant implications for water quality – exposed and fractured aquifers will be more easily and more rapidly contaminated by various pollutants such as human faecal waste or agricultural fertilizers.

2.1.1 The Maghreb

In the mountain ranges (Atlas, Kabylie) the major water resources are surface waters, while along the coastline, where most big cities are located (Algiers, Casablanca), most of the water is withdrawn from aquifers. Numerous reservoirs have been built in the last 20 years, particularly in Morocco.

Water quality monitoring started recently in the Maghreb on rivers, reservoirs and ground waters. At the present time Tunisia, Morocco and Algeria have regular surveys of ground waters, Morocco has intensive reservoir eutrophication studies and Algeria a network for surface-water quality monitoring. However, the information on water quality problems is scanty, consisting mainly of data for total suspended solids, major ions and nitrates. Information on heavy metals, micro-organic pollutants and, in some cases, bacterial pollution is lacking. Usually the analytical facilities for these pollutants are available but underused.

Natural water quality problems in the Maghreb sub-

Table 2.1 Estimated per caput river flow in selected African river basins

River	Drainage area (10^3 km^2)	Mean annual flow ($m^3 s^{-1}$)	Population (10^6)		Per caput river flow ($m^3 a^{-1}$)	
			1970	2000	1970	2000
AFRICA	30,300	136,000	350.0	770.0	12,000	5,500
Congo	4,015	40,000	18.0	41.2	69,000	30,000
Niger	1,114	6,100	16.7	40.9	11,200	4,600
Nile	2,980	2,800	50.0	106.0	1,720	810
Orange	640	350	4.7	10.9	2,300	990
Senegal	338	700	2.4	5.0	9,100	4,500
Zambezi	1,295	7,000	5.6	12.0	38,700	18,000

Source: Szestay, K. 1982 *Wat. Qual. Bull.* 7, 155–162.

region are; high salt content of non-perennial rivers (up to 5 g l^{-1} in some Tunisian oueds); high Total Suspended Solids in rivers during the winter rainy season (up to 50 g l^{-1} – erosion rates exceed 1,000 t km^{-2} a^{-1}, leading to very fast reservoir siltation); and high fluoride content in some Moroccan ground waters.

The main water quality issues associated with human activities are a lack of proper municipal and faecal waste treatment (as a result rivers have high organic pollution) and ground-water nitrate pollution from fertilizers used in major agricultural developments (e.g., in Morocco or in the Mitidja Plain south of Algiers). In the Mitidja surficial aquifer, 35 per cent of examined wells exceeded the 50 mg l^{-1} standard for nitrates. Although pesticides are not monitored, they are likely to occur in various places. Two examples of pollution from Algeria are probably representative of the Maghreb situation – out of 38 surface-water quality stations for the whole country in 1987, only 16 could be considered as acceptable or fairly good and seven were poor.

In the Sahara Desert, the major water resources are found in the combined Nubian sandstone and Continental Intercalaire aquifers which extend from Egypt to Mauritania. Their water quality is generally fairly good, although local pollution from intensive agriculture in oases is likely. Since these aquifers are not renewable, great care must be taken in their use. When ground waters in karstic limestone aquifers are the major water resources, contamination is more direct and rapid (in the Saida region, Algeria, 22 wells out of 27 had faecal contamination).

Ore and mining activities also present major permanent or potential sources of water pollution; for example, cadmium-rich waters released from phosphate mines (as happened in the Mitidja Plain) or pipe-line breaks.

Eutrophication of reservoirs, particularly in Morocco where seven major dams have been built, causes severe problems for drinking-water quality which require treatment (tainting and discolouration of water, oxygen depletion and consequent formation or release of toxic substances from sediment).

2.1.2 The African Great Lakes

There are three lakes of global significance (in terms of volume, area, and fishery resources) found in Africa: Tanganyika, Malawi and Victoria, all of which lie across international boundaries (see Table 2.2 where the North American Lake Superior and Siberian Lake Baikal are included for comparison).

Lakes Tanganyika and Malawi (ex-Nyassa) are quite similar in size and depth to Lake Baikal. They have a comparable geological origin (rift valleys) and age (more than 2 million years for Tanganyika and Malawi). The biological evolution of these three lakes is parallel and has culminated in an exceptionally high proportion of endemic species; unique crabs, jelly-fish, sponges, and aquatic snails and snakes are found in Lake Tanganyika, as well as more than 100 species of fish, mostly from the cichlid family.

Although numerous studies have been carried out on the African Great Lakes, none of these lakes is regularly monitored for water quality owing to a lack of sampling equipment (there is a need for large research vessels such as those which exist for the monitoring of Lake Baikal), a lack of laboratory facilities (small laboratories exist in Kampala, Uganda within the World Meteorological Office Hydromet project and in Uvima, Zaire), and to general lack of political agreement about the use of the Great Lakes amongst the riparian countries.

High water residence time (more than 100 years) and the present economic development of their basins mean that Lake Tanganyika and Lake Malawi are unlikely to be polluted at the present time or in the near future unless a catastrophic event should occur. Such an event cannot be ruled out because there is now intense oil exploration being carried out around the two lakes and significant resources are being found. It is not known if appropriate environmental impact assessments and contingency measures in case of accident have been considered.

Lake Victoria lies within Tanzania, Uganda and Kenya and is much more sensitive to pollution due to its relatively short water residence time (23 years). Evidence of pesticide contamination has been found in some fish and there have been reported decreases in the dissolved oxygen in bottom waters of some sheltered bays. These decreases may be a result of increasing algal production associated with increased nutrient inputs, but complete biological studies are still lacking. Lake Victoria's catchment has some of the highest population densities in Africa and sewage treatment is largely insufficient.

All three lakes provide essential fish protein for the surrounding populations and, if properly fished with modern techniques, could be the main source for the whole region from Uganda to Zambia. The total potential fish catch of these three lakes exceeds 300,000 t a^{-1}. Together with Baikal and the Laurentian Great Lakes, the African Great Lakes represent 30 per cent of the total freshwater volume of the planet (glaciers excepted) and are still of very good quality. It is important that they are immediately recognized as highly valuable water bodies of global significance and are monitored and managed in a similar way to the other major lakes.

2.1.3 East African Countries

Water resources and use

The estimated total surface run-off from rainfall in Malawi is 18.5×10^9 m^3 a^{-1}. The volume of water nominally available from the lake represents about 70 per cent of the country's total surface-water resources. The remaining resources are the drainage basin around Lake Chilwa and the Shire River and its tributaries. River flow rates, especially in smaller tributaries, are seasonally variable. The Kamazu barrage on the Shire is used to compensate for variable flow.

The best aquifers in Malawi are geological formations of sand and gravel deposited over time by rivers and lakes (yields range from 0.5 to 5 l s^{-1}). The basement complex of rocks contains an extensive aquifer within a thick mantle of weathered and fractured rock (yields range from 0.5 to 1.5 l s^{-1}).

The current consumption of water in Malawi by irrigation (1×10^9 m^3) and water supply (86×10^6 m^3), is

Table 2.2 African lakes of global significance

Lake	Volume km^3	World rank in terms of volume	Area km^2	Maximum depth m	Water renewal time years	Biological value[(a)]	Fisheries resources[(b)]
Tanganyika	17,827	2	32,000	1,471	500	+++	50
Malawi	8,400	4	6,400	706	150	+	50
Victoria	2,750	7	68,800	84	23	+	200
Baikal[(c)]	22,995	1	31,500	1,741	350	+++	
Superior[(c)]	12,221	3	82,367	406	191		

(a) +++ unique proportion of endemic species.
++ exceptional proportion of endemic species.
+ important proportion of endemic species.
(b) Potential fish catch in 1,000 t per year.
(c) Included for comparison.

The total volume of the African Great Lakes constitutes 29.4 per cent of the total world volume of freshwater lakes.

The Caspian Sea is not taken into account here.

small compared with the total resources. Ground water is used largely for domestic water supply purposes. Of the estimated total ground-water abstraction in 1985 of 17.3×10^6 m^3, some 1.3×10^6 m^3 (or 7.5 per cent) were used in urban areas. Surface water is used primarily for irrigation. Water is supplied to 70 per cent of the urban and 36 per cent of the rural population. Only 10 per cent of Malawi's urban population is served by piped sewerage systems; 70 per cent of the urban population and 20 per cent of the rural population are served by pit latrines or septic tanks of variable efficiency.

Kenya's water resources are divided into five catchment areas: the Lake Victoria basin, the Rift Valley basin, the Athi River basin, the Tana River and the Ewaso Ngino basin. The total annual mean surface run-off is 14.8×10^9 m^3. River flows tend to be highly variable, with low or no flow at certain times of year, alternating with high flow periods with high erosion. Large areas of Kenya are arid or semi-arid.

Ground-water abstraction is estimated to be 17 to 36×10^6 m^3 a^{-1}. Total water use in Kenya (1985–1987) is about 600×10^6 m^3 a^{-1} which is projected to rise to 2.5×10^9 m^3 a^{-1} by the year 2000. The estimated sectoral use for 1985–1987 was 18 per cent domestic, 69 per cent agricultural and 13 per cent industrial. Water is supplied to 15 per cent of the rural and 85 per cent of the urban population and sanitation is available to 19 per cent of the rural and 89 per cent of the urban population.

Tanzania has five hydrographic networks: the Indian Ocean network, the endorheic (i.e., no water outflow from the drainage basin) basins of Lake Eyasi and Bahi depression, the Lake Rukwa basin, the upper basin of the Nile in Tanzania and the interior basin (Lake Tanganyika and Malagarasi River). The total annual surface run-off is 74×10^9 m^3. Most of the smaller watercourses in the centre and north of the country are dry for part of the year.

Close to river valleys or other zones of unconsolidated geological deposits, ground water is exploited by shallow wells. In the sedimentary and pre-cambrian formations, ground water is exploited by boreholes. A quarter of Tanzania's population depends upon ground water, a proportion which is likely to increase in future years.

Ethiopia has 14 river basins with an annual flow of 105×10^9 m^3, of which 101.5×10^9 m^3 flows out of the country, 78.7×10^9 m^3 to Sudan (77.5 per cent), 16.1×10^9 m^3 to Kenya (15.9 per cent), 6.5×10^9 m^3 to Somalia (6.4 per cent) and the remainder (0.2 per cent) to the Red Sea. Many of the rivers have a very irregular seasonal flow. Ethiopia has a large number of lakes, some of which are saline.

Ground water is the main supply for domestic and industrial purposes in 67 urban centres. Elsewhere it is used as a supplementary source.

Water quality monitoring

Malawi has no routine water quality monitoring at the present time, although localized monitoring took place during the late 1970s. In Kenya, all water quality monitoring has been decentralized to six regions under the authority of the Ministry of Water Development. The Central Water Laboratory in Tanzania is responsible for running zonal and regional water laboratories and the supervision of various water quality programmes in the country. A general lack of resources and manpower makes the implementation of the water monitoring programmes difficult.

Sub-regional water quality issues

Ground water with high fluoride content has long been known in East Africa. High fluoride can lead to skeletal and dental problems. In Kenya, 61 per cent of boreholes had a fluoride concentration above 1 mg l^{-1} and almost 20 per cent were above 5 mg l^{-1}. The northern part of Tanzania has high fluoride concentrations in surface as well as ground waters and in Malawi, fluoride content (2–10 mg l^{-1}) in the ground water of alluvial zones is high enough to constitute a health hazard.

Faecal contamination of surface waters and of shallow wells and boreholes is a serious problem over much of the region, the cause being the lack of sewage disposal facilities and inadequate protection of water sources from contamination.

Some water bodies receive high loads of organic matter from domestic and industrial wastes. For example, in Tanzania, the sisal factory in Tanga region is polluting major water resources, such as the Pangani River. In Kenya, the waste water from wet processing of coffee is characterized by high biochemical oxygen demand (BOD) (5,000–9,000 mg l^{-1}). The discharge of waste water from coffee factories caused an increase in BOD of water courses to more than 100 mg l^{-1} which has resulted in fish mortality.

Salinity is a major problem for some ground-water sources. For example, in Kenya, one borehole in seven yields undrinkable water in the eastern part of the country. This is due to low rainfall, low recharge of aquifers and high evaporation rates which together result in increased salinity of ground waters. In Tanzania, there is a saline coastal belt of aquifers extending from Tanga to Dar es Salaam, Lindi and Mtwara. In Ethiopia, saline deposits formed by evaporation of surface water in regularly flooded plains have made the water of the alluvial aquifers brackish in some parts of the low plains and the Rift Valley. In some cases, water from saline aquifers has contaminated the fresh water of other aquifers.

High nitrate concentrations are found in ground water in some areas. In Tanzania, for example, the most severely affected areas are in Singida region where as many as 15 per cent of the samples have NO_3-N concentrations above 22.7 mg l^{-1}.

In non-perennial water courses over much of East Africa, the turbidity from suspended sediment increases dramatically following a period of heavy rainfall, leading to poor drinking-water quality.

There is high heavy metal content in some surface and ground waters. In Malawi, iron content in ground water is above the guideline value of 0.3 mg l^{-1} set by the World Health Organization (WHO). Unfortunately, the resulting bitter taste and coloration can prompt people to use water which is more agreeable to the taste and eye but more harmful for health because of faecal contamination or other factors. In Tanzania, high concentrations of iron and manganese are major problems in Rukwa and Mtwara regions. On average, 23 per cent of all samples analysed from 1970 to 1978 in Tanzania had iron concentrations higher than 2.1 mg l^{-1} while 13 per cent had above 4.1 mg l^{-1}.

Pesticides are widely used in East Africa. The annual amount of pesticides used in Kenya (between 1979 and 1983) was 5,728 t. It should be noted that DDT is widely used. No data for pesticide contamination is available owing to the lack of monitoring capabilities.

2.1.4 The Nile Basin

Water resources and use

The Nile system is the major source of water in Egypt and Sudan. The Nile Basin is also important in recharging underground water sources. The average annual natural flow of the Nile, estimated at Aswan, is about 84 km^3 a^{-1} of which 55.5 km^3 and 20.35 km^3 are available to Egypt and Sudan respectively. In Sudan, outside the Nile system, surface-water sources are highly seasonal. Such resources provide water during the wet season (three to four months in summer). The Aswan High Dam (AHD) reservoir's operating volume is 157 km^3, of which 30 km^3 is dead volume (i.e., not available for use), 90 km^3 is live storage capacity volume and 37 km^3 is reserved for flood waters.

The main aquifers in Egypt are the Nubian sandstone and the alluvial aquifers (river-deposited) in the Nile Valley and Delta, and in Sudan the Nubian sandstone, the Um Ruwaba and Geziera formations, alluvial deposits and basement complex.

Data for the balance of water supply and demand for the Nile show that Egypt and Sudan have surplus capacities of 2.6 and 4.18 x 10^9 m^3 a^{-1} respectively. However, a deficit for both countries will develop by the year 2000 if the aims of the existing water management plan are not attained.

In Egypt, the annual demands for water by municipal and industrial sectors are 4 x 10^9 m^3 and 3.4 x 10^9 m^3 respectively. In Sudan, the water consumption for domestic supply is about 240 x 10^6 m^3 a^{-1}. Total ground-water abstraction in Egypt for the year 1984 was about 2.46 x 10^9 m^3 and it is projected that a total withdrawal of up to 4.9 x 10^9 m^3 a^{-1} would be available by 1992 from the Nile Valley and Delta aquifers and up to 1 x 10^9 m^3 a^{-1} from the Nubian Sandstone in the Western Desert. Twenty-five per cent of the total water supply in Egypt is derived from ground water (in Cairo and Helwan, 30 per cent of the total). In Sudan, ground water is used for water supply, industry, irrigation and desertification control. Almost 75 per cent of the population and 80 per cent of the livestock rely on ground water.

Water quality monitoring

In Egypt, the AHD Side-Effect Research Institute and the Environmental and Occupational Health Centre are responsible for Nile water quality monitoring. The Research Institute for Ground Water is responsible for ground-water monitoring.

No records of water quality for Sudan were found at any state organization and it is understood that no monitoring of water quality is routinely conducted.

Water quality issues in the Nile Basin

The construction of the old Aswan Dam, AHD and major Nile barrages has led to greater control of flow and water levels in the river. As a consequence, the ability of the river to flush its bed of sediment and associated pollutants at periods of high flow has fallen significantly. The control of flow by the dams has had a particular influence on the delta. The water quality of the Nile above the reservoir in Sudan is fairly good, as is that of the river from Aswan to Cairo. The Delta is characterized by stagnant water, low flow, low dilution and assimilation of wastes, production of macrophytes and high growth of algae, high levels of nutrients and high organic matter loads.

The present water quality of the river in the irrigation network continues to be within acceptable limits, except for a few locations. However, deterioration of water quality between 1975 and 1985 is evident from the results of Nile monitoring in Egypt.

In Egypt, only a small fraction of municipal sewage is treated and high faecal contamination affects both the Nile and, to a greater extent, the waters of the Delta.

The BOD values as a result of organic matter in the waters of the Nile Delta and Nile Valley in Egypt are high, due to the return of irrigation drainage water from

Table 2.3 Ground-water availability in different geological formations in the Sudan

Formation	Surface area of total country area as %	Ground-water availability	Water quality and suitability for human and animal use
I. Basement Complex	49	Low	Low
II. Nubian Sandstone	28	High	High
III. Umm Ruwaba Formation, Gezira Formation	19	High	High
IV. Other form	4	Low	Low

Source: Whiteman 1971 *Geology of Sudan.*

upper Egypt to the Nile, discharge of industrial and municipal effluents and the re-use of drainage water in the Delta. The drainage water contains hazardous chemicals, fertilizers and industrial and domestic waste waters with hazardous implications for downstream drinking-water abstraction points. In Sudan few data are available on organic matter and BOD values in the Nile.

A distinct rise in phytoplankton density associated with eutrophication is a characteristic of the Nile after the construction of the AHD. This is attributed to the low turbidity, the sharp reduction in the flow rate of the Nile downstream of the AHD, and diffuse and point source nutrient pollution which encourages plant growth. There is a serious problem with aquatic macrophytes, especially water hyacinth (*Eichhornia crassipes*), which leads to clogging of irrigation and navigation canals. This eutrophication-related phenomenon is one of the side effects of the AHD and causes difficulties for water treatment and use.

In Sudan, the sudden seasonal changes in the sediment load (in the Blue Nile, the Blue Canal and non-perennial water courses) cause significant problems for water treatment.

There is high natural salt content in ground water in Sinai and the Eastern Desert in Egypt and a local high salt content in some aquifers in Sudan.

Owing to the development of irrigation in the Nile Valley and Delta following the construction of AHD, the water-table has risen by an average of 2 m in upper Egypt and 1.5 m in the Delta. As a consequence of this, the quality of the ground water has been deteriorating because the high water-table leads to soil waterlogging. Evaporation from the waterlogged soils results in an accumulation of salt in soil and ground water. In the Delta, the salinity of ground water varies considerably, ranging from 500–4,000 mg l^{-1} and even higher. West of the Delta, salinity can reach 7,500–16,000 mg l^{-1}. Salt intrusion near the coast could also be another reason for the high salt content of ground water - salt intrusion into the delta has been associated with lower river flow following dam construction and high irrigation. In Sudan, locally high salt content caused by the return of irrigation water is recorded (for example, in the Valley of Khor El Gash).

In Egypt the total amount of nitrate and phosphate fertilizers introduced increased from 0.88 x 10^6 t for 1951–1952 to 6.19 x 10^6 t in 1987–1988. This quantity greatly exceeds the amount of sediment-bound nitrogen and phosphorus lost after the AHD construction which is estimated to be 12,000 t a^{-1} and 6,000 t a^{-1} respectively. In Sudan the ground water in the area of Semeiat has moderate to very high nitrate concentration. In the Ruwaba aquifer nitrates in some samples exceed the permissible concentration (45 mg l^{-1}).

Few data are available on the concentrations of pesticides in the Nile Basin. The only data available for 1985 demonstrate that the concentrations of BHC, Lindane, Endrin and DDT in the Nile Valley and Delta in Egypt are well below the acceptable limits for drinking water, although pesticides are widely used.

A few data are available on the concentration of industrial micro-organic pollutants in the Nile Basin. The concentration of PCBs ranged from 5–59 ng l^{-1} in

1982 at various stations on the Egyptian Nile.

Localized pollution problems from a range of industrial processes (metal processing, fertilizers, pesticides, food processing) occur as a result of low pH, high BOD, high suspended solids and high heavy metal content.

2.1.5 Zaire River Basin

The Zaire river (Congo) is 4,700 km in length with a basin area of 3.8×10^6 km^2 and lies within nine countries (three of them, Congo, Zaire and the Central African Republic, contain 80 per cent of the basin area). The basin lies across the equator and occupies the central part of the African continent. Average annual precipitation for the whole basin is greater than 1,200 mm.

The centre of the Zaire basin consists of a depression (340 to 700 m above sea level). The Basin is bordered to the north by the watershed of the Oubangui river, to the east by the mountain range of the African Rift (2,300-3,800 m above sea level), to the south and south-east by the Kasai and Shaba plateaus (1,000-2,000 m above sea level) and to the west by the Mayumbi hills (800 m above sea level) and the coast. Eighty per cent of the water used by the population comes from surface waters but ground water is becoming more and more important as an alternative because of pollution problems.

Natural water quality is good both for surface and ground waters. The surface waters frequently have low pH and low salt content, originating from ground water. Natural problems arise from organic matter and low pH in the north of Zaire, from highly mineralized water in Kuru Lake (magnesium, manganese) and from suspended soils in the south.

For ground water, saline intrusion (Congo, Atlantic

Figure 2.1 Water supply and sanitation development in Africa

Source: World Health Organization 1988 *Towards the Targets*, WHO/CWS/88.2.

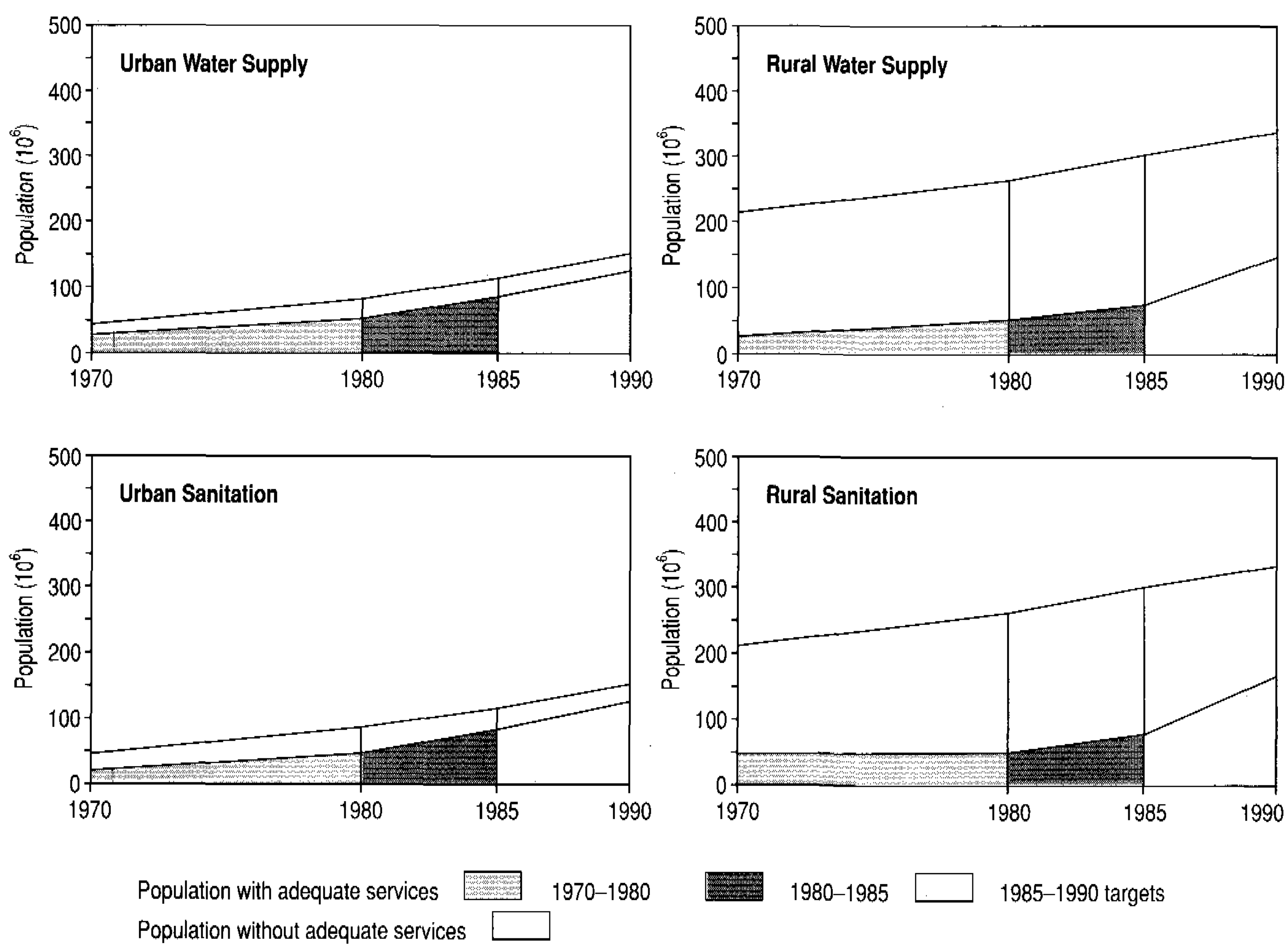
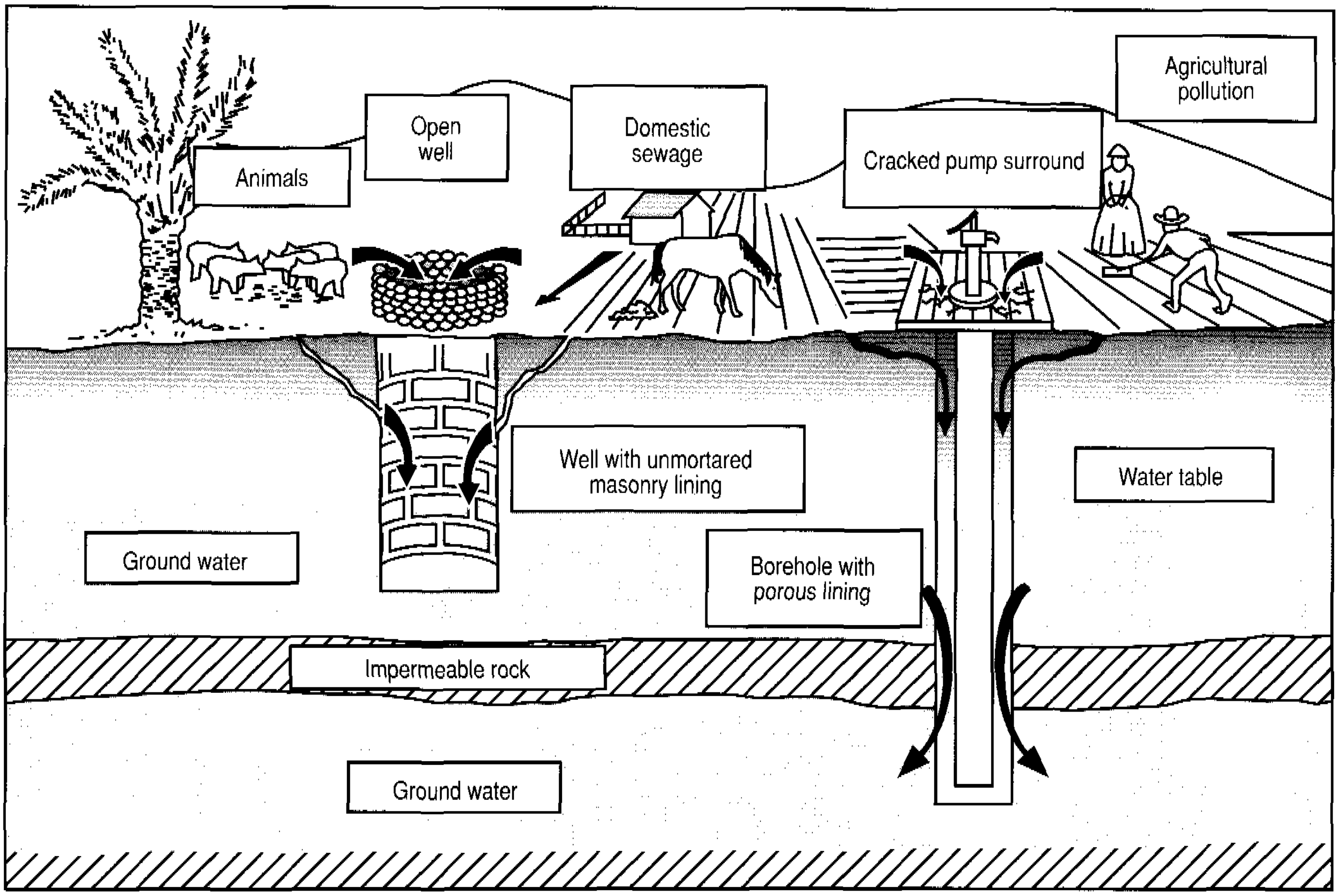


Figure 2.2 Ground-water contamination

Source: WHO/CEPIS 1987 *Ground water: an undervalued resource in need of protection.*



Arrows show routes of contaminants from domestic and agricultural activity to ground water. Wells and boreholes are polluted directly or via infiltration from soil or rock. Protected aquifers can be polluted via boreholes or through fissures in overlying impermeable rocks.

coast) and karstic water flow induced by pumping (Lower Zaire) may bring some problems. Also, high iron content is noted in the Bateke plateau aquifer (Zaire and Congo).

The main water quality problem is faecal pollution, arising from the discharge of untreated rural and urban domestic wastes to rivers, either directly or through open sewers. Almost all domestic waste is disposed of in this way. Sanitation facilities are almost completely absent from both rural and urban areas. It is reported that in 1986, 74 per cent of disease was related to poor sanitation. All shallow wells in Congo and Zaire appear to be faecally contaminated. The absence of proper sanitation is a particularly dangerous problem in Karstic areas in the lower Zaire region. Programmes to combat water-related endemic diseases and epizootics (onchocerciasis, bilharzia, trypanosomiasis) require an increased use of pesticides. Pesticides in turn have potentially adverse health effects, should transfer to humans via water or biota occur.

Approximately 15 per cent of industrial wastes (primarily organic) from textiles and brewing industries are discharged untreated to rivers. Water quality problems are also associated with mining for various ores, especially in Shaba region in Southern Zaire.

The high natural discharge of the Zaire basin means that the large rivers (Oubangui and Zaire) have a high assimilative capacity for wastes which softens the pollution impact of the large cities of Bangui, Brazzaville and Kinshasa. No national monitoring schemes exist and chemical and bacteriological water quality controls are performed only for treated wastes. Research and monitoring of Zaire river water quality has been carried out in Congo by the French overseas research organization (ORSTOM) but national laboratory facilities and programmes are not yet available, nor is the legislation which is necessary for establishing water quality control.

2.1.6 Gulf of Guinea

This region contains the countries bordering the Gulf of Guinea (between about 4°N to 10°N). These are Guinea, Sierra Leone, Liberia, Côte d'Ivoire, Ghana, Togo, Benin, Nigeria and Cameroon. Average temperatures in this region range between 24°C in the north to 30°C in the south and annual precipitation ranges between 1,000 mm in the north to 2,000 mm in the south (with peaks of up to 10,000 mm).

The total population is about 150 million in an area of 2.5×10^6 km^2 (Nigeria has a population of 90 million in 924,000 km^2). A steadily increasing proportion of the population live in urban areas (at present 30 per cent).

In 1985, 80–100 per cent of the urban population and 30–40 per cent of the rural population were supplied with drinking water. Sanitation services were available to 30–60 per cent of the urban population and to 10–20 per cent of the rural population. Until now, water resources have been sufficient to meet demands, but in future demand may exceed resources in some countries, such as Benin and Togo.

In geological terms, most of the countries have two rock types; crystalline or metamorphic rocks in the north and sedimentary rocks in the south down to the coast. A saline wedge is present in aquifers along the coast, in fragile equilibrium with fresh ground water.

In this region, surface water is the main source of water but ground water is an important source during the dry season, even in a country such as Liberia (2,000–5,000 mm annual precipitation). Ground water will be of increasing importance in the future as sectoral demands from domestic or agricultural sectors increase.

The countries in the region may be divided into two groups on the basis of monitoring, assessment and pollution control, a division which reflects the greater economic and industrial development of certain areas. Côte d'Ivoire, Nigeria, Cameroon and, to a lesser extent, Ghana are relatively more developed than Togo, Benin, Guinea and Liberia. Routine monitoring only takes place for chemical and bacteriological quality control of treated drinking water.

The major water quality issue is the quality of surface waters, which are especially vulnerable during the dry season. Few data are available but an outline assessment of existing pollution problems and future trends can be made. The main problems are:

- faecal pollution;
- eutrophication related to domestic wastes and industrial organic wastes;
- industrial inorganic waste discharges; and
- salinization of ground waters caused by excessive abstraction.

These problems are most pronounced in the more developed countries listed above, especially with respect to industrial pollution, from which the less developed countries are partially spared.

The absence of sanitation and sewerage means that domestic wastes are scattered in the fields, leading to faecal pollution of surface waters and of aquifers (especially on crystalline and metamorphic rocks where fractures in the rocks allow infiltration of contaminated water to aquifers). Twenty to thirty per cent of wells in Côte d'Ivoire have been contaminated in this way. The effluents from Abidjan are discharged directly into the Ebrié lagoon where up to 50,000 faecal coliforms/100 ml have been measured. The same situation is found in the lagoon at Lagos in Nigeria. High incidences of diarrhoea and gastroenteritis are associated with contaminated wells such as those along the Kaduma River in Nigeria. Disease will also be spread through the use of irrigation water from ponds which receive wastes – consumption of market garden produce can be a means of contracting dysentery. The problem of faecal contamination of water supplies is worst during the wet season, especially at the beginning when the open sewers are flushed.

Eutrophication arises sometimes from the discharge of domestic wastes from areas of high population density, but more usually from industrial organic waste discharges such as those from breweries and fruit juice processing (Maraone in the Côte d'Ivoire and Nokove Lake in Benin), canneries, palm oil and sugar processing (Côte d'Ivoire), wood processing (Nigeria) and cocoa and coffee (Côte d'Ivoire, Ghana and Togo). Rivers act as sewers in many areas.

Industrial effluents containing non-biodegradable substances arise from a variety of sources: petrochemical (Lagos), ore mining and metal refining (Ghana) which can contain a wide range of metals (copper, cadmium, arsenic, mercury, manganese, lead, iron, zinc) and, in almost all areas, textile industries. Agricultural pollution is associated with fertilizers in restricted areas (high price prevents widespread use), leading to nitrate levels of up to 200 mg l^{-1} NO_3. Deforestation and domestic pollution are major contributors to high nitrate levels. Pesticides are used primarily in plantation agriculture (pineapple, cocoa and coffee) and in disease control programmes.

Saline intrusion into aquifers is a potential problem all along the Gulf of Guinea coast and can only be controlled by careful regulation of ground-water abstraction.

Existing surface-water and ground-water supplies are threatened by faecal contamination and uncoordinated industrial development which are not matched by progress in sanitation and treatment. In conclusion, there is a general need in the area to balance demand with quality and supply through rational use of existing resources. This may mean reliance upon different sources in different seasons (Togo, Benin) or the investigation and use of deeper aquifers. Protection zones for ground and surface waters, including lagoons, are needed in concert with treatment expansion. The last decade has seen a race between development and population growth with no significant increase in the percentage of the population with access to piped drinking water or sanitation services.

2.1.7 The Sahel

This region consists of the countries south of the Sahara, from Senegal on the Atlantic coast to Chad between 10°E and 15°E.

There are two factors limiting the quality of renewable resources - the annual rate of precipitation (ranging from 400 mm in the north to 1,000 mm in the south) and the character of the aquifers. These are either sedimentary (sandstone, sands, limestones with high porosity or, if of low porosity, with fracturing) or crystalline or metamorphic rocks (which are of low porosity but fractured or overlain by weathered rocks). The region is subject to a continental effect - oceanic influence in the west and an increasing temperature gradient towards the interior of the continent.

The Sahel is flat (0–300 m) and crossed by two main rivers: The Senegal (773 $m^3 s^{-1}$) which flows to the Atlantic Ocean and the Niger (1,550 $m^3 s^{-1}$ at Fouta Djalon in Guinea) which flows into Bight of Biafra in the Gulf of Guinea flowing through areas with diverse rates of precipitation. The precipitation corresponds to the interaction between two types of air mass: the marine equatorial and the continental subtropical. This varying interaction results in two seasons: a dry season from October to May and a wet season from May to September. Ninety per cent of the vegetation is a mixed savanna woodland, gradually becoming grass and scrub towards the northern semi-desert. High temperature and torrential rainfall favour the formation of laterites (hard, relatively impermeable soils).

Particular relationships exist between rivers and aquifers in areas with crystalline rocks. At a basic level, ground water supplies the main rivers but smaller tributaries may feed ground water by percolating through fractures - a possible route for pollution of ground water. Water budget calculations demonstrate that annual recharge of aquifers ranges between 1 per cent (Senegal) and 6 per cent (Burkina Faso).

Water used in the Sahel comes primarily from ground water (80 per cent) but the Rivers Niger and Senegal and their tributaries also provide some water. Some dams on the rivers create reservoirs and help to prevent saline intrusion. Many smaller valleys are dammed, sometimes in a very rudimentary way, to create storage reservoirs for water from the rainy season. Few large lakes exist (Lac de Guier in Senegal and Lake Bam in Burkina Faso). The few large cities lie on rivers (Niamey, Bamako) or on the coast (Dakar).

Until recent years, water quantity was the primary concern in the Sahel but there is increasing recognition, with severe droughts and water scarcity, that water of good bacteriological and chemical quality is of great importance.

Water quality is basically good except in certain places where lower quality is associated with habitat type or human activity. Domestic waste water and lack of purification are particular water quality problems (up to 400 mg l^{-1} NO_3 in Burkina Faso and up to 800 mg l^{-1} NO_3 in Senegal). Less than 15 per cent of urban or rural populations have sanitation services in the Sahel region. The main water quality problem is faecal pollution. Other problems arise from the release of effluents from various industries such as textiles (Burkina Faso), tanneries and slaughter houses (Niger) and breweries (Maradi, Niger) which discharge untreated effluents directly to the rivers.

In coastal areas, saline intrusion presents the most serious problem for quality of surface and ground waters in Senegal. Due to low river flow in the dry season and because of the low gradient of rivers, salt water invades the rivers (River Casamance in Senegal and the River Gambia up to 250 km inland) and prevents use of water for irrigation. This saline water can seep into aquifers and contribute to soil salinization and acidification (River Casamance in Senegal). As stated above, dams to prevent saline intrusion into rivers have been built and more are planned. Over-pumping of the littoral sandy aquifer in Dakar has allowed saline intrusion which prevents use for drinking water or agriculture.

In the Sahel region, statistics for 1984 indicate that at least 15 per cent of disease is related to poor water quality with a maximum in the dry season. Water-associated disease in Burkina Faso ranks as the second highest cause of morbidity and the sixth highest cause of mortality. Diarrhoea is endemic.

There are particular problems associated with the Sahel, the recommendations for which will be incorporated into the general recommendations for Africa. Difficulties associated with the lack of control or treatment of domestic and industrial wastes have been mentioned above. The difficulties in obtaining equipment leads to breakdown in supply of high quality water which forces people to resort to polluted supplies. Water quality problems are often made more serious by the lack of co-ordination between supply and

Table 2.4 Concentrations of faecal bacteria in drinking water from various sources in Africa

		Faecal organisms per 100 ml[(a)]	
Type of source	Country	Coliforms	Streptococci
Rainwater	Tanzania	3	13
Boreholes	Tanzania	1	11
	Nigeria (piped)	Up to 35	Up to 6
	Uganda	0–60	NR
Springs	Kenya	0	0
	Tanzania (protected)	15	40
	Lesotho (protected)	200	250
	Tanzania (unprotected)	20	58
	Lesotho (unprotected)	900	1,700
Ponds and dams	Kenya (dams)	0–2	0–14
	Lesotho (small dams)	260	360
	Nigeria (ponds)	1,300–1,900	1,300–3,900
Waterholes	Tanzania	61	974
	Kenya	11–350	50–90
	Lesotho	860	1,600
Hand dug wells	Tanzania (protected)	7	33
	Nigeria	200–580	180–360
	Tanzania (open)	343	1,761
	Gambia	Up to 100,000	NR
Streams and rivers	Tanzania (streams)	128	293
	Uganda (rivers)	500–8,000	NR
	Lesotho (streams)	5,000	4,100
	Kenya (large river)	0–100,000	10–10,000

(a) Where only a single value is given it is a geometric mean.

Source: World Health Organization.

NR Not reported.

sanitation. Monitoring is irregular, not existing at all in Burkina Faso or Niger. There are water quality problems associated with programmes to combat vector-carried endemic and episodic disease. Excessive use of insecticides may cause the death of large numbers of non-target organisms, leading to long-term changes in aquatic communities. In addition, DDT is still used to combat sleeping sickness. Little progress has been made to combat water-associated diseases through biological means.

2.1.8 Regional Summary

Numerous natural water quality problems limit the use of some African water resources, for drinking-water and other uses:

- high salt content in both surface and ground waters (parts of the Maghreb, Ethiopia and the Rift Valley);
- salt-water intrusion into coastal aquifers – usually enhanced by over-pumping

(e.g., Senegal, Gulf of Guinea and Egypt);
- high fluoride content in both surface (the Rift Valley) and ground waters (Morocco, Senegal and the Rift Valley) leading to widespread dental and skeletal fluorosis; and
- very high suspended solids in some rivers at the beginning of the rainy season (Maghreb and East Africa).

The primary water quality issue is that of faecal contamination, both in rural areas, where less than 25 per cent of the population have appropriate sanitation, and in urban areas where most of the installed sewerage systems (which are few in number, serving less than 12 per cent of the African urban population) are not served by any sewage treatment facilities. It can be said that the status of water quality in Africa is very similar to that of Western Europe 150 years ago, with the additional concern of organic micropollutants. Associated with faecal pollution is widespread nitrate pollution of ground waters in rural areas, originating from domestic wastes.

Local pollution problems can be found downstream of significant point sources. For most large cities, industrial development areas (including breweries, sugar cane factories, pulp and paper mills, textile mills), and mines (gold, copper, aluminium, phosphates) there are generally no appropriate waste-water treatment systems. These pollution problems are directly related to the economic development of the country and may become of greater significance when there is a combination of three factors: pollution sources, water shortage and water demand. Such problems have already been identified in the Nile Delta and are likely to occur in the Maghreb, south Nigeria and mining districts in Zaire and Zambia. Reservoir eutrophication is also widespread from Morocco to South Africa.

In addition, the widespread occurrence of water-related parasitic diseases such as onchocerciasis has led to massive pest control programmes which make use of various pesticides in rivers, particularly in West Africa.

Africa is not yet able to combat these problems on a significant scale. There is a general lack of information on water quality (no or insufficient monitoring in 90 per cent of African countries) and a shortage of equipped laboratories, trained technicians and engineers. In addition, water quality issues are not identified as priorities

Table 2.5 Summary of water quality issues in Africa

Quality issue	Maghreb	Sahel	Gulf of Guinea	Congo Basin	Nile[a] Basin	Eastern and southern lakes	Great Lakes
Pathogenic agents	1–2	1–3	1–3	1–2	1–2	1–3	1
Organic matter	1–2	1–2	1–2	0–1	1–2	1–2	0
Salinization	0–2	0–2	0–1	0	0–1	1–2	0
Nitrate	0–2	1–2	1–2	0–1	0–1	1	0
Fluoride	0–3	0–2	0	0	0	1–3	0
Eutrophication	0–2	0–1	1	0	0–2	0	1[b]
Heavy metals	0–1	0–1	0–1	0–2[c]	0–1	0–1	0
Pesticides	0–1	1	1–2	1	0–1	0–1	1[b]
Industrial organics	0–1	0	0–1	0–1	0–1	0	0
Sediment load	1–3	0–2	0	0	0–2	0–2	0
Acidification	0	0–1[d]	0	0	0	0	0
Thermal discharges	0	0	0	0	0	0	0
Radioactivity	0	0–1[e]	0	0	0	0	0

0 No pollution or irrelevant.
1 Some pollution, water can be used if appropriate measures are taken.
2 Major pollution.
3 Severe pollution affecting basic water uses.

(a) The worst quality is generally found in the Nile Delta.
(b) Local problems.
(c) Upper Zaire rivers.
(d) Soil acidification.
(e) Niger uranium mines.

in many countries. In the whole continent (Republic of South Africa excepted) the research institutions devoted to water quality and biology are few and mostly located in North Africa - the research in much of Africa is still mainly carried out by European, North American and Japanese teams. Public awareness of water quality, even at the most basic level of faecal contamination, is very low. Government concern over water quality tends to be restricted to water quality laws which, if they do exist, are usually not enforced. African waters are still considered as renewable, unpolluted resources which can be used free of charge both in rural and urban areas. International co-operation in the field of water management already exists in Africa but water quality aspects are very seldom taken into account, even in UN programmes.

Finally it must be remembered that on a global scale Africa has 30 per cent of all fresh lake waters (Lakes Tanganyika, Malawi, Victoria) and the second largest river (Zaire). None of these water bodies, crucial to the development of Africa and essential on a global scale, is yet monitored, protected or adequately managed. The following recommendations are made to bridge these numerous gaps.

2.2 Regional Recommendations

2.2.1 Principles of Water Quality Management

a. Programmes for the supply of safe drinking water to increased proportions of rural and urban populations should be closely tied to parallel programmes to control domestic wastes and to protect water sources. Excreta disposal and domestic waste-water treatment should be adapted to local conditions, taking account of cultural factors. Regular inspection of water quality at rural abstraction points and of efficiency of waste-water treatment and disposal must be made.

b. There is an increasing need for recognition that water is a valuable and limited resource and that maintenance of quality under increasing user demand has a cost. Fees for water supply would provide a financial basis for quality control for abstraction and for treatment of waste water.

c. Prior to substantial agricultural, industrial or natural resource developments, environmental impact assessments should be performed, including specific reference to water quality. Long-term plans which involve land-use changes should take account of possible influences on water quality.

d. In addition to the environmental assessment, large hydro-projects should include a water quality component with monitoring and assessment before, during and after the completion of the project.

e. Special attention should be given to the protection of water quality in lakes and in the surficial fractured crystalline aquifers with thin weathered layers which occur widely in Africa.

2.2.2 Institutional Arrangements and Monitoring

a. Enactment, particularly in West and Central Africa, as well as enforcement of water pollution control legislation is a prerequisite for effective water quality management.

b. Recognizing the multiple interests of various sectoral agencies with a part to play in the control of water quality, it is necessary to establish strong inter-agency co-ordination mechanisms. In addition, water quality monitoring should be undertaken by a single agency to enable a comparable and comprehensive data base for water quality management decisions.

c. Effective water quality control would be greatly enhanced by the establishment of centralized Water Authorities in each country. The Water Authority would concentrate valuable resources and personnel and provide a focus for a systematic approach to planning for regulation of water resources.

d. Water quality monitoring must be recognized in African countries as an integral part of the evaluation of water resources and as a valuable tool for water management and planning.

e. Hydrological monitoring and water quality monitoring should be conducted simultaneously in each drainage basin.

f. Where intensive agricultural development and/or intensive pest control (e.g., anti-*Simulium* and anti-*Glossina*) are taking place, specific pesticide monitoring programmes should be established as a part of the operations.

g. Monitoring of major effluents should be initiated to obtain an information basis for pollution control planning and management. Industrial and municipal effluents should receive particular attention, depending on the economic development problem of each country. Programmes for the monitoring of effluents must be established in African countries as an essential part of water quality control.

h. Agro-industrial effluents are the most important individual waste-water sources. Many agro-industrial plants work on a seasonal basis, requiring the application of specially designed waste-water treatment and disposal schemes.

i. Mining areas and ore smelters constitute "hot spots" of heavy metal contamination. This includes gold, copper and phosphate mines as well as aluminium smelters. Special measures for treatment and disposal have to be taken to avoid or reduce widespread and lasting damage.

2.2.3 Research and Development

a. Pesticides for aquatic pest control should be field tested with specific reference to tropical conditions prior to commercial use to ensure that no adverse effects occur to humans, cattle or the environment.

b. African surface waters have special importance as sources of fish protein. Research, monitoring and impact assessment of the possible effects of biomagnified micropollutants in food chains should be conducted.

c. Development and field testing of reliable low-cost methods for biological monitoring of water quality are required, with specific relevance to African conditions and needs.

d. There is an urgent need for the creation of a network of International Limnological Research Institutes devoted to water quality and aquatic biology. The institutes should have a major training role. Possible locations would be on The Volta reservoir, Lake Victoria, Lake Tanganyika and the Zaire river.

e. The influence of African wetlands on water quality is still very poorly understood. Urgent research is required on the costs and benefits of wetland clearance before the complete disappearance of potentially valuable resources occurs.

f. Information on ground-water quality and the vulnerability of aquifers to pollution should be made available through ground-water maps.

g. Low-cost domestic waste-water treatment for both rural and urban areas should be adapted to African conditions and field tested on a community basis to develop proper protection of water resources.

2.2.4 Human Resources Development

a. Training of low- and medium-level technical staff should be undertaken at the country or provincial level. Training handbooks on water quality monitoring procedures and treatment plant operation should be provided.

b. Special training of technicians and engineers in environmental issues should be carried out at interstate schools and institutes such as those for Hydrology and Rural Engineering (Ouagadougou), Agrometeorology and Hydrology (Nyamey), Meteorology (Kenya), Water Resources (CEFIGRE, France) and Sanitary Engineering (Tampere, Finland).

c. Among other problems, many African laboratories face serious shortages of reagents and spare parts for equipment. An appropriate way of improving the efficiency of African laboratories would be twinning (on a one-to-one basis) with specialized water quality laboratories in industrialized countries. Provision of equipment, training and documents could be arranged in this way. Funds from bilateral donors and NGOs (Non-governmental Organizations) could be used in these co-operative links.

d. There is a general lack of literature on specific methodologies for water quality monitoring, assessment and management in university and water authority libraries. A critical analysis of recent manuals, especially those taking account of the relevance of methods to African conditions and resources, should be carried out and published.

2.2.5 Public Awareness

a. Programmes to promote public awareness of water use, conservation and associated water quality problems should be established, with special reference to faecal pollution. Provision of posters, brochures and manuals in local languages, teaching aids and television programmes should be part of the schemes.

b. Special programmes are required in the Great Lakes regions to publicize to local populations the value and need for protection of the lakes. International concern for protection should be raised through television and other media.

2.2.6 Transboundary, River Basin and International Co-operation

a. There is a pressing need for the inclusion of water quality considerations in all transboundary co-operative programmes dealing with water resources. A tentative list of existing International Commissions is: Senegal River, River Niger, River Volta, River Zambezi and River Nile.

b. International financial and technical co-operation in regular monitoring and in management of trans-boundary rivers, lakes and ground waters of global significance is needed. Such globally significant resources would include:
   - the Saharan aquifers;
   - the Zaire, Niger and Zambezi rivers; and
   - Lakes Tanganyika, Malawi and Victoria.

International action and co-operation, especially on the Great Lakes and large rivers, could be conducted through transboundary commissions under the aegis of the United Nations.

3

The Americas

North and South America are continents of great contrasts. Climate ranges from the dry arctic of northern Canada and Alaska, through temperate, subtropical and tropical savanna to deserts with mean annual rainfall of less than 50 mm and tropical rainforest with annual rainfall of more than 2,500 mm. The Laurentian Great Lakes and the Amazon are among the most significant water resources in the world, emphasizing the great variation in the distribution of resources in the continents.

3.1 Present Situation and Major Issues

In human terms, the distribution of resources means great differences in the amount of water available per person in different countries, ranging from the huge quantities available in Canada to very restricted resources in some South American and Caribbean states. Both North and South have increasing urban populations and expanding industry, although different countries have very different capacities to match these changes with suitable water resources development. Water demands in some countries remain primarily rural. For the purpose of this synopsis the countries of the American continents were divided in three groups according to common water quality issues: North America; Central and South America (including Mexico); and the Caribbean countries.

3.1.1 North America

Water resources and use

The two countries occupying most of North America, Canada and the United States, have advanced economies, high per capita income and sufficient water resources. Within each country there are, however, large variations in the availability of water between regions.

In Canada, most of the water flow (60 per cent) drains north while 90 per cent of the population lives in the south, within 300 km of the Canada-US border. Certain parts of Canada – the southern prairies, the interior of British Colombia and the high Arctic – have arid or semi-arid climates. The distribution of population in relation to available water resources is also an issue in the United States. The south-western states, such as Arizona and California, have large and fast increasing populations and a chronic shortage of water.

Industrial and agricultural activities, combined with urban development, have resulted in a number of stresses on water resources and on the aquatic environment in both countries.

Water quality issues

Approximately 100,000 chemicals are used commercially today, and many new chemicals are created each week. Many of these are toxic and they may enter the lakes, rivers and aquifers through waste disposal and everyday use at home, in agriculture and industry. Over 360 compounds have been identified, for example, in the Great Lakes, many of them persistent and toxic to humans, aquatic organisms and wildlife. They threaten the drinking-water supplies of millions of people living around the Great Lakes. In spite of strict controls on the

Figure 3.1 Nitrates in USA well waters
Source: WHO/UNEP 1989.

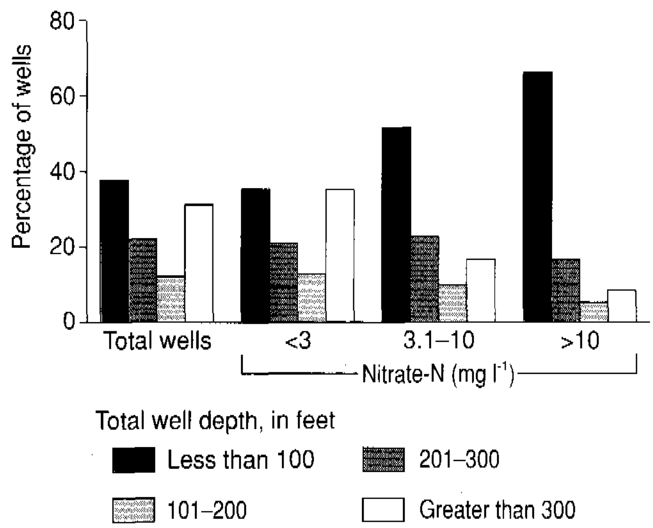
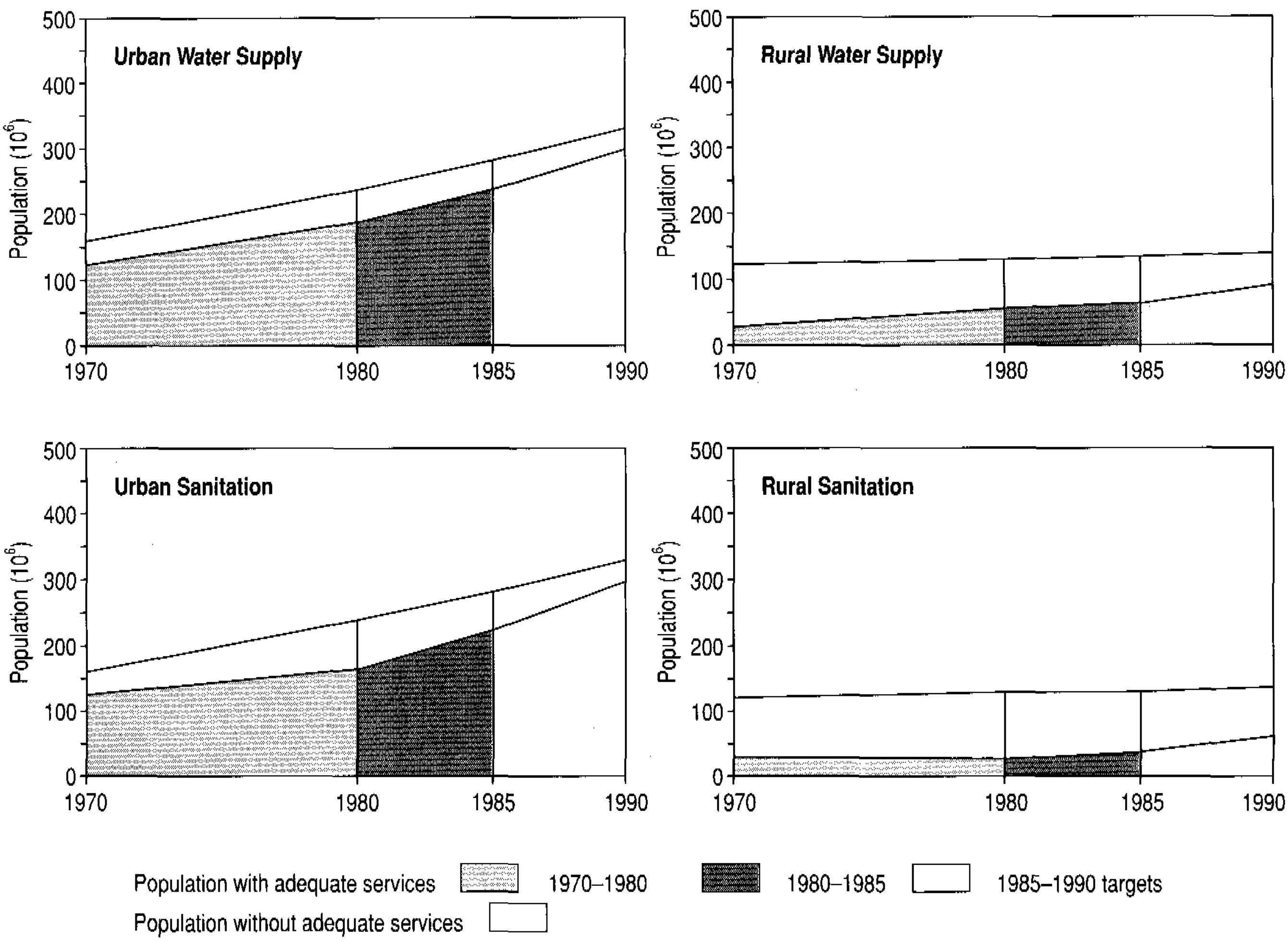


Figure 3.2 Water supply and sanitation development in Latin America

Source: World Health Organization 1988 *Towards the Targets*, WHO/CWS/88.2.



quality of drinking water, public concern is high because studies continue to find toxic chemicals in drinking-water sources, although most of the concentrations determined are below the recommended guidelines.

Of equal concern is the threat from toxic substances to aquatic ecosystems, illustrated by the disappearance of seven of the 10 most highly valued species of fish in Lake Ontario and by the decline in population of the beluga whale in the St Lawrence River.

The widespread use of chemicals in agriculture as fertilizers and for pest control has resulted in a series of environmental problems (including poor water quality). Examples are the presence of many pesticides in the environment (even in the high Arctic where they have never been used), eutrophication of water bodies due to phosphorus entering through run-off, and the presence of nitrate in ground water as a result of seepage from agricultural land.

In the United States in 1985, it was reported that agriculture was the most important non-point source of pollution. It affected water quality in 64 per cent of river-miles and 57 per cent of lake-acres in the country. In Canada, the full extent of the impact of agricultural chemicals on water quality and the environment is not yet known. A good assessment of this problem is difficult to carry out because of the diffuse nature of the sources, whether surface run-off, ground-water infiltration or atmospheric transport.

Sewage treatment is still a topic of concern for North America as a whole. Although the percentage of the population served by waste-water treatment increased in the 1980s, problems such as connecting widely-dispersed communities still remain and treatment services only served 70 per cent of the population by the end of the decade.

Table 3.1 Estimated per caput river flow in selected American river basins

River	Drainage area (10^3 km^2)	Mean annual flow ($m^3 s^{-1}$)	Population (10^6)		Per caput river flow ($m^3 a^{-1}$)	
			1970	2000	1970	2000
NORTH AMERICA	20,700	191,000	315.0	406.0	19,000	15,000
Colorado	629	580	2.0	3.5	6,600	5,100
Mississippi	3,222	17,300	56.0	72.2	9,600	7,500
Rio Grande	352	120	5.0	6.5	750	590
Yukon	932	9,100	0.1	0.2	1,580,000	1,050,000
SOUTH AMERICA	17,800	336,000	190.0	400.0	54,500	26,000
Amazon	5,578	212,000	4.0	8.9	1,620,000	740,000
Magdalena	241	7,500	18.0	41.9	12,800	5,500
Orinoco	881	17,000	4.5	10.0	116,000	53,000
Parana	2,305	14,900	61.0	110.1	6,800	4,200
San Francisco	673	2,800	12.5	27.9	7,000	3,100
Tocantins	907	10,000	2.2	4.9	145,000	65,000

Source: Szestay, K. 1982 *Wat. Qual. Bull.* **7**, 155–162.

Secondary treatment (using biological action to break down organic matter) is not yet used in all sewage treatment plants and tertiary phosphorus removal treatment is found with even lower frequency. This means that many substances are not removed from waste water leading to increased concentrations of those substances in receiving waters, and a consequent degradation of water quality. In many urban areas storm-water run-off is discharged directly into lakes and rivers, carrying contaminants which lead to general environmental degradation, closure of beaches in the summer and deterioration in the quality of drinking-water supplies. Many older urban areas have to deal with a deteriorating sewage collection infrastructure. In some instances such as pipe ruptures, this has led to the direct discharge of untreated sewage to receiving waters.

Human activities – industrial, agricultural and residential – release large quantities of different substances to the atmosphere. Once in the air, these substances may be carried hundreds of kilometres away from their place of origin, across state, provincial, regional and international boundaries.

The best known LRTAP (Long-range transport of airborne pollutants) phenomenon is acid rain which affects the eastern part of Canada and the north-east part of the United States. Acid rain is associated with atmospheric emissions of nitrogen and sulphur oxides and has killed aquatic life in thousands of lakes, destroyed trees and damaged structures throughout the region.

Toxic wastes have been stored at many sites over the last 50 years in both the United States and Canada. Accidents and leakage from the containers used pose an increasing threat to surface and ground waters. Although the extent of the problem is still unknown, it is considered to be serious because of the difficulty, or even impossibility in the case of aquifers, of cleaning up any such contamination. The contamination of the Niagara River from storage sites on the Niagara Peninsula, for example, has still not been solved despite many years of studies.

3.1.2 Central and South America

Water resources and use

Although the geography, geology and the climate of the 21 countries located in this part of the Americas are different, they share several characteristics that affect the state of the water resources.

As a whole the region has sufficient water but the distribution of resources is very uneven. Three big rivers, the Amazon, Orinoco and La Plata, account for two-thirds of the flow of South America. However, the population density in both the Amazon and Orinoco basins is very low. In Mexico, a country which at first appears to have sufficient water and rainfall, 80 per cent of the flow occurs at less than 500 m altitude while 85 per cent of the population lives above this level.

Most of the population in this subregion (approximately 70 per cent) lives in urban areas which are mostly located in the coastal zones. The region has 13 large urban centres with populations of more than two million. Among them are Mexico City and São Paulo, projected to be the largest cities in the world by the end of the century. Obviously, such a concentration of population puts incredible stresses on the environment in general and on water resources in particular. In Mexico City, São Paulo and Lima, for example, drinking-water supplies are becoming more and more difficult and costly to find.

For many years this region has been in an economic crisis, characterized by high inflation, high foreign debt, unemployment, and a general decrease in the standard of living. In water resource management this has been reflected by low expenditure for capital investment, poor maintenance of existing structures, few data collection and assessment programmes, and a lack of training and education.

Finally, the region is also characterized by fragmented jurisdiction over water resources and poor co-ordination between the agencies responsible. This aspect is more critical when financial resources are scarce, as in this case.

Water quality issues

Bacterial pollution of water supplies is a continuing problem in this area with adverse effects on human health. Approximately 80 per cent of the urban and 30 per cent of the rural population of the region have sewerage services. This relatively high percentage of coverage has resulted in water quality problems because only about 10 per cent of sewage collected receives any treatment before discharge. The population not served by sewerage facilities also contributes to water pollution through overland run-off and seepage to ground water. Similarly, industrial effluents receive little or no treatment before discharge. Some of the important industries of this region, such as slaughter houses (Brazil, Argentina, Uruguay), sugar processing (Cuba, Brazil), coffee processing (Colombia, Brazil) and fish processing (Brazil, Peru) also discharge high organic loads to water bodies.

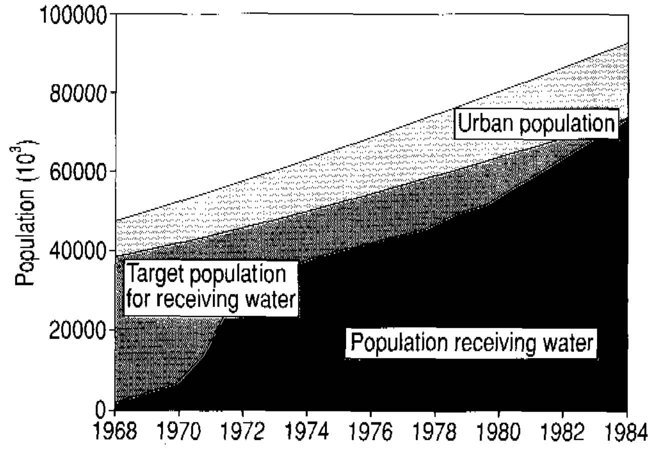
The problems caused by high bacterial and organic loads range from poor quality drinking water, eutrophication and disappearance of aquatic life to food contamination and the presence of water-transmitted diseases. Data which quantify the extent of these water quality issues exist although they are dispersed among various national and international agencies.

In a study that consolidated the relevant data from lakes and reservoirs located in Mexico, Central and South America, of the almost 40 lakes for which data were found, half were classified as eutrophic or hypereutrophic.

If findings regarding industrial chemical pollution from developed countries in other regions also hold true for the more developed parts of this region (such as the São Paulo - Rio de Janeiro region of Brazil, Mexico City, Monterey and Guadalajara in Mexico and Buenos Aires in Argentina), in addition to organic matter discharged by some industries, industrial plants discharge a variety of toxic substances.

Figure 3.3 Water demand and supply in Brazil

Source: Pompeu, C. T. 1984 *Water Quality Bulletin* 9(4), 205–207.



Lack of equipment for sample collection and analysis, reagents, methodologies and trained personnel, combined with the different priorities of the respective governments and water quality monitoring agencies, mean that there are no reliable data to assess the nature and the magnitude of the problems in the region.

Several countries of this sub-region practice intensive agriculture for a variety of crops, many for export. Both fertilizers and pesticides are used. Brazil, for example, is the world's third largest consumer of herbicides. As with industrial chemicals, data on the environmental concentrations, fate and effects of these substances are non-existent in most cases (with some exceptions such as Mexico and the State of São Paulo), in particular in aquatic systems.

A lack of appreciation of the importance of agricultural chemical pollution has hampered attempts to gain a better understanding of potential risks to human and environmental health. The costs of good data and assessment for this problem are probably small in comparison with the benefits which will arise from better knowledge and consequent control.

Peru, Chile, Mexico, Bolivia and Brazil have large mining industries for a variety of metals and other minerals. When discharged without treatment, mining effluents are particularly toxic to exposed aquatic life and humans. Available data indicate such water quality problems in certain regions of Chile and Peru. Mercury pollution in the Orinoco and Amazon River basins is relatively recent and is associated with gold extraction from river sediments. In these areas, mercury is imported for use in primitive gold extraction processes.

Soil erosion caused by deforestation or poor agricultural practices is increasing the suspended sediment loads carried by many rivers. In Venezuela, gold exploration in the Orinoco has a similar result. The increased sediment load affects aquatic life, treatment techniques for drinking water, and the capacity and useful life of reservoirs built on affected rivers.

Acid rain is not as widespread a problem as in the United States and Canada. It is of local nature and due mainly to vehicle exhaust fumes (e.g., Mexico City and Santiago) or the burning of sulphur-rich oils.

3.1.3 The Caribbean

Water resources and use

Water availability does not appear to be a problem in the Caribbean. When the available surface flow in relation to population is calculated, this sub-region seems to have less available water than Central and South America (280 m^3 s^{-1} compared with 863 m^3 s^{-1} per million people), but the distribution of the water resources is much less of a problem. The Caribbean also lacks the big urban centres that characterize the other parts of the continent.

Although its geography, demography, climate and, to some extent, socio-economic and cultural characteristics are different from the other two sub-regions of the American continent, the Caribbean sub-region faces some of the same water quality issues.

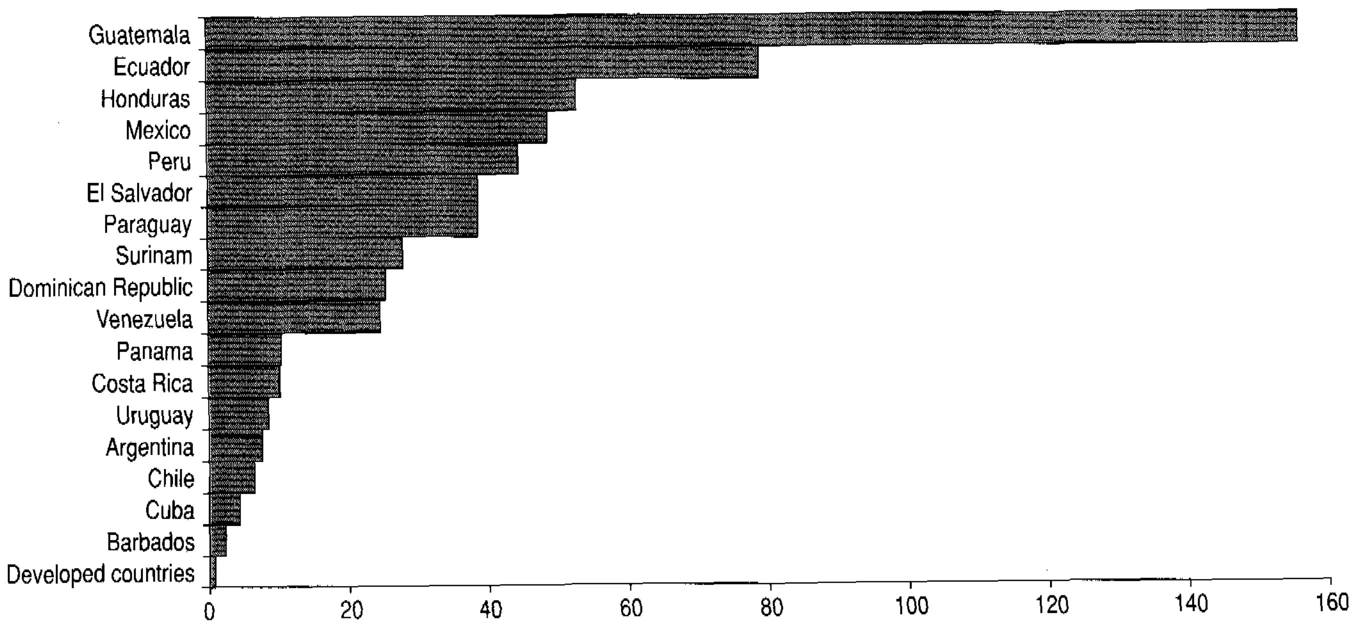
Water quality issues

A high proportion of the population is connected to sewerage systems. Because very little of the sewage is treated, its discharge into fresh or coastal waters results in bacterial and organic matter pollution. Food processing, such as sugar-cane, fish and canning, also contributes significantly to the organic matter content of surface waters.

The discharge of untreated municipal and industrial

Figure 3.4 Deaths from water-borne disease

Source: World Health Organization, information for various years.



Death rate per 100,000 population from typhoid fever and other intestinal infectious diseases.

Table 3.2 Summary of water quality issues in the Americas

			Mexico, Central and South America	
Quality issue	Canada and US	Caribbean	Amazon & Orinoco Rivers	Other
Pathogenic agents	0–1	1–2	0	1–3
Organic matter	0	1–2	0	1–3
Salinization	0	1–2	0	0
Nitrate	0–1	1	0	0–1
Fluoride	0	0	0	0
Eutrophication	1–2	1–2	0	1–3
Heavy metals	0–1	0–1	0–1[(a)]	1–3
Pesticides	0–1	ND	0	1–3
Industrial organics	0–1	0–1	0	1–3
Sediment load	0–1	0–1	0–1[(a)]	1–3
Acidification	0–2[(b)]	0	0	0–1
Thermal discharges	0	0	0	0
Radioactivity	0	0	0	0

0 No pollution or irrelevant.
1 Some pollution, water can be used if appropriate measures are taken.
2 Major pollution.
3 Severe pollution affecting basic water uses.

(a) Mercury and suspended sediment pollution due to gold exploration on some rivers.
(b) Eastern Canada and north-east USA.

ND No data obtained.

sewage is the major problem in this region. It affects a number of water uses, such as drinking-water supply and recreation. This is especially important because tourism is the major industry in many of the countries of this region.

Data on the presence and effects of pesticides on the environment are absent for the Caribbean. Experience in other parts of the world would suggest that these toxic substances are entering the environment and that their effects can be only detrimental to the terrestrial and aquatic life of this area.

In a water quality survey conducted in this area, Cuba and Trinidad and Tobago have identified salt water intrusion of aquifers as one of their water quality problems, a phenomenon of particular significance for small islands.

3.1.4 Regional Summary

The natural distribution of rainfall and water resources has implications for water quality in the Americas, as it does in other parts of the world. This is of particular concern where populations are increasing and putting increasing demands on water resources for abstraction and waste disposal. In arid and semi-arid areas water is a limiting factor for development and is coming under increasing human pressure. Water quality issues which are common to the whole region are those of toxic contamination from industry, agriculture and waste disposal, eutrophication from agriculture and human settlements and conservation issues. In Central and South America, these issues are joined by huge and increasing problems associated with the absence of sewage treatment, especially in the rapidly expanding urban areas. The concentration and increases in population also result in difficulties in supply of water of adequate quality. Industrialization, mining and intensive agriculture are presenting water quality problems. Management difficulties in the south are compounded by lack of funds and problems in organization. Management of water resources in North America is characterized by a high degree of organization and relatively good legislative and regulatory tools for pollution control. Conservation and ecosystem management issues associated with water resources are receiving greater attention throughout the whole region - the most notable being the Amazon basin and the protection of the Laurentian Great Lakes.

3.2 Regional Recommendations

The water quality problems in the Americas are serious and they demand urgent action. Concerns about the state of the environment, including water quality, are expressed throughout the continent by experts and the general public alike. Surveys in Canada, for example, have shown that environmental concerns rank as high in importance as economic issues in public opinion. In the developing countries of the region, economic issues are still most important, but environmental protection is receiving much more attention than in the past. In some countries, such as Brazil and Canada, environmental protection has become a major political issue.

3.2.1 Municipal Sewage and Industrial Effluents

a. Municipal sewage and industrial effluents must be treated before release to water bodies and before re-use for other purposes such as irrigation. Sewage treatment requires huge investments and poses large technological problems.

b. Past experience has shown that building isolated treatment plants does not produce a significant improvement in the quality of the receiving water bodies. It is recommended that sewage treatment be addressed on an integrated river basin level. Concentrating the efforts on a particular basin or basins should result not only in significant and visible improvements in the basins concerned but also in additional benefits, such as:
   - increased credibility for the authorities involved and their actions; and
   - mobilization of public opinion in support of actions that enhance and protect the water resources.

   In this context, the integrated basin approach means:
   - identifying the nature and magnitude of all significant point and non-point pollution sources, such as effluents, run-off, dry and wet precipitation, and the release of polluting substances from sediments;
   - planning a pollution abatement programme for the basin as a whole;
   - having adequate resources, both financial and human, not only to build the treatment facilities, but also to operate and maintain them properly;
   - having appropriate legislation and regulations in place that allow implementation of effluent and/or ambient water quality standards in the basin; and
   - having adequately resourced agencies to plan, implement, enforce and assess the effectiveness of the measures taken.

It is important for the success of a pollution abatement programme that all these elements are in place.

c. A variety of municipal sewage and industrial effluent treatment technologies exist throughout the world and new ones are being developed. However, most of these technologies were designed for use in developed countries and are not always suitable for the conditions in many developing countries. The following specific points must be observed:
   - low cost and simplicity of equipment;
   - equipment geared to the skills of personnel;
   - arrangements for the easy provision of replacement parts and chemicals;
   - consideration of the different environmental conditions under which this equipment has to operate;
   - adjustment of treatment processes to the composition of sewage; and
   - effluent standards to be set in accordance with environmental objectives and technological feasibility.

It is recommended that information be made available on technologies used successfully in developing countries, while the search for even better, more appropriate technologies continues. Policies of national governments, international agencies and financial institutions should favour the application of the most efficient technology from the point of view of the country which will be using it. Such policies should operate in the long term, rather than in the short or medium terms.

3.2.2 Toxic Organic Chemicals

Toxic organic chemicals include agricultural and industrial synthetic chemicals. Pesticides enter the environment in a variety of ways, usually from non-point (diffuse) sources. The American continent is a heavy producer and user of these substances. Toxic organic substances originate from a variety of industries and they enter water bodies through effluents, spills, air emissions, and the storage and disposal of hazardous materials. To limit the presence and impact of toxic organic compounds in the environment, several measures should be implemented concurrently:

a. Finding and using substitute chemicals for pest and weed control which have less adverse environmental impact.

b. Treating industrial effluents to meet acceptable standards for discharge. Effluent standards, either as components of a permit system or as part of regulations and legislation, must consist of both concentrations for effluents and loading limits for receiving waters.

c. Modifying manufacturing processes so that emissions of toxic compounds, as either gaseous or liquid effluents or solid wastes, are minimized or eliminated.

d. Disposal of hazardous wastes through high temperature incineration.

To improve control over release of toxic organic compounds to the environment, Canada has passed legislation that introduces "life-cycle management". This consists of strict controls over their manufacture, importation, use and disposal backed up by severe penalties for not obeying the law. Although expensive to implement, the costs to society (in terms of effects on human health, medical care and deterioration of environmental quality), would be even higher had such a system not been implemented.

e. It is recommended that other countries that face problems with management of toxic chemicals implement similar systems for their control and that the experience gained in the United States and Canada be shared freely with the other countries of the region.

3.2.3 Pollution from Mining Effluents

Mining is an important activity in several countries of the Americas. Mining effluents are usually very toxic, especially to aquatic life, because of their high content of heavy metals, such as arsenic, copper, lead, nickel and zinc.

a. The processes and the technology exist to deal with mining effluents by treatment and recycling. The most serious barrier in implementing them is cost. Governments should adopt and implement an appropriate pricing structure for water (see also recommendation on Economic Tools). Such a structure would encourage a mine to re-use water many times and treat its effluents before discharging them into the environment.

b. Complementary regulatory tools to deal with mining effluents are effluent standards. It is recommended that such standards be based on the protection of the most sensitive use of the receiving water body, be it the protection of aquatic life or wildlife, recreation or drinking-water supplies.

c. It is recommended that information and technology for dealing with acid rain problems in Europe and North America be shared with countries that have identified this as a priority issue and need assistance.

3.2.4 Protection of Globally Important Water Basins

Some of the most important freshwater rivers and lakes of this planet are located on the American continent. The large basins of The Amazon, Orinoco and Mackenzie rivers, and the unique Lake Titicaca have, until now, maintained their natural water quality. Owing to their importance to the world's freshwater balance, it is imperative that their quality be conserved for future generations.

a. It is recommended that special conservation programmes, properly monitored, be implemented in these basins.

The deforestation of Central America and of the Amazonian forest is very important regionally and globally. Although the impacts of these forest losses on the water resources of the region can be anticipated to a degree from studies carried out elsewhere, the Central American and the Amazonian regions have unique characteristics that make any predictions risky without more precise data.

b. It is recommended that studies be performed to examine the impact of deforestation on water quality in these regions. The results of these studies should be used in conservation and sustainable development plans.

3.2.5 Improved Management of Water Resources

The protection, conservation and enhancement of water quality is most effective when the principles of ecosystem management and sustainable development are applied. In practical terms this means that all the components of the aquatic ecosystem and factors such as climate, land use and population must be considered in water resources management - the ecosystems approach to management.

a. It is recommended that economic tools be developed for managing water resources which reflect costs of both quality and quantity aspects. This should result in economic decisions which include the true costs of environmental and water resources protection.

b. Although most countries have policies and legislation to protect water resources, they lack specific regulations to accompany the more general provisions of law or of government policies. It is recommended that responsible agencies for implementing and enforcing water-related legislation be clearly identified and given adequate resources.

c. It is strongly recommended that a plan of action to raise the level of understanding of the role of water quality in the economy of a country and the health of its citizens be prepared and implemented as soon as possible. Such a plan of action should be directed primarily towards high government officials, politicians, and senior officials of the international financing agencies of this region.

d. It is recommended that co-operation between agencies active in water quality and water resources management be strongly promoted. Such agencies include government departments, universities, research institutes, the private sector, and professional and non-governmental organizations.

e. An important element of the ecosystem approach is the integrated management of water quality, quantity and use. The integrated approach has major implications for agencies participating in the management for water resources in this region. It is recommended that agencies responsible for planning of water resources and for managing them develop the appropriate tools for integrated management. Such tools include integrated data storage and retrieval systems, methodologies for joint assessment, and forecasting and planning models.

f. Water quality issues in the 1990s are complex, requiring sophisticated approaches, science and technologies for their solution. No nation has sufficient resources or time to deal with its own water quality issues as well as with other environmental issues. In such circumstances increased international collaboration becomes very important. It is recommended that increased collaboration in water quality between the countries of the region, and outside the American region, be promoted through joint projects, work sharing and seminars.

3.2.6 Water Quality Monitoring and Assessment

Access to good, comprehensive information is a vital requirement for good decisions, much more so when large financial resources are involved and when human health is at stake. Both these elements are present when dealing with water quality. Data and information on the basic water quality variables have been collected throughout the region for many years. The collection of data has not been very systematic; in addition, little quality control has taken place and data are therefore of limited value. Whatever data exist are dispersed amongst a large number of national and international agencies active in the water field in this region.

a. It is recommended that as a basic step towards attacking some of the water resource management issues in the region, a consolidation of existing information, country by country take place. It is important that such a consolidation include information about the quality of the data.

b. Many agencies throughout the region need a systematic, reliable and fast method of storing and accessing water quality data. A computerized data storage and retrieval system is the answer to this need and the availability of microcomputers makes the establishment of computerized water quality data banks feasible even in small organizations. It is recommended that a "standardized" water quality data bank be developed and made available, free of charge, to interested agencies. Such a data bank, beside its direct usefulness to the water quality agency, would be useful for regional and global water quality assessments and would facilitate the implementation of more sophisticated data analysis and presentation techniques, improving the quality of the work in the region.

c. Water quality assessment has advanced considerably in the last few years. It is recommended that means be developed by which most recent developments in this field can be brought to the attention of the agencies responsible for water quality assessment. This can be done through the publication of manuals and articles in Spanish, Portuguese and English, seminars, twinning of agencies, bilateral co-operation, and governmental and non-governmental multilateral organizations.

d. Some of the more serious water quality problems of the region are associated with agricultural and industrial organic chemicals and heavy metals. The lack of resources for water quality work in most countries has not allowed monitoring programmes to keep up with developing water quality issues. It is recommended that surveys be carried out which will define the extent of the problem of aquatic ecosystem contamination in those basins of Latin America where problems are suspected. It is also recommended that the surveys be followed by well-designed monitoring programmes.

3.2.7 Public Awareness

Government-funded water quality agencies compete for resources with many other agencies. In most countries, the resource allocations are made by politicians and senior government officials and it is important to have public support for the water quality programmes.

It is recommended that a public awareness programme for water resources be promoted throughout the region. Information on water quality issues should be made accessible to the general public in non-technical language in the form of leaflets, posters, television advertisements, films, games, computer diskettes or exhibits. To decrease the costs of such programmes, basic information material should be made available to countries to be adapted to their specific needs.

3.2.8 Research, Development and Training

For water quality management to be successful, it must be supported by research and development, and trained professionals must be available. The region, especially in Canada, the United States and Brazil, has a number of institutions in which research, development and training of professionals in the field of water resources are taking place. Few of these institutions have programmes specific to water quality issues.

It is recommended that a research, development and training collaborative programme be developed for the region as a whole, especially for the Spanish and Portuguese speaking countries. Such a programme will include the preparation of a report detailing the research, development and training needs for water quality in the region, and identifying existing capabilities. Some specific water quality topics that need to be addressed by a research and development programme are:

- appropriate technologies for municipal sewage treatment, including alternative uses and recycling;
- appropriate water conservation and quality protection methods and equipment;
- improved methods for the planning of water resources, with emphasis on the integration of quality, quantity and use aspects;
- short- and long-term effects on human, aquatic and other terrestrial life resulting from the presence of toxic contaminants in the environment as a whole, and in aquatic systems;
- water and ecosystem quality guidelines for use in legislation and regulations, or in assessing progress in water quality protection activities;
- improved water quality monitoring and assessment methods, including planning of networks, methods for sample collection and preservation, analytical methods for various media, and data analysis methodology;
- improved methods for water quality information dissemination to decision makers and the general public; and
- impact of new water resources management strategies, such as economic tools, on societies and the economies.

It is also recommended that research and development activities be integrated with training programmes. This will ensure that the professionals of the region keep up with the advances made in the field of water resources and that research and development programmes address topics of real importance to the countries of the region.

4

West Asia

The West Asian countries are divided into two groups, the first of which consists of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates and Yemen. These countries are located in the Arabian Peninsula. Iraq, Lebanon, Syria, Jordan and Turkey (as far as the drainage basins of the Euphrates and Tigris are concerned) form a second group in the Eastern Mediterranean region.

4.1 Present Situation and Major Issues

All West Asian countries are located in the arid and semi-arid zones - 70 per cent of the region is arid, water resources being limited. Adverse climatic conditions are reflected in a low (90 per cent of the area receives less than 100 mm a^{-1}), unpredictable and variable rainfall and high evaporation rate (mean evaporation rate is about 2,000 mm a^{-1}, range is 600-5,000 mm a^{-1}). The drought period is about 5-9 months each year; dry and wet cycles alternate but periodicity may be irregular in some areas.

Data for water quality are scarce or unavailable for most of these countries, so a proper evaluation cannot be made. In addition, there are many discrepancies among published data for water resources, population, water and sanitation services.

4.1.1 The Arabian Peninsula

Low precipitation and scarce ground waters are the only natural water resources. A few aquifers (fossil and rechargeable) are shared between Saudi Arabia and neighbouring countries. Perennial streams or rivers do not exist in these countries.

These countries (except Yemen) desalinate sea water and brackish ground water to meet their water demands. Quantities desalinated range between 20-80 per cent of the total water requirements. Further development of aquifers is generally not possible. Current over-pumping of ground water has caused a movement of brackish water inland and lateral sea-water intrusion into aquifers on the coasts. This has resulted in some coastal aquifers yielding ground water with a salinity of 5,000-20,000 mg l^{-1}. Treated sewage, slightly saline brackish water and good quality ground water are used for irrigation. Yemen is facing increasing demands on its water resources and may need desalination in the future. The country is arid although it has relatively more water resources than other countries in this group.

The percentage of the total population which had access to safe drinking water in 1985 ranged from 53-94 per cent, the percentage of the urban population served ranged from 90-100 per cent and the percentage of the rural population served ranged from 25-100 per cent. The percentage of the total population which had access to sanitation services in 1985 ranged from 31-100 per cent; 83-100 per cent of the urban population were served while 25-100 per cent of the rural population were served. Data from certain countries are not available.

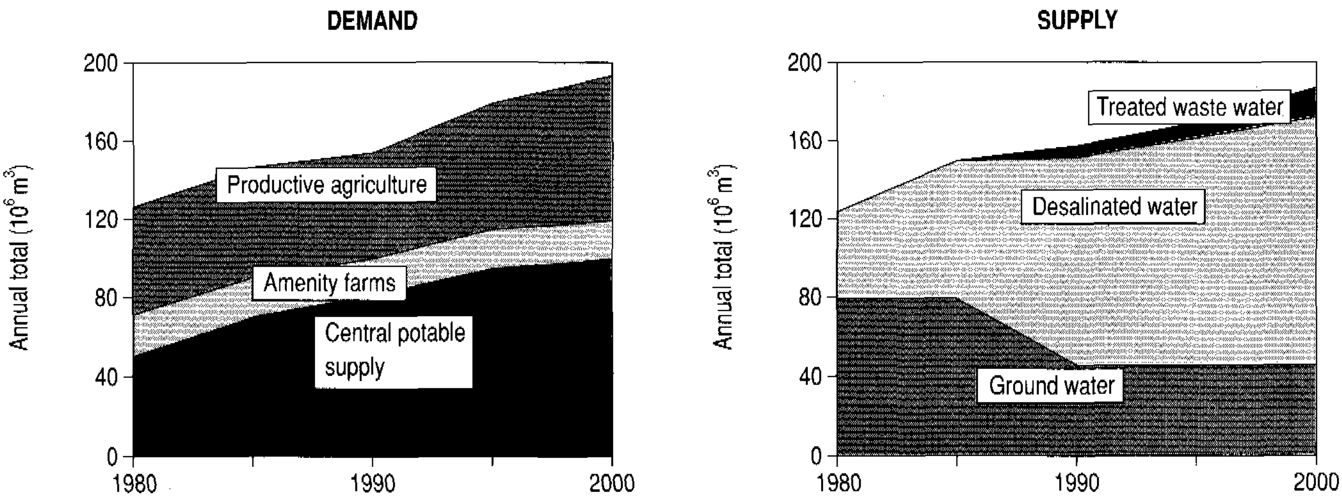
Re-use of waste water treated at tertiary level (advanced treatment to tackle specific water quality problems) is practised in most of this sub-region, the remaining countries re-use waste water treated to secondary level (biological). Treated waste water is used mainly in irrigation and constitutes 10-40 per cent of water resources in many countries.

Water consumption per capita is generally very high in most of these countries; it is about 300-750 l per person per day in urban areas where most of the population is located. This is mainly due to the low price paid by consumers for water use, and high water losses in the network. Thus the region is characterized by the anomaly of high per capita consumption on the basis of very limited freshwater resources.

Water quality and sanitation services have almost doubled during the Water Decade. In addition, management of water resources has improved, but problems with institutional organization place limits on its efficiency. The establishment of comprehensive inventories of land-based pollution sources (covering air, water and soil pollution) has been initiated in the countries of the Arabian peninsula.

Water quality monitoring and environmental establishments are now fairly well organized. Although data are not yet available it is expected that during the coming decade this will change and the availability will improve.

Figure 4.1 Water supply and demand in Qatar
Source: After Annesley, T. T. et al. 1983 *Intern. J. Water Resources Develop.* **1**, 31.



A major constraint in these countries is the lack of local, skilled, experienced man-power at all levels. Accordingly there is a high dependence on expatriates.

The countries of the Arabian peninsula (except Yemen) are oil producers with very high GNP (gross national product) per capita - among the highest in the world. These countries can afford to install and operate desalination plants, but the question arises as to the feasibility of using good quality water for irrigation. Good management and development of Yemen's water resources are the only strategies to prevent further rapid deterioration of ground-water quality - the low per capita GNP of Yemen means that such policies are more likely to be implemented with aid assistance.

The geographical concentration of industrial complexes in coastal and estuarine areas around the Arabian peninsula means that many pollutants enter the sea directly but the threat to coastal aquifers (which are already stressed by over-pumping) is significant and imminent.

4.1.2 Eastern Mediterranean

These countries are semi-arid and all have perennial rivers. The annual wet period is about six months (50-1,500 mm a^{-1} of rainfall), but evaporation rates are high (600-4,000 mm a^{-1}) and there are extensive desert areas. The land is fertile and agriculture forms a large part of the economy and provides jobs for the rural population. However, salinization and degradation of soils occurs in certain areas.

The proportion of the total population which has access to safe drinking water ranges from 74-100 per cent; 95-100 per cent of the urban population are served and 54-100 per cent of the rural population are served. The proportion of the total population which has access to sanitation services ranges from 50-70 per cent; 56-92 per cent of the urban population are served while 0-28 per cent of the rural population are served. Complete sets of data are unavailable.

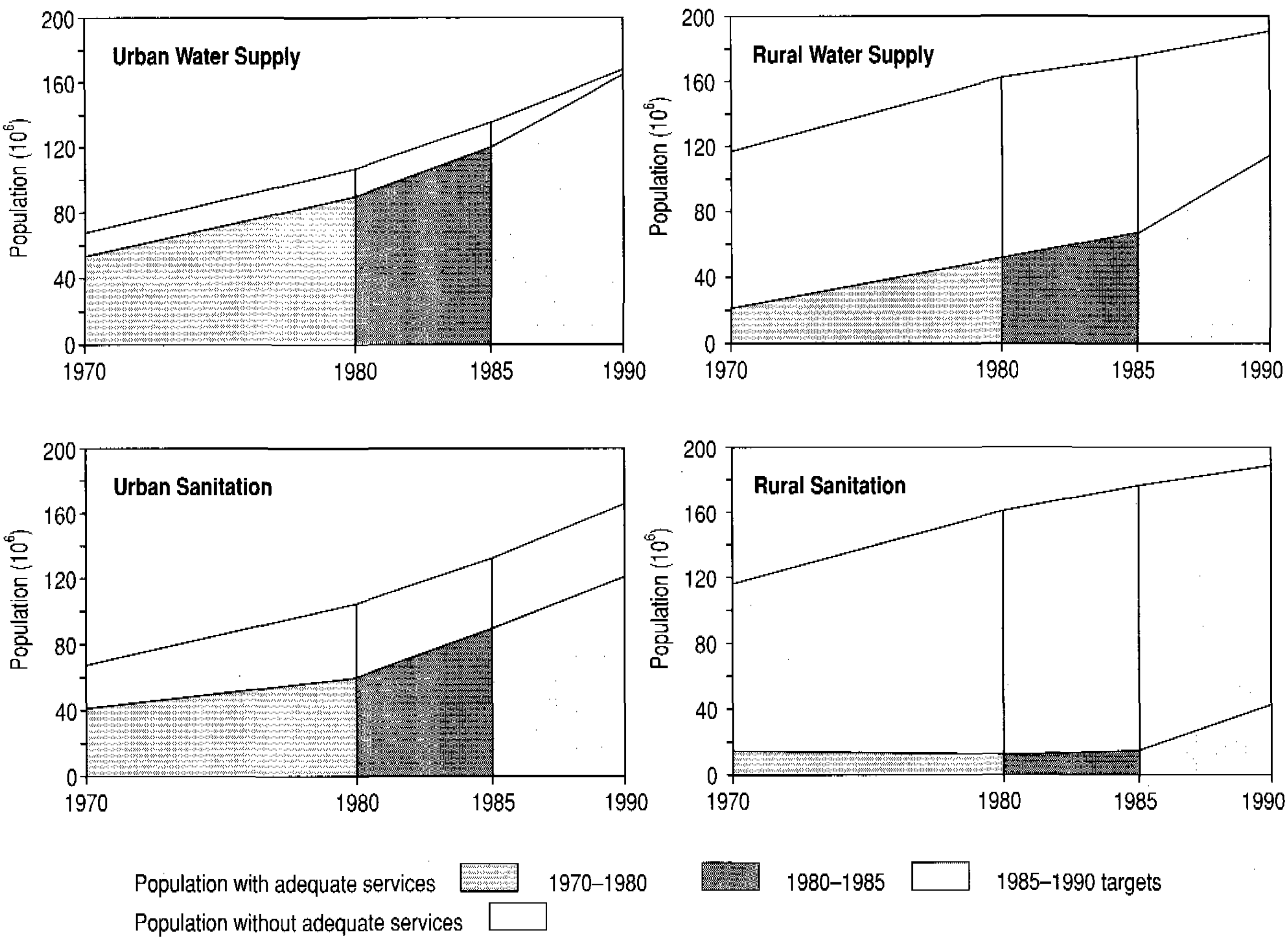
Waste water is re-used in these countries, but not to the the degree practised in the Arabian peninsula countries. However, Jordan re-uses waste water efficiently after secondary treatment. The re-used water constitutes about 5 per cent of its available water resources and about 25 per cent of its domestic consumption.

Per capita water consumption is high due to agricultural activities and water losses in the network. Data are not available for all countries but consumption can be in the range of 700-1,500 l per person per day. However, domestic consumption is low. An example is Jordan (lowest in this group), where the average is 160 l per person per day and the range between 54-201 l per person per day.

Water quality control and sanitation services have expanded by a factor of two during the Water Decade and management of water resources has improved dramatically. Awareness is high amongst the population, but metering and increased use of water tariffs are yet to be introduced.

Water quality monitoring and environmental activities are widespread and in recent times have become better organized. Although data are not published, improved management will become apparent in the coming decade. Better institutional arrangements are

Figure 4.2 Water supply and sanitation development in West Asia
Source: World Health Organization 1988 *Towards the Targets*, WHO/CWS/88.2.



Includes data for Pakistan and Afghanistan.

evolving in each country.

These countries have more skilled manpower than the Arabian peninsula countries and most of them depend on local people for implementing water policies. The Eastern Mediterranean countries export skilled manpower to the Arabian peninsula.

One of the constraints on these countries is the lack of funding to develop their water resources. Even Iraq, which is an oil producing country, has problems because of large debts.

One major problem for this group is that they share both surface water (rivers) and ground water and there is not always regulation of the use of this water. A continuing factor in disagreements between Israel and other countries in the region is the distribution and use of water resources. Iraq, Syria and Turkey are still negotiating (since 1950) the sharing of the resources of the Euphrates. A recent report has mentioned that by the time Turkey completes its development projects on the Euphrates (in the year 2000), Syria and Iraq will have almost lost the use of this river upon which they depend and which constitutes about 50 per cent of their water resources. Regional agreements to share water resources are needed immediately. Some reports suggest that due to lack of sufficient water resources for all countries and with projected increases in use, further conflicts over water resources will occur in the next decade.

Jordan's situation is now critical and the country may be forced to desalinate water (either brackish ground water or sea water) if new freshwater resources are not found soon. Lebanon has experienced numerous problems since 1975 and the environmental situation deteriorates further every year.

4.1.3 Regional Summary

West Asia has an arid or semi-arid climate with unevenly distributed water resources. Some countries have access to large permanent rivers such as the Tigris and the Euphrates while others have to obtain water from seasonal rivers and ground waters. There is increasing pressure on all the water resources of the region, in terms of quantity and of quality. Intensive agriculture is demanding an ever-increasing quantity of water and in some areas irrigation is resulting in salinization and degradation of soils. Concentrated industrial development is leading to pollution problems for ground and surface waters in certain areas. The locally concentrated industrialization of most countries in the region has led to areas of potentially severe industrial pollution of surface- and ground-water bodies. Uncontrolled discharge of industrial effluents, undetected seepage of toxic substances into aquifers and the unprotected dumping of hazardous wastes are increasing as rapidly as industry expands. Several countries depend heavily upon ground-water resources and over-pumping is leading to saline intrusion into coastal aquifers. Oil-rich countries are able to desalinate sea water to boost their water resources, but this is not an option for the greater part of the population of the region. The Water Decade saw improved water management, drinking-water supply and sanitation in the region.

4.2 Regional Recommendations

4.2.1 Water Management and Water Conservation

a. Limited freshwater resources and water demands which grossly exceed naturally available amounts make rational planning and management of waters essential throughout the region. This implies that water quality considerations, including the possible conflict of requirements of different users, be considered simultaneously with quantitative water resource management.

b. It is essential that the countries of this region employ to a greater degree economic tools for water conservation and management. These tools, such as abstraction and use charges, discharge fees and

Table 4.1 Summary of water quality issues in West Asia

Quality issue	Arabian Peninsula[a]	Eastern Mediterranean	Regional average[b]
Pathogenic agents	0	1	1
Organic matter	0	1	1
Salinization	3	1	2
Nitrate	0	1	1
Fluoride	0	0	0
Eutrophication	0	1–2	1
Heavy metals	0	0	0
Pesticides	0	1–2 [c]	1
Industrial organics	1 [d]	1[c]	1
Sediment load	0	1	1
Acidification	0	0	0
Thermal discharges	1 [d]	0	0
Radioactivity	0	0	0

0 No problem or irrelevant.
1 Some pollution, water can be used if appropriate measures are taken.
2 Major pollution.
3 Severe pollution affecting basic water uses.

(a) No surface water. Mostly ground water and desalination.
(b) Based generally on population affected in the region.
(c) Possibly on rivers or streams.
(d) Possibly coastal areas.

realistic costing for treatment and supply, are necessary if sustainable use of scarce water resources is to be attained.

c. A variety of practical measures for water conservation are urgently needed to utilize the scarce water resources in an optimal way and to minimize spillage and wasting. Practical approaches include the following:
   - reduction of water losses in municipal distribution networks through technical interventions;
   - reduction/limitation of per capita water consumption through public awareness and education, metering and household water saving devices;
   - introduction of new and efficient irrigation technologies which minimize water losses and avoid salinization of irrigated soils; and
   - systematic water harvesting, e.g., rainwater collection, storage reservoirs and reduction of evaporation losses.

4.2.2 Desalination and Waste-water Re-use

Re-use of waste-water and effluents of various kinds is already considered in many water administrations as a valuable additional resource. Their use for various purposes is largely determined by their quality and the treatment technology available to meet the water quality requirements of the users. Use of domestic sewage, for example, requires only limited treatment if used for restricted crop irrigation. Stabilization ponds for bacteria and helminth removal should be used to this end throughout the region. Epidemiological studies in pilot areas within the region should accompany and facilitate the acceptance of waste-water re-use.

a. A target for the portion of domestic water demand to be covered by waste-water re-use should be set in each country. A level of up to 25 per cent may realistically be achievable.

b. The present and future water needs of the region can only be met by the rational use and allocation of water of certain minimum quality to different users. Ground-water mining (abstraction of non-renewable resources) should only be permitted for domestic water supply for limited periods and strict criteria and quality guidelines regulating the exploitation of non-renewable aquifers have to be established and rigorously enforced.

c. Desalinated water use should only be permitted for high-quality demands such as domestic water supply and certain industrial applications. True costs, including energy inputs, must enter the pricing policy and tariff structure. Re-use of waste water, after appropriate treatment, for crop irrigation has proven to be safe and beneficial both for increasing agricultural production and for protecting the environment. However, sound economic criteria have to be applied when evaluating the cost-effectiveness of agricultural expansion schemes relying entirely upon artificial irrigation.

4.2.3 Co-operation and Development

a. Rational management of water quality, in the same framework as water quantity, is at present not feasible due to inadequate data. Therefore, it is of paramount importance that national authorities responsible for various water quality issues (health, agriculture, environment, drinking-water supply and industry) strengthen their inter-sectoral linkages to establish harmonized national water quality monitoring services.
   For the countries sharing the Euphrates/Tigris basin, and others sharing some smaller rivers, this implies the establishment of a network of stations capable of monitoring the impact which planned river regulations, abstractions, discharges and new reservoirs or diversion schemes will have on river water quality. Modern techniques such as remote sensing, automatic monitors, electronic data transmission and processing should be applied in order to overcome the problems of long distances and of sample transport and site accessibility.
   For the countries relying almost entirely on ground water the monitoring of a short list of highly indicative quality parameters would provide key information for aquifer management. Mathematical modelling of ground-water quality is an important tool for such management decisions and should be introduced for well-defined objectives. Naturally or artificially recharged ground-water bodies could thus be used optimally in a comprehensive quality/quantity framework.

b. The countries of the region are characterized by a high degree of linguistic, cultural, judicial and geopolitical homogeneity. Regional co-operation on planning of shared resources (rivers and ground waters) must include considerations of water quality. Close co-operation through expert meetings, within-region expatriate work assignments and a variety of inter-country and professional associations allows for a harmonized approach to water quality management. More efforts are needed, however, to promote the development of compatible water legislation, regulations, standardized terminology, codes of practice and technical specifications in Arabic which correspond to English versions in common practice world-wide.

c. Public awareness of water quality issues relating to public health and environmental pollution is inadequate and, as a consequence, community participation in water quality/quantity management decisions is almost absent. Programmes to remedy this situation should be developed in Arabic for the region and circulated between the countries. Public appreciation of the scarcity of water as a limited natural resource and of the economic value attached to the quality of water should thus lead to a more careful and rational use for competing sectors (domestic, agricultural and industrial).

4.2.4 Pollution

a. Accurate knowledge of the amount and composition of all waste streams and emission sources is essential to develop effective plans for pollution control and the protection of vital ground-water resources along the eastern coastline of the Arabian peninsula.

b. Long-term pollution control master plans must be developed together with contingency plans for industrial accidents during manufacture, transport and disposal of harmful chemicals. Oil spills are of particular importance with regard to their detrimental effects upon water quality. This is of equal concern for coastal waters used for sea-water desalinization and for ground water abstracted directly for public supply.

4.2.5 Organization and Training

a. Single water authorities are needed in most West Asian countries. As in most countries around the globe, the water sector is administered in a fragmented manner with a multitude of responsibilities for water quality. Each country should, therefore, be scrutinized with regard to its existing structure and then proposals should be made to outline the needs for water quality management and the most suitable agency to be made responsible. Specific to the region, the key aspects are:
   - legislation, policy and administrative structures;
   - ground-water quality;
   - agricultural water quality requirements;
   - drinking-water quality standards;
   - desalinated water quality;
   - domestic waste waters and their re-use;
   - industrial effluents; and
   - hazardous wastes.

   Laboratory services for water quality monitoring are basic needs. When analytical data and water quality reports are submitted to water resource management institutions, the ability to evaluate water quality and quantity issues together is essential. Such abilities have yet to be developed fully.

b. Whereas the countries of the Eastern Mediterranean sub-region already have a relatively balanced and skilled staff structure in their water administrations, there is a chronic lack of trained national personnel in the Arabian peninsula countries. Expatriates are filling this gap at present and there is a need to train staff at all levels, from treatment plant operators to programme managers. Whereas the first group should be trained on-site, the responsible senior level staff should receive specific training abroad. The problem is less a financial one, but more of motivation of junior professionals to work in the water sector. Relevant promotional efforts should be initiated by the national governments.

c. The region-specific use of different types of water resources necessitates the study of basic technical, scientific, ecological, epidemiological and economic issues related to water quality assessment and management. Topics for research and development should include:
   - epidemiology of long-term use of desalinated drinking water and the related control of mineral content;
   - epidemiology of waste-water re-use for farm workers and crop consumers;
   - appropriate treatment requirements and technology for waste-water re-use in agriculture and industry;
   - optimization of design and operation of waste stabilization ponds suitable for the region;
   - economic evaluation of alternative water resource use patterns with due consideration to treatment requirements and water quality requirements for different users;
   - water quality requirements for various agricultural applications and different crops;
   - recirculation of waters in industry and related water quality refinements;
   - ground-water recharge possibilities and related water quality needs; and
   - economic tools and tariff structures to control water consumption and to incorporate water quality into economic considerations.

5

Asia and the Pacific

Asia and the Pacific include over forty countries and dependent territories which have large differences in terms of natural and human resources. Climates range from desert to tropical rainforest between 90°N and 60°S. The water resources of the region also range between extremes - some of the largest rivers are found in Asia, but in the Pacific there are coral atolls which rely entirely on collecting rain for their water requirements. The Indian sub-continent, China and south-east Asia support some of the densest agricultural and urban populations in the world but other areas are inhabited only by a few pastoral nomads or hunters. The whole region contains over half of the world's total population. The countries vary from the poorest to the most developed industrial economies. The water quality issues for the region are similarly varied. Natural quality problems, agricultural activities resulting in eutrophication, salinization and erosion, rapidly increasing industrial pollution and large increases and movements of populations all place a considerable pressure on water resources. Management techniques are becoming more sophisticated and large-scale management plans are now in use for some of the most important water resources. For the purpose of this report the area has been divided into five sub-regions:

1. The Indian sub-continent, Iran and Afghanistan;
2. South-east Asia;
3. The Pacific Islands;
4. China and Mongolia; and
5. Japan, Australia and New Zealand.

5.1 Present Situation and Major Issues

5.1.1 The Indian Sub-continent and Adjacent Areas

This sub-region includes India, Pakistan, Nepal, Bangladesh, Sri Lanka, the Maldives, Bhutan, Myanmar (Burma), Afghanistan and Iran. Many of these countries are densely populated and most have a rainy season of three to four months between June and September. The distribution of water resources is uneven, however, ranging from desert conditions in the west (less than 200 mm rainfall each year in Pakistan) to tropical rainforest in the south and east (over 10,000 mm annual rainfall in parts of eastern India). The region has several major rivers - Ganges (Ganga), Irrawady, Brahmaputra and Indus - and an action plan has been established on the Ganges (Ganga Action Plan) with responsibility for water quality monitoring and improvement.

Various degrees of control of water quality are found in the area. Some countries have environmental protection agencies or central pollution control boards which operate national programmes of monitoring for drinking-water, surface-water and ground-water quality while others may have no environment ministry and may carry out only very limited monitoring of drinking-water quality. Many of the countries obviously have difficulties in financing and maintaining long-term and detailed monitoring networks. Although there are variations in population density, industrial development, water resources and use, similar water quality problems are faced by the countries of this sub-region.

Faecal pollution is a serious problem in Pakistan and less severe, but nevertheless important, in India, Sri Lanka, Bangladesh and Nepal. Diseases resulting from faecal pollution include hepatitis, cholera and dysentery. In Pakistan, for example, contamination of surface water by domestic waste water led to faecal coliform numbers of over 600,000/100 ml (mean values 1979–1981, GEMS (Global Environment Monitoring System) data). Surface waters in Sri Lanka and India in the same period gave values of almost 11,000/100 ml (mean values 1979–1981, GEMS data). Contamination of ground water by faecal coliforms is severe in certain areas; for example, in Sri Lanka, a mean of around 20,000/100 ml was obtained for data from 1979–1981. There is a unique situation in India when, during the religious festival of Kumbh Mela, between 1 million and 10 million people bathe in the river Ganges on the same day, resulting in high bacterial pollution (1,400–3,800/100 ml, compared with the Indian standard of 500/100 ml).

Organic pollution is directly related to faecal pollution in many cases and may be caused by run-off from open latrines, domestic waste-water discharges or industrial waste discharges. In this sub-region it is mainly due to domestic waste-water discharges. The gravity of the situation is illustrated by the 212 cities in India with a population of over 0.1 million, of which only eight have sewerage systems.

During the Water Decade, a large number of villages have been provided with sanitation facilities and the target is to serve 90 per cent of the population throughout India. The programme continues into the 1990s.

Organic pollution is severe in surface water in Sri Lanka, important in India and of less importance in Bangladesh and Pakistan. During the years 1979–1981, mean BOD (biological oxygen demand) values for various water bodies were 10 mg l^{-1} in Sri Lanka, 5.7 mg l^{-1} in India, 2.7 mg l^{-1} in Bangladesh and 2.3 mg l^{-1} in Pakistan. Ground water in Sri Lanka showed severe pollution with BOD values of 8.0 mg l^{-1}, 3.0 mg l^{-1} in Bangladesh and 2.5 mg l^{-1} in India during the same period.

Suspended solids are associated with heavy rainfall during the monsoon which causes natural soil erosion and erosion from open and agricultural lands. The problem of suspended solids is seasonal and results in rapid silting of reservoirs and creates problems in drinking-water supplies. This contamination of drinking water is important in Nepal, Pakistan and India, but is only occasionally reported in Bangladesh and Sri Lanka.

Organic micro-pollution is associated primarily with the use of pesticides and fungicides in agriculture. The problem may be significant in Pakistan, India, Sri Lanka and Bangladesh. Sophisticated equipment is needed to measure pesticide residues (GC, GLC, HPLC) and the gravity of the situation will only be known on the completion of thorough surveys of these countries which, until now, have been limited. In India, the consumption of pesticides increased fifty-fold from 1958 to 1975 and, in 1982, 55,000 t were used. Aldrin and Dieldrin concentrations of 171–862 ng l^{-1} have been found in the River Ganges (Ganga) which is many times more than the recommended WHO (World Health Organization) guideline of 30 ng l^{-1} for drinking water. In Sri Lanka, Aldrin values of 10–70 ng l^{-1} and Dieldrin values of 40–200 ng l^{-1} have been found, higher than the WHO guidelines. Present water treatment practices do not remove pesticides unless activated carbon is used and this is expensive. Much of the water consumed is not treated.

Salinization is severe in the Maldives where high abstraction of fresh ground water has depleted the freshwater lens, causing salt-water intrusion into the aquifer. In India this problem is important in coastal areas and some inland waters.

Nitrate pollution is of concern with respect to ground water. The main sources of nitrate pollution are nitrogenous fertilizers (which are carried in run-off and in irrigation return flows) and domestic waste waters. This problem is of local importance in Pakistan, India and the Maldives. In a survey of 100 wells around Nagpur in India, 70 per cent of the wells had nitrate levels far in excess of the guidelines and in some cases had above 400 mg l^{-1}. In many developing countries the

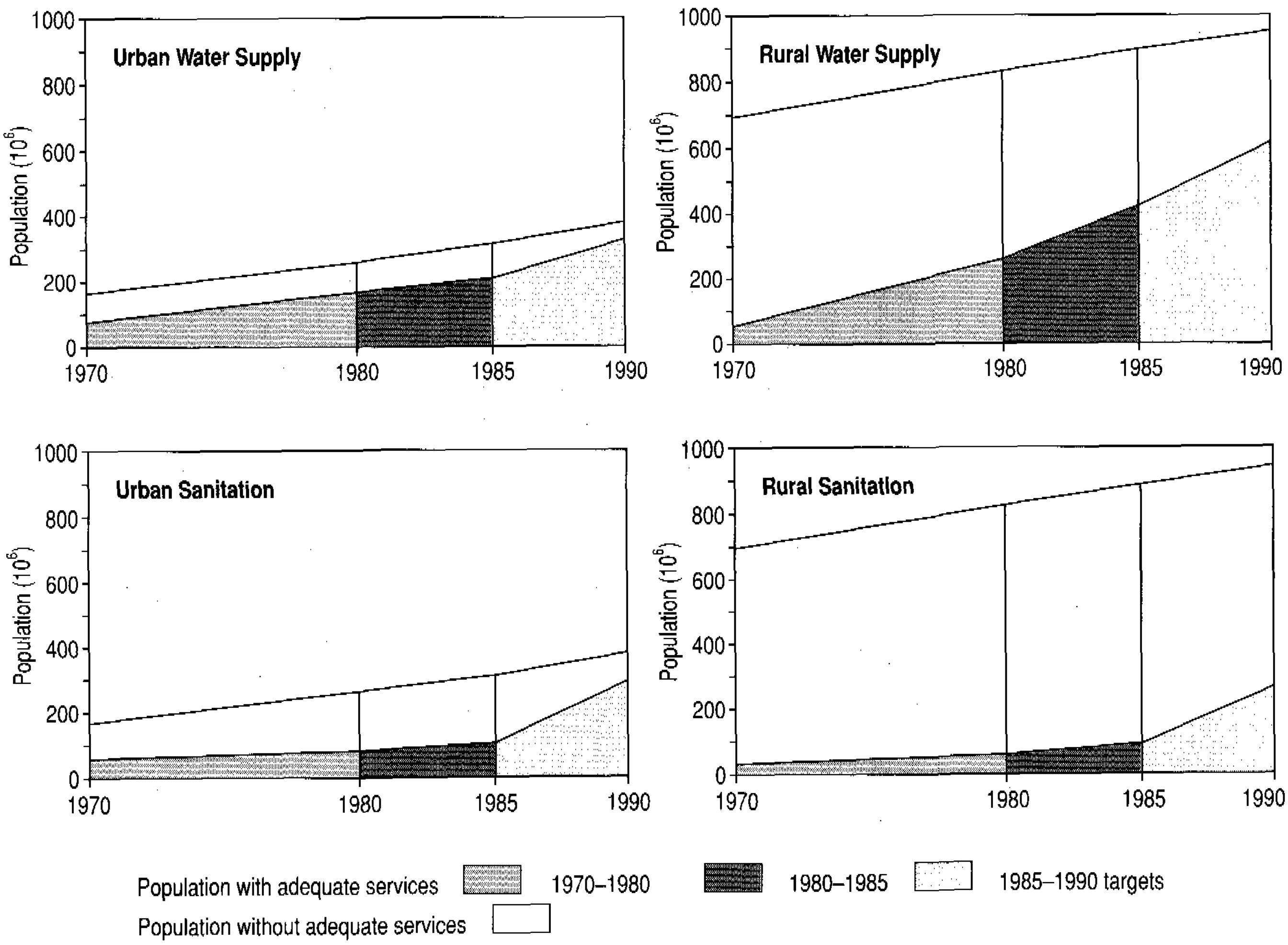
Table 5.1 Estimated per caput river flow in selected Asian river basins

River	Drainage area (10^3 km^2)	Mean annual flow (m^3 s^{-1})	Population (10^6)		Per caput river flow (m^3 a^{-1})	
			1970	2000	1970	2000
ASIA	45,000	435,000	2,047.0	3,800.0	6,550	3,550
Brahmaputra	935	20,000	51.8	110.4	11,200	5,600
Ganges	1,060	19,000	300.0	585.0	1,920	980
Indus	927	5,600	70.6	171.7	2,450	1,050
Irrawaddy	430	13,600	20.0	39.6	21,000	10,300
Mekong	803	11,000	45.6	102.2	7,500	3,300
Ob-Irtysh	2,430	12,000	32.4	42.0	11,100	8,800
Tigris-Euphrates	541	1,500	26.3	68.7	1,760	680
Yangtze	1,943	22,000	202.0	300.0	3,400	2,300
Yellow River (Huang Ho)	673	3,300	110.0	163.6	930	620

Source: Szestay, K. 1982 *Wat. Qual. Bull.* 7, 155–162.

Figure 5.1 Water supply and sanitation development in South-east Asia

Source: World Health Organization 1988 *Towards the Targets*, WHO/CWS/88.2.



adoption of low-cost sanitation in urban and rural areas has contributed to high nitrate levels, especially in ground waters. Eutrophication exists to some extent in Pakistan, India and Bangladesh.

Heavy metal pollution has not yet been adequately addressed for this sub-region. Bangladesh and Pakistan are known to be affected but few data are available. Studies conducted on the Ganges in India indicated that concentrations of heavy metals are close to WHO guidelines. On the Ganges, cadmium exceeds limits near Kanpur, where contamination is due to tanneries. On other Indian rivers assessments have not been carried out – it is probable that heavy metal contamination is a severe but localized problem in India. More investigations are needed in other countries.

High fluoride concentrations occur naturally in some Indian aquifers such as in Rajasthan, Andhara Pradesh and Tamil Nadu, where dental fluorosis occurs. No information is available from other countries.

5.1.2 South-east Asia

The south-east Asian sub-region includes Thailand, Malaysia, Laos, Viet Nam, Indonesia, North and South Korea, Papua New Guinea, the Philippines, Singapore, Brunei and Cambodia. Population density is variable ranging from large cities (Jakarta, Singapore, Manila, Bangkok) to sparsely populated rainforest. Annual rainfall is usually over 1,000 mm, in many places over 2,000 mm, and more seasonal with distance from the equator. The Mekong is the largest river and flows through China, Myanmar (Burma), Laos, Thailand, Cambodia and Viet Nam. The lower Mekong is the focus for international co-operation on water quality and pollution control.

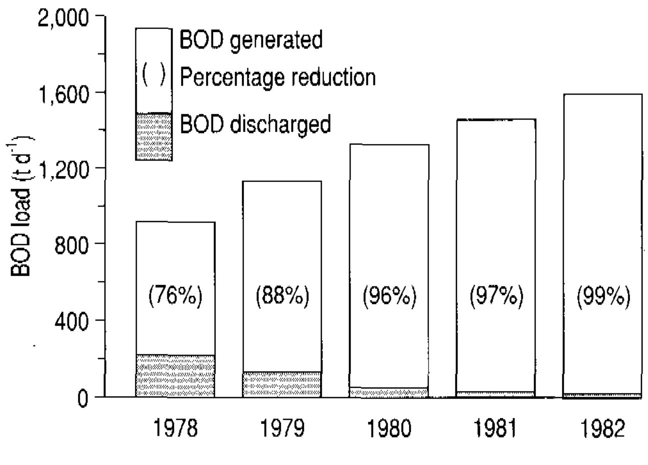
Many of the countries have been largely dependent on surface water. With increased demand for water and deterioration of water quality due to increase in population, industrialization and agriculture, the amount of clean surface water has decreased. Over the past few years, ground water has played an increasingly important role.

Organization for water quality control and monitoring is uneven, but most of these countries have basic networks for surface-water monitoring. A Malaysian National Water Quality Monitoring Programme currently includes 87 major rivers and 575 monitoring sites with 3,009 samples comprehensively analysed (1988). Monitoring of ground waters is being developed and data are regularly reported in an annual *Environmental Quality Report*.

Faecal pollution is a significant problem in Indonesia, Malaysia, the Philippines, South Korea, and Papua New Guinea and to a lesser degree in Thailand, Viet Nam and Laos. This is illustrated by faecal coliform data for selected surface-water monitoring stations (means 1979–1981): 1.67 x 10^6/100 ml in Indonesia, 11,725/100 ml in the Philippines and 9,000/100 ml in Malaysia. Total coliforms in the Kelang River in Malaysia during 1985 were reported to be 525,000/100 ml. The public health threat from this is evident from the incidence of water-borne diseases, including cholera, typhoid and hepatitis, which are still widespread due to uncontrolled discharge of sewage and night soil. There is no information for contamination of ground water by faecal coliforms.

Figure 5.2 Treatment of organic waste

Source: Modified from Singham, 1982, in Meybeck et al. 1989.



Reduction of BOD discharged into waters from the crude palm oil industry in Malaysia.

Organic pollution is locally severe in most countries. In countries such as South Korea, the Philippines, Papua New Guinea and Malaysia, significant pollution occurs through discharge of domestic and industrial waste waters. It is of less importance in Laos, Thailand and Viet Nam. The quality of selected ground waters in Sri Lanka was poor with mean BOD values of 8.0 mg l^{-1} and in Indonesia 2.0 mg l^{-1} for 1979–1981. Several rivers on the west coast of peninsular Malaysia are badly polluted by ammoniacal-N due to the heavy loadings of sewage and animal wastes. This is accentuated by the rural-urban drift which continues to place pressure on water resources and waste disposal. The urban population for 1990 was estimated as 42 per cent of the total which compares with 25 per cent in 1960. Some 69 per cent of the total BOD in certain Malaysian rivers was from sewage and 23 per cent from livestock, the remainder being from manufacturing industries (5 per cent) and from the agro-industries (oil, rubber - 2 per cent). The contribution from sewage is increasing annually but from other sectors is decreasing.

Suspended solids are of concern in Malaysia and to a lesser extent in other countries. During seasonal monsoon floods, turbidity resulting from erosion can rise to 20,000 units compared with less than 100 units at other times. In Malaysia, this problem is due to monsoon erosion and to increased erosion associated with deforestation for timber and mining.

Salinization of surface waters is severe in certain areas of Thailand from natural sources (salty halite soils in the Khorat plateau) and due to salt production techniques. In Viet Nam, river salinization occurs through salt wedge intrusion in the Mekong and the Hong Deltas. The Philippines, Laos and South Korea also report salinization to lesser degrees.

Heavy metal pollution is significant in Malaysia, Philippines and Papua New Guinea from mining activity. In the Philippines, mining tailings are dumped in the sea. In Malaysia, tin and gold mining and in Papua New Guinea gold, silver and copper mining lead to pollution. In Thailand industrial waste waters and tin mining are the sources of pollution. Mining effects in Malaysia, principally erosion and siltation, and heavy metal pollution from electroplating, semiconductor industries, rubber-based industries, and other point sources (including chemical industries) all contribute to water quality problems.

Pesticides are likely to be a contaminant in many surface waters (on the basis of use tonnages) in countries such as Indonesia (50,000 t in 1982), Malaysia, South Korea, the Philippines and Thailand. Surveys in Thailand up to 1984 showed that, from certain rivers, 15–20 per cent of samples had pesticide concentrations in excess of 150 ng l^{-1}.

Nitrate pollution exists in the ground waters in Laos, Malaysia and South Korea and to a lesser degree in Indonesia and Papua New Guinea. The problem is due to fertilizers, agricultural drainage and irrigation return flows, some industrial waste, discharges and also to low-cost sanitation practices. Some eutrophication problems were reported in the Philippines, Laos, Indonesia and Thailand.

Acidification in the Mekong Delta of Viet Nam is due to natural soil conditions. The area affected covers 1.6 x 10^6 ha, located mainly in the Plain of Reeds and Long Xuyen, the two largest flood zones in the lower Mekong Basin.

5.1.3 Pacific Islands

This sub-region contains many islands ranging from larger islands, such as Fiji and Samoa, to tiny atolls. Rivers are either few or non-existent and on many islands, sources of water are limited to ground water or rain water collected from roofs or in catchment ponds. Water quality problems are generally few. Monitoring of raw waters is carried out in only a few places where rivers are present, such as Fiji. In most islands, only basic drinking water analysis is performed.

The Marshall Islands, Fiji, Kiribati and the Federated States of Micronesia (FSM) have reported that faecal bacteria pollution from domestic waste water is the major cause of surface water pollution. Shallow wells in the FSM and ground water in Fiji, Kiribati and the Marshall Islands show faecal bacteria contamination.

Salinization is a problem in ground waters of the FSM, Kiribati and the Marshall Islands, more so in the latter two countries because of saline intrusion into aquifers caused by over-pumping.

Nitrate pollution is a problem in the ground waters of the FSM and Kiribati, arising from contamination by domestic waste water.

Suspended solids and organic pollution are a problem in some surface waters of FSM and Fiji.

5.1.4 China and Mongolia

With a territory of 9.56 x 10^6 km^2 and a population in excess of 1.1 billion, China supports more than 20 per cent of the world's population on only 6.4 per cent of the land surface area. Furthermore, 95 per cent of all Chinese live on less than 50 per cent of the land. Consequently, while population density averages over 100 persons per km^2, actual density in many areas is much greater. Per capita consumption of water is approximately 37 l d^{-1} (range 10–93 l d^{-1}).

Annual statistical yearbooks including sector statistical yearbooks are well developed in China. An *Atlas of Endemic Diseases and their Environments* and a *Drinking-Water Atlas of China*, illustrated with 221 and 86 maps respectively, detail the health and environmental conditions. Some 28,000 data points have been used to evaluate water quality. Such data are being used as a basis for improving the water quality.

Water resources and use

China embraces a wide range of climatic and biotic zones from the cold steppes of the north-east to the tropical forests of the south, and from the coastal islands to the deserts and high mountain plateaux of the west. Distribution of the total annual precipitation of 60 x 10^9 m^3 depends on climatic zone. Thirty-two per cent of the country is in the moist category, 37 per cent in semi-moist and 31 per cent is arid. Water shortages in Beijing, Tianjin, Hebei, Shanxi, north Henan, north Shandong, Jiaodong Peninsular, and south central Liaoning affect a population of 170 million. The mean annual volume per capita in these provinces is only 20 per cent of the average for the whole country.

There are 2,350 natural lakes in China of area greater than 100 ha with 130 exceeding 10,000 ha, giving a total lake area of 75,600 km^2. Of 750 x 10^9 m^3 of lake surface waters some 215 x 10^9 m^3 is fresh water. Water reservoirs add 447 x 10^9 m^3 capacity. The drainage area of rivers covers 9.5 x 10^6 km^2 with an annual flow of 2,600 x 10^9 m^3.

Drought affected about 25 x 10^6 ha with serious crop losses on 13 x 10^6 ha in 1987. This was a moderate drought year, not only producing widespread drought in North China but also in many provinces. Effectively irrigated areas throughout China have decreased from around 45 x 10^6 ha (1978) to around 44 x 10^6 ha (1987).

Floods occurred in extensive areas of China also, with 8.5 x 10^6 ha affected of which 4 x 10^6 ha were seriously affected (1987). Economic losses of 1 billion yen have been estimated.

An examination of the populations supplied from different water sources in all provinces, autonomous regions and municipalities shows that ground water supplies 72 per cent of the requirements. Shallow wells account for the major amount - 55 per cent of the total. The sanitary protection of this water is poor however, so the deep well water is recommended for improving water quality in rural areas. Of the surface waters, the most important sources are rivers, streams and canals which account for 20 per cent of supply. The Huangpu River, for example, is a water source for 60 per cent of the population of Shanghai although it is of poor quality.

Across the whole of China, grade III waters, which are unsatisfactory and unsanitary waters, supply 65–70 per cent of the population (680 million people). Only about 100 million people have access to Grade I water, the remainder have access to Grade II water.

Water supplies to 62 per cent of the population are drawn by manpower. Only 10 per cent of the population has access to completely treated tap water. Partially treated or untreated tap water is supplied to a further 11 per cent.

Within the provinces, access to community water supplies varies from 7.5 per cent for Shaanxi to 40 per cent of the population for Shanxi. In Beijing and Shanghai municipalities the numbers are 86 per cent and 66 per cent respectively. Access to completely treated tap water in Beijing and Shanghai is available to only 43 per cent and 62 per cent of people respectively.

Mongolia has about 65,000 km of rivers and over 3,500 lakes. Monitoring of water quality is conducted for 33 rivers and 3 lakes and drinking-water quality is regularly monitored both in cities and in rural areas. Several rivers and a lake are reported to be polluted by industrial effluents and domestic sewage but no detailed information is available.

Water quality issues

A number of water quality measurements are made in China. The pH of natural water in the country is commonly in the range 6.5–8.5. Only a small number have pH 6.0, mainly in Heilongjiang, Zhejiang and Fujian Provinces. Water with a pH of more than 9.0 is rare and is mainly of the deep well type in northern provinces. Surface waters in the east and middle south of the country are neutral or slightly acidic, especially where the southern part of the Yangtze River expands.

In the dry and rainy seasons the highest BODs are in surface water. In the dry season, surface water with high BOD is common in Jiangsu Province where the topography is flat and along the Yangtze River of the Sichuan Basin.

Nitrate levels are higher in the north, north-west and north-eastern regions than in other areas. In Inner Mongolia, Heilongjiang and Jilin Provinces, values of over 23 mg l^{-1} NO_3-N occur and cyanosis (blue colouring of the skin associated with methaemoglobinaemia, in which high nitrate exposure has resulted in low oxygen-carrying capacity of the blood) has been recorded, while in most southern areas values are less than 10 mg l^{-1} NO_3-N. Shallow well waters contain higher concentrations of nitrate than deep wells. Nitrate content of surface waters is almost always lower than 2 mg l^{-1} NO_3-N nation-wide.

Some water samples, particularly surface waters, are coloured due to the occurrence of algae and water weeds or high concentrations of iron and manganese. High colour is found especially in Jiangsu Province where the water table is high, rainfall abundant, population density is high and environmental pollution serious. High turbidity in surface waters occurs everywhere due to soil erosion, being especially high in the rainy season. Eutrophication of lakes and reservoirs is widespread and increasing in many of them.

Chloride in water comes mainly from geological strata and varies from region to region, especially in surface waters during the dry season. High chloride levels are mainly found in the north-west, the north-east and the Huang Huas Hai Plain, whereas values are low in the southern provinces, usually less than 100 mg l^{-1}.

In most areas of China the total coliforms in ground water are high and this is believed to be the most serious health problem for drinking water in the country. In only a few areas are the levels acceptable and most of these are found in urban areas. Less contaminated sites are in the north-east and Xingiang where the population is sparse and the climate is cold.

Typical of many rapidly industrializing countries, pollution episodes and continuous pollution have been reported from various industries. Mercury pollution of the Songhua Jiang and Ji Yun rivers has been recorded. This pollution affects water, sediments and fish and is caused by effluents from chloralkali industries.

Mines and smelters, especially those producing copper, zinc and lead, have also produced effects on communities and the environment, either directly from metal effects or from erosion of mine tailings. Arsenic from smelting emissions has also been reported to give rise to effects in some areas.

Acidification is a problem of increasing concern, particularly in the south-west, and arises predominantly from acid rain from coal combustion and metal smelting activities. Hydrochemical data indicate that streams are not yet acidified, although data in mountainous areas are sparse. Although emissions of sulphur dioxide are high in the north, effects of the alkaline airborne dust from the Loess plateau have reduced acidification problems. Particularly acid-sensitive soils have been identified – acid soils are mainly oxisols with low buffering capacity. Acid drainage from mine tailings occurs in some areas, but no comprehensive study has been undertaken.

Pesticide use and animal wastes are also issues where research has shown that particular problems exist in some provinces. Monitoring of DDT, HCH and other pesticides is carried out at a number of river and lake sites.

Geological considerations

With wide geological variation and many soil types across the country, relationships are well characterized between endemic diseases and constituents of water and local foods. Three such diseases are fluorosis, goitre and arsenicism.

First recorded in the Jin Dynasty (223–262 AD), endemic fluorosis affects people in all provinces, autonomous regions and municipalities except Shanghai. It arises principally from the drinking of high fluoride waters, although exposure via other routes such as crops, high fluoride teas and high fluoride coal smoke can be significant in some areas. The disease is prevalent on the plateaux and in mountainous districts, plains and coastal areas and urban and rural areas, affecting over 125,000 villages. Based on population surveys, some 37.5 million people are considered to suffer from dental fluorosis and 1.7 million from skeletal fluorosis. The total exposed population is approximately 86 million.

Fluorosis is particularly serious in Shaanxi, Inner Mongolia, Shanxi, Henan, Shandong, Hebei, Heilongjiang, Liaoning, Jilin and Tianjin. In these regions collectively it accounts for approximately 80 per cent of cases of dental fluorosis and 90 per cent of cases of skeletal fluorosis in the whole of China. In Henan Province the incidence of dental fluorosis is very high, affecting 89 per cent of the population, while in Jilin Province, skeletal fluorosis is very high at 6.5 per cent. Over the whole country, morbidity from dental fluorosis is 43 per cent and 2 per cent for skeletal fluorosis. Endemic fluorosis also occurs in the hot springs areas of China - Gangdong, Fujian, Hubei, Jiangxi and Yunnan Provinces.

The concentration of fluoride in river waters and in well water in southern China is low, around 0.6–0.8 mg l^{-1}, but is higher in well water in northern China, typically around 2–4 mg l^{-1} with values of over 30 mg l^{-1} being recorded. The water quality standard in China is 1 mg l^{-1}.

Endemic goitre is a serious disease caused by deficiency or excess of iodine in the diet and in drinking water. In China 20 million people are affected and there are almost 1 million cretins. This can be compared with the global figures of 190 million and 3.25 million respectively. Water is one of the sources of iodine, accounting for up to 20 per cent of the intake, with food accounting for the remainder. The disease is commonly seen in all provinces, autonomous regions and municipalities except Shanghai. The incidence of the disease is highest in mountainous areas, high on hilly areas, low on the plains and lowest on the coast. An affected proportion of the population of 14 per cent for Xinjiang has been recorded and up to 19 per cent in Xizang (Tibet).

Iodine content of drinking water has been examined over the whole country with areas classified in six scales from 5 g l^{-1} to 50 g l^{-1}.

The prevalence of endemic goitre is correlated with the iodine content of the drinking water, the correlation being especially high with concentrations of iodine in deep ground water of 6 g l^{-1}. High iodine goitre caused by drinking high iodine-content deep ground water has been recorded, for example, in Shandong Province.

Relatively small areas of arsenicism are recorded in China, giving rise to the typical hyperkeratosis of the palms and soles of the feet together with hyperpigmentation and skin tumours. In certain villages in Xinjiang Province 46 per cent of the population was affected by arsenicism from drinking deep well water, the incidence increasing with age. Mean arsenic concentrations reached 0.75 mg l^{-1} in the most seriously affected areas. In other villages in the same province where some 50,000 people were affected by exposure over a 10-year period to an arsenic concentration of 0.12 mg l^{-1}, mild arsenic poisoning was reported. A dose-response relationship has been recorded from studies examining many wells of different arsenic concentrations.

Nature reserves

There are about 7 x 10^6 ha of low production land affected by waterlogging and some 24 x 10^6 ha liable to waterlogging. The country has more than 25 x 10^6 ha of what are defined as wetlands, including about 11 x 10^6 ha of marshes and bogs. Approximately 80 per cent (20 x 10^6 ha) of the wetlands are fresh water. Some 5–7 x 10^6 ha of saline-alkaline soils have been recorded.

The major threats to China's wetlands, with their great diversity of animal and plant life, have been identified as siltation, reclamation for agriculture, drainage for disease control, conversion to fish ponds and pollution. Progress has been made in nature conservation in such areas and almost 200 sites have been detailed in inventories. Around one-third of these are included within national or provincial nature reserves.

5.1.5 Australia, New Zealand and Japan

Water resources and use

Australia and New Zealand

Australia, with a land area of 7.7 x 10^6 km^2 and a population of 16.7 million is sparsely populated except for coastal developments. Eighty-five per cent of the population live in cities, towns and areas abutting the coast. Per capita withdrawal of water averages some 3,600 l d^{-1}. New Zealand is a relatively small country of 0.27 x 10^6 km^2 with a population of 3.34 million of whom some 74 per cent live in the North Island. Eighty-four per cent of the people are urban dwellers. Per capita consumption of water averages some 1,000 l d^{-1}.

Reasonably detailed statistical data for environmental and other variables are reported in annual yearbooks and perspectives on water resources needed by the year 2000 have been published. There is still a scarcity of data on some aspects of water quality and protection of aquatic species and habitats.

Australia stretches over 30° of latitude and it covers many climatic zones from alpine to tropical. Over 75 per cent of the land surface area of Australia is classified as dryland, which are areas of deficient and uncertain rainfall where the growing season is limited through lack of moisture and where drought poses major land management problems. Serious droughts are reported periodically, for example, 1979-1983. New Zealand is in the temperate latitudes from 34°S to 47°S and is surrounded by vast oceans, making the climate maritime-temperate. There is frequent rain, with the rainfall controlled by geographical features and maritime conditions. The mean annual rainfall in the North Island varies between 1,200 to 1,800 mm, while overall it ranges from less than 400 mm in Central Otago to 12,000 mm in the Southern Alps.

Run-off from mainland Australia accounts for 390×10^9 m^3 and ground water accounts for 38.94×10^9 m^3. The annual run-off is only approximately 20 per cent of the value for Europe which is similar in terms of area; this is because of low mean rainfall and high loss through evaporation and transpiration. Freshwater resources are limited compared with other continents and this has led to extensive programmes to regulate supplies by construction of dams, reservoirs, large tanks and other storages. Some 80 dams of gross reservoir capacity exceeding 100×10^6 m^3 have been built. The availability of water resources controls, to a large degree, the possibility and density of settlement, which in turn influences the quality of water through production and disposal of wastes. Ground water accounts for 14 per cent of water used in Australia. In the Northern Territories 47 of the 50 largest communities use ground water for their main supplies. Ground water as shallow aquifers occurs beneath some 25 per cent of the continent but has a high ratio of sodium to calcium and magnesium ions. Deep aquifers within sedimentary basins underlie around 65 per cent of Australia but the water quality is poor.

Central sewage systems are in place in the major cities and towns, serving almost 100 per cent of their populations. In Sydney, ocean outfalls of primary-treated sewage effluent have given rise to health and environmental concerns (such problems should ease by 1992 when the deep-water outfall at North Head Station at Malabar and Bondi becomes fully operational).

With frequent rain, the freshwater resources of New Zealand are adequate for the present population. Dams for hydroelectric power generation serve a dual role. Eighty-seven per cent of water is supplied by the public water supply and more than two-thirds of the population is served by waste-water treatment plants. Central sewage systems are in place in all cities and towns.

The annual sectoral withdrawal of water in Australia is 65 per cent : 2 per cent : 33 per cent for domestic/industrial/agricultural respectively which can be compared with 46 per cent : 10 per cent : 44 per cent for New Zealand.

Japan

The situation of Japan is similar in many ways to that of western Europe, both in terms of water resources and use and in terms of water quality problems. Japan has a population of over 100 million, over 75 per cent of which is found in cities. There is a highly developed industrial sector and much intensive agriculture, both of which influence water quality in parallel to domestic activities. 70 per cent of drinking water is taken from surface waters, the remainder from ground-water wells.

Monitoring of water quality is good, with an extensive network of stations measuring a range of physical and chemical variables. Monitoring is carried out by the regional authorities and is co-ordinated by the national Environment Agency. A network of automatic monitoring stations is being established on water bodies of special importance and high quality (122 stations in 1985). Chemical measurements cover a wide range of metals and organic compounds and biotic monitoring has been of importance for some time. Ground water is monitored for a range of substances, including solvents such as tetrachloroethylene and 1,1,1-trichloroethane.

Water quality issues

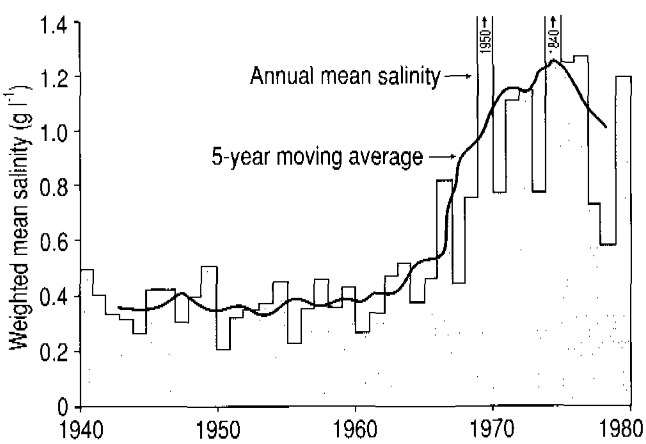
Australia and New Zealand

The quality of Australian surface waters varies greatly and is influenced by climate, geology, stream flow rates, biological activity and land use. Salinization is a major problem affecting significant areas of Australia. The problem in surface waters is regional, of high severity and considered to be increasing. In ground waters salinization is now of national importance, of moderate severity and believed to be increasing. The total area of salt-affected land, both natural and as a result of human activities, is 32.4×10^6 ha or 4.3 per cent of Australia. Scalding, or the removal of topsoil to expose the naturally saline subsoil, has affected 3.8×10^6 ha, mostly in arid areas.

Some local and regional water quality issues affect New Zealand. The relatively high rainfall in some hilly areas contributes to erosion. High sediment loads from major rivers of the western Southern Alps, South Island have been reported. For example, in the Hokitikma catchment with an annual rainfall of 9.4 m, some 17,000 t km^{-2} a^{-1} of material are eroded, giving it one of the highest erosion rates on a global basis. Volcanic

Figure 5.3 Salinity of Kent River, Western Australia

Source: Williams, W. D. 1987 *Ambio* **16**,180–185.



activity and hydrothermal activity affect water quality locally and generally in the Central Plateau of the North Island of New Zealand. Sulphates and especially arsenates occur locally at concentrations with potential health risks. Likewise, mercury and other heavy metals from geothermal and some hot and cold springs can be bioaccumulated in aquatic organisms. Such areas are identified and problems minimized.

Microbial contamination of Australian surface waters is a national problem of high severity and of increasing importance. Other water problems in this category include turbidity, nutrient inputs and consequential algal growth. For example, over a five-year period, total phosphorus and orthophosphate in the River Murray have almost doubled. Run-off from agricultural lands and urban run-off, especially phosphate fertilizers, contribute to the major problems of eutrophication. As New Zealand has an extensive grass-fed agricultural industry, fertilizer applications are high, amounting to over 1,000 kg ha^{-1} a^{-1} on arable land which can be compared with 25 kg ha^{-1} a^{-1} in Australia, 102 kg ha^{-1} a^{-1} in Malaysia and 163 kg ha^{-1} a^{-1} in China (1981–1983). Of these, 1.1×10^6 t are of phosphate fertilizers. Rural run-off and urban sewage treatment effluents contribute to the problems of eutrophication in large lakes. The management of ground waters and their protection from contamination is of increasing concern for regional authorities, particularly in the South Island.

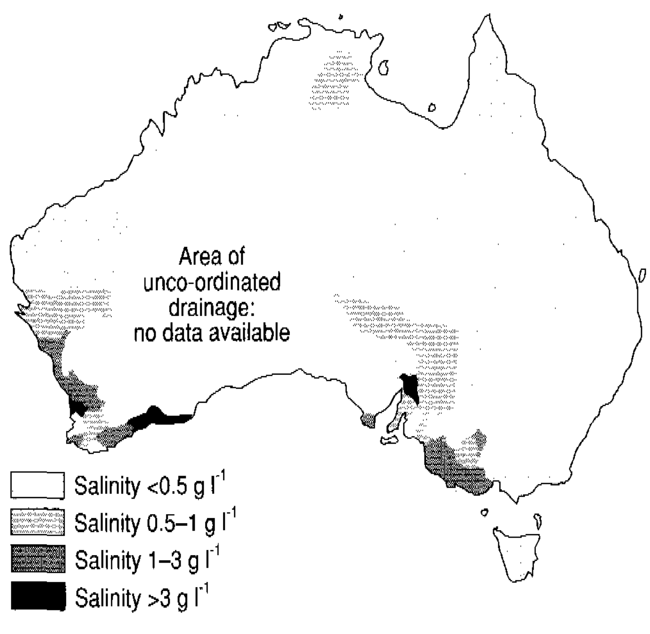
The use of pesticides in Australian intensive cropping contributes significantly to levels of toxic materials in waters. Pesticide levels in a number of reservoirs, rivers and lagoons have been reported, along with fish kills, but a direct causal relationship is not always observed. Heavy metal problems and pesticide pollution are diminishing. Acid mine effluents are still reported, particularly in Tasmania.

Industrial wastes in New Zealand, particularly from pulp and paper processing, have been reported to affect water quality locally, especially in earlier years, while logging still leads to erosion and high sediment loads in rivers. Pesticide pollution has been reported in localized areas but data are scarce.

Nitrates in ground waters are of regional concern and low severity, but are increasing. Soluble iron and organics in surface waters, as well as taints, are important during low river flow.

Figure 5.4 Salinity of major rivers in Australia

Source: Williams, W. D. 1987 *Ambio* **16**, 180–185.



Australia is one of the driest continents, and its few wetlands are therefore of great importance. Over 1,300 wetlands are recognized, some 29 of which are wetlands of international importance comprising 3.3×10^6 ha. In Victoria, for example, which has a wetlands conservation policy, 0.5×10^6 ha of wetland have been identified, comprising 3 per cent of the total land surface of the state. In New Zealand, 12 national parks covering more than 2×10^6 ha, 21 forest parks covering 1.7×10^6 ha and 4,000 reserves have been gazetted. Two wetlands of international importance covering 15,000 ha have been preserved. Hence, over 10 per cent of the national land area is protected. Numerous rivers have created extensive freshwater wetlands although many have now been drained to increase land area for agriculture. Extensive wetlands still exist in the west of the South Island.

Table 5.2 Summary of water quality issues in Asia and the Pacific

Quality issues	Indian sub-continent	South-east Asia	Pacific Islands	China	Japan, Australia and New Zealand
Pathogenic agents	1–3	1–2	2–3	1–3	0–1
Organic matter	1–3	0–2	0–1	1–3	0–1
Salinization	0–1	0–1	0–3	0–2	0–2
Nitrate	0–1	0–1	1–2	0–2	0–1
Fluoride	0–1	0	0	0–2	0
Eutrophication	0–1	0–3	0	0–2	0–1
Heavy metals	0–1	0–2	0–1	0–2	0–2
Pesticides	0–1	0–1	0–1	0–1	0–1
Industrial organics	ND	ND	ND	ND	ND
Sediment load	0–2	0–2	0–1	0–3	0–1
Acidification	0	0–1	0	0–1	0–1
Thermal discharges	ND	ND	ND	ND	ND
Radioactivity	ND	ND	ND	ND	ND

0 No pollution or irrelevant.
1 Some pollution, water can be used if appropriate measures are taken.
2 Major pollution.
3 Severe pollution affecting basic water uses.

ND No data obtained.

Japan

In Japan, high organic loads are a serious water quality problem in urban areas, arising from discharge of domestic and industrial wastes. Sewerage networks and sewage treatment are not always adequate to meet the needs of increasing populations and several model projects for improvements are under way in various cities. Disposal of sewage sludge is receiving increasing attention. Eutrophication is also associated with organic pollution in Japan and problems are arising in various inland waters and in enclosed sea areas caused by domestic, agricultural and fisheries waste. However, controls of phosphate and nitrate discharges are being enforced and programmes to protect vulnerable water bodies are in progress. High technology in water treatment means that most unwanted substances can be removed before supply.

As in Europe, high priority is given in Japan to the control of metals, industrial organic chemicals and pesticides in water. Great efforts are being made to control such substances as mercury, cadmium and PCBs in water and in food fish through environmental quality standards (EQS) and improvement programmes for degraded waters (sediment oxidation or removal of contaminated sediment). Greater emphasis is now being placed on transboundary pollution and on the influence of freshwater inputs on marine water quality.

5.1.6 Regional Summary

Asia and the Pacific is an area of great contrasts. It contains some of the world's largest rivers – the Ganges (Ganga), Brahmaputra, Chang Jiang (Yangtze Kiang), Ob and Yenisey. Some areas are deserts, such as Rajasthan, Sinkiang, Iran and Australia, while others in the equatorial and tropical monsoon belt have very high rainfall. Population density and industrial development vary enormously. Human impacts upon water quality in certain areas are far smaller than natural influences which limit water use. High salinity in desert ground and surface waters (Tibet, Iran) and from salt outcrops (Thailand), high fluoride (Rajasthan and China) and low iodine or selenium (China) and high flood turbidities and volcanic influences such as arsenic or radioactivity all influence water quality and thus limit suitability for certain uses.

Monitoring is extensive in many countries and could be said to be among the best in the developing world.

Water quality in this region is closely related to natural problems, state of development and population density – the most pressing problems are found in India, Indonesia and China where very high population densities and patchy availability of suitably high quality water are of concern.

As for the USSR in Europe, little relevant information is available for Asian Siberia.

The major water quality issues for this region presented in more detail in the synoptic table are:

1. Faecal pollution and organic pollution;
2. Industrial pollution – concentrated in certain areas;
3. Pesticides – high and uncontrolled use, few data;
4. Natural water problems – not preventing use but affecting health;
5. Eutrophication; and
6. Salt-water intrusion in the Pacific islands.

5.2 Regional Recommendations

a. Protection of potable water resources from faecal contamination and nitrate level increases is needed – this requires sewage collection and treatment, both in rural and urban areas, to prevent uncontrolled contamination.

b. Upgrading and extension of existing water supply and sewage collection and treatment in large cities is needed to deal with expanding populations and to reduce pressure on existing facilities.

c. Control programmes for suspended solids content of surface water will have the combined effect of reducing erosion and improving water quality. Water basin management should be introduced to combine land use control with water quality management. Tight control of deforestation is an essential part of such management.

d. To combat salinization of water resources, deforestation control on saline soils will control the problem to some extent in certain areas. Saline intrusion of ground waters must be controlled by careful analysis of ground-water resources and subsequent controls on abstraction through licensing or economic tools.

e. Nitrate in ground water and surface waters originates from domestic waste and fertilizers. Domestic waste control is described above. Fertilizer contributions to nitrate levels can be limited by controlling sales and by developing and encouraging good agricultural practice specifically adapted to local conditions and farming techniques.

f. Acidification of surface waters through industrial emissions in the Philippines and China can only be controlled by reducing emissions of sulphur and nitrogen oxides.

g. High fluoride and iodine should be reduced in drinking water by blending with water with lower concentrations – this requires both organization of water supply and transport of waters which may be impractical in some countries. Low-cost methods of reduction are essential and must be investigated.

h. Industrial discharges must be subjected to suitable effluent or receiving-water standards and to effective enforcement. Reviews of industrial processes should be regularly carried out with respect to their influence on water quality and options for control.

i. Monitoring networks exist in many areas, with good data produced. There must, however, be an inclusion of monitoring for heavy metals and pesticides. Monitoring networks should be established for surface and ground waters in those countries currently only measuring for drinking-water quality.

j. Management of water resources requires that considerations of both quantity and quality be incorporated at all levels, from policy-making to user needs. This is doubly essential in a region with such a wide variation in spatial and seasonal availability of water. Recycling of water in dry areas after suitable treatment, control of land use and adaptation of use patterns to flow variations should all be developed in this region.

k. Requirements for Environmental Impact Assessments (EIAs) should be fully integrated with existing structures for water management and quality control.

l. Source inventories for rivers should be developed as an aid to pollution control. Inventories for the Ganges and the Mekong exist but should be developed for rivers such as the Brahmaputra, the Chang Jiang and the Amur.

m. The legal framework for environmental management must be developed further in many countries as an essential forerunner of national regulation of

water quality within integrated environmental protection. The expansion should contain at least the following four elements:
- comprehensive laws for water quality and water management including aspects on EIA, dam projects and irrigation;
- mechanisms for establishing regulations and enforcement;
- transboundary agreements for distribution and quality control of water resources; and
- conservation of natural resources.

n. Rationalization of responsible agencies for water quantity and quality is essential in many countries. Current lack of co-ordination is an impediment to effective management and monitoring. The use of basin authorities for quality control, supply, treatment and with influence on land use and planning may provide a good means of concentrating resources.

o. Conservation of natural resources should receive increased attention in the region. The value of wetlands and mangroves in maintenance of water quality is recognized to some degree but this is not yet reflected in integrated policies for conservation and environmental protection. Major world rivers should be recognized as global resources and therefore requiring protection.

p. Education and training should be upgraded, although human resources are already good. This should include:
- training of engineers and scientists for environmental management;
- training of treatment plant operators; and
- public awareness through manuals, publicity and other media should be promoted and information adapted to local culture and literacy levels.

q. A variety of areas need research and development work but the following are priorities:
- applied research on urban water pollution, low-cost treatment and storm water controls;
- low-cost eutrophication controls by biological means;
- epidemiology of health problems linked to natural chemistry, low-cost fluoride treatment;
- re-use and recycling techniques, especially in dry regions; and
- good agricultural practice to control pesticide and nitrate pollution.

6

Europe

Europe contains over 25 countries with topographical features ranging from small islands to continental plains and high mountains. Environments are diverse and range from arctic tundra to Mediterranean scrub. The region is characterized by high population densities, industry and agriculture, and some areas have relatively advanced provisions for water quality monitoring and management. Information on water quality is difficult to obtain for some areas of Europe. Water quality and availability in Europe are generally adequate but there are several areas of concern.

6.1 Present Situation and Major Issues

6.1.1 Water Resources and Use

Water resources vary widely in distribution across Europe. North-western Europe has high rainfall but most of the Mediterranean countries have problems of water availability, especially in coastal areas where there are population concentrations and low rainfall. While much of Europe receives adequate rainfall for its needs, local problems in supply occur because of high population densities. Europe is characterized by a high degree of industrial activity and intensive agriculture in many areas.

Abstraction and use of water in northern Europe are relatively stable or falling slightly with decreasing per capita use. The use of ground water as a percentage of total use is stable or rising slowly. Population increase is slow.

In eastern Europe, increases in use are projected for a variety of reasons such as increased irrigation in Romania and Bulgaria or increased industrial use in Hungary. Population increase rates are relatively slow.

Southern Europe also has projected increases in use with an increasingly high degree of utilization of total ground-water resources (by the year 2000; Greece 98 per cent, Portugal 70 per cent and Turkey 78 per cent).

Ground water generally constitutes a higher proportion of drinking water than it does of other sectoral uses and in several countries most drinking water is obtained from ground water (e.g., France 64 per cent and West Germany 75 per cent).

6.1.2 Water Quality Monitoring

Monitoring of water quality is widespread in Europe for the most basic of parameters (BOD_5, dissolved oxygen) but there is a considerable difference in theory and operation of monitoring strategies on a European scale. This ranges from the integrated monitoring programmes in Scandinavian countries, through detailed quality monitoring in some EC (European Community) countries, to less sophisticated approaches where a few fixed parameters are measured at a large number of sites. Finland is establishing integrated monitoring in certain limited areas - "simultaneous physical, chemical and biological monitoring of the environment of a particular area". In Europe a wide variety of different organizational structures on national and more local scales result in a diversity of monitoring strategies with little uniformity in analytical methods, statistical approaches or interpretation. Attempts to co-ordinate monitoring between individual countries and on a regional basis are developing and in some cases have made good progress, for example, through the Rhine Commission.

6.1.3 Water Quality Issues

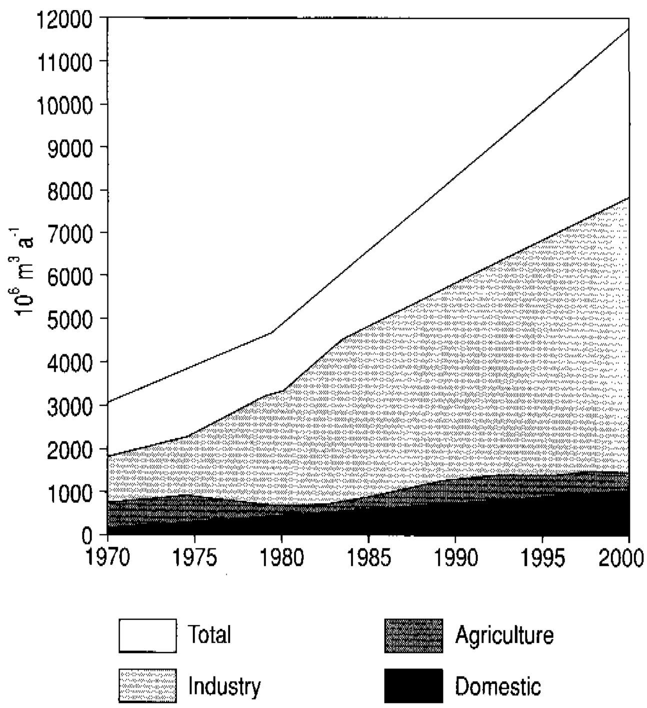
Nitrates in ground and surface water are considered to be a major problem in Europe because of possible health risks (the World Health Organization recommended limit is 10 mg l^{-1} NO_3-N). The main sources of nitrate are agricultural fertilisers and effluent discharges of treated and untreated sewage. Concentrations in both surface and ground waters are rising.

Strategies of control have been developed in some countries but nitrates from fertilizers are very difficult to control because of widespread diffuse use. Little systematic analysis of the level of nitrates in ground water in parts of Eastern Europe appears to have taken place.

Acidification of surface waters has occurred in many countries in Europe, mostly on a fairly local scale where

Figure 6.1 Water use in Hungary

Sources: Hungary Central Office for Statistics (in *State of the Hungarian Environment, 1990*).
ECE 1989 *Water use and water-pollution control: Trends, policies, prospects,* ECE/ENVWA/10, Economic Commission for Europe, Geneva.



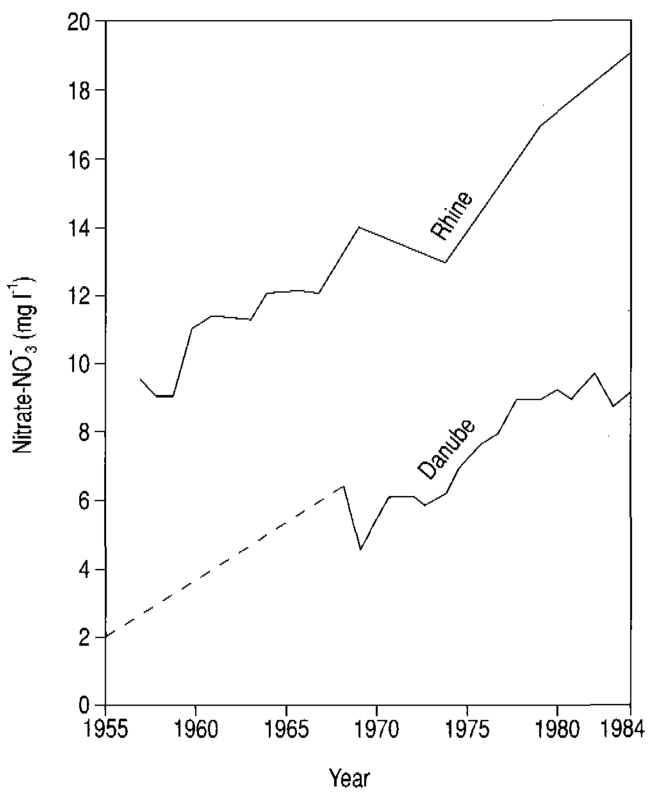
soils are vulnerable to acidification but it is a widespread water quality problem in Norway, Sweden and West Germany. Depletion of fish stocks has been observed. Application of lime to lakes and rivers has been used with some success to increase pH.

Organic enrichment and eutrophication are widespread problems in Europe as a whole. The primary effects of the high BOD (biological oxygen demand) which results from organic enrichment are increased risk of deoxygenation of the water (causing fish deaths), release of sediment-bound metals to the water column and production of toxic hydrogen sulphide. Eutrophication is often associated with high phosphate levels which encourage algal growth, and this in turn may lead to a fall in water quality. Organic enrichment in Europe is caused by the discharge of sewage effluents and some industrial wastes, either untreated or treated. Eutrophication is associated with organic enrichment but is also caused by the leaching of phosphate fertilizers from agricultural land. Both organic enrichment and eutrophication are caused by the discharge of animal manure directly to water or leaching of manure nutrients from land where it has been spread as a fertilizer. Many European rivers and lakes are vulnerable to these effects (Lake Balaton, Lake Maggiore and others where control programmes have been implemented). Some controls on agricultural practice, sewage treatment and phosphate use (for example in detergents in Switzerland) have led to improvements in certain areas (Sweden, Denmark, Germany, Austria and Switzerland).

Heavy metals in water in Europe have been a matter for concern for some time and there are indications that stringent controls in western Europe have led to declines in concentrations in water. Controls consist of strict limits for discharge and recovery of metals from effluents. However, considerable effort is being made to reduce levels further and the European Community is attempting to eliminate all pollution by mercury and cadmium and to reduce that of several other metals. Industrial organic chemicals are also of great concern because of their presence in surface, ground and drinking waters and possible toxicity and carcinogenicity. Monitoring is far from universal and there is little indication of the extent of contamination in Eastern Europe.

Figure 6.2 Nitrates in rivers

Source: State of the Hungarian Environment, 1990.



Annual mean nitrate concentrations in the Danube and Rhine.

Figure 6.3 Surface-water acidification in the Netherlands

Source: After Leuven et al. 1986, in WHO/UNEP 1989.

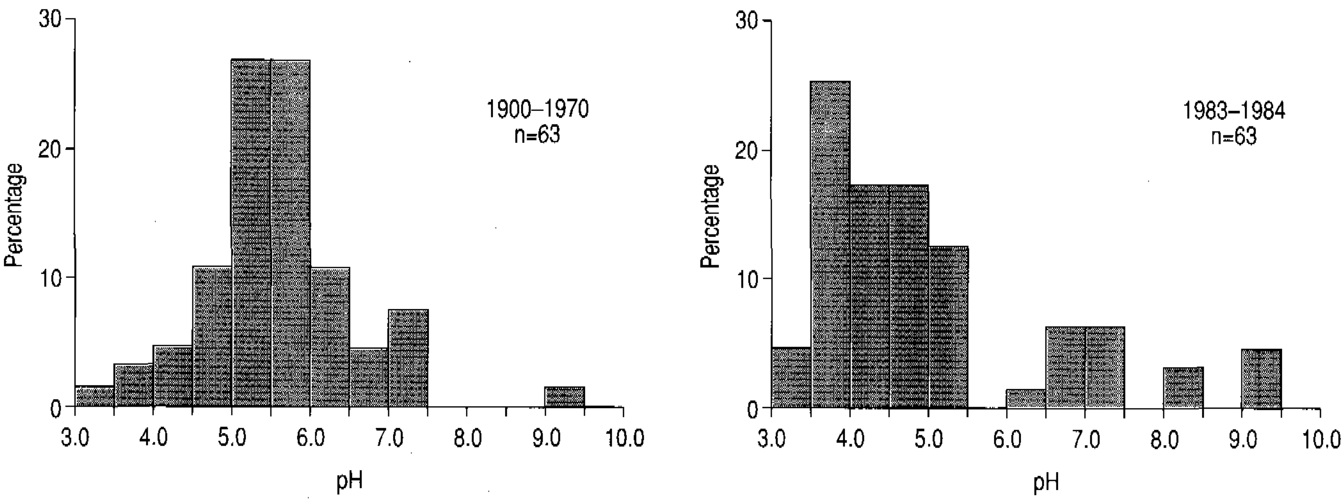
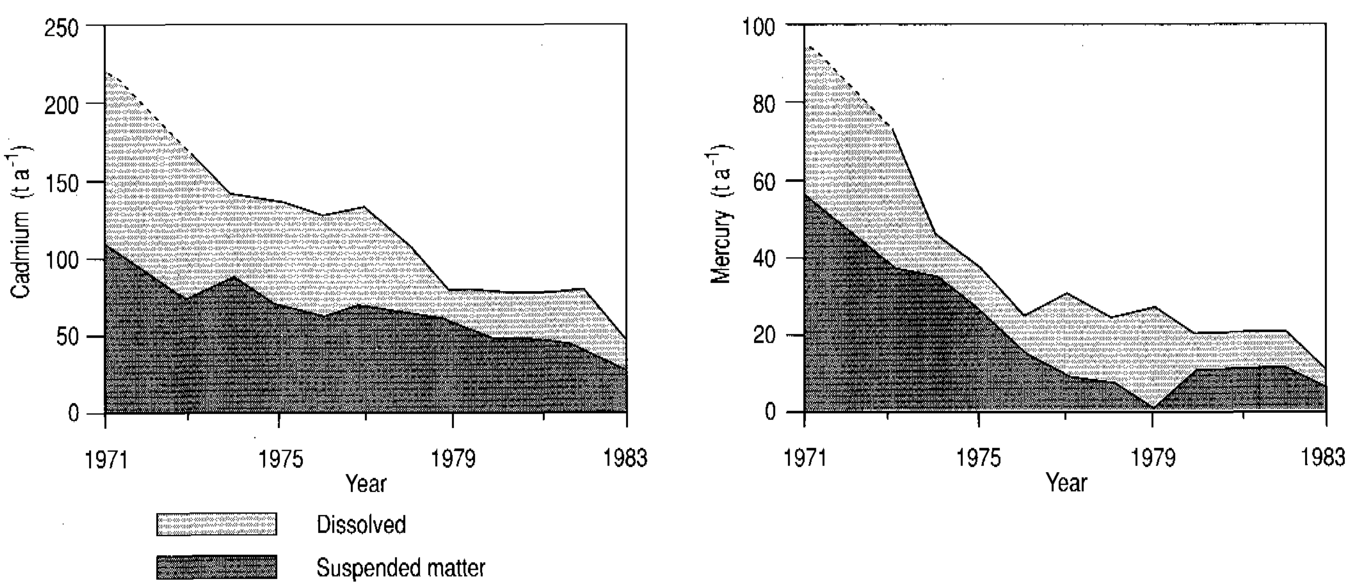


Figure 6.4 Mercury and cadmium in the Rhine

Source: After Malle 1985, in WHO/UNEP 1989.



Samples taken at the border between the Netherlands and the Federal Republic of Germany.

In the EC and in other western European countries, priority selection procedures are used to identify the most hazardous substances (metals, industrial chemicals and pesticides) and to control release or use. This procedure, however, is not yet operating smoothly. There is an increasing emphasis on good planning, monitoring and management for waste dumps in order to limit potential leakage of hazardous substances.

Pesticides are also a significant and widespread contaminant in Europe and, although in general concentrations are not high enough to hinder water use (although treatment may be needed), western European countries take precautionary approaches to control, as they do for industrial organics. This means that although proof of exposure and environmental adverse effects may not be conclusive, control is imposed on the basis of scientific assessment of likely levels and effects. Monitoring of pesticides (e.g., lindane) is spreading but is by no means universal. Control of pesticide levels is a particular problem because of their diffuse sources.

Saline intrusion into coastal aquifers is a problem in countries such as Spain where reliance on ground water is combined with high densities of coastal population.

Irrigation may have a significant impact on water quality for two main reasons – it can transport fertilizers and pesticides to watercourses and abstraction for irrigation may reduce the flow and assimilative capacity of the river from which water is taken. There are not abundant data for this sort of problem, but it is known that the Aral sea has been particularly affected by high abstraction from its feeding rivers.

An increasing influence on policy for water quality in western Europe is the influence of river water quality and its control upon marine water quality in enclosed seas. Extensive international co-operation is now taking place on the North and Baltic Seas to reduce riverine inputs of nutrients and dangerous chemicals through better controls on sewage treatment, fertilizer and pesticide use and chemical discharge. Eutrophication of the Baltic, the Wadden Sea and parts of the Mediterranean is serious and can lead to deoxygenation and ecosystem damage. The North Sea Conference has agreed to reduce inputs (to rivers and the sea) of substances which are toxic, bioaccumulative and persistent through the use of treatment, point source control and the use of precautionary approaches to diffuse source pollutants.

Table 6.1 Summary of water quality issues in Europe

Pollution type	Nordic countries	Western Europe	Eastern Europe	Southern Europe
Pathogenic agents	0–1	0–1	1–2	1–2
Organic matter	1	1–2	2	2
Salinization	0	0–1	ND	1
Nitrate	1	1–3	1–2	1–2
Fluoride	0	0	0	0
Eutrophication	0–1	1–2	1–2	1–2
Heavy metals	0–1	0–2	0–2	0–2
Pesticides	0–1	2	2	1–2
Industrial organics	0–1	0–2	ND	ND
Sediment load	0–1[a]	0–1	1	1–2
Acidification	0–3	0–1	0–1	0
Thermal discharges	0–1	0–2	0–2	ND
Radioactivity	0	1	ND	ND

(a) Iceland.

ND No data obtained.

0 No pollution or irrelevant.
1 Some pollution, water can be used if appropriate measures are taken.
2 Major pollution.
3 Severe pollution affecting basic water uses.

Groups

Nordic countries:	Western countries:	Eastern countries:	Southern countries:
Finland	Austria	Bulgaria	Albania
(Greenland)	Belgium	Czechoslovakia	Cyprus
Iceland	Denmark	East Germany	Greece
Norway	France	Hungary	Italy
Sweden	Ireland	Poland	Malta
	Luxembourg	Romania	Portugal
	Netherlands	USSR	Spain
	Switzerland		Turkey
	United Kingdom		Yugoslavia
	West Germany		

6.1.4 Regional Summary

The summary and table indicate that water quality in Europe is relatively good. It is worth emphasizing that there are areas of concern - acidification, nitrates, toxic substances and eutrophication. Adequate control methods exist for some of these problems but are not always used to the best effect. There is increasing pressure in Europe to adopt precautionary and anticipatory approaches to environmental quality. There is not much epidemiological evidence for adverse effects in or via the aquatic environment for many pesticides or industrial synthetic compounds, but control is frequently exercised on the basis of scientific prediction - precautionary approaches.

One of the basic concepts for water quality management is that both water quality and availability must be integral to long-term planning and the implementation of policy. This does not only mean that the likely effects of policy on water quality must be predicted, but that water quality should be a central element in the inception and development of plans and policy.

This has led to ideas of sustainable use and development which emphasize that water resources are not infinite. Plans for development should be made on the basis of finite quantity with a consequently limited assimilative capacity for wastes. It is important that quantity and quality are seen to be linked - high abstraction from a water body will reduce its capacity to dilute and assimilate effluents without adverse effect. This connection is central to existing water management techniques in Europe but has only recently begun to have any influence on long-term planning. In practical terms this is leading to an emphasis on an ecological basis for the analysis and management of water quality and planning for water use.

The Economic Commission for Europe (ECE) has proposed a declaration of policy on the Rational Use of Water. This sets down ideas and policies to promote rational co-ordination of water uses within environmental and economic frameworks. The declaration emphasizes unified management strategies for water abstraction, use, discharge and quality together with priority for drinking-water requirements and environmental protection. It is suggested that this should be done in parallel with economic planning and using economic instruments for management. Integrated land use and water management planning is essential, where possible using the river basin as the basic unit for planning and management. Good data and analysis of trends are critical to rational approaches to use and quality. Again, these concepts are used in some areas of Europe to a greater or a lesser degree.

Other trends in Europe are towards the use of precautionary approaches to the control of hazardous substances (control on the basis of predicted effects and exposure) and the use of economic tools for water quantity and quality management (fees for abstraction and discharge, the "Polluter Pays" approach).

6.2 Regional Recommendations

6.2.1 Monitoring and Assessment

a. As emphasis increases upon the quality of water with reference to the environment (in addition to human uses), there is a greater need to produce a unified conceptual framework for physico-chemical and ecological aspects of monitoring.

b. Networks for quality monitoring exist in many European countries but there is an urgent need for a rigorous scientific assessment of conceptual and operational aspects of monitoring on a regional scale to ensure effectiveness and comparability of monitoring and data. This should be done through existing regional organizations and could be based on the ECE proposals for standard water use classification and standard water quality classification. The assessment should be made on a country-by-country basis and should include the following points:
   - justification of the existing network and range of parameters analysed in terms of water use and quality influences (this would require source inventories and assessment of diffuse inputs);
   - description, justification and degree of validation of methods of analysis;
   - assessment and justification of statistical methods;
   - degree of validation and open publication of data;
   - recommendations for scientific regional monitoring of water quality and use;
   - comparative analysis of various methods of *in situ* and laboratory biological monitoring; and
   - monitoring of radioisotope levels in parallel with routine monitoring.

6.2.2 Ground-water Protection and Use

a. The use and protection of ground water should be co-ordinated with that of surface water. The ECE has produced a *Charter for Ground Water Management* which outlines in general terms the requirements in Europe as follows:

- specific legal provision for ground-water use;
- economic instruments for management; fees and penalties; and
- planning controls for abstraction, land use and disposal of wastes.

b. More specific requirements for control of nitrate, pesticide and industrial contamination in ground waters are:
   - establishment of ground-water protection zones where land use, agricultural and industrial activities are controlled;
   - specific guidelines on good agricultural practice in the application of fertilizers and pesticides, cropping practices, drainage methods and stock densities to be developed in co-operation with farmers;
   - guidelines on the application of manure to soil, requirements for storage and options for removal of manure from exposed aquifers;
   - planning for spillage containment and removal in the event of pesticide or industrial chemical accidents; and
   - enforceable regulations for the design and management of waste disposal sites, environmental assessments for the use of landfill or mines for hazardous waste disposal or storage.

6.2.3 Eutrophication and Organic Loads

The recommendations with respect to nitrate input to surface waters and the contribution of animal manure to eutrophication and high organic loads are essentially the same as for ground-water protection - good agricultural practice and planning for land use. There is increasing demand for the use of fines for agricultural accidents but a preventative approach should take precedence. The recommendations for domestic and industrial organic waste treatment are:

- treatment of all wastes where lack of treatment is leading to environmental damage;
- upgrading methods of treatment to be consistent with quality objectives;
- regular reviews of efficiency of existing treatment plants;
- no overloading of capacity of existing plants - parallel planning for sewage treatment with demographic change;
- discharges consistent with assimilative capacity of receiving waters;
- diversion of effluents of high BOD from vulnerable waters; and
- controls on the sale and use of products containing phosphates which are likely to enter waterbodies via surface run-off or effluents.

In addition, the problem of oxygen depletion from high BOD may be linked to high abstraction and consequently lower flow - this emphasizes the need for joint planning for water use and quality.

6.2.4 Acidification

There are two well-publicized options for the reduction of artificial acidification of surface waters - reduction of emissions of nitrogen and sulphur oxides or liming of affected water. Both are expensive and liming is only a temporary solution.

6.2.5 Hazardous Substances

Although the precautionary approach described above is used, there is a pressing need for a more systematic approach towards the control of heavy metals, pesticides and industrial synthetic substances which can be agreed between governments as the basis for control. This must include:

- agreed priority selection procedures for identifying substances with most urgent need for control;
- agreement on key parameters and test systems which accurately reflect exposure and effects to both humans and the environment; and
- expansion of verified data bases for environmental and chemical data.

Point source directories are required in several countries to enable monitoring and control to be carried out more effectively. Technologies for the removal of dangerous substances are becoming more widespread but governments should devise economic incentives for their use. There is a general need for the development of methods of analysis for many substances and their use in monitoring. Assessment of the validity and effectiveness of the precautionary approach must ultimately be based upon the observed adverse effects caused by substances known to be present in the environment. There is continued difficulty in finding unified strategies for the definition and control of pollutants from both diffuse sources and point sources.

6.2.6 Saline Intrusion

This may become an increasing problem in countries with a high use of coastal aquifers. Good prediction of use and accurate mapping and assessment of ground-water resources are needed, together with good general planning policies for affected regions.

6.2.7 Marine Inputs from Rivers

Identification and control of pollution of the Baltic and North Seas from rivers has been a priority in northern Europe for several years, with progress being made in some areas. There is a need for far more basic information on the dynamics of enclosed southern European seas and on human impact via rivers, especially with regard to the Black and Mediterranean Seas. The Aral and Caspian Seas are of increasing concern and here little detailed information is available.

6.2.8 Co-operation on Transboundary Waters

The ECE is currently giving a high priority to co-operation on transboundary waters on issues of quality and availability, laying stress on the need for a unified approach to transboundary waters and the value of harmonization of policies and practice of different transboundary commissions. This is an issue with a wider application than to Europe alone. It is proposed that co-operation should take place for protection of ecosystems, the prevention of transboundary water pollution and the harmonized use of water resources through various policies:

- detailed co-operation on planning for quality and quantity, including the setting of joint water quality objectives and criteria;
- operational management;
- selection of priority pollutants;
- compatible monitoring methodology and networks, including early detection and warning systems;
- agreement of analytical methodology;
- harmonized data collection and assessment;
- agreed measures for the reduction of pollution and the emergency control and treatment of accidental spillages;
- joint land use planning;
- exchange and dissemination of information; and
- public involvement in quality control.

6.2.9 Regional Co-operation

a. In addition to progress being made on transboundary co-operation for pollution control, there should be greater emphasis on the transfer of pollution control strategies and technology between countries in Europe. Institutional arrangements already exist which have varying degrees of success in certain regions. Another area in which contact is apparently lacking is between the Economic Commissions for UN regions – the ECE produces information on the classification and measurement of water quality but there seems to be no formal contact with other regions.

b. In conclusion, it must be said that many of these approaches are used in some parts of Europe but by no means the majority. Even where international co-operation is common there are remaining problems in making joint approaches to water quality, for example, the continuing controversies over quality standards and quality objectives in western Europe. In general terms, the greatest need for water quality in Europe is the adoption of a common basis for the assessment and control of water quality through the agreement of common conceptual and practical approaches.

7

Global Synopsis of Water Quality Issues

The impacts of human activities on freshwater quality are numerous and have existed for a long time. Industrial development, the advent of intensive agriculture, the exponential development of human populations and the production and use of tens of thousands of synthetic chemicals are among the main causes of water quality deterioration from local to global scales. Eleven major issues of water quality are considered on a global scale in this section. The basic information used in this evaluation is derived from the preceding regional reports and from the relevant chapters of *Global Freshwater Quality: A First Assessment* (WHO/UNEP, 1989, Basil Blackwell). Direct information is scarce for many countries, either because of a lack of proper monitoring activities or because of difficulties in obtaining existing information, and therefore this section cannot claim to be comprehensive. However, well-documented geographical areas are often representative of water quality issues for a larger region.

The 11 issues cannot all be considered to be of equal importance. Some concern human health alone, others the aquatic environment, some are important for various uses of fresh waters, others for pollutant fluxes to oceans. These aspects are summed up in Tables 7.1 and 7.2. Two major issues which are not treated in this report are radioactivity in fresh waters and thermal pollution.

Table 7.1 Limitations of water use owing to water quality degradation

	Water use						
Pollutant type	Drinking water	Aquatic wildlife & fisheries	Recreation	Agriculture (including irrigation)	Industrial uses	Power & cooling	Transport
Pathogens	+	0	+	+	++[a]	00	00
Suspended solids	+	+	+	+	+	+[b]	++[c]
Organic matter	+	+	+	0[d]	++[e]	+[f]	00
Algae	+[f]	+[g]	+	0[d]	++[e]	+[f]	+[h]
Nitrates	+	+	00	0[d]	++[a]	00	00
Salts	+	+	00	+	++[i]	00	00
Metals	+	+	+	+	+	00	00
Industrial organics	+	+	+	+	0	00	00
Acidification	+	+	+	0	+	+	00

++ Marked impairment requiring major treatment or precluding this use.
\+ Minor impairment.
0 No known impairment.
00 Irrelevant.

(a) Food industries.
(b) Abrasion.
(c) Sediment settling in channels.
(d) Water quality changed in this way may be beneficial for this specific use.
(e) Electronic industries.
(f) Filter clogging.
(g) In fish ponds higher algal blooms can be accepted.
(h) Development of water hyacinth (*Eichhornia crassipes*).
(i) Iron and manganese in textile industries, etc.

Table 7.2 General characteristics of major water quality issues on a global scale

Quality issue	Water bodies mostly concerned	Major problem area	Time-lag between causes and effects	Space scale of issue[(a)]
Pathogenic agents	++ rivers + lakes + ground waters	++ health	<1 year	local
Organic pollution	++ rivers + lakes + ground waters	++ aquatic environment	<1 year	local
Salinization[(b)]	++ ground waters + rivers	++ most uses + aquatic environment + health	1–10 years	regional
Nitrate pollution	++ ground waters + rivers	+ health	>10 years	regional
Heavy metals	all water bodies	+ health + aquatic environment + ocean fluxes	<1 to >10 years	local to global
Pesticides and industrial organics	all water bodies	+ health + aquatic environment + ocean fluxes	1–10 years	local to global
Acidification[(a)]	++ rivers, lakes + ground waters	+ aquatic environment + health	>10 years	regional
Eutrophication[(c)]	++ lakes + rivers	++ aquatic environment + most uses + ocean fluxes	>10 years	local
Sediment load[(d)]	+ rivers	+ aquatic environment + most uses + ocean fluxes	1–10 years	regional
Hydrological modifications[(e)]	++ rivers + lakes ++ ground waters	++ aquatic environment + most uses	1–10 years	regional

++ Very *important* issue on a global scale.
\+ Important issue on a global scale.

(a) Including atmospheric transport of pollutants.
(b) Including high fluoride or arsenic contents.
(c) Including *river nutrient* loads.
(d) Increase or decrease of loads.
(e) Water diversion, damming and over-pumping of aquifers.

7.1 Pathogenic Agents

Freshwater bodies polluted by faecal discharge from man and other animals may transport a variety of human pathogens (pathogenic bacteria, viruses, protozoa, and multi-cellular organisms). Among the most common water-borne bacterial pathogens are *Shigella, Salmonella, Campylobacter, Escherichia coli, Vibrio, Yersinia,* and to a lesser extent *Mycobacterium, Pasteurella, Leptospira* and *Legionella.* Faecal contamination is generally detected by bacterial counts of *E. coli* or of faecal or total coliforms which are widespread tests performed in many freshwater bodies of the world (almost 60 per cent of GEMS/WATER stations performed counts for total or faecal coliforms in 1985–1987).

Faecal contamination of fresh waters does not have an even geographical distribution. It is usually associated with the most densely populated regions of the world where domestic wastes and waters contaminated by cattle excreta are not yet adequately treated, for example, in the Indian subcontinent, China and south-east Asia. In less densely populated regions of Africa or South America, for example, high contamination may be found either in surface water or in ground water and is associated with direct contamination of wells or surface water intakes by human waste. Coliform counts reach maxima in rivers (with values exceeding 100,000 per 100 ml in Central American and Indian rivers) and minima in ground waters and reservoirs.

If the rates of population increase and development of waste-water collection and effective treatment are compared, it seems likely that despite major improvements noted in North America and Western Europe, the problem of bacterial pollution will become more severe in the next decade in developing countries. This is particularly so in the megacities where severe outbreaks of infectious diseases seem likely to occur in future years (for example, the recent outbreak of hepatitis in Shanghai).

7.2 Organic Pollution

Organic pollution in this context means the release of organic wastes which, when acted upon by micro-organisms, lower the oxygen level of the receiving water body. Organic pollution is closely associated with bacterial pollution - both arising from the release of insufficiently treated domestic wastes. This pollution is mainly of concern in the aquatic environment where many organisms, for example fish, require high oxygen levels. A serious side affect of water anoxia is the release of toxic or undesirable substances (such as hydrogen sulphide, ammonia, iron and manganese and other heavy metals) from particulates and sediments in rivers, lakes and ground waters.

Table 7.3 Statistical distribution of oxygen balance indicators in GEMS/WATER rivers 1979–1984

	5%	10%	50%	90%	95%
BOD (mg l^{-1})	1.3	1.6	3.0	6.5	9.0
COD (mg l^{-1})	4.0	6.0	18.0	44.0	60.0
	95%	90%	50%	10%	5%
Oxygen saturation %	110	105	90	70	55
				← significant organic pollution →	

Figures give values below which a corresponding percentages of samples fall.

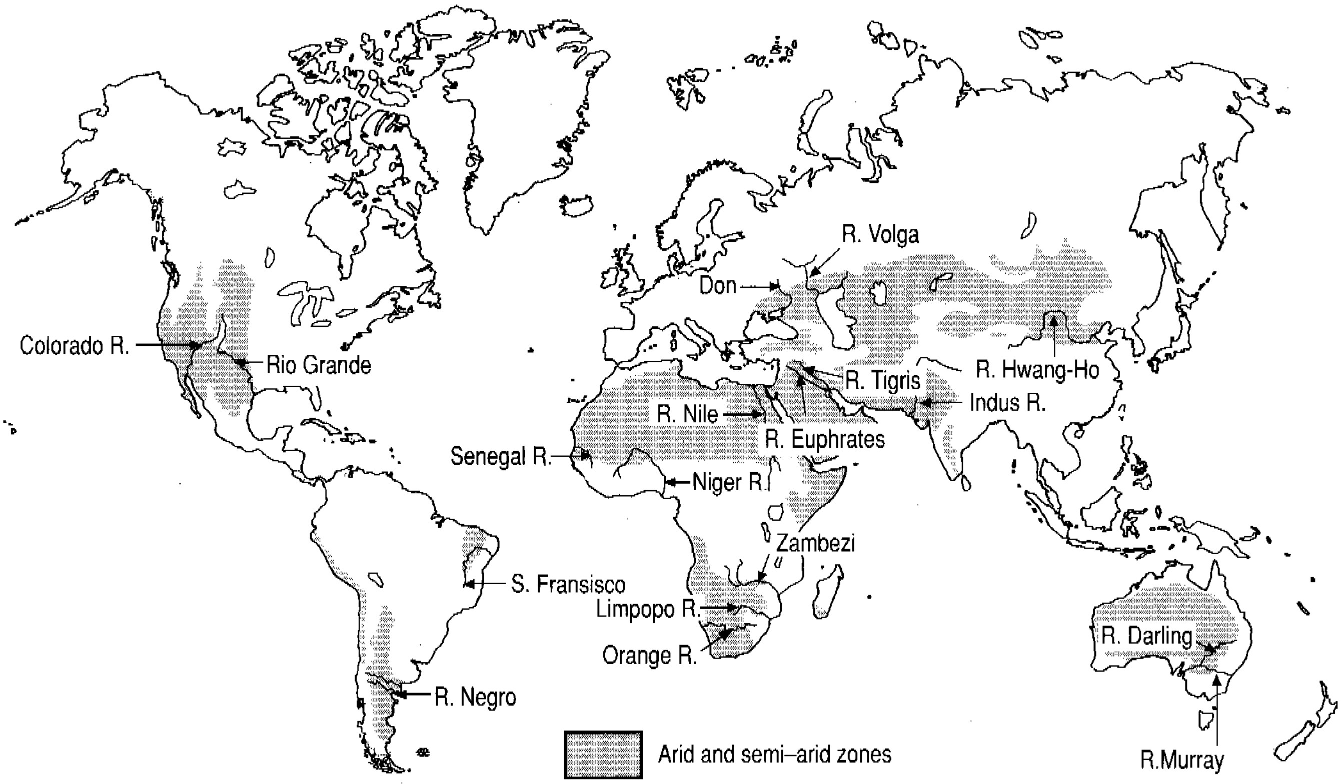
Due to their good self-purification capabilities, rivers are seldom anoxic except for short stretches. Most major rivers of the world have sufficiently high oxygen levels to support a healthy aquatic environment (see Table 7.3). However in small rivers receiving wastes from large populations in Malaysia, Turkey, India, Belgium, Mexico, Equador, Guatemala and other countries, dissolved oxygen values of less than 30 per cent saturation have been found.

For faecal contamination, the development of domestic waste treatment in the last 30 years in most OECD (Organisation for Economic Co-operation and Development) countries has led to a marked decrease of biological oxygen demand levels (BOD) in rivers. In developing countries, particularly those developing most rapidly, organic pollution cannot be tackled properly until organized programmes are in place, such as the Ganga Action Plan in India. In Central and South America only 5 per cent of municipal waste waters are at present collected efficiently and treated adequately.

7.3 Salinization

The problems caused by inorganic ions in water may arise either from the overall ionic content of the water

Figure 7.1 Arid and semi-arid zones
Source: Williams, W. D. 1987 *Ambio* **16**, 180–185.



or from specific ions, such as fluoride, sodium or chloride, which may impair use for drinking water for humans and cattle, irrigation and even industry. More rarely, low levels of certain ions such as iodine in water and food may lead to deficiency and cause severe health problems.

High salinity of water may arise from natural evaporation as, for example, in many countries in the belts of acid rocks from Morocco to Rajasthan and from Chile to Australia (see Figure 7.1). In these places salinization may be enhanced greatly by the continually increasing use of water for irrigation which allows rapid surface evaporation. These trends have been noted in some of the world's major rivers (such as the Colorado, Rio Grande, Murray, Amu-Dar'ya and Syr-Dar'ya) where total salt content has reached levels at which most uses are impaired, including for some agricultural purposes.

In coastal aquifers, which are now exploited all over the world, excessive extraction of fresh water has commonly led to intrusion of salt water into the freshwater zone.

Mining activities, particularly salt, potash, and iron mines as well as ore fields, release brines which contain high concentrations of ions (such as sodium, chlorine and sulphate) into aquatic environments. Several European rivers, such as the Rhine, the Elbe, and the Vistula, have been seriously affected by these activities for decades.

Naturally high salinity (mainly in the form of sulphate- and chloride-rich waters) due to peculiar local geochemistry is observed in regions as diverse as Thailand, north-west Canada, Chile and Turkey. Specific problems from high fluoride content in ground waters (commonly exceeding 5 mg l^{-1}) are also found over wide areas of Africa (such as Senegal and Tanzania) and Asia (Rajasthan). Severe dental and skeletal fluorosis is observed in exposed populations. In China alone 30 million people are suffering from dental fluorosis and 2 million from skeletal fluorosis. High natural arsenic levels are also reported in China. Deficiencies of iodine in Chinese waters are reported to cause widespread cretinism and goitre.

Increasing areas are being irrigated in dry tropical countries where 80 per cent of the 270 x 10^6 ha irrigated world-wide are found. Irrigation may lead to salinization in two ways – evaporation of irrigation water leads to higher concentrations of existing ions which then are returned to rivers or allowed to seep to ground water.

High evaporation may lead to salt deposition on the soil surface or high irrigation may cause the water table to rise - if the ground water is naturally saline, the soil will be adversely affected. High evaporation from the surface of waterlogged soil after water table rise from irrigation can lead to concentration of ions and high salinity in surface soil layers. Salinization of fresh waters will therefore be one of the primary water quality problems in the next decade. It is estimated that 20-30 x 10^6 ha of irrigated land are already seriously affected by soil and water salinization, 16 x 10^6 ha in the Indian subcontinent alone.

7.4 Nitrate Pollution

Nitrate pollution of aquifers has two different origins; first, fertilizers and second, human and cattle wastes in rural areas. Contamination from fertilizers is the most common - an exponential increase in use of nitrogen fertilizers is occurring in most countries. This increase started in the 1960s in Western Europe and North America and has now reached countries such as India and Brazil. In some places, fertilizers as the primary nitrate source are supplemented by untreated domestic wastes. Nitrate contamination of ground water was first noted in the early 1970s and its primarily agricultural origin demonstrated by nitrogen isotopic studies. In general, it first affects shallow ground water then, within 10 to 20 years, deep aquifers and rivers.

Nitrate levels exceeding the WHO (World Health Organization) guideline value (10 mg NO_3-N l^{-1}) are now widely found in European and in some North American aquifers. High nitrate concentrations may

Table 7.4 Statistical distribution of nitrate - nitrogen in world river waters

	5%	10%	50%	90%	95%
Asia and Oceania	0.02	0.04	0.35	2.01	4.00
N. and C. America		0.05	0.30	1.3	
S. America		0.10	0.20	0.50	
Africa			0.25		
Europe		0.25	4.50	14.00	20.00

WHO guideline: 10 mg NO_3-N l^{-1}.
Figures give nitrate nitrogen (mg NO_3-N l^{-1}) below which corresponding percentages of samples fall.

reduce the oxygen-carrying capacity of blood with adverse health effects in infants. This type of pollution can affect extensive aquifers - causing major problems in drinking-water availability for certain areas. Preventative measures, such as reducing fertilizer use or changing agricultural practices, are only effective after long periods, probably at least 10 years. It is therefore likely that nitrate pollution from fertilizers will be one of the most pressing water quality problems in Europe and some regions of North America in the coming decade and will start to be a serious problem in other countries during the next century.

Severe nitrate pollution of up to 100 mg NO_3 l^{-1} is found in certain African and Asian wells. This problem is of a totally different nature to those of Europe because it is caused by direct infiltration of human and cattle excreta into shallow aquifers. This type of pollution has not yet been adequately studied because its health effects have been overshadowed by the effects of faecal contamination. Even if dramatic improvements in excreta disposal take place, this problem will remain very severe in these regions.

Within the GEMS/WATER network (see Table 7.4), European rivers are the most severely affected by nitrate pollution from fertilizers.

7.5 Eutrophication

Eutrophication is the enhancement of the natural process of algal production in rivers, lakes and reservoirs, caused by increases in levels of nutrients, usually phosphates but sometimes nitrates. It results in visible algal blooms, floating plant mats and benthic macrophyte aggregations. These will die and decay and can thus lead to the depletion of dissolved oxygen in the water which in turn can lead to secondary problems: fish mortality from lack of oxygen and liberation of toxic substances which were previously bound to oxidised sediments. Eutrophication was first observed in many Western European and North American lakes and reservoirs in the 1950s and spread rapidly. It now also affects slow flowing rivers, particularly if they have extended low-flow periods during the dry season. It causes major deterioration of the aquatic environment and serious problems for water use, particularly in drinking-water treatment.

Eutrophication is widespread in all continents and is one of the best documented water quality issues (see Table 7.5). In rivers, as in lakes and reservoirs, eutrophication is marked by a very high phytoplanktonic biomass. The oxygen depletion associated with the eventual decay of this high biomass is often found

Table 7.5 Selected eutrophic lakes and reservoirs

AFRICA	
L. Chad	Kariba Reservoir
L. Victoria	L. George
L. Mariout	Hartbeespoort Reservoir
CENTRAL AMERICA	
L. Cajititlan	L. San Roque Reservoir
L. Amatitlan	L. Titicaca
L. Valencia	Poza Honde Reservoir
L. Paranoa	
NORTH AMERICA	
L. Simcoe	L. Washington
L. Erie	L. Mendota
L. Ontario	L. Tahoe
	L. Memephremagog
ASIA	
L. Kasimigaura	Dong Hu
L. Biwa	Xi Hu
L. Suva	Xuanwu Hu
Laguna de Bay	Mochou Hu
L. Songkhla	Mogu Hu
EUROPE	
Mjosa	L. Constance
Vattern	L. Leman
Malaren	L. Zurich
L. Paajarvi	L. Baldegg
L. Esrom	L. Sampach
Lough Neagh	L. Hallwil
L. Plon	L. Lugano
Lac de Nantua	L. Como
L. Ladoga	L. Iseo
L. Balaton	Wahnbach Reservoir
OCEANIA	
L. Burley Griffin	

downstream in the estuary and has been documented in many European rivers.

Unless drastic efforts are made to reduce inputs of phosphates from point and diffuse sources (such as phosphate stripping in waste-water treatment or banning phosphate detergents), eutrophication is likely to be an important issue in the control of water quality. It must be emphasized that if proper action is taken, successful restoration of eutrophic lakes is possible, as in Lake Erie. However, the response time of the ecosystem generally exceeds the water residence time in lakes (which commonly varies from one to 100 years). Preventative action is therefore the best course if long-term impairment of ecosystem quality and water use is to be avoided.

7.6 Heavy Metals

Contamination of water bodies with heavy metals (cadmium, mercury, lead, zinc, chromium, copper, nickel and cobalt, etc.) and arsenic is widespread in all industrialized regions and in mining areas, sometimes located in regions with very low population (e.g., northern Canada, Papua New Guinea, Siberia, Zaire and South America). This type of pollution is best assessed through the analysis of sediments and suspended solids. Affinity for particulate matter means that the bulk of low-solubility metals released by human activity (including cadmium, lead and mercury) is associated with soils, landfills, mine tailings etc., and only a minor fraction has yet been leached into water bodies, as Figure 7.2 demonstrates.

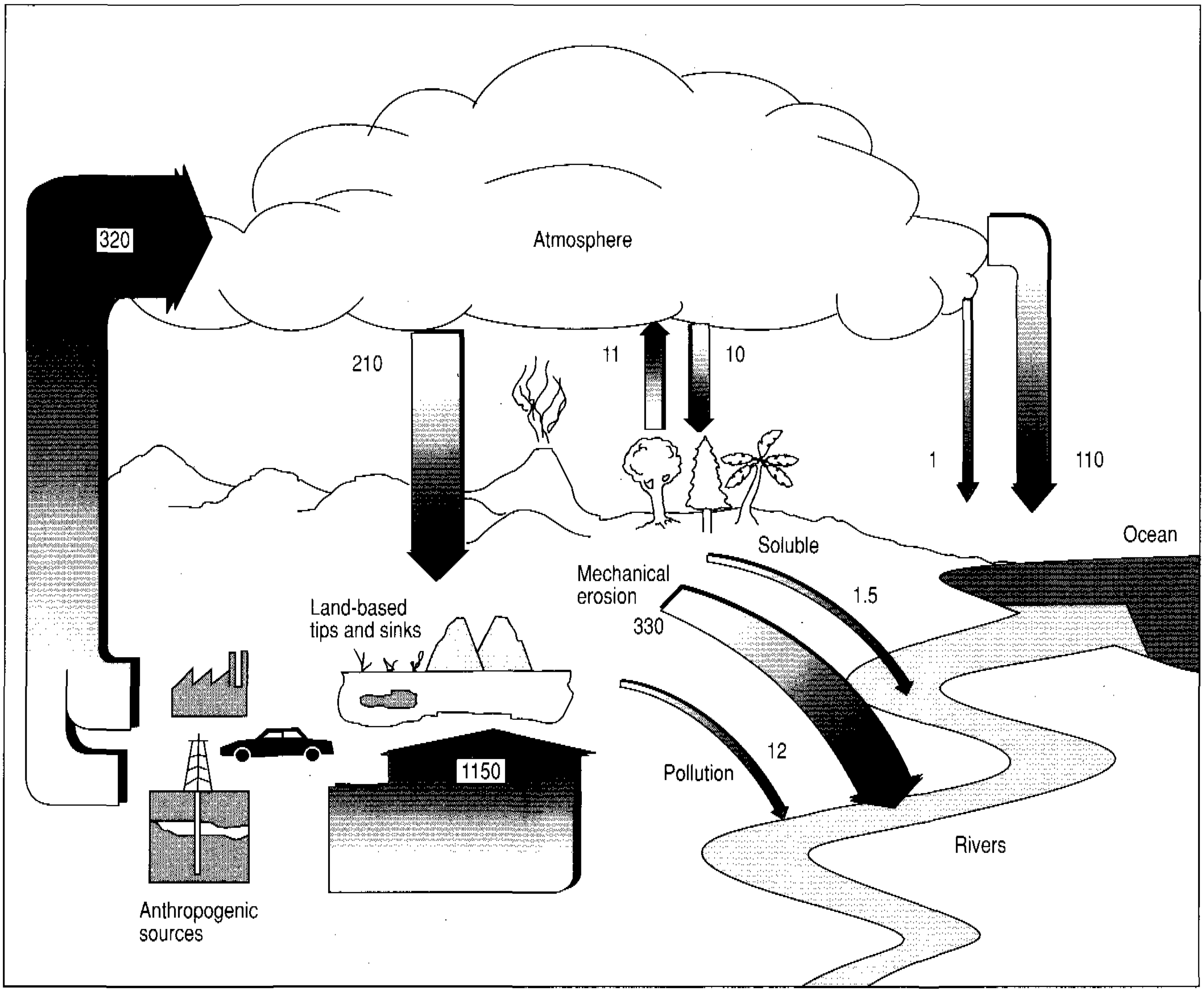
Heavy metal pollution will probably extend over long periods even if appropriate measures to cut direct (sewage outfalls) or indirect (atmospheric releases of industrial and vehicle origin) inputs are taken. Leaks from forgotten and unsafe landfills and leaching from tailings will continue, enhanced by rain acidification which increases metal mobility from particulates. However, falling trends in metal pollution resulting from appropriate control measures have been observed in rivers such as the Rhine and the Mississippi (for lead) and give grounds for some optimism.

7.7 Pesticides

The exponential increase in the use of pesticides for the last three decades is now affecting some of the larger fast-developing countries such as Brazil or India. New

Figure 7.2 Simplified lead cycle

Source: Meybeck, M. 1990 *La Recherche* **21**, 608–617.



Figures are annual global fluxes of lead in 10^3 t.

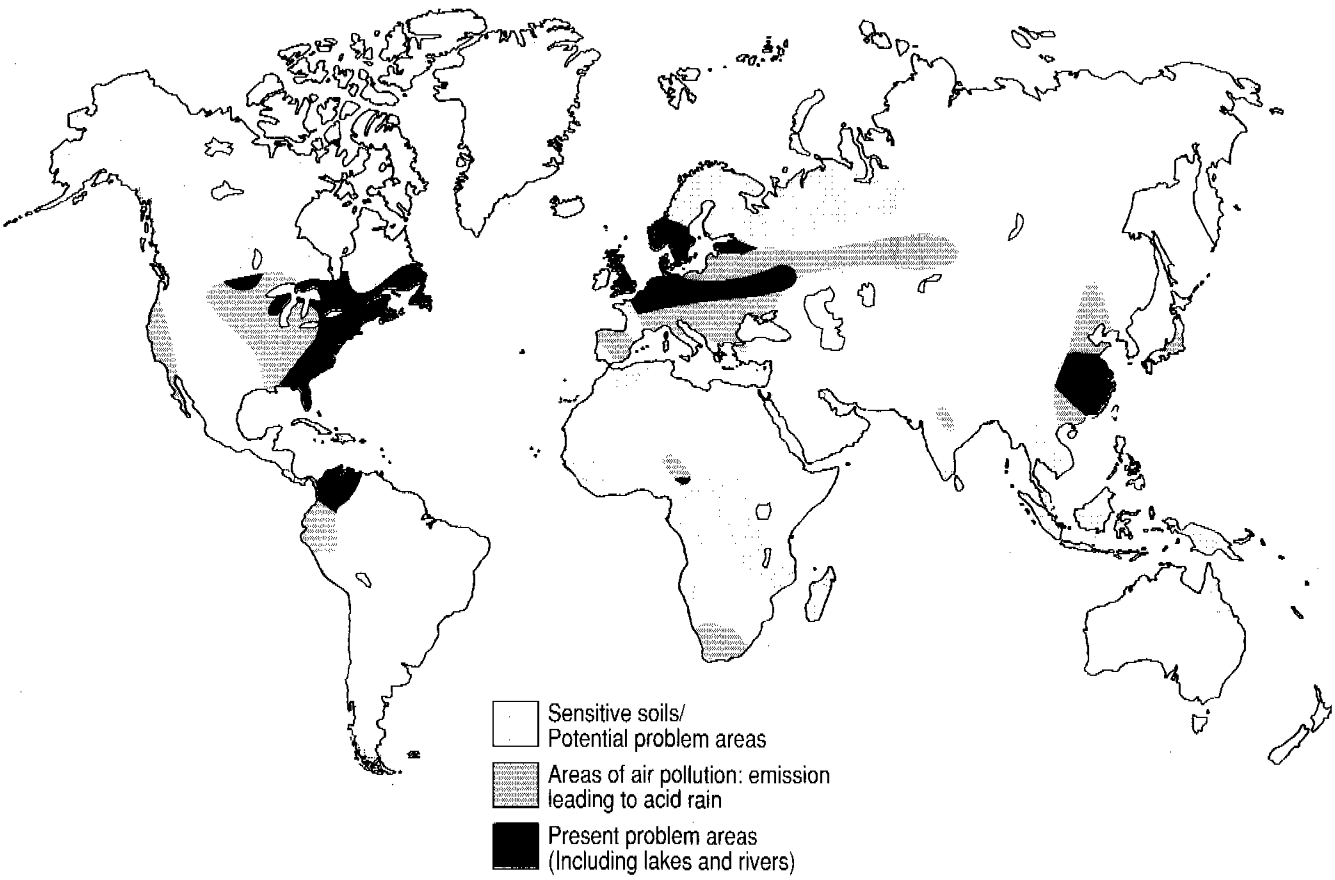
The natural lead cycle consists of inputs to water from mechanical erosion and in soluble form, transfer from the land to the atmosphere as particulates (11 x 10^3 t) and atmospheric deposition on land (10 x10^3 t) and sea (1 x 10^3 t). Other parts of the lead cycle are of human origin.

specific insecticides, herbicides and molluscicides are launched every year and some of them, such as triazine, are widely used within a short time. The aquatic environment is now exposed to growing numbers and quantities of pesticides and the corresponding monitoring is both costly and complex. As for heavy metals, most older pesticides have low solubility but some newer organochlorine pesticides have higher solubility and lower persistence. Detection in water is difficult and monitoring in biota and particulate matter must also be performed.

Pesticide contamination is poorly documented for the aquatic environment on a global scale. Evidence for contamination by DDT is present all over the world, from Amazonian rivers to Arctic ice, as a result of long-range atmospheric transport. Although banned in most European and North American countries, DDT is still manufactured and used in Africa, India and south-

Figure 7.3 Acidification

Source: Lean, G. et al. 1990 *Atlas of the Environment*, Arrow Books, London.



east Asia. Even 10 to 20 years after it was last used in certain areas, DDT is still found in rivers and lakes because of its extreme persistence. New pesticides are generally far more degradable. In tropical countries where intensive aquatic disease vector control is taking place (for example, in west Africa), enormous quantities of insecticides and molluscicides are used to control schistosomiasis, onchocerciasis and malaria, and corresponding contamination by control chemicals is likely, although poorly documented.

7.8 Industrial Organic Substances

As for pesticides, the development of the variety and scale of production of synthetic organic chemicals used in industrial activities has led to global pollution by a wide variety of products, such as solvents, chlorinated hydrocarbons and polycyclic aromatic hydrocarbons. These reach the aquatic environment either through direct contamination from waste waters or dump site leakage, or through the atmosphere. The latter pathway is particularly common for the most volatile substances. Industrial organic pollution has now grown to a global scale and such substances are being found in very remote places.

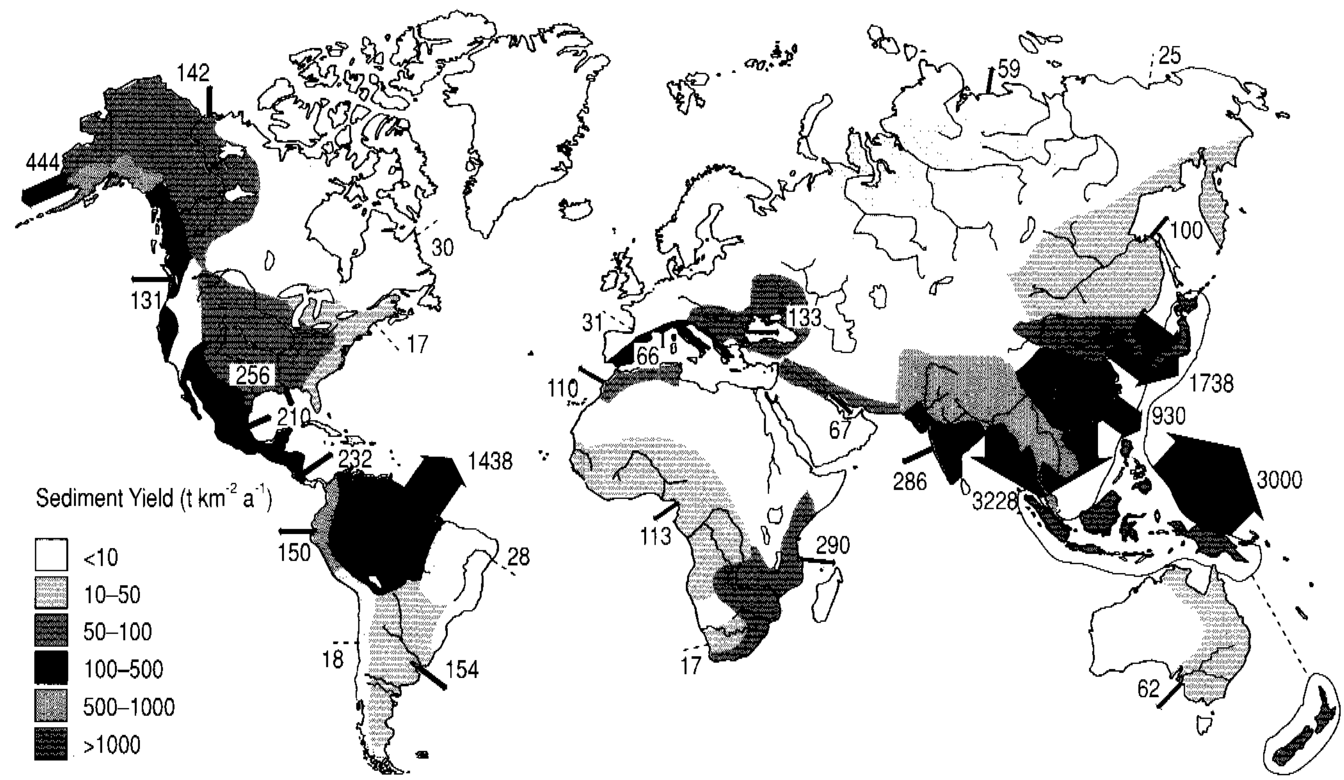
Monitoring of these substances in the aquatic environment is very difficult in analytical terms and is still insufficient on a world-wide scale. Good monitoring has shown evidence of contamination from industrial activities such as oil refining, coal mining, organic chemical synthesis, textile industries and wood pulp industries. Urban run-off and domestic use of products such as solvents are also important sources, but data are extremely limited for many countries.

In the coming decade, three different problems concerning industrial organics are likely to arise:

- increase of global pollution through atmospheric contamination;
- severe contamination problems in aquifers,

Figure 7.4 Sediment yield and discharge

Source: Millman and Meade 1983, in WHO/UNEP1989



Annual discharge of suspended sediment and sediment yield from different regions of the world. Arrow width corresponds to relative discharge. Numbers give mean annual discharge in 10^6 t. Arrow direction is not significant.

arising from waste disposal landfill sites; and

- accidents in manufacture, storage, transport or use of chemicals, resulting in pollution of the aquatic environment.

7.9 Acidification

Acidification of surface and some ground waters is a slow process caused by increased atmospheric deposition of inorganic acids (mostly nitric and sulphuric) on areas with vulnerable rock types such as sandstone or crystalline rocks. These rocks have a limited capacity to buffer acids (i.e., maintain the original pH). As a result of pH decrease in water (up to 2 pH units in some areas over the last 30 years), major acid stress on the aquatic environment has been observed, also associated with increases in dissolved aluminium and other metals. This stress is apparent in the loss of many aquatic biota, with fish deaths attracting the greatest attention.

Acidification began to be recognized as a major issue in the early 1970s in Scandinavia and north-east USA. It is now of great concern over the whole of northern Europe, particularly around the Baltic and North Seas, and in most of the eastern part of North America. More recently, major problems have arisen in south-west China. Acidification is likely to cause problems in many other regions of the world: Venezuela and Colombia, southern Brazil and Uruguay, the Gulf of Guinea, the west coast of India, and an extended part of south and east Asia (Figure 7.3).

7.10 River Sediment Loads

The natural sediment loads of rivers have been greatly modified through a variety of human activities, in some cases for several hundred years.

General deforestation, as a result of clearance of land for agricultural development, mining, urban development and timber production, has led to a considerable increase of mechanical erosion and soil loss. In the largest rivers, this material may not reach the river mouth and may be accumulated naturally in alluvial plains, especially during flood periods. This storage process within the river basin has been accelerated by the construction of dams on many of the world's major rivers. The two processes of erosion and deposition are very difficult to estimate on a global scale. However, it has been estimated that global mechanical erosion processes, enhanced by human activities, correspond to 80–100 x 10^9 t a^{-1} of sediment, of which 15–20 x 10^9 t a^{-1} would reach the oceans naturally. Due to dams, the total quantity reaching the sea may already have been reduced by 10 per cent.

The settling of suspended matter in large reservoirs may have serious adverse effects downstream by reducing the quantity of natural nutrients available to agricultural land or to coastal waters. This nutrient depletion can lead to increased fertilizer use and decreases in coastal fishery yields – the Nile provides a good example. Additional effects are the loss of storage capacity of reservoirs and increased erosion downstream of dams.

Human enhancement of erosion by medium-sized or major rivers such as the Huang He (Yellow River), may cause enormous turbidity problems (exceeding 10 g l^{-1}), resulting in water quality impairments and coastal siltation. High erosion and turbidity are widespread all over south-east Asia from China to India (see Figure 7.4).

7.11 *Modification of Natural Hydrology*

Many human activities greatly modify the general processes of water bodies: enhanced evaporation through the construction of reservoirs and irrigation, water diversion from one basin to another and over-abstraction from aquifers. In all cases these changes have direct influences on water bodies: salinization of rivers, lakes and soils, salt intrusion in coastal aquifers, reduction of the dilution and self-depuration capacities of rivers. Reductions in flow which result from development of water resources are of concern in that they lead to conflicts over quantity and quality. Loss of unique wetland resources is a continuing trend. These effects are still to be properly documented on a global scale but severe problems are already well known in various basins such as the Colorado and Rio Grande basins, the Nile river, the Indus basin, and the Aral Sea (which combines drastic reduction of water discharge of inflowing rivers with pollutant inputs from a major agricultural area). Major dammed rivers in the world

Table 7.6 Links between water pollution and other environmental issues

	Pathway				
Pollutant	Air to water	Water to soil	Water to tap water	Water to food	Water to sea
Pathogens	+	+	+++	+++	+++
Decomposable organic matter	0	+	+	00	+
Nutrients[(a)]	+	+	0	0	+
Nitrate	0	0	+	+++	+++
Salts	0	+++	+	0	00
Metals	+	+	+	+++	+
Synthetic organic substances	+	+	+++	+++	+++
Acids	+++	+	+	0	00
Suspended solids	0	00	+	00	+

+++ Severe impairment.
++ Important impairment.
\+ Minor impairment.
0 No impairment.
00 Irrelevant.
(a) Excluding nitrate.

include the Columbia, Colorado, Rio Grande, Tocantins, Caroni, Parana, Nile, Senegal, Volta, Zambezi, Niger, Indus, Yangtse, Yenisey, Ob and Volga.

7.13 Water Quality Degradation and Related Environmental Issues

Water quality degradation is linked to many other key environmental quality issues: air, soil, food, drinking water, and coastal marine waters. Water quality may be strongly influenced by air quality, acidification being the best known example. In turn the quality of water influences the other components of our environment. The nature of these interactions between environmental compartments and the implications for water quality will change according to the water quality variable, the characters of the natural systems and the type of associated human activities. Table 7.6 summarizes the links and illustrates the need for a comprehensive joint assessment of all environmental issues.

8

Global Strategy for Water Quality Management

Since the Water Conference at Mar del Plata and throughout the Water Decade, tremendous efforts have been made to supply water to cities, agriculture and industry, following increased awareness of the pivotal role of water resources in development. All economic sectors place continually increasing demands upon water resources which, although relatively plentiful, are ultimately limited. During the past decade we have witnessed a general deterioration in the quality of most of the vital water resources on all continents. Most societies, including the individuals responsible for water policies, have long overlooked the fact that water quality and water quantity are different aspects of the same resource, intrinsically linked. Quality cannot be managed independently of quantity. Different users of water have specific quality requirements and their activities have specific degradation influences on water quality which in turn restrict subsequent options for use. To ignore the interaction of quality and quantity factors in water management will give rise to severe social, economic or human health consequences. By managing water resources with regard to availability, demands, effects and future options for use with the ultimate aim of maintaining water at the highest quality, more water becomes usable to meet pressing basic needs of different water-dependent sectors.

The perception of water as a freely available public good must be abandoned, and its limited supply and competitive economic value fully recognized. Rational use and quality-conscious management are the most powerful tools in managing the water quality problems to be faced today and in the coming century.

The experience of many industrialized countries has demonstrated that the costs of cleaning up polluted waterways are a severe financial burden. Preventative measures should be taken early (when costs are more likely to be affordable) and should be built into management practice and financial structures of any water resource use plan. In this way the levels of pollution from industrial and agricultural development can be contained within sustainable limits. In this chapter, a strategy is presented which integrates water quality aspects into emerging global programmes for the sustainable management of freshwater resources. This water quality strategy is based broadly on recommendations from recent regional and global meetings of experts, as well as policy papers issued by authoritative international organizations. Regional studies were undertaken for this document which aims to develop a comprehensive follow-up programme for the Water Conference.

The strategy outlined in detail below includes objectives, approaches, components and required international support action. In addition, a priority list of 10 key issues is given, highlighting the problems of crucial importance for the decade to come (see box opposite).

8.1 Strategy Objectives

Integration of water quality elements into water resource management requires that three goals be pursued concurrently:

Maintenance of Ecosystem Integrity

Good water quality and suitability for all uses can only be maintained on a long-term basis if the aquatic environment is understood as a single ecosystem. Water quality then becomes the key element, not only affecting ecosystem health but also human water use and health, water-dependent agricultural systems and industrial developments. Sufficient water of required quality can be made available for current and future use if the aquatic ecosystem is effectively protected from direct and indirect pollution.

Public Health Protection

Maintenance of human health by prevention of disease cannot be achieved without an adequate supply of water for drinking and other domestic purposes. This

Ten Key Water Quality Issues in the 1990s

Quantity vs Quality	Water quality and quantity are intrinsically linked. Sustainable development of water resources cannot occur without recognition of user requirements for water of specific quantity and quality.
Ecosystem Integrity	Fresh waters must be considered as a single aquatic ecosystem. Rivers, reservoirs, lakes and ground waters must be managed in an integral fashion, taking account of climatic, hydrological and socio-economic influences.
Basin Framework	Water quality should be managed within the drainage basin. This provides the most practical hydrogeographic unit within which the quality of rivers, lakes, reservoirs and aquifers can be effectively controlled.
Drinking Water	The provision of good quality drinking water takes priority over all other uses. The human right to have access to drinking water in quantities and of a quality to meet basic needs was recognized by the Water Conference.
Health Impacts	Water-related diseases are still a major health problem. Diseases caused by microbial contamination of water supplies or transmitted by water-associated vectors are the greatest problem for health care in developing countries.
Chemical Safety	Synthetic chemicals pose the most ubiquitous and persistent threat to aquatic ecosystems. Chemical products, particularly pesticides, and wastes affect many beneficial water uses. These substances are often highly toxic, non-biodegradable and bioaccumulated.
Ground Waters	Ground waters are crucial aquatic resources. They provide a vital support for life for many people, but are increasingly threatened by over-exploitation, salinization and long-term, cumulative contamination.
Law Enforcement	Effective regulatory enforcement mechanisms are prerequisites for water quality management. Water pollution can only be controlled on the basis of comprehensive legislation and through competent implementing institutions.
Public Awareness	The involvement of the public is essential for policy implementation. The importance of good quality water for human health and for economic development should become common knowledge and relevant policies must be supported by broad public consensus and political will.
Problem Assessment	Reliable water quality data bases are indispensable. Assessment of water quality and forecasting of global impacts on aquatic ecosystems demand high quality and continuously evolving monitoring networks and information systems.

implies the provision not only of sufficient quantities of water but also of water which is free from pathogens and harmful chemicals. Therefore, either water resources must be protected from disease agents OR adequate treatment must be provided where sufficient protection cannot be guaranteed. Diseases are not only caused by insufficient availability of good-quality water, but also by disease vectors breeding in surface waters. Aquatic ecosystems, particularly those involved in agricultural production, must be managed so that vectors are controlled without introducing new chemical contamination problems.

Sustainable Water Use

Most socio-economic sectors cannot be developed and sustained without adequate provision of water in sufficient quantity and of specific quality. Fisheries, agricultural crop production and livestock rearing, manufacturing industry, fossil, nuclear and hydropower plants, tourism and recreational activities – all in addition to ever-growing municipal demands – are dependent to a varying degree upon certain water quality criteria. Deterioration in water quality, resulting from over-use of resources, must be prevented in the early stages, necessitating policy decisions on competing sectoral water uses. A rational balance between water quality and quantity, taking account of possible treatment and re-use of waters, must be developed. Relevant policy-making should become an integrated element of rational water resource management.

8.2 Management Approaches

Considerable progress has been made in most industrialized countries on a variety of water pollution issues. This is reflected both in the field of water policy and in the design and operation of technical installations for water quality control. The global extent of water quality issues, including long-range pollution from diffuse sources and environmental degradation in forest or desert areas, presents a challenge in devising viable policies for environmental management. Such policies require profound insight into the mechanisms of demographic, social and economic developments and particularly into their influences on water resources. Based upon past experience – successes as well as failures – and in view of current and emerging water quality issues, the following four common elements have been condensed from the regional action programmes.

Integrated Water Policy

If the interdependence between water quality issues and the quantitative use of water is ignored, rational and sustainable management of this limited resource will not be possible. Aquatic ecosystem protection is by nature an intersectoral task. Hence, a comprehensive policy framework which takes into account quantitative and qualitative aspects of water resource management is essential. Users competing for limited resources have greatly varying water quality requirements. This makes it imperative to provide sound water management based upon policies which reflect environmental needs and public preferences. Newly emerging problems, such as salinization and salt-water intrusion, and growing potential for water conservation through industrial recycling or waste-water re-use, constitute priority areas in which water quantity and quality relationships play a crucial role in policy formulation.

Comprehensive Basin Development

It is now recognized that the drainage basin provides the most useful hydrogeographic unit in which to manage rivers and lakes with regard to hydrology as well as quality. Within the watershed, aquatic ecosystems can be most effectively maintained and protected when consideration is given to the diversity and interdependence of all components of the hydrological cycle. This includes surface and corresponding ground waters, atmosphere-water and soil-water interactions and the interface between fresh and marine waters . The necessary political and administrative arrangements (obviously on an intercountry level where transboundary watersheds are concerned) must be made to ensure that river and lake basin authorities are given the necessary power to control use of the resource and maintain its ecological quality. This power must include regulatory control and land-use planning, siting of industry and control of pollution associated with socio-economic development plans.

Ground-water Resource Protection

Several droughts and the effects of continuous ground-water depletion during the past decade have emphasized that underground water resources constitute a vital life-support system which must be fully protected to permit sustainable use. Costly and often irreversible damage has been inflicted on ground-water resources in all continents. Ground-water mining of non-renewable fossil aquifers and the over-pumping of deep ground-water bodies produce major problems which must be remedied in many arid and semi-arid areas. Contamination of ground waters with toxic substances from non-point sources or accidental spills is a major threat in all industrialized countries. Ground water contamination is a long-term, cumulative process, far more serious than river pollution because aquifers require extensive time periods for rehabilitation. Only a comprehensive approach, transcending national boundaries and supported by the necessary political will, is capable of reversing current trends and avoiding dramatic socio-economic consequences during the decade ahead. All countries depending primarily on ground water for basic water needs should develop suitable policies and resource management plans as a matter of urgency.

Joint International Action

International co-operation is essential for multi-objective planning and integrated basin development, since these approaches are beyond the technical, human and financial resources of many developing countries sharing transboundary water resources. Transfer of experience from intensively managed industrialized basins to newly established basin programmes is urgently needed in the short and long term, particularly on pollution monitoring and control technology. Regional programmes in need of such international support include the Niger and the Zambezi rivers and Lakes Victoria and Tanganyika. These and many other large transboundary water bodies, particularly those located in developing countries, are of global significance and should also be monitored in co-operation with the international scientific community. Determination of global fluxes of critical pollutants is one of the purposes of such joint programmes. Similarly, vital ground-water bodies, such as the Nubian Sandstone and the Saharan Continental Intercalaire aquifers, must receive international programme support to maintain their role as a crucial resource for the large populations depending on them.

8.3 Strategy Components

In comprehensive water resource management, there are a number of activities geared specifically towards the maintenance of water quality. On the technical and scientific side, the key elements are monitoring, assessment and control of water pollution. In management of water quality, key support is provided by legal and institutional structures as well as by economic and financial instruments. These components are summarized in the box below.

Key Components of the Global Strategy

- Water monitoring and problem assessment
- Water pollutant control methods
- Legal instruments and institutional capabilities
- Economic tools and fiscal measures

8.3.1 Monitoring and Assessment

Scientifically sound information must be the basis for any rational water quality management decision. Monitoring of water quality is not therefore an end in itself, but provides the data base for assessing the water quality situation, describing the aquatic ecosystem, forecasting trends, estimating the impact of pollution sources and supervising the effectiveness of pollution control measures. Many of the necessary approaches and methods were developed during the past decade, particularly within the framework of the global water quality monitoring programme GEMS/WATER. Much remains to be done in the establishment of basin-wide monitoring networks, particularly in the African continent. Internationally supported action is needed during the next decade on the following:

- establishment of purpose-oriented water quality monitoring systems which serve multiple objectives such as ecosystem assessment, policy option development, water-use planning and environmental impact assessment;
- harmonization, if not standardization, of sampling programmes, analytical procedures, data processing and data reporting over entire river and lake basins or extended aquifers;
- integrated multi-media monitoring of aquatic ecosystems, including the water column, biota and sediments, and their interactions;
- integrated monitoring of related environmental compartments should be performed to provide good information for integrated management of all environmental sectors;
- improvement of the reliability of monitoring data

through up-grading and maintenance of laboratory services, rigorous analytical quality control, inter-laboratory comparison studies and designation or establishment of reference laboratories in each country and in each major basin area;

- training of laboratory managers, analysts and technicians with particular emphasis on good laboratory practice, analytical quality control and maintenance of laboratory instruments;
- establishment of water quality data bases for whole basins for use with corresponding hydrological and socio-economic information systems. These should be based upon compatible data handling systems;
- operation and maintenance of sensitive analytical equipment through national or regional service centres or through "twin" arrangements between laboratories in developing countries and well-equipped partners in industrialized countries; and
- assessment of regionally or globally significant issues such as pollutant fluxes to regional seas or oceans, long-range atmospheric transport of pollutants, deforestation and desertification or climate change.

8.3.2 Water Pollution Control

Technology is becoming available today which can eliminate pollution from municipal and industrial point sources, although its application is much delayed in many newly industrializing countries. The challenge for the next decade, however, is in the control of pollution from diffuse sources which reaches the aquatic environment through urban or agricultural run-off, leaching into ground waters or atmospheric deposition. The nature of pollutants has changed from biodegradable organic wastes to highly sophisticated synthetic organic chemicals with long-term persistence in the environment. New strategies must be devised and field-tested during the next decade to control traditional pollution problems and, at the same time, to cope with new and dangerous contaminants. In contrast to industrialized countries, which had to face these problems consecutively, newly industrializing countries must meet all these problems simultaneously. The following action proposals concern every country to some degree:

- identification of pollution sources and quantification of pollutant loads through rapid assessment procedures, effluent monitoring, investigation of industrial processes and verification of the use of agrochemicals;
- identification and multi-media surveillance of potentially toxic chemicals throughout their "life cycle" from production to waste disposal (or application for pesticides) with subsequent control to minimize impact on aquatic ecosystems and to prevent harmful health effects on water users;
- development of intersectoral policies, regulatory and technical measures to prevent over-exploitation of vital ground-water resources and to control pollution from point and non-point sources;
- design and application of simplified and readily applicable methods to assess the environmental impacts of proposed major development projects upon aquatic ecosystems and the possible impairment of intended water uses;
- adoption of appropriate technical pollution control measures, such as low-waste industrial techniques, recycling of wastes or by-product recovery;
- introduction of regulations to promote the rational use of agrochemicals, the designation of ground-water protection zones and environment-oriented master plans for land-use and basin-wide development;
- establishment of intersectoral pollution control programmes which take into consideration the vulnerability of aquatic ecosystems and the quality requirements of water users;
- development of new concepts and approaches for water quality management. For example, the control of point and diffuse pollution sources within megacities where sanitary installations and environmental health services are increasingly inadequate; and
- initiation of contingency plans at national or regional level to control accidental spills which might contaminate vital surface or ground waters and render them unfit for public supply and other uses.

8.3.3 Legal and Institutional Requirements

Water quality cannot effectively be controlled without a strong political and organizational framework which facilitates the implementation of pollution control measures. Although management at the drainage basin level would be the best institutional structure, this is not always feasible because legal and administrative arrangements are generally made at the national level and water bodies frequently lie across national boundaries. Water quality issues such as transboundary pollution, long-range atmospheric transport of pollutants and accidental spills in international waters demand inter-country arrangements which range from notification to jointly established basin commissions and operational authorities. Whatever type of organization is set up, its effectiveness is often determined by its practical independence in developing environmental protection and pollution control plans and issuing regulations for their implementation. The following key features are necessary in various contexts to achieve water quality management objectives:

- enactment of water-specific or comprehensive environmental laws which cover all aspects of aquatic ecosystem protection and pollution source control, and which enable the implementing organization to issue regulations and standards and to enforce their application;
- closing the enforcement gap which currently exists in many developing countries. Relevant legislation has been adopted in some cases but resources or political will to apply strict pollution control measures may be lacking, particularly when conflict arises with ambitious economic development plans;
- establishment of national co-ordination mechanisms for water resources management. In many countries, this is a fragmented, multidisciplinary and inter-sectoral field with responsibility divided between different agencies;
- performance of water quality monitoring and assessment by one organization to generate a coherent data base and to use limited analytical and skilled staff resources efficiently;
- development of technical facilities and manpower to fulfil the large variety of tasks within an organization covering all aspects of water quality management from field sampling to policy formulation;
- encouragement of public involvement through regular public awareness campaigns, consumer information, co-operation with civic movements for environmental protection and resource conservation and the introduction of environmental issues in educational curricula at all levels;
- adoption of compatible policies and regulations for pollution control and prevention throughout transboundary watersheds; and
- development of water quality guidelines for specific aquatic ecosystems, for example, different environments in the dry and wet tropics.

8.3.4 Economic and Fiscal Measures

Water should not be considered a freely available public good. An important element of any water policy is therefore a fiscal policy which promotes pollution control and helps internalize related costs (the individual user or polluter pays for quantity used and quality changes caused by them – pollution costs would be paid either by a fee for treatment or by installing and operating individual treatment technology). The economic justification for pollution control has in the past been based on a calculation of the external costs of pollution – the user must pay to purify water polluted by someone else. Although these costs can be estimated by calculating expenses of water treatment, it is difficult to quantify health, social and environmental benefits from pollution control in monetary terms. As a consequence, water quality management cannot be based solely upon the application of economic criteria. Economic tools, for example, fees for effluent discharge or tax incentives for environmental investments, are nevertheless used successfully in many countries. The full potential for use of economic tools in protecting and improving the quality of water resources has not yet been explored and more innovative efforts need to be launched during the forthcoming decade. Some general recommendations with regard to the main pollution problems are:

- charging point sources of pollution directly for the quantity and environmental hazard of wastes discharged in accordance with the "Polluter Pays Principle";
- levying a surcharge on water supply and abstraction which covers costs of waste-water treatment and disposal from urban multi-point sources which are difficult to regulate individually;
- introducing a product surcharge on hazardous chemicals sold to domestic, agricultural or industrial users. Revenue from this surcharge would be used exclusively for water treatment and ecological protection measures;
- subsidizing environmentally-sound agricultural practices and compensating for restrictions on crop or livestock farming. Such a policy aims to reduce surface- and ground-water pollution from diffuse agricultural sources;
- increasing the price of water in areas of ground-water over-exploitation for the purpose of water conservation and prevention of salt-water intrusion and other contamination; and
- providing tax incentives and other economic benefits to industry with the aim of stimulating water conservation, recycling of water and minimizing waste discharges.

8.4 International Support Actions

The increasing complexity of water quality issues and the range of necessary measures to safeguard aquatic ecosystems mean that most developing countries are facing considerable problems in planning and implementing programmes for monitoring and assessment of surface and ground-water resources. Measures to control pollution at source are hampered by technical, operational and maintenance problems and even more so by the acute lack of financial resources. Without massive and dedicated support from the scientific community and financial donor agencies of the more affluent countries, many of the most precious world freshwater resources will experience severe and, in some cases, irreversible damage during the next decade. With the declining economic situation in large parts of Africa, south Asia and Latin America, basic needs will have far greater political and economic priority than the conservation of aquatic ecosystems. External support agencies must insist on environmentally sustainable development in the agricultural and industrial sectors and should incorporate mechanisms such as environmental impact assessment, water quality monitoring laboratories, effluent treatment facilities and appropriate agricultural practices into their project plans.

The strategy on water quality management in this document focuses on the support needed by responsible agencies in developing countries to fulfil their aims. General aspects of water resource development are left to other fora. Proposals for technical co-operation on quality aspects of water resources in three key areas are listed below.

8.4.1 Research and Development

Co-operative research projects are needed to develop solutions to technical problems which are appropriate for the conditions in each watershed or country. Monitoring and assessment of complex aquatic ecosystems often require multi-disciplinary studies involving several institutions and scientists in a joint programme.

Suitable mechanisms to reinforce the research and development sector include:

- better communication between water scientists through the exchange of scientific results, provision of literature and staff exchange programmes;
- development and networking of research centres, including the establishment of regional water research institutes in Africa;
- back-up of field studies by international water research institutions and by north-south twinning of research centres;
- allocation of a minimum percentage of funds for water resource development projects to research and development, particularly those externally funded; and
- orientation of international water quality programmes, such as GEMS/WATER, towards the water quality monitoring and assessment problems of developing countries.

Research and Development Topics

- Field-testing of appropriate waste and pollution control technologies
- Use of water of marginal quality for irrigation or ground-water replenishment
- Elimination of health risks from waste-water re-use for crop irrigation
- Simplified procedures for water quality monitoring and assessment
- Study of distribution and pathways of inorganic and organic micro-pollutants, particularly agrochemicals, in aquatic ecosystems
- Ecotoxicological studies of the long-term effects of particularly harmful chemicals on aquatic biota
- Simplified mathematical models of water quality for management purposes

8.4.2 Development of Institutional Capabilities

Water quality management programmes require a certain minimum infrastructure and staff to implement technical solutions and to enforce regulatory action. Considerable investments in water treatment and in laboratory equipment have been made during the past decade. One of the key problems today and for the future is the sustained operation and maintenance of these facilities. In order not to allow resources gained from previous investment to deteriorate further, immediate action is required in the following areas:

- maintenance of laboratory equipment through regular servicing of instruments, repair of malfunctioning equipment and advance procurement of essential spares;
- development of water quality assessment capabilities in water management authorities through co-operative studies or twinning arrangements,

for example;

- operation and maintenance of water pollution control installations, including regular efficiency verification, advance procurement of essential spare parts and regional co-ordination of manufacturing services; and
- establishment of a permanent, multi-sectoral follow-up evaluation mechanism for the planning and management of water resource developments, including hydrological as well as water quality aspects.

8.4.3 Human Resources Development

Technical capabilities in any water quality management organization are intrinsically linked to the level of staff skill. Although basic technical and operational work can be taught through local or national training programmes, innovative approaches must be adopted for professional and managerial staff training in order to cope with changing needs and challenges. Flexibility and adaptability to emerging water pollution issues must be developed. Suitable approaches may include:

- full range of training activities to be undertaken periodically at all levels within the organizations responsible for water quality management;
- innovative teaching techniques to be adopted for specific aspects of water quality monitoring and control. These should include development of training skills, inservice training, problem-solving workshops and refresher training courses;
- loss of trained chemists, biologists and laboratory technicians to be kept under control through the provision of career ladders, incentives and recognition of merits;
- introduction of new water quality management methods to be combined with national and regional workshops and subsequent pilot projects;
- establishment of regional technical and engineering courses on water quality control subjects at existing inter-country schools, such as the Ecole Inter-Etats des Ingénieurs de l'Equipement Rural in West Africa, or at established academic centres such as the Water Engineering and Development Centre in the UK; and
- development of curricula and teaching aid packages for water treatment plant operators.

Bibliography

Chinese Academy of Sciences 1985 *The Atlas of Endemic Diseases and Their Environments in the People's Republic of China*, Science Press, ISBN 7-03-001200-3.

Demayo, A. 1990 *Water Quality Issues in the Countries of the American Continent*. Unpublished consultant report.

El Ghobary, H. 1990 *Water Quality Issues in the Nile Basin and East African Countries*. Unpublished consultant report.

Khan, K. R. 1990 *Regional Synopsis of Water Quality Issues for Asia and the Pacific*. Unpublished consultant report.

Ramadan, S. A. 1990 *Regional Synopsis of Water Quality Issues for West Asia*. Unpublished consultant report.

UN 1991 *Water Resources: Progress in the Implementation of the Mar del Plata Action Plan*, E/C.7/1991/8, United Nations Committee on Natural Resources.

UNDP 1990 *"The New Delhi Statement"* - Global Consultation on Safe Water and Sanitation for the 1990s, 10–14 September 1990, New Delhi (issued by the United Nations Development Programme, New York).

UNEP 1989 *United Nations Environment Programme Environmental Data Report*, Basil Blackwell, Oxford.

UNEP 1991 *United Nations Environment Programme Environmental Data Report*, Basil Blackwell, Oxford.

UNEP/WHO/UNESCO/WMO 1990 *GEMS/WATER Data Summary 1985–1987*, World Health Organization Collaborating Centre for Surface and Groundwater Quality, Canada Centre for Inland Waters, Burlington, Ontario.

UNEP/WHO/UNESCO/WMO 1991 *GEMS/WATER 1990–2000 The Challenge Ahead*, WHO/PEP/91.2, United Nations Environment Programme, Nairobi; World Health Organization, Geneva; United Nations Educational, Scientific and Cultural Organization, Paris; and World Meteorological Organization, Geneva.

WHO/UNEP 1989 *Global Freshwater Quality: A First Assessment*, M. Meybeck, D. Chapman and R. Helmer (Eds), Basil Blackwell, Oxford.

WHO/UNEP/UNESCO *Water Quality Assessments*, D. Chapman (Ed.), World Health Organization, Geneva; United Nations Environment Programme, Nairobi; and United Nations Educational, Scientific and Cultural Organization, Paris. In preparation.

Abbreviations used in the Report

ACC-ISGWR	Administrative Committee on Co-ordination – Intersecretariat Group on Water Resources (UN)
AHD	Aswan High Dam
CDP	Committee on Development Planning (UN)
CEFIGRE	Centre de Formation Internationale pour la Gestion des Resources en Eau
CEHA	Centre for Environmental Health Activities (WHO)
CNR	Committee on Natural Resources (UN)
DIESA	Department of International and Economic Affairs (UN)
DTCD	Department of Technical Co-operation for Development (UN)
ECA	Economic Commission for Africa (UN)
ECE	Economic Commission for Europe (UN)
ECLAC	Economic Commission for Latin America and the Caribbean (UN)
ECOSOC	Economic and Social Council (UN)
EDI	Economic Development Institute
EC	European Community
EIER	Ecole Inter-Etats des Ingénieurs de l'Equipement Rural
ESCAP	Economic and Social Commission for Asia and the Pacific (UN)
FAO	Food and Agriculture Organization (UN)
FSM	Federated States of Micronesia
GEMS	Global Environment Monitoring System
GEMS MARC	Global Environment Monitoring System – Monitoring and Assessment Research Centre
GEMS/WATER	Global Freshwater Quality Monitoring Programme (UNEP/WHO/UNESCO/WMO)
IBRD	International Bank for Reconstruction and Development (World Bank)
IDWSSD	International Drinking Water Supply and Sanitation Decade
OECD	Organisation for Economic Co-operation and Development
ORSTOM	Institut Français de Recherche Scientifique pour le Developement en Cooperation
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
WEDC	Water Engineering and Development Centre
WHO	World Health Organization
WMO	World Meteorological Organization

Units

a	year
g	gramme
ha	hectare
km	kilometre
l	litre
m	metre
mg	milligramme
mm	millimetre
s	second
t	tonne

Chemistry

BOD	Biological oxygen demand
COD	Chemical oxygen demand
DDT	Dichlorodiphenyltrichloroethane
GC	Gas chromatograph
GLC	Gas-liquid chromatograph
HCH	Hexachlorocyclohexane
HPLC	High-pressure liquid chromatograph
PCB	Polychlorinated biphenyl

Progress in the Implementation of the Mar del Plata Action Plan and a Strategy for the 1990s