Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring - Second Edition

Edited by
Deborah Chapman

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Foreword to the first edition

Hydrological problems related to artificial and natural changes in the quality of inland water bodies were discussed by the Co-ordinating Council of the International Hydrological Decade (IHD) in the late 1960s. As a result, the Secretariats of UNESCO (United Nations Educational, Scientific and Cultural Organization) and WHO (World Health Organization), with the assistance of FAO (Food and Agriculture Organization of the United Nations) and IAHS (International Association for Hydrological Sciences), established an international working group, primarily to:

- identify and define the hydrological processes and phenomena directly concerned with the means of entry, distribution and self-purification of pollutants in surface and groundwater;

- review the known effects of such pollutants on any aspect of these processes and phenomena.

The outcome of the IHD working group and their collaborators was not meant to constitute a treatise on water chemistry or water pollution problems, but was a document attempting to link water quality considerations to aspects of the quantitative hydrology of surface and groundwater bodies. Advice was also included on the organisation of hydrological services, methods of conducting water quality surveys, and interpretation and evaluation of water quality data for hydrological purposes. An attempt was also made to meet the needs of developing regions by describing methods likely to be applied in these regions, both from the point of view of practicability and economy. On the other hand the report also aimed to be attractive to industrialised countries by including references to sophisticated methods.

It appeared that many hydrologists found difficulty in coping with water quality problems, and that hydrological surveys and water quality studies were not often adequately linked. The joint UNESCO/WHO publication *Water Quality Surveys* (1978) was, therefore, intended to harmonise these aspects and to synthesise the assessment of the hydrological regime and quality changes brought about by nature and man. The publication became a success world-wide and soon ran out of stock. The two Secretariats of UNESCO and WHO considered a re-print of the 1978 version, but decided to compile a completely new edition in view of the following:

(a) The progress in water quality research had been enormous over the past years and this needed to be taken into account.

(b) Water quality had become a regional, if not a global, concern encompassing more pollutants than in the past; an ecological approach could combine the physical, chemical, biological and microbiological aspects; x Water Quality Assessments heavy metals and synthetic organic compounds have called for a change in the strategies for water quality surveys and monitoring.

(c) There is no need to describe the operational aspects of water quality monitoring and the laboratory procedures since they are mostly contained in the *GEMS/WATER Operational Guide,* a revised third edition of which appeared in 1991.

(d) Basic guidance on methodology is given in the *GEMS/WATER Handbook for Water Quality Monitoring in Developing Countries* which will be available by the end of 1991.

In October 1987, the two Secretariats compiled an annotated outline for the revised *Water Quality Surveys* on the understanding that the new book would describe, in a much broader way, the application and interpretation of water quality information in water resource management. The methodological and technical aspects could be largely omitted since the reader could be referred to the above-mentioned GEMS/WATER literature.

Authors were designated in 1988 and a first meeting of authors and contributors, supported by the United Nations Environment Programme (UNEP) and the USSR Centre for International Projects, took place in Sochi (former USSR) from 14 to 20 November 1988, followed by a second editorial meeting at Baikalsk (former USSR) from 3 to 10 August 1990. A final editorial panel meeting was then convened in Geneva, 22-23 November 1990. The result of these meetings is this guidebook, now renamed *Water Quality Assessments.*

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Foreword to the second edition

Much has happened in the water sector at national and international level since the preparation of the first edition of this guidebook. One major event was the International Conference on Water and the Environment which was held in January 1992 in Dublin, Ireland. In dealing with the protection of water resources, water quality and aquatic ecosystems, the conference made rather specific requests regarding the need for more and better water quality assessments, including:

- Purpose-orientated water assessments and predictions, taking into account the specificity of both surface and groundwaters, water quality and water quantity, and addressing all pollution types.

- Assessments harmonised for natural basins or catchments (including station networks, field and laboratory techniques, methodologies and procedures, and data handling) and leading to basin-wide data systems.

- New appropriate assessment and prediction techniques and methodologies, such as low-cost field measurements, continuous and automatic monitoring, use of biota and sediment for micro-pollution monitoring, remote sensing, and geographic information systems.

In June 1992 in Rio de Janeiro, Brazil, the United Nations Conference on Environment and Development resulted in an agreement on the action plan known as Agenda 21 which, in its chapter on freshwater, largely endorsed the recommendations from the Dublin conference. The stated objectives of Agenda 21 include issues which this guidebook aims to address, specifically:
- to make available to all countries water resources assessment technology that is appropriate to their needs, irrespective of their level of development, and

- to have all countries establish the institutional arrangements needed to ensure the efficient collection, processing, storage, retrieval and dissemination to users of information about the quality and quantity of available water resources, at the level of catchments and groundwater aquifers, in an integrated manner.

The concerns expressed at these conferences, together with the feedback from readers and users of the first edition of this guidebook, have guided the editor and authors in preparing the second edition. Latest developments in strategies, as well as on

technologies and methods, have been taken into account to make the book useful for water resources managers charged with the monitoring, assessment and control of water quality for a variety of purposes. Thus this guidebook should contribute to the capacity building initiatives launched in a number of countries in the aftermath of the Rio de Janeiro conference by supporting the scientifically-sound assessment of water resources which are tending to become more sparse and polluted.

One major change from the first edition, which is in addition to the general review and updating, is the introduction of a new chapter on reservoirs. The construction of dams along many rivers has increased rapidly over recent years, including some more controversial large dam projects. The multiple use of the resulting reservoirs requires a sound water quality assessment component to their management strategies. A separate chapter has been devoted to reservoirs because many have complex hydrodynamic features and all are subject to potential or actual human intervention in their natural chemical and physical processes. The original rivers and lakes chapters of the first edition have been modified accordingly.

The other major development in preparing the second edition concerns the production of the companion handbook *Water Quality Monitoring: a practical guide to the design and implementation of freshwater quality studies and monitoring programmes.* The manuscript for the *Water Quality Monitoring* handbook emerged and was finalised in parallel to the second edition of this guidebook. *Water Quality Monitoring* provides the practical and methodological details whereas *Water Quality Assessments* gives the overall strategy for assessments of the quality of the main types of water body. Together the two books cover all the major aspects of water quality, its measurement and its evaluation.

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Summary and scope

This guidebook concentrates on the process of setting up monitoring programmes for the purpose of providing a valid data base for water quality assessments. The choice of variables to be measured in the water, the sediment and in biota are described in Chapters 3, 4 and 5 and the common procedures for data handling and presentation in Chapter 10. Interpretation of these data for the purpose of assessing water quality in rivers, lakes, reservoirs and groundwaters is presented in Chapters 6, 7, 8 and 9 respectively. These chapters, specific to the type of water body, focus on monitoring strategies, requirements for water quality and quantity data and interpretative techniques. The choice of the appropriate methods is illustrated by case studies for typical water pollution situations. In view of the varying levels of resources which countries can put at the disposal of this activity, the strategies for water quality assessment are developed according to three different levels of monitoring operations: simple, intermediate and advanced.

For the purpose of this presentation of water quality assessment techniques the following types of water resources have been taken into consideration:

- Rivers and streams of all sizes from source to tidal limit (i.e. the influence of salt water intrusion). Canals and inter-connecting river systems are also included.

- Lakes of all sizes and types, including marshes and bogs.

- Reservoirs of various types, especially river impoundments.

- Groundwaters of various types, shallow or deep, and phreatic or confined.

These types of water bodies include all major freshwater resources subject to anthropogenic influences or intentionally used for municipal or industrial supply, irrigation, recreation, cooling or other purposes. However, certain types of waters are outside the scope of this book, including: estuaries, coastal lagoons, salt marshes and other saline waters, wastewaters of different origins, thermal and mineral springs, saline aquifers, brines and atmospheric precipitation such as rain and snow.

Within the range of water quality issues addressed in this guidebook efforts have been concentrated on major areas of vital importance. Several complementary publications

are readily available which cover other specific aspects in great detail and, when referred to, their use in conjunction with the present guide is strongly recommended.

There are no geographical limits imposed on the applicability of the guidance provided in this book since an effort was made by the authors to address all kinds of environmental conditions occurring in aquatic ecosystems world-wide. Thus, the specific situations of humid and dry tropics, as well as of mountainous and lowland waters, in water abundant or semi-arid and arid climatic zones, are all covered by means of examples. Attempts have been made to find examples from all world regions but, inevitably, there is more literature available from the developed world than the developing world and this is reflected in the reference lists attached to each chapter. Water quality, and its monitoring and assessment, is also greatly influenced by the size of the water body and, therefore, relevant guidance is provided for different levels of magnitude.

Within this guidebook various water quality problems (organic pollution, eutrophication, acidification, toxic contamination etc.) and their related descriptors are discussed at various levels of complexity. Chemical constituents and contaminants, as well as the biological characteristics of water bodies, are covered extensively. However, the consequences of temperature changes due to thermal discharges are only addressed in relation to their effects on aquatic life.

Human health is affected, in many world regions, by vector-transmitted diseases associated with vector organisms which breed in the aquatic environment. This problem is enormous since there are 200 million people suffering from one such disease alone, i.e. schistosomiasis. However, since the occurrence of such diseases, and their containment, is closely linked to water resource development projects, rather than to pollution sources and effects, this issue is not dealt with in this book. Further information on these topics can be found in the internationally recognised literature on the subject (WHO, 1980, 1982, 1983).

Pathogenic agents causing water-borne diseases include bacteria and viruses as well as protozoa and helminths. Although they interfere only marginally with aquatic life in general, they cause severe public health problems and are considered responsible for most of the infant mortality in developing countries. Monitoring is usually done indirectly by identifying and quantifying indicators of faecal pollution such as the coliform groups. This guidebook follows the same concept and interested readers are referred to further background information in the relevant literature published by the World Health Organization (WHO, 1976, 1985, 1993).

Radioactive isotopes, natural or man-made, are not included in this publication because the monitoring of radiation is covered by the work of the International Atomic Energy Agency (IAEA).

The basic methods, procedures, techniques, field equipment and analytical instruments required to monitor water quality have been developed and field-tested in a wide range of situations over the last two decades. A wealth of experience has been accumulated and communicated through guidebooks and reports on water quality. As a consequence, the authors of this book felt that the monitoring methods and procedures already published adequately cover the necessary techniques. Therefore, they have

concentrated more on the principles, approaches and design for water quality assessment and on the interpretation of the resulting data.

With respect to the field operations for monitoring, a comprehensive and practical booklet has been produced by the World Meteorological Organization (WMO, 1988). It describes essential factors to consider in monitoring such as the location of sampling sites, the collection of surface water samples, field measurements, sampling for biological analysis, shipment of samples, field safety and training programmes related to all of the above. Similar publications are not widely available for groundwaters but a description of techniques is given in Barcelona *et al.* (1985). The international project on global freshwater quality monitoring, GEMS/WATER (WHO, 1991), has based its monitoring operations on a practical guidebook, the *GEMS/WATER Operational Guide* (WHO, 1992) which gives in detail information on site selection, sampling, analysis, quality control and data processing. Most chemical analyses required for water quality monitoring are adequately covered by such reference books, whereas non-standardised methods for biological monitoring have to be developed for local or regional situations. However, although analytical reference methods are given in several general publications, it is also necessary to consult the International Standards Organization (ISO) “Standard methods” series of publications and to refer to recognised national publications, such as the standard methods produced by the American Public Health Association (APHA, 1989), the German standard methods (Deutsche Einheitsverfahren zur Wasser-, Abwasser und Schlammuntersuchung (DIN)) and those of the USSR State Committee for Hydrometeorology and Environmental Control (1987, 1989) which are now used in Russia and other CIS countries.

Hydrological measurements are an indispensable accompaniment to any surface water quality monitoring operation. Groundwater quality data also require adequate hydrological information for any meaningful interpretation. The World Meteorological Organization has developed practical guidelines as part of its Operational Hydrology Programme (WMO, 1994) and the United Nations Educational, Scientific and Cultural Organization (UNESCO) has also issued groundwater hydrology guidebooks. These publications provide methodology for water quality data collection, interpretation and presentation (UNESCO, 1983).

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WMO 1994 *Guide to Hydrological Practices.* Fifth edition, WMO Publication No. 168, World Meteorological Organization, Geneva, 735 pp.

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Abbreviations used in text

AAS	Atomic absorption spectrophotometry
AES	Atomic emission spectrophotometry
ANC	Acid neutralising capacity
ANOVA	Analysis of variance
AOX	Adsorbable organic halides
APHA	American Public Health Association
AQC	Analytical quality control
ASPT	Average Score Per Taxon
BMWP	Biological Monitoring Working Party-score
BOD	Biochemical oxygen demand
CEC	Commission of the European Communities
CIPEL	International Surveillance Commission of Lake Geneva
COD	Chemical oxygen demand
DDT	Dichlorodiphenyltrichloroethane
DIN	Deutsche Einheitsverfahren zur Wasser-, Abwasser und Schlammuntersuchung
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DON	Dissolved organic nitrogen
EDTA	Ethylenediaminetetraacetic acid
EIFAC	European Inland Fisheries Advisory Commission
EQI	Ecological Quality Index
EU	European Union (formerly European Community)
FAO	Food and Agriculture Organization of the United Nations
GC	Gas chromatograph(y)
GC/MS	Gas chromatography/mass spectrometry
GEMS	Global Environment Monitoring System
GIS	Geographic information systems
GLOWDAT	GLObal Water DATa Management System
IAEA	International Atomic Energy Agency
IAHS	International Association for Hydrological Science
IC	Ion chromatography
ICP/AES	Inductively coupled plasma atomic emission spectrometry

ICPS	Inductively coupled plasma spectroscopy
IHD	International Hydrological Decade
IR	Infra red
IRPTC	International Register of Potentially Toxic Chemicals
ISO	International Standards Organization
JTU	Jackson turbidity units
LC	Liquid chromatography
LOD	Limit-of-detection
LOWESS	Locally weighted scatter plot smoothing
LT	Less than values
MAC	Maximum allowable concentration
MATC	Maximum allowable toxic concentration
MCNC	Most common natural concentrations
MLE	Maximum likelihood estimator
MPN	Most probable number
MS	Mass spectrometer (spectrometry)
NAQUADAT	The NAtional Water QUALity Accounting DATa Bank(Canada)
NCPB	National Contaminant Biomonitoring Program (USA)
ND	Not detected
NOEC	No observed effect concentration
NTU	Nephelometric turbidity units
OECD	Organisation for Economic Co-operation and Development
OII	Odour intensity index
OPP	Oxygen Production Potential
PA	Apatitic phosphorus
PAH	Polychlorinated aromatic hydrocarbons
PCA	Principal components analysis
PCBs	Polychlorinated biphenyls
PCs	Personal computers
PFU	Plaque forming units
PINA	Non-apatitic inorganic phosphorus
PM	Particulate matter
PO	Organic phosphorus
POC	Particulate organic carbon
PON	Particulate organic nitrogen
PTFE	Polytetrafluoroethylene
RAISON	Regional Analysis by Intelligent Systems on a Microcomputer
RCRA	Resource Conservation and Recovery Act, USA
RIVPACS	River In Vertebrate Prediction and Classification System
SA	Sediment accretion
SAR	Sodium adsorption ratio
SEF	Sediment enrichment factor
SM	Suspended matter
SOE	State of the Environment

SR	Settling rate
SRP	Soluble reactive phosphorus
TAC	Total absorbance colour
TCDD	Tetra chlorinated dibenzo dioxin
TDS	Total dissolved solids
TOC	Total organic carbon
TP	Total phosphorus
TSS	Total suspended solids
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
US EPA	United States Environmental Protection Agency
UV	Ultra violet
VA	Voltammetry
WASP	Water Analysis Simulation Programme
WHO	World Health Organization
WMO	World Meteorological Organization

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