

Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes

Edited by Jamie Bartram and Richard Ballance

Published on behalf of United Nations Environment Programme and the World Health Organization

© 1996 UNEP/WHO

ISBN 0 419 22320 7 (Hbk) 0 419 21730 4 (Pbk)

Table of Contents

FOREWORD

ACKNOWLEDGEMENTS

Chapter 1 - INTRODUCTION

- 1.1 Elements of a water quality monitoring programme
- 1.2 Monitoring for management
- 1.3 Monitoring and assessment

Chapter 2 - WATER QUALITY

- 2.1 Characteristics of surface waters
- 2.2 Characteristics of groundwater
- 2.3 Natural processes affecting water quality
- 2.4 Water use and water quality deterioration
- 2.5 Water and human health
- 2.6 Source literature and further reading

Chapter 3 - DESIGNING A MONITORING PROGRAMME

- 3.1 Purpose of monitoring
- 3.2 The need for information for management
- 3.3 Objectives of water quality monitoring
- 3.4 Preliminary surveys
- 3.5 Description of the monitoring area
- 3.6 Selecting sampling sites
- 3.7 Selecting sampling stations
- 3.8 Monitoring media and variables
- 3.9 Frequency and timing of sampling
- 3.10 Source literature and further reading

Chapter 4 - RESOURCES FOR A MONITORING PROGRAMME

- 4.1 Laboratory facilities
- 4.2 Transport
- 4.3 Staffing
- 4.4 Human resources development and training

- 4.5 Communication
- 4.6 Inventory of sampling stations
- 4.7 Schedules for sampling expeditions
- 4.8 Source literature and further reading

Chapter 5 - FIELD WORK AND SAMPLING

- 5.1 Sample containers
- 5.2 Types of sample
- 5.3 Water samplers
- 5.4 Manual sampling procedures
- 5.5 Recording field observations
- 5.6 Sample preservation
- 5.7 Transportation and storage of samples
- 5.8 Reception of samples by the laboratory
- 5.9 Safety during field work
- 5.10 Source literature and further reading

Chapter 6 - FIELD TESTING METHODS

- 6.1 Temperature
- 6.2 Transparency
- 6.3 pH
- 6.4 Conductivity (or specific conductance)
- 6.5 Dissolved oxygen
- 6.6 Thermotolerant (faecal) coliforms
- 6.7 Quality assurance in the field
- 6.8 Source literature and further reading

Chapter 7 - PHYSICAL AND CHEMICAL ANALYSES

- 7.1 Preparation and use of chemical reagents
- 7.2 Alkalinity
- 7.3 Aluminium
- 7.4 Biochemical oxygen demand
- 7.5 Chemical oxygen demand
- 7.6 Boron
- 7.7 Calcium
- 7.8 Chloride
- 7.9 Chlorophyll a
- 7.10 Fluoride
- 7.11 Iron
- 7.12 Magnesium
- 7.13 Manganese
- 7.14 Nitrogen, ammonia
- 7.15 Nitrogen, Kjeldahl
- 7.16 Nitrogen, nitrate
- 7.17 Nitrogen, nitrite
- 7.18 Phosphorus
- 7.19 Potassium
- 7.20 Selenium
- 7.21 Reactive silica
- 7.22 Sodium
- 7.23 Sulphate

- 7.24 Total dissolved solids
- 7.25 Total suspended solids
- 7.26 Source literature and further reading

Chapter 8 - ADVANCED INSTRUMENTAL ANALYSIS

- 8.1 Atomic absorption spectrophotometry (AAS)
- 8.2 Gas chromatography
- 8.3 Flame photometry
- 8.4 Total, organic and inorganic carbon
- 8.5 Source literature and further reading

Chapter 9 - ANALYTICAL QUALITY ASSURANCE

- 9.1 Quality assurance
- 9.2 Internal quality control
- 9.3 External quality control
- 9.4 Source literature and further reading

Chapter 10 - MICROBIOLOGICAL ANALYSES

- 10.1 Characteristics of indicator organisms
- 10.2 Selecting a bacteriological analytical technique
- 10.3 Multiple fermentation tube technique
- 10.4 Membrane filter technique
- 10.5 Quality assurance
- 10.6 Source literature and further reading

Chapter 11 - BIOLOGICAL MONITORING

- 11.1 Selection of appropriate methods and organisms
- 11.2 Ecological methods
- 11.3 Measurement of chlorophyll a
- 11.4 Physiological techniques
- 11.5 Controlled biotests
- 11.6 Contaminants in biological tissues
- 11.7 Site selection and sampling frequency
- 11.8 Quality assurance
- 11.9 Source literature and further reading

Chapter 12 - HYDROLOGICAL MEASUREMENTS

- 12.1 Rivers
- 12.2 Lakes and reservoirs
- 12.3 Mass flux computation
- 12.4 Groundwater
- 12.5 Source literature and further reading

Chapter 13 - SEDIMENT MEASUREMENTS

- 13.1 Types of sediment transport
- 13.2 Sediment measurement
- 13.3 Sampling for sediment
- 13.4 Measuring suspended sediment

- 13.5 Sediment quality
- 13.6 Source literature and further reading

Chapter 14 - USE AND REPORTING OF MONITORING DATA

- 14.1 Quality assurance of data
- 14.2 Data handling and management
- 14.3 Basic statistical analysis
- 14.4 Use of data and the need for supporting information
- 14.5 Simple graphical presentation of results
- 14.6 Reporting
- 14.7 Recommendations
- 14.8 Source literature and further reading

Appendix 1 - PORTABLE FIELD KITS

Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes

Edited by Jamie Bartram and Richard Ballance

Published on behalf of United Nations Environment Programme and the World Health Organization

© 1996 UNEP/WHO

ISBN 0 419 22320 7 (Hbk) 0 419 21730 4 (Pbk)

FOREWORD

According to Agenda 21 of the United Nations Programme of Action following the Earth Summit in Rio de Janeiro:

“The complex interconnectedness of freshwater systems demands that freshwater management be holistic (taking a catchment management approach) and based on a balanced consideration of the needs of people and the environment. The Mar del Plata Action Plan has already recognised the intrinsic linkage between water resource development projects and their significant physical, chemical, biological, health and socio-economic repercussions”

The approaches and methods for water quality monitoring described in this handbook are based upon the experience gained, over two decades, with the design and establishment of the global freshwater quality monitoring network, GEMS/WATER. The GEMS/WATER programme is co-sponsored by the United Nations Environment Programme (UNEP) and the World Health Organization (WHO), together with the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the World Meteorological Organization (WMO). One of the goals of GEMS/WATER is:

“to strengthen national water quality monitoring networks in developing countries, including the improvement of analytical capabilities and data quality assurance”.

This handbook supports this goal by providing a practical tool for use in water quality management by national and local agencies and departments dealing with water quality issues.

Water Quality Monitoring and its companion guidebook *Water Quality Assessments. A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring*, Second edition (edited by Deborah Chapman and published on behalf of UNESCO, WHO and UNEP by Chapman & Hall, London, 1996) constitute principal methodology guidebooks developed and used in the monitoring and assessment activities of GEMS/WATER. Together they make a direct contribution to capacity building in the area of water quality monitoring and assessment.

This book brings together the information necessary to design and implement a water quality monitoring programme and provides a basis for water quality assessments and studies of the impact of pollution on the natural environment. Freshwater quality is addressed in a holistic way, considering both surface waters and groundwaters. Emphasis is given to monitoring the natural environment and to detecting and monitoring trends in water quality.

The book outlines general considerations related to water quality monitoring, provides a general protocol for a monitoring programme and includes such elements as staff requirements, staff training and the equipping of analytical laboratories. It also includes consideration of the problems that may be encountered when implementing programmes in remote areas and developing countries and when establishing water quality monitoring programmes from scratch.

It is hoped that the approaches and methods described will be useful for anyone concerned with water quality monitoring whether they have a scientific, managerial or engineering background and including, particularly, field staff and those who may not be water quality experts. Potential users may be from local, regional or national government agencies, research groups, consulting firms or non-governmental organisations. This book will be especially useful to those who plan and manage the various aspects of water quality monitoring outside the framework of large established programmes, as may be the case in many developing countries and for specific projects and studies world-wide.

Material on sampling and analytical methods for the most important physical, chemical and bacteriological variables has been brought together here in a convenient form, with an emphasis on field techniques at a level suitable for those implementing water quality programmes. An overview of the principles underlying, and the importance of hydrological, biological and sediment measurements and their relevance to water quality monitoring is also included. Information on some of the commercially available analytical kits for use in the field is included in an appendix.

Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes

Edited by Jamie Bartram and Richard Ballance

Published on behalf of United Nations Environment Programme and the World Health Organization

© 1996 UNEP/WHO

ISBN 0 419 22320 7 (Hbk) 0 419 21730 4 (Pbk)

ACKNOWLEDGEMENTS

The co-sponsoring organisations, UNEP and WHO, wish to express their appreciation to all of those whose efforts made the preparation of this book possible. Special thanks are due to the Department of International Development and Co-operation, Ministry of Foreign Affairs of Finland which provided generous and continued financial support to the preparation of the book as well as for the organisation of several regional review workshops. The Tampere University of Technology, Finland and the National Board of Waters and the Environment, Finland both supported the initiation of this handbook. Thanks are also due to Dr Veerle Vandeweerd of UNEP/GEMS for her enthusiasm and energy during the initiation of the project which led to the preparation of this document and for her tireless support throughout the subsequent development and refinement of this book.

An international group of authors provided material and, in most cases, several authors and their collaborators contributed to each chapter. It is difficult to identify precisely the contributions made by individuals and we apologise for any oversights in the following list of principal contributors.

Dick Ballance, formerly of World Health Organization, Geneva, Switzerland (editor, and contributor)

Jamie Bartram, European Centre for Environment and Health, World Health Organization, Rome, Italy, formerly of the Robens Institute, University of Surrey, Guildford, UK (editor and contributor)

Ray Briggs, Robens Institute, University of Surrey, Guildford, UK (contributions to Chapter 9)

Deborah Chapman, Environment Consultant, Kinsale, Ireland (contributions to Chapter 11)

Malcolm Clarke, University of Victoria, BC, Canada (contributions to Chapter 14)

Richard Helmer, Urban Environmental Health, World Health Organization, Geneva, Switzerland (contributions to Chapter 1)

John Jackson, formerly of UNEP GEMS Monitoring and Assessment Research Centre, Kings College London, UK (contributions to Chapters 11 and 14)

Merete Johannessen, Norwegian Institute for Water Research (NIVA), Oslo, Norway (contributions to Chapters 3 and 9)

Falk Krebs, Federal Institute of Hydrology, Koblenz, Germany (contributions to Chapter 11)

Esko Kuusisto, National Board of Waters and the Environment, Helsinki, Finland (contributions to Chapters 1, 2 and 12)

John Lewis, Data Processing, Aberdare, UK (contributions to Chapter 14).

Ari Mäkelä, National Board of Waters and the Environment, Helsinki, Finland (contributions to Chapters 1, 2, 3 and 5)

Esko Mälkki, National Board of Waters and the Environment, Helsinki, Finland (contributions to Chapters 1, 2 and 5)

Michel Meybeck, Université de Pierre et Marie Curie, Paris, France (contributions to Chapters 2 and 3)

Harriet Nash, Wardel Armstrong, Newcastle-under-Lyme, UK (contributions to Chapters 5 and 14)

Ed Ongley, Canada Centre for Inland Waters, Burlington, Ontario, Canada (contributions to Chapters 12, 13 and 14)

Steve Pedley, Robens Institute, University of Surrey, Guildford, Surrey, UK (contributions to Chapter 10)

Alan Steel, Consultant, Kinsale, Ireland (contributions to Chapter 14)

Paul Whitfield, University of Victoria, BC, Canada (contributions to Chapter 14)

Dr Richard Helmer, WHO, Geneva, Dr Veerle Vandeweerd, UNEP, Nairobi and Dr Jeffrey Thornton, International Environmental Management Services, Wisconsin critically reviewed early drafts. Later drafts were reviewed by John Chilton, British Geological Survey and Ms Harriet Nash, Wardel Armstrong, who made useful suggestions concerning groundwater and basic data checks respectively.

Drafts of the text were reviewed at a series of regional workshops convened in the framework of the GEMS/WATER programme in Tanzania (1992), Zimbabwe (1993), Uganda (1994) and Jordan (1994). More than 60 people contributed to the review process in this way and the orientation of the final document towards real, practical problems is largely due to their efforts.

Thanks are due to Verity Snook, Mary Stenhouse and John Cashmore for secretarial services to the review meetings and for secretarial and administrative assistance at various stages of the project. The editorial assistance of Sarah Ballance is also much appreciated during the preparation of the final manuscript. Thanks are also due to Helen MacMahon and Alan Steel (preparation of illustrations) and to Deborah Chapman (editorial assistance, layout and production management).

United Nations Environment Programme
World Health Organization