ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC

SOURCES AND NATURE OF WATER QUALITY PROBLEMS IN ASIA AND THE PACIFIC

UNITED NATIONS

822-AAS98-14983

ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC

SOURCES AND NATURE OF WATER QUALITY PROBLEMS IN ASIA AND THE PACIFIC

LIBRARY IRC
PO Box 93190, 2509 AD THE HAGUE
Tel.: +31 70 30 689 80
Fax: +31 70 35 899 64
BARCODE: 14983
LO: 822 AAS 98

UNITED NATIONS

New York, 1998

ST/ESCAP/1875

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Mention of firm names and commercial products does not imply the endorsement of the United Nations.

This publication has been issued without formal editing.

CONTENTS

Preface i

Abbreviation ii

Executive Summary vi

I. INTRODUCTION 1

A. Background 1
B. Development of the questionnaire 2

II. OVERVIEW OF THE ESCAP REGION 3

A. General features of selected rivers in the ESCAP region 5
B. Selected rivers having water quality problems 5
C. Organizations responsible for water quality in rivers 19
D. Coordination and strategic planning 36

III. STATUS OF WATER QUALITY IN RIVERS OF THE ESCAP REGION 42

A. Identification of water quality problems 42
B. Water quality problems in selected countries 46
C. Sources of pollution to rivers 52
D. Impacts of water quality problems on availability and use of water 63
E. Management of water quality in rivers 70
F. Activities planned for water quality protection and rehabilitation 83

IV. CASE STUDIES OF WATER QUALITY MANAGEMENT IN RIVERS 93

A. Water quality issues in Australian rivers 93
B. Status of water quality and water quality management in the rivers of Bangladesh 96
C. Sources and nature of pollution in the rivers of Cambodia 98
D. Sources and nature of water quality problems in China 100
E. Sources and nature of pollution in the rivers of India 103
F. A study of water pollution problems in the Brantas River basin, Indonesia 105
G. Status of water quality management and pollution control in the Lao People's Democratic Republic 110
H. Sources and nature of pollution in the rivers of Myanmar 113
I. Sources and nature of pollution in the rivers of Nepal 115
J. Status of water quality problems in Pakistan 117
K. Sources and nature of pollution in the rivers of the Philippines 131
L. Water quality management in the Republic of Korea 133
M. Water quality problems and management in the rivers of Sri Lanka 135
N. Sources and nature of pollution in the rivers of Thailand 141
O. On problems of the quality of water in the Aral Sea Basin 143
P. Water resources potential and water quality in the rivers of Viet Nam 145

V. CONCLUSIONS AND RECOMMENDATIONS 153

VI. REPORT OF THE REGIONAL SEMINAR TO REVIEW THE STATUS OF WATER QUALITY PROBLEMS IN ASIA AND THE PACIFIC 155

List of tables

1. Water resources availability and use in selected countries of the ESCAP region 4
2. Main features of rivers in selected countries of the ESCAP region 6
3. Identification of problem rivers 10
4. Examples of organizations responsible for water quality in selected countries of the Asia Pacific region 20
5. Importance of water sources to socio-economic development in selected countries of the ESCAP region 47
6. Status of recognised uses of rivers in selected countries of the ESCAP region 48
7. Activities contributing to water quality problems in rivers in selected countries of the ESCAP region 58
8. Threats to recognised uses of rivers in selected countries of the ESCAP region 67
9. Management tools for water pollution in selected countries of the ESCAP region 74
10. Constraints to effective management of water quality in selected countries of the ESCAP region 75
11. List of relevant legislations for natural resources management 111
12. Estimated resultant water quality at selected barrages in upper Indus region 119
13. Impacts of right bank outfall drain (RBOD) discharges on Indus water quality in Kotri . 120
14. Kotri mixed water quality 120
15. Common pollutants associated with industry 121
16. Quality of Ravi River during November and December, 1988 126
17. National Environmental Quality Standards (NEQS) for municipal and liquid industrial effluent 130
18. Water balance at frequency of 75 per cent by the year 2000 147
19. Water balance at frequency of 75 per cent for dry season by the year 2010 147
20. Water balance at frequency of 75 per cent by the year 2040 148
21. Water quality of rivers in the North and South Viet Nam 149
22. Water quality at some locations along Red River 150
23. Water quality at some locations along Saigon River 150

List of figures

Figure 1. Location map of Brantas and Surabaya rivers 107

Figure 2. Location map of major rivers in Viet Nam 146

PREFACE

The availability of good quality water resources is and always will be paramount to the sustained socio-economic development of countries in the region. Yet, water shortages and water quality deterioration have continued to place great pressure on the region's water resources.

Most countries in the region are dependent on their rivers for development. The steadily declining trend of the water quality in their rivers poses a serious threat to development as the shortage of freshwater supply of acceptable quality will soon become a major constraint on their sustained development.

In chapter 18 of its Agenda 21, the Earth Summit in 1992 called for the protection of the quality and supply of freshwater resources. The general objective is to make certain that adequate supplies of water of good quality are maintained for the entire population and to safeguard the limited water resources against pollution.

In pursuit of the above general objective and in assisting member countries in achieving sustained socio-economic development by ensuring adequate supplies of fresh water, the ESCAP secretariat has launched a project on the rehabilitation of water quality in contaminated rivers in the region, with funding assistance from the Netherlands. The project consists of two phases. Under phase I, a study on the sources and nature of water quality problems in selected rivers in Asia and the Pacific was carried out based on information collected from countries through the circulation of a questionnaire and field visits, which was then reviewed, discussed and adopted at a regional seminar in November 1997.

The present publication is the outcome of this study. It is intended to provide a clear picture of the state of water quality in rivers of countries in Asia and the Pacific, to identify the sources of water quality problems in rivers and to provide a basis for the development of the practical manual and guidelines for the protection and rehabilitation of contaminated rivers, which will be carried out under phase II of the project in 1998.

The publication was prepared by the secretariat with the assistance of an international consultant, Dugald C. Black of Water Resources Consulting Services Australia. National experts contributed country case studies and provided relevant data and information. The contributions of all national experts at the regional seminar in reviewing the contents of the publication and in sharing their experiences are deeply appreciated. The crucial role played by Dr Black in producing this publication deserves special acknowledgement.

ABBREVIATIONS

ACT	Australian Capital Territory
Al	Aluminum
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASEAN	Association of South East Asian Nations
AWBs	Area Water Boards
BHC	Benzenhexachloride
BMR	Bangkok Metropolitan Region
BOD	Biochemical oxygen demand
BVOs	International River Commissions (of the Amudarya and Syrdarya Rivers)
Ca	Calcium
Cl_2	Chlorine
CBO	Community Based Organization
CEA	Central Environmental Authority, Sri Lanka
CEPCA	Commission for Environmental Pollution Control and Abatement
CHEB	Central Health Education Bureau
CISIR	Ceylon Institute of Scientific and Industrial Research, Sri Lanka
CIWTP	Central industrial waste treatment plants
COAG	Council of Australian Governments
COD	Chemical oxygen demand
CPCB	Central Pollution Control Board, India
CRP	Clear River Programme
DEG	Directorate of Environmental Geology
DDT	Dichloro-diphenol-trichloroethane
DDC	District Development Committee
DENR	Department of Environment and Natural Resources, the Philippines
DGWRD	Directorate General of Water Resources Department
DHM	Department of Hydrology and Meteorology
DIW	Department of Industrial Works of Thailand
DLWC	Department of Land and Water Conservation of New South Wales, Australia
DO	Dissolved oxygen
DOH	Department of Health, the Philippines
DPW	Department of Public Works of Thailand
EBI	Extended Biotic Index
EFW	Energy from waste
EIA	Environmental Impact Assessment
EMB	Environmental Management Bureau, the Philippines
EMPAS	Environmental Management and Protected Areas Sector (the Philippines)
EPAs	Environmental Protection Agencies
EPC	Environmental Protection Council, Nepal
EPCP	Environmental Protection Council, Punjab, Pakistan
EPD	Environmental Protection Department, Pakistan
EPL	Environmental Protection Licences
EQPD	Environmental Quality Promotion Department, Thailand
ESCAP	Economic and Social Commission for Asia and the Pacific
ESD	Environmental Sanitation Division
EUAD	Environment and Urban Affairs Division, Ministry of Housing and Works, Pakistan

Fe^+	Iron
FMB	Forest Management Bureau, the Philippines
GDHM	General Department of Hydrology and Meteorology, Viet Nam
GDLA	General Department of Land Administration, Viet Nam
GEMS	Global Environmental Monitoring System
GLOFS	Glacier lake outburst floods (Nepal)
HAOM	Headworks Administration, Operation and Maintenance, Sri Lanka
HCO_3	Bicarbonate
HD	Harbour Department of Thailand
Hg	Mercury
HID	Hetauda Industrial District
H_2S	Hydrogen Sulphide
IFS	Institute of Fundamental Studies
IHP	International Hydrological Programme
IUCN	World Conservation Union, International Union for Conservation of Nature
JICA	Japan International Cooperation Agency
K	Potassium
KEI	Korea Environment Institute, Republic of Korea
LBOD	Left bank outfall drain
LITE	Landhi Industrial Trading Estate, Pakistan
LNMC	Lao National Mekong Committee
MAF	Ministry of Agriculture and Forestry, Lao People's Democratic Republic
MARD	Ministry of Agriculture and Rural Development, Viet Nam
MDBC	Murray-Darling Basin Commission
Mg	Magnesium
MHPP	Ministry of Housing and Physical Planning
MIH	Ministry of Industry and Handicraft, Lao People's Democratic Republic
MINARS	Monitoring of Indian National Aquatic Resources
MLD	Ministry of Local Development
MMI	Matt Macdonald International, United Kingdom
MNDV	Main New Valley Drain
MOC	Ministry of Construction, Viet Nam
MOCT	Ministry of Construction and Transportation, Republic of Korea
MOE	Ministry of Environment, Republic of Korea
MoFish	Ministry of Fisheries, Viet Nam
MOI	Ministry of Industry, Nepal
MOIN	Ministry of Industry, Viet Nam
MOMAF	Ministry of Marine Affairs and Fisheries, Republic of Korea
MOPE	Ministry of Population and Environment
MOSTE	Ministry of Science, Technology and Environment, Viet Nam
MoTAC	Ministry of Transport and Communication, Viet Nam
MOWP	Ministry of Water and Power, Pakistan
MPN	Most Probable Number
MPW	Ministry of Public Work
MW	Megawatts
MWR	Ministry of Water Resources, China and Nepal

Na	Sodium
NARA	National Aquatic Resources Agency
NBRO	National Building Research Organization, Sri Lanka
NCS	National Conservation Strategy, Pakistan
NDP	National Drainage Programme, Pakistan
NEB	National Environment Board, Thailand
NEQA	National Environmental Quality Act, Thailand
NEQS	National Environmental Quality Standards, Pakistan
NESPAK	National Engineering Services, Pakistan
NESS	Nepal Environmental and Scientific Services
NGOs	Non-Governmental Organizations
NH_4^+	Ammonium
NIER	National Institute of Environmental Research, Republic of Korea
NLEP	National Law on Environmental Protection (Viet Nam)
NO_2^-	Nitrite
NO_3^-	Nitrate
NOCs	Notice of Compliances
NPC	National Planning Commission, Nepal
NSW	New South Wales
NWFP	North-West Frontier Province
NWSDB	National Water Supply and Drainage Board, Sri Lanka
O_2	Oxygen
ODA	Overseas Development Administration
OEPP	Office of Environmental Policy and Planning of Thailand
OPCV	Overseas Project Corporation of Victoria, Ltd., Melbourn, Australia
PCB	Polychlorinated biphenols
PCCs	Pollution Control Committees, India
PCD	Pollution Control Department of Thailand or Singapore
PEPA	Pakistan Environment Protection Agency
PEPC	Pakistan Environmental Protection Council
pH	Acidity
PIDs	Provincial Irrigation Departments, Pakistan
PIDAs	Provincial Irrigation and Drainage Authorities, Pakistan
PJT	Jasa Titra Public Corporation, Indonesia
PO_4	Phosphate
POE	Panel of Experts
PRIS	Provincial Irrigation Service
PUB	Public Utilities Board of Singapore
Q-B	Qadirabad-Balloki
RBMP	Right Bank Master Plan
RBOD	Right bank outfall drain
RONAST	Royal Nepal Academy of Science and Technology
SA	South Australia
SAR	Sodium Absorption Ration
SCARPs	Salinity Control and Reclamation Projects
SDWA	Surabaya's Drinking Water Authority
SITE	Sindh Industrial Trading Estate
SiO_2	Silicon dioxide
SO_4^{-2}	Sulphate

SS	Suspended solid
STENO	Science, Technology and Environmental Organization, Lao People's Democratic Republic
SPC	State Planning Committee of the Lao People's Democratic Republic
SPCBs	State Pollution Control Boards, India
SPK-TPA	Coordination Secretariat, Ministry of Public Works, Indonesia
TDS	Total dissolved solids
TSS	Total suspended solids
UN-ACC	United Nations Administrative Committee on Coordination
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
UNIDO	United Nations Industrial Development Organization
VDC	Village Development Committee
WA	Western Australia
WAPDA	Water and Power Development Authority, Pakistan
WARPO	Water Resources Planning Organization, Bangladesh
WATSAN	Water and Sanitation
WECS	Water and Energy Commission Secretariat
WHO	World Health Organization
WMA	Wastewater Management Authority of Thailand
WQDB	Water Quality Database
WUA	Water Users Association

EXECUTIVE SUMMARY

A. Introduction

The importance of rivers to social and economic development of countries has been widely acknowledged in the region. The region's significant economic achievement in recent years has been accompanied by rapid growth of urban population and industrialization that has resulted in the contamination of its rivers by indiscriminate discharges of industrial and human wastes, making the water from many rivers unfit for human use. The problem has been exacerbated in some cases by surface water runoff from agricultural land carrying pesticides, fertilizers, and in some cases soil salinity that are harmful chemicals. In some cases the rivers have become contaminated to such an extent that it has become impossible for fish and other forms of aquatic life to exist. Increased water requirements resulting from the necessary expansion of agricultural and industrial sectors, combined with the deterioration of water quality, have considerably reduced the availability of acceptable quality fresh water for human consumption. The alarming situation facing fresh water resources with regard to water shortage and water quality deterioration calls for strategies leading to the reduction of pressure on water resources, while also ensuring adequate supplies of fresh water for present and future generations.

The ESCAP secretariat, in addressing the above fresh water availability issue faced by its members, has launched a project on rehabilitation of water quality of rivers in the region. The present study on the sources and nature of water quality problems in the region is a preparatory step towards developing a set of guidelines and manual for protection and rehabilitation of contaminated rivers in the region.

B. Overview of the ESCAP region

Water resources availability and use in the region vary widely for different countries depending on their respective physiographic conditions as well as socio-economic development. The region has some of the world's most important river systems. In general, the ratio of water use to water availability may be taken as an indicator of the degree of water scarcity in a particular situation. It is estimated that water tends to become a limiting factor in national socio-economic development when water withdrawal exceeds 20 per cent of annual total renewable water resources. However, the availability of water within many countries is not uniform and in several countries where there may appear to be abundant water resources overall, there may be local areas within these countries where water is already a limiting factor because of high demands, scarcity of water or poor water quality.

Government agencies feature prominently in the management of water resources in the ESCAP region. Other organizations include bodies with strong links to the particular government, such as statutory boards and also non-government organizations. Although water is considered a "sector" in the economy, it is the only sector which is not managed as an entity, largely because of the wide range of issues that are relevant to water. As a consequence, water management is fragmented amongst a variety of sectors and agencies such as agriculture, public health, municipal and industrial management, and navigation. Therefore, it is important to ensure that there is cooperation between all agencies involved, and that there are no overlaps or gaps in responsibilities. Based on the experiences of several countries in the ESCAP region there are several successful models for providing the necessary coordination of agencies and functions. Selection of the most appropriate model in other countries will depend on the institutional arrangements that apply, and it is quite possible that these models will require modification before they can be used directly in some other contexts. The models in operation include:

- Establishing a central agency with a full time role of providing coordination of activities and possibly technical support as well.

- Establishing a coordinating committee comprising predominantly representatives of agencies with an interest in water resources management. This approach will work best when there is a single agency available which can provide most of the support needed to enable the committee to function, and to which other agencies can refer on a day-to-day basis.

C. Status of water quality in the ESCAP region

In general terms the main pollutants of concern across the ESCAP region are sediment, nutrients, pesticides and fertilizers, salinity, sea water intrusion, pathogens, organic material, heavy metals and toxic chemicals. The relative importance of these vary widely depending on the particular circumstances in each river system. In some cases, where specific pollutants are not a concern in their own right, they are still a concern in terms of their association with other pollutants.

The type and extent of river water quality problems in the ESCAP region, depend on factors such as location, ecosystem characteristics, catchment land uses taking place, degree of development and the length of time land and water resources have been developed. Common and significant sources of pollutants to waterways include forestry, agriculture, urban development, quarries and mines, salt water intrusion, sewage wastes, industries, construction and drainage.

In some countries certain social occasions and festivals are also a source of pollution to rivers.

D. River water quality management

The objective of water quality management in the ESCAP region generally centres around the maintenance of water in the rivers and groundwater aquifers and, where necessary, improve it to meet the agreed needs of competing water users, including the environment, and to ensure sustainable development.

The two main concerns with regard to river water quality management in the ESCAP region are that resources do not become depleted or degraded. To help meet future needs for water, increased development of water resources will be necessary. It is becoming increasingly difficult to satisfy demands for water, at the level of reliability that is expected by the community or is required economically. Strategies for managing water resources must consider management in a sustainable and equitable manner that has community acceptance and minimizes environmental and other adverse impacts, and health and safety risks to the community.

The number of factors influencing the management of rivers within the ESCAP region is enormous. This means that the establishment of management and regulating agencies and the development of strategies, policies, legislation, rehabilitation measures, etc. cannot always consider every single inter-linking factor. However, it is important that all key factors are taken into account whenever possible and practical. Key factors to consider include:

(a) Water resources development
(b) International and interstate agreements on sharing of waters

(c) Identification and quantification of pollution sources
(d) Competition for water between categories of users
(e) Availability and use of water resources
(f) Information and database requirements
(g) Performance indicators
(h) Monitoring for performance
(i) Pollution control legislation and compliance
(j) Catchment management
(k) Community roles in water quality management
(l) Public awareness and education
(m) Capacity building and technological issues.

E. Rehabilitation of rivers in the ESCAP region

In view of the inextricable links between water quality, water quantity and land use, it is necessary to consider appropriate measures and procedures for improving water quality in the context of integrated land and water resources management. Urban development, altered vegetation cover and other human activities create point and diffuse sources of pollution and change the runoff regime, adversely affecting the quality, quantity and seasonal availability of water. Water resources developments also have adverse impacts, to varying degrees depending on the nature of the development. Rehabilitation of water quality in any given river system therefore requires an approach which links both social and economic development with the protection of natural ecosystems, and land and water uses across the entire catchment area, and should also provide for consistency of approach between river systems, and between river systems and aquifers.

Measures to rehabilitate rivers in the ESCAP region can be placed under the following broad management categories:

(a) Formulating/review of national water policy
(b) Storage management
(c) Urban and rural drainage
(d) Management of erosion and sediment
(e) Fertilizer and agrochemical control
(f) Reduce saline agricultural drainage effluent
(g) Municipal and industrial wastewater and solid waste management
(h) Adopting clean technology in industry to reduce waste at source
(i) Institutional and legal arrangement
(j) Management coordination, strategic policy and planning
(k) Licensing, performance criteria, and monitoring
(l) Integrated watershed management
(m) Public participation in water resources management
(n) Regional network on exchange of information and technology
(o) Management of atmospheric sources of pollution
(p) Uniform water quality monitoring system
(q) Management of radio active waste material
(r) Water conservation and reuse/recycling of water.

F. Conclusions and recommendations

In spite of the extensive variety of features in the Asia-Pacific region, such as differences in environmental conditions, demographics and socio-economic status, a number of common themes can be identified. The main point is that the current availability, use and status of water in the ESCAP region requires that urgent attention be paid to links between the nature and source of river pollution and socio-economic development.

Most countries in the region have serious river water quality problems. Pollution problems are common in type to many countries but the extent to which they create problems differs. However, in all areas, river water quality has been impacted by various uses. Those uses of rivers which are threatened by water quality issues can also degrade water quality, particularly in the industrial, agricultural and municipal sectors. Therefore, issues dealing with the use, release and treatment of water from these sectors is of the utmost importance.

The most successful stories with respect to water resources management appears to come from those countries where water policies promote a multisectoral and multidisciplinary approach to integrated planning and management, while aiming to optimize sustainable development.

Recommendations to help with directions in improving the current status of river water quality management in the ESCAP region have been put forward and cover national capabilities and water resources development, future activities with water and sustainable development and data review.

I. INTRODUCTION

The availability of good quality water resources is and always will be paramount to the sustained socio-economic development of countries around the world. Yet, water shortages and water quality deterioration have continued to place great pressure on global resources.

"Maintaining freshwater resources is one of the most critical and principal elements of sustainability" said Mr Nitin Desai, Under-Secretary General for Policy Coordination and Sustainable Development during his press briefing on 21 January 1997 as he introduced the two United Nations reports on global sustainable development issues. He also said that the water quality situation was very serious in both developed and developing countries, in terms of freshwater resources and the impact that fresh water has on oceans.

The alarming situation facing freshwater resources with regard to water shortages and water quality deterioration calls for strategies leading to the reduction of pressure on water resources, while also ensuring adequate supplies of fresh water for present and future generations. The United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992 discussed the problems related to such a situation. It was recognized that there was a need for integrated water resources planning and management, covering all types of interrelated freshwater bodies, and taking into consideration water quality and quantity. Within this holistic framework, action should be taken to improve the efficiency of water utilization, prevent contamination of known resources and ensure that all potential water resources are identified and protected. This will require an approach to water resources management which links both social and economic development with the protection of natural ecosystems, and land and water uses across a catchment area or groundwater aquifer. For those rivers in which the quality of water has deteriorated to such an extent that the quantity of water available for drinking and domestic use has been significantly reduced, appropriate remedial measures are required to rehabilitate the quality of water to maintain sustained socio-economic growth in developing countries.

A. Background

In recognition of the relationship between the availability of adequate fresh water of acceptable quality and sustained socio-economic development of countries in the region, the ESCAP secretariat organized an expert group meeting on protection of water resources, water quality and aquatic ecosystems in Bangkok from 17 to 21 October 1994 and published a set of guidelines on protection of water resources in the region. Again in 1995, a project on the formulation of guidelines on water and sustainable development was launched to minimize the effect of water resources development on the environment and the effect of water use by various sectors of economic development on the quantity and quality of water resources. This project has now culminated in a set of guidelines for water and sustainable development.

The above activities were focused mainly on preventive measures to protect the quality and quantity of water resources before more serious deterioration takes place. It was decided to consider separately the remedial measures required to rehabilitate rivers and streams with high levels of pollution. With the rapid growth of urban populations and industrialization many rivers are now severely contaminated by the discharge of industrial and human wastes making the water from these rivers unfit for human use. In some cases the contamination has reached such high levels that it has become impossible for the existence of fish and other forms of aquatic life. These conditions dictate the necessity of formulation and application of appropriate rehabilitation measures that will improve the quality of water and re-establish the life supporting role of the rivers for sustainable development.

In response to the above need the ESCAP secretariat is implementing a project on the rehabilitation of water quality in contaminated rivers in the region which consists of two phases. Phase I of the project comprises a study on the sources and nature of water quality problems in selected rivers in Asia and the Pacific, which is based on information collected from countries through the circulation of a questionnaire and field visits. The draft report was reviewed and discussed at a regional seminar on the subject which was held in Bangkok from

10-14 November 1997. The present document comprises the final report for this phase and incorporates the outcomes of the regional seminar. This document is intended to provide a clear picture of the state of water quality in rivers of countries in Asia and the Pacific. Under Phase II, a manual and guidelines on appropriate methods and procedures to protect and rehabilitate contaminated rivers would be prepared and their practical usefulness and applicability to countries in the region would be discussed and adopted at an expert group meeting on the subject. The proposed manual and guidelines will identify the latest available technological options for rehabilitating the water quality of rivers and effect transfer of technology to developing countries in this field.

The work that has been undertaken in preparing this document is in line with the provisions of Agenda 21, particularly Chapter 12 Managing fragile ecosystems; Chapter 14 Promoting sustainable agriculture and rural development; and Chapter 18 Protection of the quality and supply of freshwater resources.

B. Development of the questionnaire

The questionnaire on the sources and nature of water quality problems and measures being undertaken in ESCAP countries was designed to obtain broad information on the following:

- Sources and nature of pollution in rivers
- Relative importance of the various sources in the rivers of each participating country
- Social, institutional and administrative settings in each participating country
- Water quality management issues.

A total of 17 countries returned 25 questionnaires. The countries were Australia (1), Cambodia (1), China (1), India (1), Indonesia (2), Islamic Republic of Iran (1), Japan (1), Lao People's Democratic Republic (1), Mongolia (1), Myanmar (1), Nepal (2), New Zealand (1), Philippines (4), Singapore (1), Thailand (3), Turkey (1) and Viet Nam (2).

All responses were entered into a database for analysis. The low number of responses to the questionnaire meant that in-depth statistical analysis was not possible. However, all responses were taken into consideration for a comparative study of the nature and sources of water quality problems in Asia and the Pacific.

The responses gained from the questionnaires and information from other relevant sources have been compiled and analysed in this paper.

It is important to bear in mind that the questionnaires returned to ESCAP have been answered by various people from different agencies responsible for water management on some level. Therefore, the responses provide only a sample of water quality problems and their relative importance, management issues and the social and administrative setting in each country.

II. OVERVIEW OF THE ESCAP REGION

The Asia Pacific region currently supports around 3.3 billion people. This figure is expected to double in just 44 years which means that food requirements would double, the need for water and sanitation would quadruple and the consumption of energy and manufactured goods would increase fivefold (ESCAP, 1996). The current availability and use of water resources in the region varies widely according to factors such as physiography, climate and socio-economic development.

Asia and the Pacific generate between 29-32 per cent of the global total volume of run-off, contributing approximately 13,260 km^3. The total volume of run-off on the earth is estimated to be between 41,000 km^3-46,000 km^3 per annum. The total amount of annual water withdrawal in the region is estimated at 1,677 km^3, accounting for around a quarter of the global total (ESCAP, 1996).

Table 1 shows water resources availability and use in selected countries in the ESCAP region. Water resources availability refers to annual internal renewable water resources (ground and surface water), excluding river flows from other countries. Water resources use refers to annual water withdrawal (ground and surface water sources).

Water resources availability and use in the region (ESCAP, 1997) vary widely for different countries depending on their respective physiographic conditions as well as socio-economic development. The region has some of the world's most important river systems. Seven of Asia's largest river systems, namely the Changhua Jiang, Huang He, Mekong, Ayeyarwady, Brahmaputra, Ganges and Indus, have a total drainage area of more than 6 million km^2, much of which is heavily populated. Therefore, the economic development and the welfare of people in the region are very dependent on the progress made in the development and management of its water resources.

It should be noted that users can obtain only part of the renewable water resources from water bodies, owing to the high variability of stream flow between low water and flood seasons and the lack of storage sites on many catchments. Since a large part of the run-off occurs in the form of flood flows of relatively short duration and runs out to sea unarrested, the volume of usable flow is substantially less than the total renewable water resources. Moreover, much of the water resources are in remote areas where it is difficult and uneconomic to undertake development activities. For example, it is estimated that in Australia only 100 km^3 out of a total of 398 km^3 of annual renewable water resources can be considered exploitable for use on a sustained basis for this reason.

In general, the ratio of water use to water availability may be taken as an indicator of the degree of water scarcity in a particular situation. It is estimated that water tends to become a limiting factor in national socio-economic development when water withdrawal exceeds 20 per cent of annual total renewable water resources.

Countries which have the ratio of water use to water availability less than 1 per cent include the Lao People's Democratic Republic, Myanmar, New Zealand and Papua New Guinea. Obviously, the water resources in these countries apparently remain largely untapped and therefore have less likelihood to face water crisis in the near future.

Countries which have the ratio of water use to water availability between 1 and 20 per cent may be considered as those which have some potential for water crisis. Countries belonging to this category include Australia, Bangladesh, Bhutan, Cambodia, China, Fiji, Indonesia, Malaysia, Mongolia, Nepal, Philippines, Solomon Islands, Thailand and Viet Nam.

Countries which have the ratio of water use to water availability exceeding 20 per cent may be considered as those which have the highest potential for water crisis. Countries which belong to this category include Afghanistan, Democratic People's Republic of Korea, India, Islamic Republic of Iran, Japan, Pakistan, Republic of Korea and Sri Lanka. These countries need urgent attention with regard to taking necessary actions to avoid a water crisis.

Owing to the uneven spatial distribution of water resources, the development of large regions of some countries, such as China, India, Pakistan, Thailand, etc. is hampered by shortage of water. On the whole about 15-35 per cent of the renewable water resources are at present exploited in those countries, except in Pakistan where a very high 73 per cent of the renewable resources are reported to be already exploited.

Table 1. Water resources availability and use in selected countries of the ESCAP region

Country	Population (thousands) (1995)	Total land area (km^2)	Water resources availability (km^3/yr)	Water resources use (km^3/yr) (1995)	Water use as a percentage of water availability
Afghanistan	20 141	652 090	60	26	43
Australia	18 040	7 682 640	398	24	6
Bangladesh	120 433	144 000	115	23	20
Bhutan	1 638	47 000	95	<1	1
Cambodia	10 251	181 035	88	1	1
China	1 227 000	9 600 000	2 812	500	18
Democratic People's Republic of Korea	23 917	120 410	67	14	21
Fiji	784	18 270	29	<1	3
India	935 744	3 287 260	1 142	552	48
Indonesia	195 756	1 811 570	2 986	49	2
Islamic Republic of Iran	67 283	1 636 000	130	75	58
Japan	125 251	377 800	435	90	21
Lao People's Democratic Republic	4 882	236 800	270	1	<1
Malaysia	19 948	328 550	566	12	2
Mongolia	2 410	1 566 500	25	<1	4
Myanmar	46 527	657 540	606	4	<1
Nepal	20 892	147 181	207	12	6
New Zealand	3 536	270 530	397	2	<1
Pakistan*	135 280	796 000	247	180	73
Papua New Guinea	4 302	452 850	801	<1	<1
Philippines	67 581	298 170	356	105	30
Republic of Korea	44 851	99390	70	30	42
Solomon Is.	378	27 990	45	<1	2
Sri Lanka	18 354	65 610	47	10	21
Thailand	59 000	511 000	210	33	16
Viet Nam	71 000	330 000	318	65	20

Source: Economic and Social Commission for Asia and the Pacific, *Report of the Ad-Hoc Group Meeting on Sustainable Development of Water Resources* (Bangkok, 10-12 July 1996). ENR/rep. 12 July 1996. pp 3/Annex 2.

* Figures provided by General Manager (Projects), NESPAK

Water availability may thus become a limiting factor in national development as a whole or in the development of certain regions in a number of countries of Asia and the Pacific region.

A. General features of selected rivers in the ESCAP region

A summary of the general features of selected rivers in Asia and the Pacific is presented in table 2. Most of the material presented in this section was obtained through the circulation of questionnaires to countries and supplemented by information collected during field visits to selected countries, as well as from UNESCO-IHP (1995) and other sources as indicated in the table.

B. Selected rivers having water quality problems

Table 3 lists those rivers identified in several countries in the ESCAP region with severe water pollution problems. Where there are more than three rivers described for a given country then the first three rivers listed have been identified as having the most severe pollution problems, and are ranked in order of the severity of these problems. Several countries in the ESCAP region are currently undertaking remediation measures on a number of rivers or are planning to do so, and these are also indicated in table 3. Descriptions of key features of a selection of these rivers are presented below.

Cambodia, Lao People's Democratic Republic and Nepal have indicated that there are no remediation works currently carried out on rivers. There are no plans to undertake any remediation measures on rivers in Cambodia in the near future. The Bagmati River in Nepal is a sacred river and it has been suggested that this may induce the Government to undertake rehabilitation works.

Most countries in the Asia-Pacific region would require technical assistance provided through ESCAP in connection with undertaking remediation works. Countries which have specifically indicated an interest included Cambodia, China, Indonesia, Lao People's Democratic Republic, Mongolia, Myanmar, Nepal, the Philippines and Viet Nam.

1. Australia

The **Cooks River** is located entirely within the metropolitan area of Sydney. It drains parts of the inner western suburbs of the city and flows into Botany Bay immediately to the south of the international airport. Its major tributaries include Wolli Creek and the Alexandria Canal. The river has been channelized and concrete lined over a considerable portion of its length. The river is badly polluted by stormwater drainage flows, sewer system overflows in wet weather, illegal dumping of liquid industrial waste and dumping of rubbish. The Alexandria Canal is particularly badly polluted by run-off and effluent from surrounding industries. Wolli Creek retains some environmentally sensitive reaches which are still in reasonably good condition but are under considerable development pressure. Policies, plans and a work programme have been implemented to clean up the Cooks River system based on a "Total Catchment Management Plan" that involves government agencies, local government and community groups in its implementation, mainly through a "TCM Committee". Enforcement is starting to prove effective in reducing illegal dumping activities.

The **Hawkesbury-Nepean River** system and its catchment borders Sydney, the capital city of the state of New South Wales to the north, west and south-west. The catchment of the Hawkesbury-Nepean River system covers an area of 22,000 km^2. The main river extends 470 km from near Goulburn to Broken Bay and is fed by thousands of kilometres of tributaries. The Hawkesbury-Nepean supplies 97 per cent of the water for residential and business purposes in the Sydney region (approximately 1,500 ML/d). The catchment supplies 10 per cent of state agricultural output and supports major manufacturing industries. Almost one million people live in the catchment. Human-induced impacts on the river system include waste from 20 major sewage treatment plants, water diversions for municipal purposes and irrigation, run-off from agricultural land and stormwater drainage (Hawkesbury-Nepean Catchment Management Trust, 1996).

The **Murray-Darling** basin covers more than 1 million km^2 over inland south-eastern Australia, which equates to approximately one seventh of the continent.

Table 2. Main features of rivers in selected countries of the ESCAP region

Country/river	Location	Catchment area (km^2)	Length (km)	Mean annual discharge (m^3/sec)
Australia				
Lockyer Creek	S.E. Queensland	3 000	100	6
Hunter	Central coast of NSW	22 000	340	50
Campaspe	North Victoria	4 800	90	8
Onkaparinga	South Australia	3 510	75	-
Hawkesbury-Nepean	NSW	22 000	470	-
Murray-Darling	Qld/NSW/ACT/Vic/SA	1 000 000	3 500	470
Burdekin	North Queensland	130 000	732	322
Pioneer	Central Queensland	1 500	120	29
Bangladesh				
Brahmaputra	Bahadurabad	39 000	260	19 500
Ganges	Harding Bridge	46 000	157	11 500
Meghna	Bhairab Bazar	35 000	403	7 500
Cambodia				
Tonle Sap	Central Part	6 375	120	387
Bassac	Southern Part	5 215	100	410
Prek Thnot	Kampong Speu	5 050	232	39
Upper Mekong	Eastern Part	17 724	390	458
Lower Mekong	SouthernPart	6 012	110	418
China				
Bei-jiang	Guangdong Province	46 710	468	1 324
Jin-jiang	Fujian Province	5 629	182	50
Jiyun-he	Hebei Province	10 288	157	2
Yangtze	Southern China	1 808 500	6 300	30 933
Yellow	Northern China	752 443	5 464	1 877
Pearl	Southern China	453 690	2 214	10 654
Liaohe	Northeast China	228 960	1 390	469
Haihe	Northern China	263 631	1 090	723
Huaihe	Middle China	269 283	1 000	1 937

Country/river	Location	Catchment area (km^2)	Length (km)	Mean annual discharge (m^3/sec)
India				
Ganga	Uttar Pradesh and Bihar	861 452	2 525	16 648
Godavari	Andhra Pradesh	312 800	1 465	2 834
Krishna	Andhra Pradesh and Maharastra	258 950	1 401	943
Subernareka	Bihar	29 196	-	180
Brahmaputra	Assam	194 413	916	17 036
Brahmani	Orissa	51 822	799	620
Baitarani	Orissa	12 789	365	178
Cauvery	Karnataka and Tamilnadu	87 900	270	674
Indus	Punjab	321 289	1 114	2 324
Pennar	Andhra Pradesh	55 213	597	119
Sabarmati	Gujarat	21 674	371	34
Mahi	Gujarat	34 842	583	127
Tapi	Madhya Pradesh and Gujarat	65 145	724	117
Purna	Gujarat	2 322	142	43
Vaitarna	Maharashtra	3 647	171	103
Netravathy	Karnataka	3 222	103	399
Bharatapuzha	Kerala	6 186	209	170
Karuvannu	Kerala	1 054	-	45
Chalakudy	Kerala	1 704	-	59
Periyar	Kerala	5 398	244	256
Vamsadhara	Orissa	10 830	221	63
Ponnaiyar	Tamilnadu	15 865	396	8
Indonesia				
Citarum	West Java	6 080	269	98
Solo	Central and East Java	16 100	600	363
Brantas	East Java	12 000	320	194
Japan				
Yoshino	Shikoku	3 750	194	144
Ara	Central Honshu	2 940	173	26
Mogami	Northern Honshu	7 040	229	174
Lao People's Democratic Republic				
Nam Ou	Northern part	24 653	3 335	403
Nam Ngum	Central part	12 605	1 403	601
Nam Theun	Central part	14 810	2 047	478
Se Bang Fai	Central part	9 413	1 124	440
Se Bang Hieng	Central part	21 516	3 442	518
Se Done	Champasack province	8 084	1 574	164
Malaysia				
Rajang	Central Sarawak	50 707	432	2 510

Country/river	Location	Catchment area (km²)	Length (km)	Mean annual discharge (m³/sec)
Myanmar				
Ayeyarwady	Central Myanmar	396 800	2 064	12 127
Chindwin	Central Western	103 500	837	4 694
Thanlwin	Eastern Myanmar	156 167	1 220	8 172
Bago	Central Myanmar	5 300	267	254
Sittoung	Central Myanmar	34 400	320	1 332
Bilin	Southern Myanmar	2 420	160	197
Lemro	Western Myanmar	10 000	270	796
Kaladan	Western Myanmar	22 600	650	1 706
Mayu	Western Myanmar	5 115	154	349
Lenya	Southern Myanmar	3 197	-	235
Great Tanintharyi	Southern Myanmar	17 777	-	1 633
Dawe	Southern Myanmar	2 885	-	271
Nepal				
Mahakali	Far Western	5 400	233	557
Karnali River	Far & Mid Western	41 360	435	1 398
Babai River	Mid Western	3 252	190	72
West Rapti River	Mid Western	6 215	257	125
Narayani River	Western & Central	31 726	451	1 767
Bagmati River	Central	3 681	163	214
Kamala River	Eastern	1 786	117	75
Kosi River	Central and Eastern	27 863	534	1 566
Kankai River	Eastern	1 317	108	73
New Zealand				
Buller	South Is.	6 480	159	426
Pakistan				
Ravi*	Punjab	40 145	900	151
Sutlej*	Punjab	121 988	1 551	118
Jehlum	Punjab	63 455	826	954
Chenab	Punjab	67 544	1 242	1 103
Indus*	All Pakistan	672 157	3199	3 628
Philippines				
Pasig	Metro Manila	4 678	25	13
Magat	Northern Luzon	4 631	205	310
Pampanga	Central Luzon	9 759	210	346
Republic of Korea				
Pyungchang	Kangwon Province	1 781	149	52
Geumho	Kyongbuk Province	2 088	118	15
Miho	Central Republic of Korea	1 861	89	25

*Water allocated to India, Discharges relate to diversions from the western rivers

Country/river	Location	Catchment area (km²)	Length (km)	Mean annual discharge (m³/sec)
Sri Lanka				
Mahaweli	Northeastern Province	10 448	335	349. 3
Kelani	Western Province	2 292	145	173.6
Kalu	Western Province	2 719	76	249.3
Walawe	Southern Province	2 442	138	69.3
Thailand				
Ping	Northern Thailand	33 898	740	262
Mae Klong	Western Thailand	30 837	520	273
Chao Phraya	Central Thailand	20 125	379	4 000 (upper CP dam) 2 500 (Singburi) 1 800 (Ang Thong)
Tha Chin		19 356	307	310
Bang Pakong	Eastern Thailand	8 679	115	-
Viet Nam				
Bang Ky Cung	North Mountain	11 200	200	290
Red-Thai Binh	North Region	86 500	370	4 344
Ma	North Central	17 600	240	637
Ca	North Central	17 730	185	767
Thu Bon	South Central	10 350	110	599
Ba	South Central	13 900	220	327
Dong Nai	South East	37 400	245	1 160
Mekong	South West	40 000	200	16 000
Srepok	Central Highland	18 430	145	498
Sesan	Central Highland	11 620	143	361

Source: Adapted from ESCAP, 1995 (a), UNESCO-IHP, 1995 and Central Water Commission, India 1993 and 1996, Laut and Taplin, 1989, Millington, 1996, and data collected through field visits to countries.

Three quarters of the state of New South Wales is in the basin as well as over half of Victoria, 15 per cent of Queensland and 7 per cent of South Australia. Over twenty rivers flow through the basin, making it one of the longest river systems in the world. Climatic zones in the basin vary from cool and humid to sub-tropical with annual rainfall ranging from 1,200 mm along the mountains in the east, to 150 mm in the arid west. The Murray-Darling basin supports approximately 2 million people and is the most significant agricultural area in Australia (Millington, 1996).

2. Bangladesh

The **Ganges River** has a length within Bangladesh of only 157 km, out of a total of approximately 2,550 km, before it joins the Brahmaputra River. The local catchment area within Bangladesh is 46,000 km². The Ganges system serves about 37 per cent of the total area of Bangladesh. The area dependent on the Ganges in Bangladesh is a large delta formed by silt deposited by the river. The tip of this delta is situated at the point where the Ganges crosses the India-Bangladesh border. From this point a series of distributaries branches off, of which two major distributaries in Bangladesh are the Gorai River and the Arial Khan River. About 40 million people, or about one-third of the population depend on the Ganges in many ways. It provides drinking water, supports agriculture, maintains fish life, forests and fauna, allows navigation and checks salt water intrusion from the Bay of Bengal.

Table 3. Identification of problem rivers

Australia (NSW)	Cambodia	China	India	Indonesia	Iran (Islamic Rep. of)	Japan	Lao People's Democratic Republic	Myanmar	Nepal	New Zealand	Philippines	Sri Lanka	Thailand	Viet Nam
Cooks*	Mekong	Huaihe**	Ganga*	Ciliwung*	Karun*	Yamato**	Mekong*, **	Yangon**	Bagmati**	Tarawera*	Tullahan-Tenejeros	Kelani	Chao-Phraya*,**	Saigon*
Hawkesbury-Nepean*	Bassac	Haihe**	Godavar**i	Citarum*	Zayandeh Rood**	Ayase**	Se Bang *,** Hieng	Bago**		Mataura*	San Juan**	Mahaweli	Tha-Chin*	Tolich
Darling*	Tonle Sap	Liaohe**	Sabarmati**	Cipinang*		Tsurumi**	Nam Ou*,**	Sittong**		Waikato*	Zapote-Las Pifias	Kalu	Mae Klong	Set
Hunter		Taihu*,**	Krishna**	Surabaya ** in BRB			Se Bang Fai*,**	Upper Myanmar rivers		Marjapito		Walawe	Bang Pakong	Song Cau
Murrumbidgee		Caohu** Lake	Sutlej**							Waitoa	Pasig*,**		Mun*,**	Tseuong
Murray*		Dianchi** Lake	Khan Kshipra	Mas						Waihou	Meycauyan**			Canal in HCM
Lachlan*			Tapi**								Marilao**			Dong Nai*
Macquarie			Betwa								Pampanga**			Song Lo
Namoi*			Narmada**								Iloilo*			Loch Chay**
			Wainganga											Song Nhui**
			Chambal											
			Cauveri**											
			Subarna-rekha**											

* water quality remediation measures undertaken

** water quality remediation measures proposed

The **Brahmaputra River** originates in the Kailash Ranges of the Himalayas at an elevation of about 5,150 m and flows for about 2,900 km through China and India before it joins the Ganges River, of which 260 km is in Bangladesh. The portion of the basin lying inside Bangladesh is about 39,000 km^2. At the confluence of the Ganges River it becomes the Padma River which flows for 144 km to the confluence of the Meghna River.

The **Meghna River** originates in India as the Barak River. Near the India-Bangladesh border it bifurcates into the Surma River and the Kushiyara River. These two rivers rejoin near Ajmiriganj in Bangladesh to become the Meghna River, which flows in a south westerly direction to meet the Padma River at Chandpur. Below Chandpur the combined stream is known as the Lower Meghna. The length of the Meghna River in Bangladesh is 403 km and the catchment area in Bangladesh is 35,000 km^2. The recorded maximum discharge of the Meghna at Bhairab Bazaar, upstream of the confluence of the Padma River, is 19,800 m^3/s.

The water in all these river systems in Bangladesh is polluted by indiscriminate discharge of various wastes and affected by salt water intrusion, particularly during the dry season. The water is also highly turbid, especially in the wet season. As a result agriculture, industry, irrigation, navigation, fisheries and water supplies for domestic use are adversely affected. Major sources of pollution are municipal sewage, industrial wastewater and increased use of agricultural fertilizers and pesticides in rural areas.

3. Cambodia

The **Tonle Sap River** is about 100 km long and is the connection between Tonle Sap Lake and the Mekong River. The river has a total catchment area of about 6,375 km^2. Twice each year the river reverses its flow direction. About mid-June, as the flows in the Mekong River increase due to melting snow in the north and the onset of the wet season, the Tonle Sap River begins to flow from the Mekong River towards the lake, increasing the area of the lake from about 2,600 km^2 to about 10,500 km^2, and its depth from about 2 m to about 4 m. From about November, as the dry season becomes established and the water levels in the Mekong River fall the Tonle Sap River begins to flow from the lake towards the Mekong River. The lake therefore acts as a natural reservoir that alleviates floods during the wet season and maintains flows in the lower Mekong River, including the delta area, in the dry season. The Tonle Sap River has four main tributaries, namely the Stung Sen, Stung Taing Krasing, Stung Chinit and Stung Boribo.

The viability of Tonle Sap Lake is currently threatened by sedimentation due to highly turbid run-off from the local catchments around the lake during the wet season (Chea Sina, 1997). Sedimentation rates of up to 4 cm per year have been reported in a survey conducted by the World Bank in 1992. There is a concern that the lake may silt up with possibly devastating impacts on the ecology and the national economy. Both the lake and the river are affected by low dissolved oxygen levels and high organic pollutant loads in the dry season, particularly from March to May. The lake is the largest permanent freshwater body in South-East Asia.

The **Bassac River** branches from the Mekong River at Chaktomuk, opposite Phnom Penh, and flows almost parallel to the Mekong River towards the southern border of Cambodia with Viet Nam where it discharges into the Mekong Delta complex. The average annual flow of this river is approximately 410 m^3/s. The river has two main local tributaries, the Stung Prek Thnot and Stung Slakou, which have their origins in the south-west region. In Cambodia the Bassac River is about 100 km long and has a catchment area, including its two main local tributaries, of 11,581 km^2. The river is affected by low dissolved oxygen levels and high organic pollutant loads in the dry season, and by high sediment loads in the wet season.

The segment of the **Mekong River** in Cambodia is considered to be in two parts, namely the Upper Mekong River and the Lower Mekong River. The Upper Mekong River is the longest and biggest river in Cambodia, being about 390 km long. In Cambodia, the river starts from the border of the Lao People's Democratic Republic in the north-east and flows southward until it is deflected westward by the basalt of the Terse Rouge area. It passes through this basalt before continuing south-eastward to Phnom Penh where the river divides into three main branches, which include the Bassac River, the Lower Mekong River and the Tonle Sap River. The Bassac River and the Lower Mekong River form the wide Mekong Delta that starts in south-east Cambodia and enlarges further in Viet Nam.

The **Upper Mekong River** has a total catchment area of about 17,724 km^2 in Cambodia and the mean daily

flow is approximately 458 m^3/s. The river has eight main tributaries, which have their origins in the north-east and eastern plateau of Cambodia.

The starting point of the Lower Mekong River of Cambodia is the ending point of the Upper Mekong River, that is at Chaktomuk which is in front of Phnom Penh. From its starting point, the Lower Mekong River flows towards the south-east border of Cambodia with Viet Nam and discharges into the delta complex in Viet Nam. In Cambodia, the Lower Mekong River is about 110 km long and has a catchment area of 6,012 km^2. The average annual flow of this river is 418 m^3/s. The Lower Mekong River has no tributaries.

4. China

There are about 50,000 rivers with basin areas larger than 100 km^2 in China. Among them, more than 1,500 rivers have basin areas of more than 1,000 km^2. Most rivers are distributed throughout eastern and southern China. In the north-west, the arid climate and scarcity of precipitation means that only few rivers exist, and considerable areas are streamless. Two-thirds of the Chinese territory contains rivers that flow to the sea while the remaining one third consists of inland draining river basins. The majority of rivers in China are fed by rainfall, but some are fed by snow melt in spring and rainfall in summer and autumn. In addition, there are some rivers partly fed by melting glacier water. Most of the rivers in North China freeze over in winter. To the south of the Huaihe River and to the north of the Yangtze River there is sludge ice in the rivers in winter, but generally, the rivers are not frozen over. To the south of the Yangtze River, ice does not generally occur.

The **Yellow River** is the second longest river and the third largest river basin in China, but ranks 23rd in the world in terms of basin area. The Yangtze River has the greatest annual stream flow in China (and the third greatest in the world). The Pearl River has the second greatest annual stream flow and the stream flow of the Yellow River ranks fifth.

According to available statistics on 1,200 rivers currently monitored, 850 are considered to be severely polluted and some major lakes are already in various phases of eutrophication. Sediment loads are especially severe in some systems such as the Yellow River. In addition, rivers in coastal areas are affected by salt water intrusion. The most highly polluted systems identified are the Huaihe, Haihe, Yellow and Taihu River systems, together with the Caohu and Dianchi Lake systems. Remediation activities are planned for these systems.

5. India

The **Ganga River** originates from the Gangotri glaciers in the Himalayas, at an elevation of about 7,010 m, in the Uttarkashi District of Uttar Pradesh and flows for a total length of about 2,525 km to its outfall into the Bay of Bengal. The principal tributaries joining this river are the Yamuna, Ramganga, Ghaghra, Gandak, Kosi, Mahananda and Sone Rivers. The total drainage area of the basin is 1,086,000 km^2 while the portion lying in India is 861,404 km^2. The Ganga and Yamuna canal systems irrigate vast areas utilizing the perennial flow of the river. To study the deteriorating water quality in the Ganga River, the Government of India has set up the Central Ganga Authority in the Ministry of Environment and Forests.

The **Cauvery River** rises at Talakaveri in the Brahmagiri Range in the Western Ghats in Karnataka state at an elevation of about 1,341 m and flows for about 800 km before discharging into the Bay of Bengal. The basin extends over an area of 87,900 km^2 and lies in the states of Tamil Nadu, Karnataka and Kerala. The important tributaries joining the Cauvery River are the Harangi, Hemavati, Kabini, Suvarnathi and Bhavani Rivers. Almost 87 per cent of the usable surface water potential is already tapped at present, and groundwater utilization is about 32 per cent of the usable potential. Currently there is a dispute among the riparian states regarding water use in the basin.

The **Sabarmati River** rises in the Aravalli Hills in Rajasthan State at an elevation of about 762 m and flows for about 371 km before draining into the Arabian Sea through the Gulf of Cambay. The river basin has an area of 21,674 km^2. The principal tributaries of the Sabarmati River are the Sei, Wakal, Harnav, Hathmati and Wartak Rivers. A considerable portion of the water resources potential of the Sabarmati River system has been developed already. The river is subject to pollution by the industrial waste discharge from the city of Ahmedabad.

The **Narmada River** rises near Amarkantak in Madhya Pradesh at an elevation of about 900 m and flows for about 1,312 km before discharging into the Arabian

Sea through the Gulf of Cambay. The principal tributaries are the Burhner, Tawa, Hiran, Barna, Kolar and Orsang Rivers. The basin extends over an area of about 98,796 km^2. Industries such as textiles, drugs and pharmaceuticals, tobacco, glass and ceramics are located within the basin at Jabalpur, Khandwa and Baruch.

The **Tapi River** rises near Multai in the Betul District of Madhya Pradesh at an elevation of about 752 m and flows for about 724 km before entering the Arabian Sea through the Gulf of Cambay. The basin extends over an area of 65,145 km^2. Its principal tributaries are the Purna, Girna, Panjhra, Vaghur, Bori, and Aner Rivers. The basin lies in the states of Maharashtra, Madhya Pradesh and Gujarat. A number of interstate agreements exist among these riparian states concerning the utilization of the water resources in the basin.

The **Khan River** is a seasonal stream that originates at Bilaoli Tank on the Indore-Khandwa Road and flows from south to north for a total distance of 75 km. It traverses the densely populated industrial city of Indore. All the domestic and industrial wastewater from this city is discharged to the river, either directly or via tributary streams and drains. One of these tributary streams, the Saraswati joins the Khan River on the left bank just upstream of Krishnapura Chhatri, the bathing ghat of Indore. Bathing has been discontinued by the people because of the continuous deterioration in water quality. About 30 km downstream of Indore the river passes through Saanwer where it collects more domestic sewage. It finally joins the **Kshipra River** at Triveni Sangam in the city of Ujjain (M.P.). The Kshipra River is not only a holy river but is also a source of drinking water supply for Ujjain. The Khan River confluence is just upstream of the pumping station at Gaughat (Central Pollution Control Board, 1995).

6. Indonesia

The **Brantas River** is 320 km in length and drains an area of approximately 12,000 km^2. The river is the second largest in Java and it passes through several cities in East Java. The upper reaches of the river are quite steep while the lower part is flat and forms a delta where the river branches into several distributaries, such as the Surabaya River. The river and its catchment are representative of many others in Indonesia with respect to high pollutant loads, such as high sediment loads, exposure to seasonal floods and droughts, densely populated areas and intensive agricultural activity.

In the wet season soil erosion and sediments originating from volcanoes contribute to high sediment loads in the river system. These sediment loads together with domestic solid waste thrown into the rivers and waste material from factories, often fibre from paper mills, result in very high suspended solid loads. Loads of organic pollutants and nutrients are also very high in the wet season.

During the dry season high loads of organic pollutants (BOD) are experienced although these loads are generally less than in the wet season. Most of the pollution is caused by factories and domestic sewage. Domestic sewage is one of the most important sources of organic, nutrient and pathogenic pollution. Industrial activities that are also major contributors include pulp and paper mills, sugar mills, chemical plants, textile factories, food processing plants, metallurgy factories, oil refining and detergent manufacturing plants, and agriculture and derivatives.

Seasonal water quality variations in the reservoirs in the Brantas River system are less obvious. The most contaminated reservoir is Sengguruh Dam, which receives polluted inflows from upstream cities and villages, particularly the city of Malang, and paper mills and tapioca factories along the Lesti River and the Juwok River.

7. Lao People's Democratic Republic

More than 85 per cent of the territory of the Lao People's Democratic Republic is situated in the Lower Mekong Basin. Tributaries to the **Mekong River** in the country generally flow in a north-east to south-west direction. About 35 per cent of all water in the Mekong River originates from catchments within the Lao People's Democratic Republic; these catchments form 26 per cent of total catchment area of the Mekong Basin. In general human activities have not yet had a significant impact on water quality in rivers in the country because of the small population and low population density. Hardness is a problem in some tributaries to the Mekong that flow from limestone areas, such as the **Nam On** and the **Nam Sebang Fai Rivers**. Sediment is a problem in areas affected by deforestation activities.

8. Mongolia

The **Tuul River** is one of the main tributaries of the Selenge River in Mongolia. The Selenge River Basin encompasses the entire northern third of the country. Flowing north into Russia, the Selenge River is the largest contributor to Lake Baikal. The Tuul River flows through two aimags and Mongolia's capital city, Ulaanbaatar. Rapid urbanization has resulted in water quality problems in the river due to discharges of domestic and industrial wastes from the city. Levels of nutrients, organic substances and pathogens are in excess of acceptable limits. As a consequence, the Selenge River is also affected by these pollutants.

Other rivers in Mongolia having water quality problems include the **Khangal River**, the **Orkhon River** and the **Kharaa River**. The Khangal River has problems with pollution by heavy metals, organic substances and salinity. Heavy metals and organic substances are also problems in the Orkhon River, which is affected by nutrients as well. Pollutants carried by the Kharaa River include heavy metals and chloroform extracts.

9. Myanmar

Water quality levels in urban areas, such as Yangon and Mandalay and industrial centres in satellite towns are showing damaging trends. Industrial effluents together with domestic wastes are causing water quality problems, especially in drains in urban areas. Industries discharging effluents include paper mills, textile mills with bleaching and dyeing facilities, tapioca starch factories, and to a lesser extent, leather tanning factories and breweries. Sediment loads are also increasing due to combinations of erodible soils, steep slopes and activities such as shifting cultivation and deforestation. The **Yangon River**, the **Bago River** and the **Sittaung River** have been identified as the rivers with water quality problems of greatest concern in Myanmar. The **Yangon River** has a catchment area of approximately 19,000 km^2. It has an important role in the water supply for the capital city, Yangon. The **Bago River** has a catchment area of approximately 5,350 km^2.

The **Sittaung River** rises just south of Mandalay, runs parallel to the Ayeyarwady River on its eastern flank and discharges into the Gulf of Moktama. The Sittaung River is 320 km in length with a total drainage area of approximately 34,400 km^2 and an average annual flow of 42,000 million m^3 (1,330 m^3/s) (UNESCO-IHP, 1995).

The **Ayeyarwady River** basin is one of Myanmar's primary drainage systems. This river and its tributaries make up some two-thirds of the total area of the country. The Ayeyarwady River system can be divided from north to south into three distinctive parts, the northern basin, the central valley and the delta (UNESCO-IHP, 1995). The total catchment area is 404,000 km^2, including the delta area. The river flows southward 2,000 km to the Bay of Bengal. It is navigable for a distance of over 1,300 km inland and its tributary, the Chindwin, for another 160 km (ESCAP, 1995). It is noteworthy that the Ayeyarwady River may be classed among the fastest eroding in the world. The average annual sediment load carried by this stream is estimated to be 236 million tons at Pye (Prome).

10. Nepal

The **Bagmati River** originates from the southern face of Shivapurilekh in Kathmandu. It drains an area of 3,681 km^2 including the Kathmandu Valley and is 163 km long. The river flows into the Ganges River in India, and main tributaries are the Manahara, Bishnumati, Kulekhani, Kokhajhor Khola and Marin Khola. The average annual flow of the Bagmati River is 214 m^3/s. The maximum daily mean discharge is 4,050 m^3/s and the minimum is 5.8 m^3/s.

Water from the Bagmati River is used extensively for irrigation in the lower reaches as it emerges on to the plains. The only storage project in Nepal, the Kulekhani Storage Hydro-electric Project (installed capacity 92 MW) is also located on this river system. This project has suffered extensively due to sedimentation of the reservoir which has compelled the relocation of the intake tunnel inlet to a higher elevation, thus reducing the active storage capacity.

In its upper reaches, which are in the Kathmandu Valley, the Bagmati River is seriously polluted with high concentrations of toxic and organic contaminants. Sewage and industrial wastes are the most visible sources of pollution along the Kathmandu section of the river, but non-point sources such as air pollutants, pesticides and fertilizers are also significant contributors. Approximately 76 per cent of industrial wastewater in the Kathmandu Valley is contributed by carpet, dairy, textile, leather, soft drink and alcohol, pulp and paper, sugar, vegetable oil and iron/steel industries. Further downstream water quality improves due to natural cleansing effects.

11. Pakistan

The **Ravi River** is the smallest of the five rivers that traverse the Indus Plain in Punjab. It has a total catchment area of 40,145 km^2 at its confluence with the Chenab River. The total length of the Ravi River is about 900 km and it enters Pakistan about 32 km north-east of Lahore. One barrage on the river exists at Madhopur in India and there are two barrages in Pakistan, at Balloki and Sidhnai. It joins the Chenab River below Sidhnai Barrage. The headwaters of the Ravi River were allocated to India under the Indus Basin Treaty of 1960. The mean annual flow of the river is 151 m^3/s, after diversions have been taken out.

The Ravi River is one of the most polluted in Pakistan, especially in the reach from its entry point into Pakistan from India to the point where the Qadirabad-Balloki (Q-B) Link joins it due to the sewage discharges from Lahore and industrial wastes from the Kala Shah Kaku and Sheikhupura Road industrial estates. The Q-B Link joins the river upstream of the barrage at Balloki. Downstream of this barrage, sewage and industrial effluents and agricultural drainage discharge to the river at a number of locations. Industries located in Lahore and the industrial estates include chemical industries, tanneries, textile mills, steel re-rolling mills, and others discharging effluents containing hydrochloric acid and high levels of organic matter. More than 250 industries in Faisalabad discharge high levels of solids, heavy metals, aromatic dyes, inorganic salts and organic materials directly into the municipal sewers and open surface drains, ultimately leading to the Ravi River. Much of Lahore's solid waste is disposed off into the landfills along the banks of Ravi River. With rainwash and seepage, it becomes a potent source of river pollution.

The **Kabul River** is a major right bank tributary of the Indus River that originates in Afghanistan. On entering Pakistan it flows through North-West Frontier Province to join the Indus River downstream of Tarbela Dam. A major reservoir on the Kabul River is formed by Warsak Dam which is located upstream of the city of Peshawar. Water quality in the Kabul River is being adversely affected by effluents from industries around Peshawar. Out of 40 major industrial operations, only two have wastewater treatment facilities, while the others discharge their effluent into lakes and tributaries of the Indus River, and the Kabul River is the main recipient of this effluent. Adverse impacts on the beneficial use of receiving water bodies for fish culture, particularly, and for domestic purposes have been identified, especially due to the discharge from leather tanning operations.

The **Chenab River**, the second longest of the rivers in Pakistan, originates in Himachal Pradesh, India and enters Pakistan territory in Sialkot District. The Chenab River eventually joins the Indus River 64 km below Panjnad. This 64 km reach is also called the Panjnad River. Total length of the river is about 1,242 km and its catchment area is 67,544 km^2 of which 34,885 km^2 is in Pakistan. The mean annual flow of the river is 1,103 m^3/s. Under the Indus Basin Treaty of 1960 the waters of the Chenab River are allocated to Pakistan.

The **Indus River**, one of the mightiest and the longest rivers of the world, originates at a spring on the north side of the Himalayan Range in Tibet (China) at an altitude of 5,486 m. The total length of the river is 3,199 km and its catchment area is about 965,300 km^2. From its origin to the Guddu barrage in Pakistan it is termed the Upper Indus while downstream of it, the river is called the Lower Indus. The Upper Indus River has 27 major tributaries. The Kabul River and the Gomal River are the two biggest tributaries in addition to the tributaries joining the Indus River just below Panjnad. The only significant tributary inflow to the Lower Indus River is from Khirther and Sulaimanki Range hill torrents which find their way to the river partly through Baran Nai and partly by being routed through Manchhar Lake, which is one of the largest freshwater lakes in Asia.

The major storage reservoir on the Indus River is Tarbela Dam, with a live storage capacity of 11.5 km^3, for irrigation water supply and hydropower production. Besides the dam there are three barrages on the Upper Indus at Kalabagh, Chashma and Taunsa. The three barrages on the Lower Indus are located at Guddu, Sukkur and Kotri. The mean annual flow of the river is 3,628 m^3/s.

Extensive canal irrigation, supplemented with groundwater abstraction and combined with a lack of adequate drainage, has severely affected the salt balance of the Indus Plain and has caused waterlogging and land salinisation. Irrigation return flows and run-off from agricultural fields are carrying salts, residues of fertilizers, pesticides and insecticides and are ultimately finding their way through drains into the rivers of the basin and other water bodies, such as Manchhar Lake.

12. Philippines

The most highly polluted river systems in the Philippines are all located in Metro Manila, and comprise the **Tullahan-Tenejeros River**, the **San Juan River**, the **Zapote-Las Pinas River** and the **Pasig River** systems. Except for the upstream parts of the Marikina River, which is a tributary of the Pasig River, all these river systems are biologically dead due to pollution by solid and liquid wastes from domestic and industrial sources.

Other rivers in the Philippines with water quality problems include the **Agno River** and the **Pampanga River**. The Agno River is located in Zambales Province in Northern Luzon, and has a catchment area of 5,952 km^2. It is important as a major source of water supply for irrigation. It has a pollution problem due to sediment loads from erosion and mine tailings. The mine tailings contain significant concentrations of heavy metals such as copper, lead, zinc and cadmium (National Irrigation Administration, undated). The Pampanga River basin is located in eastern Central Luzon. It covers an area of 9,759 km^2 and includes all or parts of the provinces of Quezon, Bulacan, Rizal, Tarlac, Nueva Vizcaya, Pampanga, and Nueva Ecija (UNESCO-IHP, 1995).

13. Republic of Korea

The **Nakdong River** has a catchment area of 23,817 km^2 and a total length of 522 km, and is the longest in the Republic of Korea. The city of Pusan, which is the second largest in the country, relies on water from the lower reaches of this river as a drinking water source. Water quality is a concern because of the large amounts of pollutants that are discharged from industrial and domestic sources in the upper and middle reaches of the river system.

Other rivers where water quality is a concern, because it has been deteriorating continuously during the last ten years, include the **Kuem River** and the **Youngsan River**. The catchment area of the Kuem River is 9,810 km^2 and its length is 396 km, while the catchment area of the Youngsan River is 3,371 km^2 and its length is 136 km. However, during this same ten year period the water quality in the Han River, which has the largest river basin in the country (26,018 km^2), has been improving.

In addition to the rivers of the Republic of Korea, lakes and reservoirs are important water resources. **Paldang Lake** supplies drinking water to 20 million residents in Seoul and surrounding regions. The area surrounding the lake has been declared a Special Measures Zone to help protect it, but the water quality has been reported to have deteriorated, threatening the safety of this drinking water source. Waste from numerous restaurants, hotels and cafes has been identified as a main source of the pollution.

14. Sri Lanka

The **Kelani Ganga** has the second largest catchment in Sri Lanka, at 2,292 km^2. It plays an important role in the national economy since it drains the most fertile land in the wet zone of the island and intersects the populated and economically important Western Province, including Colombo, the capital. The Kelani Ganga is the major source of water for Colombo. Water quality in the Kelani Ganga is affected by organic matter from sewage and industrial effluents, nitrates from sewage and fertilizer run-off, and heavy metal contamination from industrial effluents (including tanning, processing and metal finishing industries), predominantly from the Colombo area. These discharges are also contributing to bacterial contamination in the river. Solid wastes dumped in urban drains and watercourses are a problem as well. Other activities contributing to water quality problems in the Kelani Ganga include deforestation, which is causing increased sediment loads, and sand extraction which is facilitating tidal flows and leading to problems of salt water intrusion. Mining of the river bed for gems is causing river stability problems and also contributing to sedimentation problems (de Silva, 1997).

The catchment area of the **Mahaweli Ganga** covers about 16 per cent of Sri Lanka's land area, or 10,448 km^2. Its discharge amounts to one-fifth of all the island's river discharge and, with its circuitous course, is the only perennial river traversing the northern dry zone. The river is important as a source of irrigation water in the Mahaweli Development Scheme. Salinity has become a problem in System H of this scheme, where about 100 ha have had to be abandoned because of adverse impacts on soil permeability. The Mahaweli Ganga is also affected by increased sediment loads due to deforestation and by gem mining in some of its tributaries, as well as washoff of agrochemical residues.

The **Kalu Ganga** is located in the southern part of Sri Lanka, and has a catchment area of 2,719 km^2. It originates from Adam's Peak and flows to the west coast. The Kalu Ganga is affected by increased sediment loads due to deforestation and by gem mining in some of its tributaries, as well as by washoff of agrochemical residues.

The **Walawe Ganga** is one of the main rivers in the Southern Province. It traverses three districts and flows to the south/south-east coast. It has a catchment area of 2,442 km^2. Part of the Walawe Ganga is polluted by paper mill effluents. The Walawe Ganga is also affected by increased sediment loads due to deforestation and by washoff of agrochemical residues.

15. Thailand

The **Chao Phraya River** basin is the largest in Thailand with total drainage area of about 178,000 km^2, or 38 per cent of the total area of the country. The river originates from mountains in the northern region as four main tributaries, namely the Ping, the Wang, the Yom, and the Nan Rivers. The Ping and the Wang Rivers join in Tak Province and this stream becomes the Chao Phraya River at Nakhon Sawan where the tributary formed by the confluence of the Yom and Nan Rivers, which combine a short distance upstream, join the main stream. The Chao Phraya River flows through fertile plains of the central region and the Bangkok Metropolitan Region (BMR) before draining into the Gulf of Thailand near Samut Prakarn. The resident population of the BMR is approximately 8 million, but this figure increases by about 50 per cent during the day. The Chao Phraya River in its lower reaches, particularly within the BMR, is one of the most polluted waterways in Thailand.

Upstream of Ayuthaya the Chao Phraya River is generally in a much better condition than in the reaches in and downstream of Bangkok. Land use is dominated by rural activities such as paddy fields, field crops, pasture, orchards and other agricultural uses. Dry season irrigation, although not extensive, is also practised. Livestock farming is undertaken as well but is not highly concentrated.

Municipal populations upstream of Bangkok are small to medium, typically well below 100,000 people and wastewater discharges are predominantly domestic in nature with only a small percentage attributable to industrial sources. There is however, a scatter of small-scale industries throughout the catchment. These range from small rice processing operations, fish drying and produce rendering to medium sized slaughterhouses and meat processing facilities.

The **Tha Chin River** separates from the main Chao Phraya River on the western side upstream of Chainat and flows through the central plain and the BMR into the Gulf of Thailand in Samut Sakorn Province. The Tha Chin River has a length of 331 km. The lower reaches of the river, like those of the Chao Phraya River, are heavily contaminated. Piggeries, duck farms as well as the large number of industries within the BMR produce a potent pollutant mix that the river cannot absorb. The upper reaches of the Tha Chin River are predominantly agricultural. There are numerous offtakes for irrigation which is also widely practised. There is only one major urban centre within the Tha Chin catchment outside of the BMR, which is Suphanburi municipality. Water quality in these reaches is generally much better than further downstream.

The lower reaches of the Chao Phraya and Tha Chin Rivers are subject to the influence of tides in the Gulf of Thailand, especially during the dry season. Also worst case water quality conditions are typically observed during the dry season due to increased river retention times, and high temperatures.

The **Bang Pakong River** is located in eastern Thailand and flows into the Gulf of Thailand. There are two main tributaries to this river, namely the Nakorn Nayok and Prachinburi Rivers, and these combine at Chachoeng Sao to form the Bang Pakong River. Water quality monitoring data shows that the Bang Pakong River has problems with low dissolved oxygen levels and high coliform counts, while BOD is a moderate problem. High coliform counts are also a problem in the Nakorn Nayok and Prachinburi Rivers but in other respects water quality in these rivers is fair to good except in populated locations. Domestic wastewater is the main cause of pollution in this river system. Saltwater intrusion causes problems during low flow periods, and sometimes occurs as far as 50 km up the Prachinburi River and 30 km up the Prachinburi River.

The **Mun River** originates in the south of Nakorn Rachasima Province in the north-east of Thailand and flows through four provinces to the Mekong River. Its

catchment area totals 69,700 km². The Mun River is one of the most important rivers in the north-east of Thailand which is the driest part of the country. Water for agriculture and domestic supply is very limited in this region and the river represents a major water source. The Mun River suffers from a growing pollution problem in the form of salinity that is already impacting on water use. This problem is the result of run-off and drainage flows mobilising salt originating from saline rocks underlying the area. The salt is being brought to the surface by water tables that are rising due to deforestation and irrigation. Mining activities in the area are also a contributing factor.

16. Turkey

The rivers systems identified as being the most polluted in Turkey are the **Sakarya River**, the **Buyuk Menderes River** and the **Seyhan River.** Of these the Sakarya River and the Seyhan River have catchment areas of approximately 58,000 km² and 20,000 km², respectively. Both these rivers provide water for irrigation, hydropower and drinking water supply (General Directorate of State Hydraulic Works, 1996).

The Buyuk Menderes River is located in the south western part of Turkey and has a total catchment area of 24,873 km². The length of the river is 584 km and it flows to the Aegean Sea near the city of Izmir. The water resources of the river system have been developed for irrigation supply and hydropower and, to a lesser extent, urban water supply. In the lower reaches of the river there is a delta area that is approximately 30 km wide. This area has been declared as a National Park because of its ecological significance. Potential threats to the delta are agriculture, stockbreeding, fishing and hunting. Water quality problems are occurring because of discharges of domestic and municipal sewage, industrial effluents and agricultural run-off. Pollutants of greatest concern in the river include suspended sediment, pesticide and fertilizer residues from agricultural areas, heavy metals and elevated levels of boron, as well as organic substances from sewage. Salinity is a problem because of the reuse of irrigation return flows as irrigation water. Changes in the flow regime because of dams, such as the Adiguzel Dam, have been identified as a potential threat to fisheries and environmental conservation. The river basin also includes Bafa Lake which is fed mainly by rainfall, but from the river as well by a connecting channel, and by small saline springs. Salinity in the lake is increasing which has adversely affected the lake's aquatic life (Anonymous, undated).

17. Uzbekistan

The water body of greatest concern in Uzbekistan is the **Aral Sea**, and its contributing rivers, including the **Syrdarya River** and the **Amudarya River**. These rivers and others in the Aral Sea Region are being polluted by run-off from agricultural areas, industrial effluents and domestic sewage, causing serious water quality problems, damage to the regional ecology and threats to human health. Pollutants of concern include salt and agricultural chemicals in irrigation return flows and a range of industrial chemicals, many of which are toxic. Pollution by sewage is also a problem, especially from major cities such as Tashkent, and this is causing high loads of organic substances and pathogens. Many of these problems are shared by the other states in the Aral Sea Region, namely, Kyrgyzstan, Tadjikistan, Turkmenistan and Kazakhstan (Umarov, 1997, and Executive Committee of the International Fund for Saving the Aral Sea, 1997).

18. Viet Nam

Waterways in Viet Nam identified as having the greatest water quality problems are **canals in Hanoi and Ho Chi Minh City**, followed by the **Cau River**, the **Dong Nai River** and the **Saigon River**. In Hanoi most of the pollution problems in the canals originate from domestic and industrial wastewater and stormwater. These canals eventually discharge to the Nhue River, via the Toloch, Set and Lu Rivers. In Ho Chi Minh City discharges of domestic sewage and industrial effluents are causing increasing water quality problems. Wastes being discharged from the Tham Luong industrial area to the Tham Luong Canal are causing high levels of BOD, suspended solids loads and concentrations of heavy metals including mercury. The Cau River is polluted by industrial wastes and domestic sewage, particularly from the town of Thainguyen. Discharges from Thainguyen represent 15 per cent of the average dry season flow in this river. The Dong Nai and Saigon Rivers are affected by domestic and industrial wastewater discharges. They are also affected by salt water intrusion, which extends more than 100 km upstream in both rivers. Salt water intrusion extends more than 100 km upstream in the Vam Co Dong River as well (Pham Xuan Su, 1997).

In addition to the above the Red-Thai Binh River is affected by pollution due to industrial discharges, particularly from the Lam Thao and Viet Tri areas, domestic wastewater discharges and run-off from agricultural land. The Red-Thai Binh River Basin is the largest within Viet Nam, with a catchment area of 86,500 km^2 inside the country. Other streams with water quality problems due to industrial effluents include the Thuong River in Bac Giang Province and Tambac River in the city of Hai Phong.

C. Organizations responsible for water quality in rivers

Government agencies feature prominently in the management of water resources in the Asia-Pacific region. Other organizations include bodies with strong links to the government, such as statutory boards and also non-government organizations. Although water is considered a "sector" in the economy, it is the only sector which is not managed as an entity. Water management is fragmented amongst a variety of sectors such as agriculture, public health, municipal and industrial management, and navigation. Institutionally, water management is fragmented across many often overlapping agencies, with national agencies overlapping provincial and local agency responsibilities. Water management decisions in one sector are often counter-productive in other sectors because of failure to manage the resource in a comprehensive manner (ESCAP, 1997). Table 4 provides a list of organizations and major areas of responsibility identified through the ESCAP questionnaire and other sources where indicated.

The role of government is being rethought in many countries, especially where market principles apply. Many tasks formerly undertaken by government are increasingly being undertaken by the private sector or by government agencies which operate within a market based economic framework.

The role that government chooses to play is quite central to how water quality is managed. There is no single correct model for government as the role will greatly depend on market forces, the social and political context of each particular country, and the type of governance that governments have defined for themselves. Generally, there are three types of governance in the water sector:

- Centralized decision-making

- Partial and/or controlled devolution of decision-making to local levels

- Fully devolved decision-making to local levels - usually at the watershed level with the government as rule maker and referee in a market economy.

Nevertheless, as part of the reform of water policy, there are administrative and institutional changes that can be adopted by any government to improve water resources management (ESCAP, 1997).

Appropriate institutional frameworks (ESCAP, 1997) are necessary for the effective enforcement of water laws, regulations, policies, etc. that have been enacted to ensure the rational planning, development, and use of water resources. Many factors have contributed to a situation whereby governments are forced to play a more active role in managing water.

Many countries in the ESCAP region have problems in developing and enforcing legal and regulatory measures creating appropriate organizational and institutional frameworks needed for implementing water quality management. Various studies by the ESCAP secretariat have indicated that water-related legislation in some countries needs to be modified to at least provide a legal framework for the sector. Such legislation should include institutional regulations to define functions, responsibilities and linkages of water sector institutions and water resources planning management regulations to improve coordination between different sectors in order to strengthen the unified management of natural resources management.

Some examples of the institutional arrangements that apply in selected countries in the ESCAP region are discussed below.

Water resources management in **Australia** is a state matter. For example, in the state of New South Wales, the organization responsible for water quality management in rivers is a government department, the Department of Land and Water Conservation (DLWC). Organizations with similar roles exist in other the Australian states, the two main territories, and at the Federal level.

Table 4. Examples of organizations responsible for water quality in selected countries of the Asia Pacific region

Country	Organization	Identified areas of responsibility
Australia	NSW Department of Land and Water Conservation NSW Environment Protection Authority NSW Department of Agriculture NSW Department of Fisheries Environment ACT Qld Department of Natural Resources Qld Department of Primary Industries Qld Department of Environment and Heritage NT Department of Lands, Planning and Environment SA Department of Environment and Natural Resources Tas Department of Environment and Land Management Vic Department of Natural Resources and Environment WA Department of Conservation and Land Management WA Department of Environment Protection WA Water Authority	Agriculture Irrigation water supply Industry water supply Urban and rural water supply and drainage Land and water management and planning Fisheries Environmental management and planning Water quality monitoring, regulation, licensing, policy development and implementation Education/research (the agencies listed at left have responsibilities in some or all of the above areas)
Bangladesh	**Ministry of Water Resources**	Coordination
	Water Resources Planning Organization	Overall planning and data management Training and assistance in monitoring and evaluation Preparation of national water plans
	Bangladesh Water Development Board	Water resources development Irrigation water supply schemes Rural drainage, flood control Hydrologic and water quality data collection, monitoring and evaluation Operation and maintenance Education and training in water resources management and project operation and maintenance
	Ministry of Agriculture	
	Bangladesh Agricultural Development Corporation	Irrigation water supply schemes Rural drainage, flood control Operation and maintenance Education and training in project operation and maintenance
	Department of Environment	Environmental protection Environmental policy and guideline development Water quality data collection Wastewater discharge classification and monitoring
	Department of Public Health Engineering	Water supply and sanitation in rural and urban areas except Dhaka and Chittagong Water quality monitoring

Country	Organization	Identified areas of responsibility
Cambodia	Ministry of Environment	National plan preparation to protect water quality Pollutant discharge control Law, standard and guideline development Water quality analysis and collection Education and research
	Ministry of Agriculture, Forest and Fishery	Irrigation water supply Hydrological data collection
	Ministry of Public Work and Transportation	Sewer system management Wastewater treatment management
	Ministry of Rural Development	Rural water supply
China (a)	Ministry of Water Resources (Supported by 13 internal departments, 6 river basin authorities, one lake basin authority and 12 research institutes)	Integrated water resources management, planning, legislation and policy development Water resources development planning and design Water quality and environmental protection Reservoir operation Education, Research Water resources assessment Hydropower project construction and operation
	National Environmental Protection Agency	Water pollution prevention and environmental protection
India	**Ministry of Water Resources** Control Water Commission State Water Resources Department	Integrated water resources planning, development, management, design and monitoring Water quality and hydrologic data collection and monitoring Legislation, policy and guidelines related to water resources Environment impact assessment and monitoring Education and research
	Ministry of Environment and Forests Central Pollution Control Board State Pollution Control Boards National River Conservation Authority Nation River Conservation Directorate	Water quality policy and standard development Water quality and environmental protection Water quality monitoring Education, Research Environmental legislation, policy and standards development Water quality and environmental protection Water quality monitoring Environmental regulation

Country	Organization	Identified areas of responsibility
Indonesia	Directorate General of Water Resources Development, Ministry of Public Works	Water resources management planning and policy development Water resources development and management advice Coordination of water sector activities Irrigation water supply Reservoir management Urban and industrial water supply Education/training
	National Environmental Agency (BAPPEDAL)	Water quality and environmental management planning Water quality and environmental standard setting Water quality monitoring Water quality management advice Environmental Regulation
Japan	Water Resources Development Council	High level planning advice on water resources development and management
	National Land Agency	Water resources development planning Supervision of other water sector bodies Land and water management
	Ministry of Health and Welfare	Urban water supply planning and development
	Ministry of Agriculture, Forestry and Fisheries	Irrigation and rural drainage
	Ministry of International Trade and Industry	Industrial water supply and hydropower generation
	River Bureau, Ministry of Construction	Flood control, erosion control and river training Construction and operation of multipurpose reservoirs
	Water Resources Development Public Corporation	Coordination of water resource development activities Integrated operation and maintenance

Country	Organization	Identified areas of responsibility
Lao People's Democratic Republic (b)	**Prime Minister's Office**	
	Science Technology and Environmental Organization	Environmental policy, coordination
	State Planning Committee (SPC) (Lao National Mekong Committee, LNMC)	Budgeting, planning, project appraisal
	Lao Mekong Committee	Coordination
	Ministry of Communications, Transport, Post and Construction	
	Department of Transport, Inland Water ways Division	Navigation, hydrology
	Lao Water Supply Authority (Nam Papa Lao)	Urban drainage, sewage/waste disposal Water management, Education/research
	Ministry of Agriculture and Forestry	
	Department of Irrigation	Irrigation, drainage, and flood protection and mitigation
	Department of Livestock and Fisheries	Livestock, fisheries and aquaculture
	Department of Meteorology and Hydrology	Meteorology and hydrology
	Ministry of Public Health Nam Saat	Clean water and sanitation in rural areas
	Ministry of Industry and Handycraft	Industrial pollution control
Malaysia (c)	Department of Environment	Environmental management and monitoring Water quality standards and guidelines Ambient water quality monitoring Effluent water quality monitoring and compliance Public accountability reporting
	Public Works Department	Urban water supply Water quality monitoring
	Department of Irrigation and Drainage	Irrigation water supply and rural drainage River stabilization and training Ambient water quality monitoring
Myanmar	**Ministry of Agriculture and Irrigation**	Water resources management
	Irrigation Department	Environmental and water quality protection Irrigation water supply Reservoir operation and maintenance
	Water Resources Utilization Department	Pump irrigation and groundwater supply for crops (river water) Rural water supply

Country	Organization	Identified areas of responsibility
Nepal	Environmental Protection Council	High level council for environment policy, monitoring and coordination
	Ministry of Water Resources and organizations under it	Water resources policy, planning, development and management including water quality data, irrigation use, etc.
	Ministry of Population and Environment	Environmental policy, regulation and coordination
	Ministry of Housing and Physical Planning	Water supply, sanitation and sewerage
	Ministry of Industry	Industrial effluent control (licensing)
	Ministry of Forest and Soil Conservation	Watershed conservation including forestry and erosion control
	Ministry of Science and Technology (Department of Hydrology and Meteorology)	Water resources data and river water quality
New Zealand (d)	Office of the Parliamentary Commissioner for the Environment	Performance monitoring and audit
	Ministry for the Environment	Environmental policy and management advice Environmental monitoring and status reporting Legislation and guideline development
	Regional councils	Water resources management Pollutant discharge control Integrated natural resource management planning Regional land use management
	Territorial authorities	Local land use control Control of the surface of rivers and lakes Local planning Water supply, sewerage and drainage

Country	Organization	Identified areas of responsibility
Philippines	Department of Environment and Natural Resources	Environmental management and pollution control Water quality standards and guidelines Water quality monitoring, compliance checking and enforcement Environmental planning Education and research
	Laguna Lake Development Authority	Water quality monitoring and environmental protection
	Department of Health	Health and sanitation
Republic of Korea	Local governments	Wastewater treatment plant construction and management Water quality monitoring (together with the regional offices of the Ministry of Environment)
	Ministry of Environment (MOE)	Water quality legislation, policy and standard development Financial and technical supports for water quality improvement Water quality monitoring and enforcement (this is the duty of regional offices of MOE)
	Ministry of Construction and Transportation	Water quantity management Development of water resources
	Ministry of Agriculture	Irrigation for agricultural water use
Singapore	Water Department, Public Utilities Board (PUB)	Reservoir operation Urban water supply Water management

Country	Organization	Identified areas of responsibility
Sri Lanka		
	Central Environmental Authority	Administration of environmental regulations Environmental protection licences Environmental Impact assessment procedures
	Ceylon Electricity Board	Hydropower; water resources assessment
	Irrigation Department	Irrigation system design, construction, operation and maintenance
	Mahaweli Authority of Sri Lanka	Construction, administration, operation and maintenance of the Mahaweli Development Programme
	National Aquatic Resources Authority	Research and investigations into aquatic ecosystems
	National Planning Department	Synthesis of Public Investment Programme
	National Water Supply and Drainage Board	Water supply, sanitation and drainage services Hydrometric data collection
Thailand	Royal Irrigation Department	Agriculture Irrigation water supply Industrial water supply Reservoir operation Urban water supply and drainage Rural drainage Water management
	Pollution Control Department (PCD)	Water quality standards in rivers Pollution control areas
	Office of Environmental Policy and Planning (OEPP)	Environmental management plans for river basin Classification of Watershed Environmental Fund EIA
	Department of Industrial Works (DIW)	Industrial effluent standards
	Department of Public Works (DPW)	Central treatment plants and drainage system
	Habour Department (HD)	Waste discharge into rivers
	Wastewater Management Authority (WMA)	Central treatment system

Country	Organization	Identified areas of responsibility
Viet Nam	**Ministry of Agriculture and Rural Development**	
	Department for Management of Water Resources and Hydraulic Works	Legislation, licensing and policies for water resources management Inspection and monitoring Hydraulic modelling Water resources management infrastructure management
	Department of Flood Control and Dike Management	Flood control Dike management
	Department of Water Management and Irrigation	Water administration Infrastructure management
	Provincial government and local organizations	Irrigation water supply Industrial water supply Fisheries Infrastructure operation and maintenance Urban water supply and drainage Rural water supply and drainage

(a) Based on information in People's Republic of China (1995) and questionnaire return
(b) Based on information in Asian Development Bank (1997) and questionnaire return
(c) Based on information in Water Resources Consulting Services (1994) and ESCAP (1997)
(d) Based on information from the New Zealand Ministry for the Environment (1997) and questionnaire return

The department expects to fulfil its vision, which is to achieve clean, healthy and productive rivers for the 21st century, through integrated catchment management, i.e. The coordinated and sustainable management of the state's natural resources. The department's work is diverse, and is increasingly undertaken in partnership with local communities and other State and local government agencies.

The functions and responsibility of the department enable it to:

- Develop policies on resource use and management
- Maintain databases on the condition of the state's land, soil, water and vegetation
- Manage assets such as the publicly owned land across the state, including the reserve system, dams and fishing ports
- Provide expertise with management of the coast, estuaries and floodplains
- Manage the planning and sharing of water across the State
- Provide survey, mapping, land titling and valuation services (the geographic information structure)
- Ensure the fundamental interests and rights of different community groups in natural resources access and management
- Undertake applied research and technology transfer in fields relevant to natural resources management.

The department has a business plan setting out targets to be achieved in a specific time-frame. The performance of the department is measured against these targets. The plan is publicly available so that the community can see the direction the department is taking (Department of Land and Water Conservation, 1996).

Also responsible for water quality in New South Wales is the Environment Protection Authority, which provides a regulatory function. Its responsibilities include licensing of point source discharges, including drainage discharges from irrigation areas, and enforcements. There is similar separation of the regulatory and management functions in other Australian states.

Institutional arrangements in **Bangladesh** have been established by legislation that provides the basic operational framework. The three primary areas of government institutional involvement are legislation, regulation and operation. Water legislation has two basic functions: conferring necessary powers over water and land on the government, while preserving or granting such rights to individual users as are consistent with the goals of the country; and establishing a basic administrative framework and necessary institutions to execute the various functions assigned. Responsibility for water resources development lies largely with the Bangladesh Water Development Board in the Ministry of Water Resources and the Bangladesh Agricultural Development Corporation in the Ministry of Agriculture. Responsibility for protection of water quality and the environment lies with the Department of Environment. Their activities are mainly concerned with wastewater management. Regulations for wastewater disposal and their enforcement are based on the Environmental Pollution Control Ordinance, passed in 1997. This Ordinance continues as the only legislation in force that covers wastewater disposal and environment protection in the country as a whole, although new more comprehensive legislation is being prepared (Alam, 1996).

One of the functions of the Department of Environment is water quality monitoring at wastewater discharge sites and in the receiving waters downstream. Other organizations undertaking water quality data collection include the Bangladesh Water Development Board and the Department of Public Health Engineering. Other government agencies involved in the management of water resources include the Water and Sewerage Authority, the Bangladesh Inland Water Transport Authority and the Local Government Engineering Department. Some local government organizations and non-governmental organizations (NGOs) are also involved (ESCAP, 1997). The activities of these agencies and organizations tend to be more at the local level.

In **Cambodia**, the Department of Pollution Control in the Ministry of Environment is the main body responsible for the administration of water management in Cambodia. The department is the manager and protector of environmental quality in the country. This is, in general terms, achieved through inspection, recording data, monitoring and control of water resources to reduce environmental pollution.

Other major stakeholders in the water sector in Cambodia include (Lon, 1996) the Ministry of Agriculture, Forestry and Fisheries (General Directorate of Irrigation, Meteorology and Hydrology and Department of Fisheries); Ministry of Public Works and Transport; Ministry of Rural Development; and the Cambodian National Mekong Committee. The Government recognizes the need to coordinate the activities, roles and responsibilities of these agencies in the water sector.

At present the legislative basis for development and management of water resources in Cambodia is the "*Environment Protection and Natural Resources Management Law*" which was passed by the National Assembly in 1996. The law defines the principles of natural resources management and environmental quality protection, but does not specify in detail the way or manner in which water resources are to be managed or in which water quality protection is to be carried out. Therefore problems have been encountered in implementing this law as well as in managing water resources. In order to overcome these problems, and improve and ensure effective water quality management, the Ministry of Environment in cooperation with other relevant ministries has just finished the draft of a sub-decree on "Water Pollution Control" to be submitted to the Council Minister at the end of 1997.

In **China**, the State Council has set up a system of unified administration on water resources in association with administration at various levels and by various Ministries. Key relevant legislation comprises the *Water Law of the People's Republic of China*, the *Law on Water Pollution Control* and the *Law of the People's Republic of China on Water and Soil Conservation*. The main mandate and responsibility for water resources development, utilization and management is assigned by the Central Government to the Ministry of Water Resources. The Ministry is supported by 13 departments, together with other offices and affiliated institutions, and six major river basin water resources commissions and one lake basin authority who develop and manage various watersheds. Local water administration agencies are responsible for development and management in their local areas (ESCAP, 1996, p.5; ESCAP, 1997).

Other Ministries under the State Council also have responsibilities related to water resources and these are fulfilled in coordination with the Ministry of Water Resources. With reference to water quality, key Ministries and their responsibilities include (Asian Development Bank, 1996, and ESCAP, 1997):

- National Environmental Protection Agency: water pollution prevention and environmental protection.

- Ministry of Geology and Mineral Resources: investigation, evaluation and management of groundwater.

- Ministry of Construction: urban water supply and water conservation.

- Ministry of Power Industry: hydropower project construction and administration.

- State Planning Commission: examination and approval of plans for harnessing of national land, and construction of water resources and hydropower projects.

An important role of the Ministry of Water Resources is scientific research. Hydrology and water resources research is undertaken at the Nanjing Research Institute of Hydrology and Water Resources. The Institute provides scientific information on flood control measures, water resources management and environmental protection.

The Constitution of **India** (Article 48-A) requires the State to endeavour to protect and improve the environment and to safeguard the forests and wildlife. As per Article 51-A it is the fundamental duty of all citizens to protect and improve the natural environment, including forests, lakes, rivers and wildlife. Responsibility for water quality protection and management is spread over a number of agencies. The Central Pollution Control Board is the key agency for organising water quality monitoring throughout the country, and operates in collaboration with State Pollution Control Boards which undertake water quality monitoring within their respective states. The Central Water Commission, which has primary responsibility for sustainable water resources development and management in India, is also heavily involved in water quality monitoring across the country. In addition, the Ministry of Environment and Forests, through their field offices located nationwide, also regularly monitor the implementation of environmental safeguards stipulated by them when providing environmental clearance to projects (Rao, 1996). In 1992, the Ministry of Environment and Forests issued a new policy statement for abatement of point source pollution. This places emphasis on pollution prevention instead of the conventional end-of-pipe treatment approach, and calls for the adoption of best available and practicable technologies as a key strategy for pollution prevention. The issue of management of non-point source pollution has yet to be formally addressed (Rao, 1996).

In **Indonesia** a number of policies for water quality protection and management have been developed, based on Environmental Law UU No. 4/1982, concerning the Principle of Environmental Management, and Water Pollution Regulation PP No. 20/1990, on Water Quality Control, which include an environmental impact system, monitoring of water quality, regulating industrial pollution, and applying measures to improve water quality. A national body termed Bappedal (National Environmental Agency) was established in 1991 to set standards, monitor water quality and assist provincial, district and local organizations in improving water quality, and it plays a lead role in furthering policies and strategies in water quality improvement (Republic of Indonesia, 1996).

The central government agency with primary responsibility for water resources development and management is the Directorate General of Water Resources Development in the Ministry of Public Works. Many other central government ministries, provincial, district and local organizations also have functions and responsibilities directly related to water resources development and management. In accordance with provisions in Water Law UU No. 11/1974, Article 5, in which it is stated that the Minister responsible for water resources is authorized to coordinate all activities related to water resources administration, the Ministry of Public Works has established a Coordination Secretariat (SPK-TPA) to provide a coordination role between all agencies involved in water resources development and management activities.

In **Japan**, conservation and creation of river environments have become increasingly important aspects of river administration (River Bureau, 1995). River administration centres on the *River Law, 1964*, which deals with such matters as comprehensive management of rivers, water utilization, and prevention of water-related diseases. Other relevant legislation includes the *Environment Basic Law, 1994*, and the *Water Pollution Law, 1970.*

In accordance with the River Law, river administration is undertaken by classifying rivers according to their national significance, and delegating responsibility for the administration of the various river sections accordingly. River systems deemed important for the national economy and people's lives are designated as "Class A river systems" and administered by the Minister of Construction. Other river systems are designated as "Class B river systems" and administered by the prefectural governors. Class A river systems are further sub-classified as "Trunk rivers" and "Others"; and the "Others" are administered, except for approval of certain specified water rights, by the prefectural governors. Some sections of small tributaries of both Class A and Class B rivers are also designated as being subject to parts of the River Law. Administration of other small rivers, to which the River Law is not applied, is the responsibility of the mayors of cities, towns and villages. The River Law stipulates that for any utilisation of land and river water within the sections defined by the River Law approval must be obtained from the designated river administrator.

In river systems where administrative responsibility lies with the Minister of Construction then the actual administrative activities are undertaken by the River Bureau in the Ministry of Construction. The River Bureau plans and implements a variety of water resources projects, including projects for environmental improvement. It also drafts laws, manages river administration, issues licences for water use, and maintains facilities for the proper management of rivers. Its activities include water quality monitoring in Class A rivers.

In addition to the Ministry of Construction, there are several other ministries and agencies directly involved in various aspects of water resources development. The National Land Agency is responsible for formulating water resources development plans in cooperation with other related government organizations, and coordinating the activities of government agencies in the water sector. The Water Resources Development Council has also been established as an auxiliary organization in the Prime Minister's Office. The Ministry of Health and Welfare is the central governmental organization dealing with public water services. It is not involved directly in the management of particular water works, but the ministry issues regulations and provides guidance for water supply in accordance with the Water Works Law (ESCAP, 1997). The Ministry of Agriculture, Forestry and Fisheries is responsible for the planning, construction and management of irrigation and drainage projects. The Ministry of International Trade and Industry is concerned with industrial water supply and hydropower generation. Under the joint supervision of the above ministries, the Water Resources Development Public Corporation has been established with the objective of promoting the construction of water resources development facilities (ESCAP, 1997).

In the **Lao People's Democratic Republic** there are 12 government agencies or bodies in six ministries directly involved in the water resources sector. Those with a direct interest in water quality are listed in table 4. A new *Water and Water Resources Law* was adopted in October 1996 and came into effect during January 1997. The Science, Technology and Environmental Organisation (STENO) in the Prime Minister's Office has the mandate to develop a national environmental policy framework; develop a set of environmental and planning processes and a regulatory framework; establish and operate a system of compliance monitoring; coordinate environmental programmes operated by line-ministries; and coordinate dispute resolution concerning environmental impacts and competing resource management (Asian Development Bank, 1997).

The Ministry of Agriculture and Forestry is a key central agency with a role in water quality management. Through its Department of Irrigation, its Hydrology and Meteorology Department and Department of Forestry it works in areas related to water quality analysis, hydrologic and meteorological data collection, protected areas and catchment management. General water quality is the responsibility of the Department of Irrigation, while specific responsibilities reside with a range of government agencies (Boun Souk, 1997).

Water resources management is also a role of the Inland Waterways Division of the Department of Transport in the Ministry of Communications, Transport, Posts and Construction. Urban water supply, sewerage and drainage is the role of the Lao Water Supply Authority in the same Ministry. Functions of these organizations directly relating to water quality management include river regulation; hydrologic data collection, data processing and reporting; and installation of sewage treatment systems for domestic water and reuse of water. The Ministry of Industry and Handicraft is responsible for industrial pollution control (Boun Souk, 1997).

In **Malaysia**, water is a state responsibility under the Constitution. However, the situation with the

environment is less clear as it is not explicitly mentioned in the Constitution, and this has implications for water resources management. As a result both federal and state governments are active in this field and responsibilities are fragmented among various federal ministries and departments as well as amongst the 13 state governments.

Overall responsibility for development of water resources for domestic and industrial water supply purposes resides with the federal Department of Public Works. The Department of Irrigation and Drainage is responsible for the planning, development and operation of irrigation and agricultural drainage schemes (ESCAP, 1997).

Water quality monitoring is undertaken by a range of federal and state government agencies including the Department of Environment, Department of Irrigation and Drainage and Public Works Department for purposes consistent with their respective responsibilities. For the Department of Environment this includes compliance monitoring of effluent discharges and monitoring of ambient water quality in rivers for the purpose of classifying rivers relative to beneficial uses, and for nationwide state of rivers reporting. The Department of Irrigation and Drainage also undertakes monitoring of ambient water quality in rivers, while water quality monitoring by the Public Works Department relates to the operation of urban water supply facilities (Water Resources Consulting Services, 1994). Interim guidelines for ambient water quality in rivers have been compiled by the Department of Environment (Department of Environment, 1987). These give guideline values for about 30 water quality parameters and also incorporate a classification system for rivers that creates six classes of water quality. The system is based on overall water quality conservation value and use-suitability based on existing conditions.

In **Mongolia**, responsibility for management of water, land, air, forests, biodiversity, minerals and related resources, and protected areas resides with the Ministry of Nature and the Environment. Its activities include drafting and updating of laws and ordinances for all areas of environmental protection. Its role also includes identification of National Water Resources Policy, introduction of economic incentives for rational use of water resources and for reduction of water pollution, introduction of sound technologies for water supply and waste water disposal and formulating requirements for potable water quality, sewage and sludge treatment processes.

In **Myanmar** there are 10 government agencies and organizations active in the urban water supply and sanitation sector while the Ministry of Agriculture has responsibility for rural water supply and water resources management. The Irrigation Department of the Ministry of Agriculture is responsible for irrigation. Water quality assessment has been carried out by the Irrigation Department in some problem reservoirs and canals. World Health Organization water quality guidelines are used as a basis for these assessments. The Water Resources Utilization Department of the Ministry of Agriculture, with the assistance of UNICEF, is the leading agency for rural water supply (U Aung Kyaing, 1996).

In **Nepal**, water sector management responsibility and authority are spread over several agencies and organizations (Chaudhary, 1996), namely, National Water Resources Development Council; National Planning Commission; Ministry of Water Resources; Nepal Electricity Authority; Water Energy Commission Secretariat; Department of Hydrology and Meteorology; Department of Irrigation; Ministry of Housing and Physical Planning; Department of Water Supply and Sewerage; and Department of Soil Conservation and Watershed Management. The Ministry of Water Resources has the role of exploiting and developing the water resources of Nepal. The Department of Irrigation in the Ministry of Water Resources is responsible for managing irrigation schemes and river training works. Urban water supply and sanitation is the responsibility of the Department of Water Supply and Sewerage and the Nepal Water Supply Corporation.

The role of the Department of Soil Conservation and Watershed Management includes planning, design and implementation of land productivity conservation and community soil conservation programmes, while the Water Energy Commission Secretariat is involved in management of water resources generally. The Ministry of Population and Environment is responsible for the development of environmental policy, guidelines, regulation and coordination. The Ministry of Industry is responsible for industrial development including industrial effluent control and licensing. The Department of Hydrology and Meteorology collects water resources data, including data on water quality.

The *New Zealand Resources Management Act 1991* provides the legislative basis for water management in **New Zealand**. Under the Act, most responsibility for natural resource management and environmental management is given to local authorities and integrated

with regional planning (NSW Department of Water Resources, 1992). Local authorities include (New Zealand Ministry for the Environment, 1997) regional councils, such as the Auckland Regional Council; territorial authorities which are usually city or district councils, such as the Christchurch City Council; and unitary authorities which carry out the functions of regional and district councils, such as the Gisborne District Council.

Regional councils have the main responsibility for managing water and the beds of water bodies, controlling the discharge of contaminants, and land use effects of regional significance (e.g. soil erosion). They share responsibility for water bodies and land use with territorial authorities and, for coastal marine areas, with the Minister for Conservation (New Zealand Ministry for the Environment, 1997). Territorial authorities have the main responsibility for the control of land use, including land subdivision, and for the control of the surface of rivers and lakes.

Responsibility for monitoring and administration of the Resource Management Act resides with the Ministry for the Environment. The Ministry was established under *The Environment Act, 1986* (New Zealand Ministry for the Environment, 1997). Under this Act, the term "environmental" does not just mean the natural world of water, air, soil, minerals, plants and animals. It also includes people and the physical, social, economic and cultural conditions of their communities.

Water quality management of rivers in **Pakistan** encompasses both water resources management and developments in the field of environmental management (Ahmad and Afzal,1997). Overall responsibility for framing policies and plans for water resources management lies with the Ministry of Water and Power (MOWP) at the Federal level. The Ministry has its execution wing in the form of the Water and Power Development Authority (WAPDA), in accordance with the 1958 WAPDA Act. The Act also makes WAPDA the custodian of the national water resources. WAPDA has a Planning Division, the main arm of which is the Water Resources Planning Organization. Within this organization, an Environmental Planning Directorate has recently been created. All new projects are executed after approval from the Planning Commission only if they satisfy the techno-economic as well as environmental requirements.

Pakistan began to act on environmental concerns in the early 1970s. The 1973 Constitution of Pakistan defined federal and concurrent legislative lists in which "Environmental Pollution and Ecology" were included for the first time. In 1974 the Environment and Urban Affairs Division (EUAD) was established within the Ministry of Housing and Works. The Division has the responsibility for national environmental policy formulation and for administration of national environmental impact assessment procedures, which it mainly undertakes through limited review of federal projects. Since 1988 the EUAD has reported to the Minister of State for Environment.

In 1983, the Pakistan Environmental Protection Ordinance was promulgated, followed by creation of a federal level Pakistan Environmental Protection Council (PEPC) consisting of the President, various federal and provincial ministers and selected environmental experts. A new Environmental Protection Act (EPA), based on the Environmental Protection Ordinance of 1983, was passed by the National Assembly of Pakistan in September 1997.

The Pakistan Environment Protection Agency (PEPA) was also established in 1983. Among the provinces, Punjab was the first one to establish an EPA, and this occurred in 1987, followed by the other three provinces. The main working areas for these EPAs are creating public awareness through press and electronic media, holding meetings, lectures and seminars, distributing literature, collecting industrial effluent data, waste sampling and analysis, issuing No Objection Certificates for industrial discharges, and training of staff for successful implementation of the Environmental Protection Ordinance. In 1995, the Punjab EPA was given the status of an independent department and it is now known as PEPD. An Environmental Protection Council, Punjab (EPCP) was created in 1996, on the pattern of the PEPC at the federal level, for policy formulation, integration of environmental considerations into provincial development plans and coordination with other agencies, bodies or persons to ensure enforcement of the Environmental Protection Ordinance.

The National Conservation Strategy (NCS) was prepared by EUAD in 1992, in collaboration with the World Conservation Union (IUCN), which provided a detailed analysis of environmental problems and a broad strategy for tackling them. In line with the policy guidelines and action plans of the NCS, National Environmental Quality Standards (NEQS) were

formulated and officially notified in 1993 to be made effective from 1st July 1994 for new industrial units and from 1st July 1996 for existing industrial operations.

In the **Philippines**, there are 32 agencies dealing with different water use sectors such as water supply, irrigation, hydropower, flood control, navigation, fisheries and pollution. These agencies are placed under 12 departments of the national government including the Department of Public Works and Highways, Department of Agriculture and the Department of Environment and Natural Resources. Their activities are coordinated by the National Water Resources Board, a central coordinating and regulatory agency created in 1974 by virtue of a Presidential Decree No. 424. This agency is mandated to implement the provisions of the *Philippines Water Code of 1976 (PD 2067)*, the primary legislative tool for water resources management in the country (Baltazar, 1996). This law includes provisions for controlling water pollution and protecting water quality.

The Department of Environment and Natural Resources (DENR) is the primary government agency responsible for the conservation, management, development and proper use of the country's environment and natural resources. It absorbed the powers and functions regarding environmental management and pollution control from the former National Pollution Control Commission and National Environmental Protection Council by virtue of Executive Order No. 192, issued in 1987 shortly after a new Administration took over. The offices tasked primarily with environmental management and pollution control are the Environmental Management Bureau, the Pollution Adjudication Board and the Regional Offices' Environmental Management and Protected Areas Sector.

The Laguna Lake Development Authority is tasked to prevent and control land based pollution in the Laguna de Bay Region which covers five cities and four municipalities in Metro Manila as well as several town in Rizal and Laguna Provinces. The Department of Health undertakes water quality monitoring to maintain public health.

In the **Republic of Korea** there are many organizations responsible for water management. Therefore, organizations involved cooperate and coordinate with each other to preserve water quality and to develop water resources.

Overall policy making for water quality control is the duty of the Ministry of Environment. The Ministry of Environment has developed for enactment and operates laws relating to water quality, such as the *Water Quality Act*, the *Sewerage Act*, and the *Night Soil and Livestock Wastewater Treatment Act*. The Ministry of Environment have two bureaus responsible for water management: the Water Quality Management Bureau and the Water Supply and Sewage Treatment Bureau. The Water Quality Management Bureau has four divisions: the Water Quality Policy Division, the Environment Investigation Division, the Industrial Wastewater Control Division and the Domestic Wastewater Control Division. The Water Supply and Sewage Treatment Bureau has the Sewage Treatment Division and three other divisions that are concerned with water supply (Lee Chan Hee, 1997).

The Ministry of Construction and Transportation has the function to develop water quantity policies such as for water resources development, while the Ministry of Agriculture is responsible for the provision of water for agricultural use. Local government has the responsibility of establishing plants to treat sewage and wastewater produced in their territory.

In **Singapore**, the Water Department in the Public Utilities Board (PUB) acts as the water authority in Singapore and is responsible for the provision of an economically feasible and reliable potable water supply and for protecting the watercourses and reservoirs. The Ministry of the Environment is responsible for the provision of infrastructure and measures to prevent and control water pollution and manage solid wastes in Singapore. The control of water pollution is under the Pollution Control Department (PCD) of the Ministry. The Drainage Department is responsible for ensuring that Singapore has an effective drainage system to protect the country against public health and flood risks (Check, 1996).

In **Sri Lanka**, the principal national agencies involved in water resources development and management include (ESCAP, 1997) the Central Environmental Authority for administration of environmental regulations, Environmental Protection Licences, and Environmental Impact Assessment procedures; the Ceylon Electricity Board for hydropower generation and water resources assessment; the Irrigation Department for irrigation system design, construction, operation and maintenance, and hydrometric surveys; the Mahaweli Authority of Sri

Lanka for construction, administration, operation and maintenance of the Mahaweli Development Programme; the National Aquatic Resources Authority for research and investigations into aquatic ecosystems; the National Planning Department for synthesis of the five year rolling Public Investment Programme which includes several water-related areas of investment to support social goals such as water supply and sanitation; the National Water Supply and Drainage Board for provision of water supply, drainage and sanitation services, and hydrometric observations; and the Water Resources Board for investigation and development of groundwater.

Sri Lanka has a policy of devolution of administrative powers from national bodies to the provincial and district level. The 13th Amendment to the Constitution devolved to Provincial Councils the responsibility for a number of water-related activities including agriculture, some irrigation, rural development and land. The "concurrent list" (carried out at both the national and provincial levels) includes provincial level planning, soil conservation, water resources planning and environmental protection. The Provincial governments have been established relatively recently and their capabilities are still being built up. National agencies are progressively handing over appropriate responsibilities to the Provinces as they become able to deal with them.

There is extensive activity in water quality monitoring for various purposes. Organizations involved include the Central Environmental Authority as part of the Environmental Impact Assessment process and enforcing environmental protection licence conditions, the National Water Supply and Drainage Board for monitoring water supplies, and several research and consulting operations.

There are more than 30 agencies and about 17 committees under eight ministries responsible for various aspects of managing water resources development in **Thailand** (Srisuda Jarayabhand and Supa Sakultanjaroenchai, 1997). The main agency with direct responsibility for water quality in rivers is the Pollution Control Department. Its main role in this area includes setting up water quality standards, monitoring water quality in major rivers of the country, and establishing measures to control and remediate water pollution in rivers. The Office of Environmental Policy and Planning is primarily responsible for policies and plans related to water resources management, particularly the conservation of water resources. Important activities include developing catchment classification, developing integrated basin-wide environmental plans and proclamation of protected areas of environmental sensitivity. The Department of Industrial Works is responsible for controlling industrial wastewater discharges to rivers through setting effluent standards, and inspecting factory wastewater treatment systems to ensure they are operating effectively. The newest organization with a role in water quality management is the Wastewater Management Authority, which was established on 14th August 1995. Its main function is to manage wastewater in the Bangkok Metropolitan Region.

In addition to the above mentioned agencies there are several other government agencies involved in managing water quality in rivers. With its main responsibility being navigation, the Harbour Department also exercises control over the dumping of waste into rivers, while the Health Department carries out monitoring programmes to ensure that river water does not pose a health hazard to people. Finally, the Industrial Estate Authority of Thailand provides wastewater treatment facilities within the government industrial estates.

In **Turkey** there are several ministries and organizations dealing with the conservation, protection and allocation of water resources. These are the Ministry of Environment, Ministry of Interior, Ministry of Public Works, and Resettlement, Ministry of Health, Ministry of Tourism, Ministry of Energy and Natural Resources, Ministry of Industries and several directorates under these ministries. The State Hydraulic Works is a leading agency responsible for almost all activities relating to water resources developments. It ensures long term supply of drinking, utility and industrial water, plans, executes and in most cases operates works for flood protection, irrigation and drainage, and hydropower generation. Its responsibilities also include performing basic investigations such a water quality monitoring, streamflow gauging, soils classification, preparation of river basin development plans and implementation of development projects.

The Turkish Constitution gives the responsibilities of protecting and developing the environment to the state and to the citizens. All surface waters and groundwaters are also considered the property of the government under the Constitution, except for some privately owned springs and small waters. Ecologically sustainable development is the basic principle underlying environmental policy.

Several laws and regulations which have been in force since 1930 are directly or indirectly related to the environment. More recently, the Environment Law, which consists of general provisions, envisaged that the various details would be governed by regulations. Some of these regulations, following the enactment of the Environment Law, which are related to water resources are the Regulation on Water Pollution Control (1988), the Regulation on Solid Wastes (1991) and the Regulation on Environmental Impact Assessment (1993). Under the EIA process environmental aspects should be considered not only during the initial planning and design phase of a project but also throughout the construction and operational phases of the project. Most water resources projects are subject to the EIA process, with the aim of providing sustainability.

In **Uzbekistan**, together with the other countries in the Aral Sea Region (namely Tadjikistan, Turkmenistan, Kazakhstan and Kyrgyzstan), individual institutional arrangements related to water quality management are beginning to emerge, although most agencies still resemble the former Soviet bodies in terms of function. In general, the Ministries/Committees for Environmental Protection are responsible for formulating policies, programmes and standards for water management, permitting approved levels of pollutants, monitoring point source pollution, and defining, collecting and redistributing charges and fines levied for the use/ degradation of water bodies. The Hydrometeorological Agencies are responsible for ambient water quality monitoring and forecasting. The regulation and monitoring of water used for agricultural purposes is the responsibility of the respective Ministries of Water Management. The Ministries of Communal Services are responsible for drinking water provision in urban areas while the Ministries of Agriculture are responsible for provision of drinking water in rural areas. Oversight of drinking water treatment and watsewater treatment is a role of the Ministry of Health. The Ministries/Committees of Geology are responsible for identifying, studying and monitoring groundwater deposits (Executive Committee of the International Fund for Saving the Aral Sea, 1997).

In order to better meet the needs of regional water management and to address the diverging water use interests of the sovereign republics, several international institutions have been established by the Central Asian republics since the dissolution of the Soviet Union. These comprise (1) the International Fund for Saving the Aral Sea which is responsible for coordination of activities and funding, and for implementing the international programme for improving the environmental situation in the Aral Sea; (2) the International Commission for Water Coordination, responsible for coordination of activities related to the allocation of the waters of the international rivers (i.e. the Amudarya and Syrdarya Rivers) and regulation their use; (3) the International Sustainable Development Council, which is responsible for the coordination of activities that control the protection and rational use of water resources; (4) the International River Commissions (BVOs) of the Amudarya and Syrdarya Rivers, established during the Soviet period with responsibility for maintenance and management of flows in these two rivers and the allocation of water to the involved countries; and (5) the Energy and Water Roundtable of the International Council for Kazakhstan, Kyrgyzstan and Uzbekistan which has the function of formulating a agreement for the operation of the Toktogul Cascade and Hydropower Facility (Executive Committee of the International Fund for Saving the Aral Sea, 1997).

In **Viet Nam**, primary responsibility for water resources management resides with the Ministry of Agriculture and Rural Development, while the Ministry of Construction and Urban Development and the Ministry of Planning and Investment also have responsibilities that affect water resources. *Decision No. 354 TTG of the Vietnamese Government dated 28th May, 1996* states that functions and responsibilities of the Ministry of Agriculture and Rural Development are to establish plans and strategies for water sources; balance the development of water sources; protect water sources and prevent pollution; manage exploitation and development of hydraulic works; and establish water laws and policies.

The Department for Management of Water Resources and Hydraulic Works in the Ministry of Agriculture and Rural Development assists the Ministry in implementing state management of water resources. The Water Management and Irrigation Department within the same Ministry has an administrative role and has overall responsibility for management of water resource development infrastructure. Related organizations are the Centre for Water Resources Survey and Evaluation and the Centre for Technology Transfer for Management of Water Resources and Hydraulic Works.

Other organizations in Viet Nam responsible for water quality management include the Ministry of Science, Technology and Environment, created with the enactment of the *Environmental Protection Law of 1993*. It sets water quality standards, carries out research and undertakes environmental management through the EIA Process. In addition, the Ministry of Transport and Communications is responsible for prevention and protection against pollution of water resources used for marine navigation and management of marine works and ports, while the Ministry of Fisheries is responsible for management of water resources used for aquaculture purposes in accordance with provisions and the Land Law.

D. Coordination and strategic planning

For successful management of water quality there should be clear lines of accountability for all activities that affect water quality. This includes clear accountabilities for all regulatory, management and operational aspects, and preferably these accountabilities should be separated so as to avoid possible conflicts of interest. As the activities and issues affecting water quality (and water resources generally) cover a very wide range, it is inevitable that there will be more than one agency with at least some interest in water quality management, or with responsibilities have some bearing on water quality management, and there is often more than one law that is relevant as well. Therefore, it is important to ensure that there is cooperation between all agencies involved, and that there are no overlaps or gaps in responsibilities. Achieving the required cooperation and coverage in responsibilities also involves using a combination of strategic, management and operational planning, which is supported by legislation and regulation as appropriate. Obtaining the required cooperation and coverage in responsibilities in water resources management, and undertaking strategic planning, has been approached in a number of different ways in several countries in the ESCAP region, and some examples are discussed below.

In the **Philippines**, for example, the management coordination role has been vested in the National Water Resources Board under the *Philippines Water Code (PD 1067)*. The Board coordinates the activities of eleven government agencies, and additional bodies within these agencies (of which it is one), having functions that directly relate to water resources management (Baltazar, 1996). The functions covered by these agencies comprise water quality and sanitation, catchment management, integrated area development, data collection, research, cloud seeding, water supply, irrigation, hydro-power, flood control, ports and navigation, and fisheries and recreation.

The National Water Resources Board has proposed the formulation of a National Water Resources Master Plan for which the main objective is to provide a framework for sustainable development and management of the nation's water resources to promote economic development and social equity and to ensure environmental quality in the long term. It would not be a rigid blue-print but a flexible plan capable of being updated on a regular basis (Baltazar, 1996).

In **India** the approach to coordination of surface water management has similarities with the approach adopted in the Philippines, but also some significant differences. In India the role of coordinating surface water management resides with the Central Water Commission which is within the Central Ministry of Water Resources (Rao, 1996). This role has an added dimension in India, as compared to the Philippines, in that responsibilities for some water resources activities, such as irrigation and flood mitigation developments, are vested in the Indian states. Part of the role of the Central Water Commission is inter-state and international coordination and technical review of project proposals from the states.

Primary responsibility for water pollution control and abatement resides with the Central Pollution Control Board, in the same Ministry. This Board and the Central Water Commission work cooperatively to manage water quality.

India also has a high level National Water Resources Council, established in 1985, which is Chaired by the Prime Minister and has a membership comprising other concerned Ministers in the Central Government and Chief Ministers of all the states (Chandra, 1996). In 1987 the Council adopted the National Water Policy which was prepared by the Central Water Commission. This Policy sets the direction for water resources management in India.

Under the National Water Policy strategic planning is undertaken on a river basin or sub-basin basis, and an integrated approach is required. To assist the planning process, and provide consistency, the Central Water Commission published *Guidelines for Sustainable Water Resources Development* in 1992. River basin organizations, that are multi-disciplinary in character, are