# Safe Piped Water

# World Health Organization titles with IWA Publishing

*Water Quality: Guidelines, Standards and Health* edited by Lorna Fewtrell and Jamie Bartram. (2001)

## WHO Drinking Water Quality Series

*Assessing Microbial Safety of Drinking Water: Improving Approaches And Methods* edited by Al Dufour, Mario Snozzi, Wolfgang Koster, Jamie Bartram, Elettra Ronchi and Lorna Fewtrell. (2003)

*Water Treatment and Pathogen Control: Process Efficiency in Achieving Safe Drinking Water* by Mark W LeChevallier and Kwok-Keung Au. (2004)

*Safe Piped Water: Managing Microbial Water Quality in Piped Distribution Systems* by Richard Ainsworth. (2004)

***Forthcoming***

*Fluoride in Drinking Water* edited by K. Bailey, J. Chilton, E. Dahi, M. Lennon, P. Jackson and J. Fawell.

*Arsenic in Drinking Water* by WHO/World Bank/UNICEF as a cooperative effort of a series of UN agencies.

## WHO Emerging Issues in Water & Infectious Disease Series

*Heterotrophic Plate Counts and Drinking-water Safety: The Significance of HPCs for Water Quality and Human Health* edited by J. Bartram, J. Cotruvo, M. Exner, C. Fricker, A. Glasmacher. (2003)

*Pathogenic Mycobacteria in Water: A Guide to Public Health Consequences, Monitoring and Management* edited by S. Pedley, J. Bartram, G. Rees, A. Dufour and J. Cotruvo. (2004)

*Waterborne Zoonoses: Identification, Causes and Control* edited by J.A. Cotruvo, A. Dufour, G. Rees, J. Bartram, R. Carr, D.O. Cliver, G.F. Craun, R. Fayer, and V.P.J. Gannon. (2004)

***Forthcoming***

*Water Recreation and Disease: An Expert Review of the Plausibility of Associated Infections, their Acute Effects, Sequelae and Mortality* edited by K. Pond.

---

For further details contact: Portland Customer Services, Commerce Way, Colchester, Essex, CO2 8HP, UK.
Tel: +44 (0) 1206 796351; Fax: +44 (0) 1206 799331; Email: sales@portland-services.com; or order online at:

www.iwapublishing.com

# Safe Piped Water

*Managing Microbial Water Quality in Piped Distribution Systems*

Edited by
Richard Ainsworth

World Health Organization

**Published on behalf of the World Health Organization by**
**IWA Publishing, Alliance House, 12 Caxton Street, London SW1H 0QS, UK**
Telephone: +44 (0) 20 7654 5500; Fax: +44 (0) 20 7654 5555; Email: publications@iwap.co.uk
**www.iwapublishing.com**

First published 2004


Printed by TJ International (Ltd), Padstow, Cornwall, UK



*British Library Cataloguing-in-Publication Data*
A CIP catalogue record for this book is available from the British Library

*WHO Library Cataloguing-in-Publication Data*
Safe Piped Water: Managing Microbial Water Quality in Piped Distribution Systems / edited by R. Ainsworth.
1.Water microbiology 2.Water supply 3.Potable water - chemistry 4.Water quality 5.Sanitary engineering - methods 6.Knowledge, attitudes, practice 7.Review literature I.Ainsworth, R.

ISBN 92 4 156251 X (LC/NLM classification: QW 80)

ISBN 1 84339 039 6 (IWA Publishing)

# Contents

# Foreword

Pressurized pipe networks provide a means for supplying drinking-water to individual dwellings, buildings and communal taps. Their widespread adoption has contributed significantly to both the reduction and control of water-related diseases. They also reduce the burden of water collection, which is borne especially by women and children, and is itself associated with much disease and injury. Further development of piped water distribution will be critical to improving health and progressing development in countries worldwide. It is no coincidence that most of our villages and towns were originally concentrated near readily available sources of fresh water such as springs, rivers and lakes.

The microbial quality of water normally changes in a piped network. Although the changes often do not have health implications, there are many documented examples of serious contamination with pathogens occurring within the piped network. When contamination occurs, it may be difficult to trace and remedy because the pipework is normally below ground and difficult to inspect.

This review looks at the factors affecting the presence and growth of microorganisms in piped networks, and the practices of water supply organizations that can directly or indirectly influence their presence and growth. The information provided is based on experience with conventional

underground systems. The special requirements for systems in conveyances (ships, aircraft and trains) or within buildings are not discussed, although many of the general considerations presented here will be relevant.

The information and conclusions presented here are intended for policy-makers and those responsible for formulating water safety plans for the supply of drinking-water, as described in the third edition of the WHO *Guidelines for Drinking-water Quality* (WHO, 2004). They are also relevant to engineers and scientists responsible for water supply planning, operations and monitoring.

Many of the practices described in this review relate to the wider aspects of maintaining the fabric and integrity of the network, not just the prevention of health risks. For example, the removal of internal pipe deposits is often undertaken to increase hydraulic capacity or reduce water discolouration. Similarly, the prevention of pressure surges is normally undertaken to reduce bursts that are expensive and inconvenient to repair. However, this review shows that there are often public health reasons for adopting a more proactive approach to many of the traditional practices used in designing, operating and maintaining distribution networks.

The first six chapters address:

- the microbiology of piped distribution systems and public health;
- composition of treated waters to minimize potential for microbiological changes;
- design and operation of distribution networks;
- planned maintenance and survey of distribution systems;
- precautions during construction and repairs;
- small animals in drinking-water distribution systems.

Chapter 7 draws together this information in the context of a framework of risk assessment and risk management, adapted for application to drinking-water supply. This approach is consistent with the water safety plans described in the third edition of the WHO *Guidelines for Drinking-water Quality* (WHO, 2004).

This review is confined to distribution networks based on pressurized pipes fed by either gravity or pumps. Open-channel networks are not considered here because they provide little or no protection from contamination.

The microbial quality of water may also deteriorate in the plumbing systems of domestic and public buildings. These plumbing systems, and the service pipes connected to the supplier's distribution pipes, have the potential to greatly affect microbial and chemical quality. Plumbing systems and service pipes may not be the direct responsibility of the water supplier, and both cross-connections and backflow situations are a threat. These issues are addressed in Chapter 3. In a typical distribution system, plumbing and services account for 82% of the total pipe length and 24% of the total surface area in the system, yet contain only 1.6% of the total storage volume (Brazos, O'Connor & Abcouwer, 1986).

Therefore, the selection of service pipe and plumbing materials, and their correct installation, is important in controlling the microbial, chemical and aesthetic quality of water at the point of supply to the consumer. These issues are not covered in this review but are the subject of another text on safe plumbing practice, presently in development (see below).

This publication forms part of a series of expert reviews developed by WHO. The reviews, which are listed below, cover various aspects of microbial water quality and health.

- *Managing Water in the Home: Accelerated Health Gains from Improved Water Supply* (M Sobsey, 2002)
- *Pathogenic Mycobacteria in Water: A Guide to Public Health Consequences, Monitoring and Management* (S Pedley et al, eds, 2004)
- *Quantifying Public Health Risk in the WHO Guidelines for Drinking-water Quality: A Burden of Disease Approach* (AH Havelaar and JM Melse, 2003)
- *Water Treatment and Pathogen Control: Process Efficiency in Achieving Safe Drinking Water* (MW LeChevallier and K-K Au, eds, 2004)
- *Toxic Cyanobacteria in Water: A Guide to their Public Health Consequences, Monitoring and Management* (I Chorus and J Bartram, eds, 1999)
- *Upgrading Water Treatment Plants* (EG Wagner and RG Pinheiro, 2001)
- *Water Safety Plans* (A Davison et al., 2004).
- *Assessing Microbial Safety of Drinking Water: Improving Approaches and Methods* (A Dufour et al., 2003).

Further texts are in preparation or in revision:

- *Arsenic in Drinking-water* (in preparation)
- *Fluoride in Drinking-water* (in preparation)
- *Desalination for Safe Drinking-water Supply* (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).

## REFERENCES

Brazos BJ, O'Connor JT, Abcouwer S (1986). Kinetics of chlorine depletion and microbial growth in household plumbing systems. *Proceedings of the American Water Works Association Water Quality Tech. Conference*, Houston Texas, (Dec 8–11, 1985), Paper no. 4B-3, 239–274.

WHO (2004). *Guidelines for drinking-water quality*, 3rd ed., World Health Organization, Geneva.

# Acknowledgements

The World Health Organization wishes to express its appreciation to all whose efforts made the production of this book possible. Special thanks are due to Richard Ainsworth, who acted as overall editor and provided continuity throughout the process of its development. United Kingdom Water Industry Research (UKWIR) provided financial support for the development of this review, and special thanks are due to both UKWIR and to its Director, Dr Mike Farrimond. An international group of experts provided the material for the book and undertook a process of mutual review. While authorship of individual chapters is noted on the following pages, the quality of the volume as a whole is due in large part to the review and comment provided by many individuals. The work of Paul Hunter, who provided the case studies illustrating health impacts of inadequate distribution systems or their management, is gratefully acknowledged.

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; to Hilary Cadman of Biotext for editing of the text, and to all those listed in the following section for their substantive contributions to this volume.

## CONTRIBUTORS

**Richard Ainsworth**
United Kingdom Water Industry Research, London, England.

**Nicholas J. Ashbolt**
University of New South Wales, Sydney, New South Wales, Australia.

**Jamie Bartram**
Coordinator, Water Sanitation and Health, World Health Organization, Geneva, Switzerland.

**Richard Carr**
Water Sanitation and Health Programme, World Health Organization, Geneva, Switzerland.

**Kay Chambers**
WRc plc, Swindon, England.

**Joseph Cotruvo**
J. Cotruvo Associates, Washington DC, United States of America (USA).

**John Creasey**
WRc plc, Swindon, England.

**David Cunliffe**
Environmental Health Branch, Department of Human Services, Adelaide, Australia.

**Annette Davison**
Water Futures, Sydney, Australia.

**Daniel Deere**
Water Futures, Sydney, Australia.

**Colin Evins**
Drinking water Inspectorate, London, England.

**Leith Forbes**
Leith Forbes & Associates Pty. Ltd., Vermont South, Victoria, Australia.

**David Holt**
Thames Water Utilities Ltd., Reading, England.

**Guy Howard**
Water, Engineering and Development Centre, Loughborough University, Loughborough, England.

**Paul R. Hunter**
School of Medicine, Health Policy and Practice, University of East Anglia, Norwich, England.

**Mark LeChevallier**
American Water Works Service Company, Voorhees, New Jersey, USA.

**Yves Levi**
Laboratoire Santé Publique – Environnement, Université Paris XI, Faculté de Pharmacie, Chatenay-Malabry, France.

**Ray Morris**
Consultant Environmental Microbiologist, Barwell, Leicestershire, England.

**Francis Pamminger**
Yarra Valley Water, Melbourne, Australia.

**Pierre Payment**
Armand-Frappier Institute, National Institute of Scientific Research, University of Quebec, Montreal, Quebec, Canada.

**Will Robertson**
Health Canada, Ottawa, Canada.

**Melita Stevens**
Melbourne Water, Melbourne, Victoria, Australia.

**Michael Storey**
School of Civil and Environmental Engineering, University of New South Wales, Sydney, Australia.

**Dammika Vitanage**
Sydney Water, Sydney, Australia.

**Tony Vourtsanis**
Sydney Water, Sydney, Australia.

# Acronyms and abbreviations used in the text

| | |
|---|---|
| AIDS | acquired immune deficiency syndrome |
| AOC | assimilable organic carbon |
| ATP | adenosine triphosphate |
| AWWA | American Water Works Association |
| AWWARF | AWWA Research Foundation |
| BDOC | biodegradable dissolved organic carbon |
| BFP | biofilm formation potential |
| CCTV | close circuit television |
| cfu | colony forming unit |
| CV | check valve |
| DCDA | double check detector assembly |
| DOC | dissolved organic carbon |
| GAC | granular activated carbon |
| GIS | geographical information system |
| HACCP | hazard analysis critical control point |
| HPC | heterotrophic plate count |
| ISO | International Organization for Standardization |
| NAS | national approval scheme |

| | |
|---|---|
| NASA | National Aeronautics and Space Administration |
| NTU | nephelometric turbidity unit |
| psi | pounds per square inch |
| RDOC | refractory dissolved organic carbon |
| RPZA | reduced pressure zone assembly |
| THM | trihalomethane |
| TOC | total organic carbon |
| UKWIR | United Kingdom Water Industry Research |
| USEPA | United States Environmental Protection Agency |
| UV | ultraviolet |
| WHO | World Health Organization |
| WHOPES | World Health Organization Pesticide Evaluation Scheme |