

Assessing Microbial Safety of Drinking Water

IMPROVING APPROACHES
AND METHODS



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This book is one of a series of texts developed to support the development of microbial aspects in the third edition of WHO's *Guidelines for Drinking-water Quality* and to provide guidance to policy-makers, regulators and practitioners in aspects of planning and implementation. The other volumes include:

- Protecting groundwater for health: managing the quality of drinking-water sources
- Protecting surface water for health: managing the quality of drinking-water sources
- Water quality and drinking-water treatment: the impact of treatment processes on microbial water quality and occurrence of pathogens and indicators in surface waters
- Microbial water quality in piped distribution systems: a review of knowledge and practice
- Managing water in the home: accelerating health gains from improved water quality
- Water safety plans: managing public water supplies for safety

Other texts of direct relevance include:

From WHO

- Water Quality: Guidelines, standards and health
- *Legionella* and the prevention of legionellosis
- A separate series of texts deals with emerging issues in water and infectious disease
- Pathogenic mycobacteria in water
- Hazard characterization for pathogens in food and water (WHO and FAO)
- Quantifying public health risks in the Guidelines for Drinking-water Quality: a burden of disease approach

From OECD

- OECD Proceedings. Biotechnology for water use and conservation: The Mexico '96 Workshop (1997)
- The price of water: trends in OECD countries (1999)
- Molecular technologies for safe drinking water (1998) (available at <http://www.oecd.org/pdf/M000014000/M00014623.pdf>)
- Drinking water and infectious disease: establishing the links (co-published by IWA, 2002)

FOREWORD

Inadequate drinking water supply and quality and poor sanitation are among the world's major causes of preventable morbidity and mortality. According to the World Health Organization (WHO) estimates, basic hygiene-related diseases have a significant impact on human health. Diarrhoeal disease alone causes 2.2 million of the 3.4 million water-related deaths per year. Many of the deaths involve children under five years of age and the poorest households and communities. The problem is not limited to developing countries. In member countries of the Organisation for Economic Co-operation and Development (OECD), waterborne outbreaks occur all too frequently. Moreover, many outbreaks remain undetected, and it is likely that, beyond the reported outbreaks, there is an unrecognised background burden of disease.

Water-related issues were high on the international policy agenda in the 1970s, following the first international conference on the environment, held in Stockholm in 1972. However, by the time of the International Drinking Water Supply and Sanitation Decade (1981-90), interest had begun to wane. In the industrialised nations, concern focused on chemical contamination, and the international agenda moved increasingly towards major environmental issues such as global climate change, ozone depletion and desertification.

There was, however, an increasing level of public and professional concern about water safety, fuelled by concerns raised by outbreaks of disease and the recognition of new agents of disease and the challenges they presented to health protection. The 1993 Milwaukee outbreak, resulting in an estimated 400 000 cases of cryptosporidiosis, clearly underscored the severe consequences of waterborne outbreaks in OECD countries. The *Cryptosporidium* outbreak reported in Las Vegas, Nevada, in the spring of 1994 demonstrated the need for better understanding of the effectiveness of indicators and treatment processes in controlling waterborne pathogens. It also indicated the need for a re-evaluation of the effectiveness of traditional indicators as a basis for risk management, since the outbreaks occurred in waters that met the safety standards set by guidelines for traditional index and indicator bacteria.

Water and health have again moved up the international policy agenda as part of a more comprehensive understanding of sustainable development. This is evident in the declarations from the World Water Forums in Marrakesh (1997) and the Hague (2000) and in the increased co-operation among international agencies, including the programme of co-operation between the OECD and the WHO. The initiative leading to this report is a first product of that programme.

The need to improve assessment and management of the world's sources of drinking water was highlighted in 1996 at the OECD Workshop on Biotechnology for Water Use and Conservation in Cocoyoc, Mexico. Then, in 1998, the OECD Interlaken Workshop on Molecular Technologies for Safe Drinking Water reviewed the effectiveness of drinking water supply systems in protecting against microbial contaminants and the reliability of current monitoring parameters and testing systems. The Interlaken workshop confirmed the need for better microbial monitoring parameters and methods for assessing the safety of drinking water and monitoring and responding to adverse events. Most importantly, given the numbers of pathogens which cannot specifically be tracked by conventional methods, especially viruses and parasites such as *Cryptosporidium* and *Giardia*, the workshop recommendations pointed out that "business as usual" was no longer a viable option.

WHO's Guidelines for Drinking Water Quality provide a scientific basis for the development of standards and regulations to protect drinking water quality and human health. They are used by countries world-wide and are regularly updated in response to new information and developments. A series of meetings since 1995 has recommended adoption of a systematic preventive management approach to the control of microbial risks from catchment to consumer for drinking water. A framework integrating aspects of risk assessment and risk management in water safety was developed at a meeting in Stockholm (1999). The framework harmonises approaches applied to drinking water, wastewater use and recreational water quality. These include "Water Safety Plans", building upon Hazard Analysis Critical Control Point (HACCP) and the "multiple barrier principle". This document (developed by OECD and WHO) is one in a series of state-of-the-art reviews, which will inform the process of updating the Guidelines.

Outdated methods do not effectively identify and prevent serious enteric waterborne disease, and there is a large and under utilised toolbox for improving assessment of the safety of drinking water. While the rationale for using index organisms to detect contamination in source water remains sound, evaluation of treatment efficacy, post-treatment contamination, etc., require multiple indicators. No single microbial (or non-microbial) indicator parameter

is adequate to determine if all steps in the entire drinking water production process are working properly in all circumstances. Thus, it is necessary to gain a better understanding of the role and usefulness of the traditional and new parameters for monitoring and of the methods available for their analysis, and of the information needed to initiate appropriate remedial and preventive actions.

The Swiss Federal Institute for Environmental Science and Technology (EAWAG) heeded the call for a major review of the state of knowledge regarding monitoring parameters and testing methods relevant to the control of the microbial safety of drinking water. Under the leadership of the Director of the Institute, Professor Alexander Zehnder, and with the generous support of EAWAG, an initiative was launched to develop a guidance document to address such needs, in co-operation with the OECD and the WHO. Responsible for the co-ordination of this initiative were Dr. Mario Snozzi and Dr. Wolfgang Köster of EAWAG, Dr. Jamie Bartram of the WHO, Dr. Elettra Ronchi of the OECD and Dr. Al Dufour of the US Environmental Protection Agency. The successful outcome of this initiative is due, however, to the exceptional efforts made by the contributing international experts. The financial support of the Industry Council for Development (ICD) for review and advance document development is gratefully acknowledged. The expert editorial assistance of Dr. Lorna Fewtrell and the secretarial assistance of Alysia Ritter have been invaluable.

Scope of the document

This guidance document seeks to respond to the need to improve the assessment and management of the microbiological safety of drinking water, by moving away from using monitoring simply as a tool to verify the safety (or otherwise) of the finished product towards using the results as a basis for risk management actions. End-product testing comes too late to ensure safe drinking water, owing to the nature of current microbial sampling and testing, which typically provides results only after water has been distributed and often consumed. Thus, this document gives guidance on the appropriate application of monitoring parameters for ensuring the safety of drinking water and to inform risk management decisions, with an emphasis on control of faecal contamination. It offers guidance on how to select and use multiple parameters to meet specific information needs as a support to safe practice throughout the whole water system: catchment protection and assessment, source water quality assessment, assessment of treatment efficiency, monitoring the quality of drinking water leaving the treatment facility and in the distribution system. It offers a comprehensive review of traditional index and indicator organisms and of emerging technologies.

The approach described here has elements of both revolution and evolution. It is *revolutionary* in that it supports a rapidly emerging approach which emphasises the need to change from a single indicator organism, primarily used for end-product monitoring to determine hygienic quality, to multiple parameters including index and indicator organisms within a broader integrated management perspective and a risk management framework. It is *evolutionary* in that the approach builds upon the multiple barrier approach and on a body of information gleaned from scientific studies and surveys on the nature and behaviour of both pathogens and indicator organisms in water systems and on the relation between indicator organisms and pathogens.

Chapter 1 sets the scene, describing the problem and establishing the need for monitoring. It outlines the history of faecal indicator parameters and describes the various information needs. The use of a range of parameters to assess the examination of process efficiency and operational integrity is outlined in Chapter 2. Chapter 3 looks at the use of microbial monitoring in risk assessment. Chapters 4, 5 and 6 offer guidance on how the wide range of parameters can be put to use. Chapter 4 describes catchment characterisation and source water quality assessment, Chapter 5 looks at treatment efficiency and Chapter 6 examines the use of indicator parameters for monitoring the quality of drinking water during storage and distribution. Chapter 7 focuses on the investigation of water during incidents and disease outbreaks, with case studies illustrating the use of various parameters for specific purposes. Chapter 8 presents an overview of the various analytical techniques for determining numbers of faecal index and indicator bacteria as well as selected pathogens in water samples. It includes conventional and new (principally molecular biology) techniques and outlines the performance characteristics of the different methods along with their economic considerations (cost of infrastructure and consumables, level of training of technical staff).

Challenges for the 21st century

The document draws attention to important challenges related to the preservation and management of safe drinking water and particularly the need to develop a predictive system that will warn that a hazardous situation is imminent and enable timely and cost-effective correction of the situation. Perhaps the greatest challenge is the renewed recognition that resurgent and emerging pathogens with a high resistance to treatment are a significant hazard, not only in less developed countries, but in countries at all levels of industrialisation/economic development. Awareness of the existence of such organisms has developed primarily because of significant localised outbreaks. The specific aetiologic agent is only identified in about half of the detected

outbreaks owing to the lack of appropriate detection methods or the lack of their application. Application of emerging molecular methods, while perhaps not appropriate for routine monitoring, are likely to make a significant contribution in this area.

The lack of available methodology to detect and quantify many such organisms, particularly those considered emerging waterborne pathogens, is an issue of great concern. Clearly, adequate assessment of the impact of such organisms on health is also directly related to the availability of appropriate detection methodology. In the post-genomics era, the tools for characterising microorganisms exist. Both genetic (nucleic-acid-based) and immunological tools are available and some molecular techniques appear particularly promising. For example, genotyping, or molecular characterisation, is a powerful new tool for identifying the source of microbial contaminants and is already in routine use for detecting *Cryptosporidium* in some countries. On the horizon, as Chapter 8 shows, are methods based on microarrays and biosensors. Advances in semiconductors and computers are expected to allow the next generation of microbial sensors to be small and simple devices, which are quick to respond. The future thus holds the promise of new techniques for detecting both existing and emerging pathogens.

Many challenges remain in the pursuit of safe drinking water for all. Resources are needed to increase the usefulness of the new molecular technologies in the pipeline. Advances in new molecular technologies should be encouraged and monitored, as they offer the best hope for improved and rapid detection of microbial contaminants in water.

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