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Water Treatment and Pathogen Control

*Process Efficiency in Achieving Safe Drinking Water*

Mark W LeChevallier and Kwok-Keung Au

World Health Organization Publishing
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Microbial contamination of drinking-water contributes to disease outbreaks and background rates of disease in developed and developing countries worldwide. Control of waterborne disease is an important element of public health policy and an objective of water suppliers.

The World Health Organization (WHO) has developed *Guidelines for Drinking-water Quality*. These guidelines, which are now in their third edition (WHO, 2004), provide an internationally harmonized basis to help countries to develop standards, regulations and norms that are appropriate to national and local circumstances. The latest edition of the WHO *Guidelines for Drinking-water Quality* is structured around an overall “water safety framework”, used to develop supply-specific “water safety plans”. The framework, which focuses on health protection and preventive management from catchment to consumer, has five key components:

- health-based targets, based on an evaluation of health concerns;
- system assessment to determine whether the drinking-water supply (from source through treatment to the point of consumption) as a whole can deliver water of a quality that meets the health-based targets;
Water treatment and pathogen control

- operational monitoring of the control measures in the drinking-water supply that are of particular importance in securing drinking-water safety;
- management plans that document the system assessment and monitoring plans, and describe actions to be taken in normal operation and incident conditions (including upgrade and improvement, and documentation and communication);
- a system of independent surveillance to verify that the above are operating properly.

Understanding the effectiveness of water treatment is necessary for:
- design of cost-effective interventions
- review of the adequacy of existing structures
- operation of facilities to maximum benefit.

WHO has also developed a series of expert reviews covering various aspects of microbial water quality and health (listed below). This publication forms part of this series of reviews.

- Upgrading Water Treatment Plants (EG Wagner and RG Pinheiro, 2001)
- Water Safety Plans (A Davison et al., 2004)

Further texts are in preparation or in revision:
- Arsenic in Drinking-water (in preparation)
- Fluoride in Drinking-water (in preparation)
- Guide to Hygiene and Sanitation in Aviation (in revision)
- Guide to Ship Sanitation (in revision)
- Health Aspects of Plumbing (in preparation)
• Legionella and the Prevention of Legionellosis (in preparation)
• Protecting Groundwaters for Health — Managing the Quality of Drinking-water Sources (in preparation)
• Protecting Surface Waters for Health — Managing the Quality of Drinking-water Sources (in preparation)
• Rapid Assessment of Drinking-water Quality: A Handbook for Implementation (in preparation)
• Safe Drinking-water for Travellers and Emergencies (in preparation)

Water safety management demands a quantitative understanding of how processes and actions affect water quality, which in turn requires an understanding of risk assessment. This volume is intended to provide guidance on using risk assessment when selecting appropriate treatment processes, to ensure the production of high quality drinking-water. It is hoped that it will be useful to water utilities, water quality specialists and design engineers.
The World Health Organization (WHO) wishes to express its appreciation to all whose efforts made the production of this book possible. Special thanks are due to the book’s authors, Mark LeChevallier and Kwok-Keung Au.

Drafts of the text were discussed and reviewed at Medmenham (1998), Berlin (2000) and Adelaide (2001); the contribution of meeting participants is gratefully acknowledged. Drafts of the text were also circulated for peer review, and the comments from Malay Chauduri (Indian Institute of Technology, Kanpur, India), Mary Drikas (AWQC, Australia); Arie Havelaar (RIVM, the Netherlands) and Jim Lauria (Eagle Picher Minerals Inc., USA) were invaluable in ensuring the quality and relevance of the final text.

This text is one of the supporting documents to the rolling revision of the WHO Guidelines on Drinking-water Quality. Its preparation was overseen by the working group on microbial aspects of the guidelines, and thanks are also due to its members:

- Ms T Boonyakarnkul, Department of Health, Thailand (Surveillance and control)
- Dr D Cunliffe, SA Department of Human Services, Australia (Public health)
Prof W Grabow, University of Pretoria, South Africa (*Pathogen-specific information*)

Dr A Havelaar, RIVM, The Netherlands (Working Group Coordinator: *Risk assessment*)

Prof M Sobsey, University of North Carolina, USA (*Risk assessment*).

Thanks are due to Ms Mary-Ann Lundby, Ms Grazia Motturi, and Ms Penny Ward, who provided secretarial and administrative support throughout the process of producing this publication (including the review meetings), and to Hilary Cadman of Biotext for editing of the text.

Special thanks are due to the Australian Water Quality Centre; the American Water Works Service Company; the Swedish International Development Cooperation Agency; the United States Environmental Protection Agency; the National Health and Medical Research Council, Australia; the Institute for Water, Soil and Air Hygiene, Germany; and the Ministry of Health Labour and Welfare of Japan for their financial support, which made it possible to finalize the 3rd edition of the *Guidelines for Drinking-water Quality*, including this volume.
### Acronyms and abbreviations used in the text

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>AOC</td>
<td>assimilable organic carbon</td>
</tr>
<tr>
<td>asu</td>
<td>areal standard unit</td>
</tr>
<tr>
<td>AWWA</td>
<td>American Water Works Association</td>
</tr>
<tr>
<td>AWWARF</td>
<td>AWWA Research Foundation</td>
</tr>
<tr>
<td>BDL</td>
<td>below detection limit</td>
</tr>
<tr>
<td>BDOC</td>
<td>biodegradable dissolved organic carbon</td>
</tr>
<tr>
<td>CC-PCR</td>
<td>cell culture-polymerase chain reaction</td>
</tr>
<tr>
<td>cfu</td>
<td>colony forming unit</td>
</tr>
<tr>
<td>DAF</td>
<td>dissolved air flotation</td>
</tr>
<tr>
<td>DE</td>
<td>diatomaceous earth</td>
</tr>
<tr>
<td>DNA</td>
<td>deoxyribonucleic acid</td>
</tr>
<tr>
<td>FAC</td>
<td>free available chlorine</td>
</tr>
<tr>
<td>FMEA</td>
<td>failure mode and effects analysis</td>
</tr>
<tr>
<td>HACCP</td>
<td>hazard analysis critical control point</td>
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<tr>
<td>HPC</td>
<td>heterotrophic plate count</td>
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<tr>
<td>IDDF</td>
<td>integrated disinfection design framework</td>
</tr>
<tr>
<td>IFA</td>
<td>immunofluorescence assay</td>
</tr>
<tr>
<td>MF</td>
<td>microfiltration</td>
</tr>
</tbody>
</table>
xvi  Water treatment and pathogen control

NA  not applicable
NF  nanofiltration
NR  not reported
NTU  nephelometric turbidity unit
PACl  polyaluminium chloride
pfu  plaque forming unit
PVC  polyvinylchloride
RO  reverse osmosis
RNA  ribonucleic acid
SFBW  spent filter backwash
THM  trihalomethane
UF  ultrafiltration
USEPA  United States Environmental Protection Agency
UV  ultraviolet
WHO  World Health Organization
WTP  water treatment plant