

Waterborne Zoonoses

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

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



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

© World Health Organization (WHO) 2004

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

Index prepared by Indexing Specialists (UK) Ltd, Hove, East Sussex, UK.

Apart from any fair dealing for the purposes of research or private study, or criticism or review, as permitted under the UK Copyright, Designs and Patents Act (1998), no part of this publication may be reproduced, stored or transmitted in any form or by any means, without the prior permission in writing of the publisher, or, in the case of photographic reproduction, in accordance with the terms of licences issued by the Copyright Licensing Agency in the UK, or in accordance with the terms of licenses issued by the appropriate reproduction rights organization outside the UK. Enquiries concerning reproduction outside the terms stated here should be sent to IWA Publishing at the address printed above. The publisher makes no representation, express or implied, with regard to the accuracy of the information contained in this book and cannot accept any legal responsibility or liability for errors or omissions that may be made.

Disclaimer

The opinions expressed in this publication are those of the authors and do not necessarily reflect the views or policies of the International Water Association, USEPA or the World Health Organization. IWA, USEPA, WHO and the editors will not accept responsibility for any loss or damage suffered by any person acting or refraining from acting upon any material contained in this publication.

In addition, the mention of specific manufacturers' products does not imply that they are endorsed or recommended in preference to others of a similar nature that are not mentioned. Errors and omissions excepted, the names of proprietary products are distinguished by initial capital letters.

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.

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

Waterborne zoonoses : identification, causes, and control / edited by

J. A. Cotruvo ... [et al.].

(Emerging issues in water and infectious diseases series)

1. Water microbiology 2. Water - parasitology 3. Zoonoses - etiology

4. Disease reservoirs 5. Emerging diseases - etiology I. Cotruvo, Joseph A.

ISBN 92 4 156273 0

(LC/NLM classification: QW 80)

ISSN 1728-2160

ISBN 1 84339 058 2 (IWA Publishing)

Contents

Preface	ix
Acknowledgements	xii
List of acronyms and abbreviations	xv
SECTION I: EXPERT CONSENSUS	1
Chapter 1: Expert consensus	3
<i>Expert Meeting Group Report</i>	
SECTION II: AN INTRODUCTION TO EMERGING WATERBORNE ZOOSES AND GENERAL CONTROL PRINCIPLES	17
<i>J. Bartram and R. Carr</i>	
Chapter 2: Emerging zoonotic diseases and water	19
<i>C. Bolin, C. Brown and J. Rose</i>	
Chapter 3: What are the criteria for determining whether a disease is zoonotic and water related?	27
<i>C.L. Moe</i>	

Chapter 4: Impacts of anthropogenic and environmental factors on the distribution of zoonoses <i>F. Dangendorf</i>	46
Chapter 5: The control envelope and risk management <i>R. Carr and J. Bartram</i>	66
SECTION III: WATER-RELATED ZOONOSIS DISEASE IMPACTS — GEOGRAPHICAL PREVALENCE <i>A. Dufour</i>	91
Chapter 6: Tropical organisms in Asia/Africa/South America <i>K. Suresh and H.V. Smith</i>	93
Chapter 7: Incidence of the major zoonotic diseases transmitted by water in Mexico, Central America, and the Caribbean <i>R. Ramirez-Porras and J. Williams</i>	113
Chapter 8: Waterborne outbreaks caused by zoonotic pathogens in the USA <i>G.F. Craun, R.L. Calderon and M.F. Craun</i>	120
Chapter 9: Symptoms, treatments, and health consequences of waterborne zoonotic diseases <i>S. Kanarat</i>	136
SECTION IV: EPIDEMIOLOGICAL DATA, CASE-STUDIES AND OUTBREAKS <i>G.F. Craun</i>	151
Chapter 10: Epidemiological studies and surveillance <i>G.F. Craun, D.G. Till and G. McBride</i>	154
Chapter 11: Zoonoses in Scotland — food, water, or contact? <i>W.J. Reilly and L.M. Browning</i>	167
Chapter 12: Potential public health risk of <i>Campylobacter</i> and other zoonotic waterborne infections in New Zealand <i>D.G. Till and G.B. McBride</i>	191

SECTION V: CATEGORIES OF WATERBORNE DISEASE ORGANISMS	209
<i>D.O. Cliver and R. Fayer</i>	
Chapter 13: Verocytotoxin-producing <i>Escherichia coli</i> and other diarrhoeagenic <i>E. coli</i>	213
<i>K. Mølbak and F. Scheutz</i>	
Chapter 14: <i>Salmonella</i> and other enteric organisms	228
<i>D. Lightfoot</i>	
Chapter 15: Prospects of waterborne viral zoonoses	242
<i>D.O. Cliver and C.L. Moe</i>	
Chapter 16: Waterborne zoonotic protozoa	255
<i>R. Fayer</i>	
Chapter 17: Cyclosporiasis	283
<i>J.H. Cross and J.B. Sherchand</i>	
Chapter 18: Major helminth zoonoses in water	291
<i>T. Endo and Y. Morishima</i>	
Chapter 19: Human fascioliasis	305
<i>S. Mas-Coma</i>	
Chapter 20: Leptospirosis and other potential zoonoses in water	323
<i>C. Bolin, C. Brown and J. Rose</i>	
SECTION VI: ANALYSIS OF ZOONOTIC MICROORGANISMS	335
<i>A. Dufour and D. Till</i>	
Chapter 21: Managing risk of waterborne zoonotic disease through water quality surveillance	338
<i>D. Till, K. Field and A. Dufour</i>	
Chapter 22: Faecal source identification	349
<i>K.G. Field</i>	
Chapter 23: Rapid methods for the detection and enumeration of microorganisms in water	367
<i>D.Y.C. Fung</i>	

SECTION VII: PREVENTION AND CONTROL OF WATERBORNE ZOOSES	377
<i>V.P.J. Gannon</i>	
Chapter 24: Control of zoonotic waterborne pathogens in animal reservoirs	380
<i>V.P.J. Gannon</i>	
Chapter 25: Control of zoonotic pathogens in animal wastes	409
<i>V.P.J. Gannon, F. Humenik, M. Rice, J.L. Cicmanec, J.E. Smith Jr and R. Carr</i>	
Chapter 26: Control of zoonotic diseases in drinking-water	426
<i>J.L. Cicmanec, J.E. Smith Jr and R. Carr</i>	
SECTION VIII: RISK ASSESSMENT AND REGULATION	437
<i>J.A. Cotruvo</i>	
Chapter 27: A regulatory perspective on zoonotic pathogens in water	439
<i>S.A. Schaub</i>	
Chapter 28: The Stockholm framework for guidelines for microbial contaminants in drinking-water	452
<i>R. Carr and J. Bartram</i>	
Chapter 29: Quantitative microbial risk assessment issues	460
<i>G.B. McBride</i>	
SECTION IX: FUTURE EMERGING WATERBORNE ZOOSES	471
Chapter 30: Waterborne zoonoses: Emerging pathogens and emerging patterns of infection	472
<i>V.P.J. Gannon, C. Bolin and C.L. Moe</i>	
INDEX	485

Preface

Investigating important emerging issues in water and infectious disease and communicating discoveries create challenges, which are addressed by an initiative being undertaken by the World Health Organization (WHO) Water Sanitation and Health Unit, the US Environmental Protection Agency (US EPA) Office of Research and Development, and other collaborators. The initiative seeks to accelerate the identification of actual and perceived issues, to bring together information and knowledge in critical areas, and to disseminate information to policy-makers and practitioners in a timely fashion. This initiative has resulted in the publication of several cutting-edge documents that critically analyse emerging issues in water and infectious disease and present balanced assessments of how these will impact disease transmission through water with emphasis on management options for preventing and controlling waterborne disease.

Other issues dealt with in the Emerging Issues in Water and Infectious Disease initiative include:

- heterotrophic plate counts and drinking-water safety;
- pathogenic mycobacteria in water;
- the H₂S method for the detection of faecal contamination of drinking-water;
- water recreation and disease;
- respiratory transmission of faecally excreted viruses; and
- toxic cyanobacteria in water.

This publication was developed from the workshop on “Zoonosis and Waterborne Disease,” held in Annapolis, Maryland, USA, on 2–4 September 2003. The workshop was sponsored by the WHO units dealing with Water, Sanitation and Health and with Strategy Development and Monitoring of Zoonoses, Foodborne Disease and Kinetoplastidae, working with US EPA’s Office of Research and Development and Office of Ground Water and Drinking Water. Twenty-nine experts from 14 countries and diverse disciplines, including sanitary and veterinary microbiology, animal health, agriculture, animal waste management, public health, water epidemiology, medicine, sanitary engineering, food safety, and regulatory policy, attended the workshop. They examined the roles of zoonoses in current and future waterborne disease and prepared the chapters published here.

Participants at the workshop were asked to:

- review current waterborne zoonotic disease threats;
- identify new disease candidates based on disease agent characteristics; and
- evaluate current control strategies to identify agents that might fall outside of the current control envelope.

The workshop participants reviewed information on zoonotic organisms linked to waterborne diseases in humans and focused on the organism characteristics, human activities, and environmental conditions that could lead to future concerns from evolving or emerging organisms. Animal vector factors discussed included feral/wild animals, domestic animals, intensive grazing, feedlots, abattoirs, and other elements. Emergence related to translocation of microorganisms resulting from human and animal movement, food production, irrigation, food handling, distribution from distant areas, climate change, and other appropriate contributing factors was discussed.

This publication was developed from technical inputs to the workshop, workshop deliberations and revisions to the technical materials based on the suggestions of expert technical reviewers.

The goal of this publication is to provide guidance to agencies concerned with human and animal health and water and wastewater service providers worldwide to anticipate potential future waterborne zoonotic disease problems

and to determine whether current practices will be protective or whether new approaches need to be developed or deployed to protect health. This publication presents information on how zoonotic pathogens can be best managed at the source (i.e., through animal management practices, treatment of animal wastes, runoff management); through water treatment (wastewater and drinking-water); or through a combination of multiple barriers.

We hope that this publication provides useful information in describing the significance of zoonotic microorganisms as threats to the quality of ambient water and drinking-water and to public health throughout the world. We hope that this will facilitate the development of cross-sectoral initiatives to manage current health threats and to anticipate and manage health threats from emerging waterborne zoonotic pathogens.

Acknowledgements

The World Health Organization (WHO) wishes to express its appreciation to all those whose efforts made the production of this book possible.

We acknowledge and appreciate the exceptional efforts of all of the workshop participants, authors who contributed to the development of individual chapters in this book, and expert reviewers as listed below:

Jamie Bartram, WHO, Geneva, Switzerland
Carole Bolin, Michigan State University, East Lansing, MI, USA
Peter Braam, WHO, Geneva, Switzerland
Corrie Brown, University of Georgia, Athens, GA, USA
Lynda M. Browning, Scottish Centre for Infection and Environmental Health,
Glasgow, Scotland
Rebecca L. Calderon, Office of Research and Development, US Environmental
Protection Agency, Research Triangle Park, NC, USA
Richard Carr, WHO, Geneva, Switzerland
John Cicmanec, Office of Research and Development, US Environmental
Protection Agency, Cincinnati, OH, USA

- Dean O. Cliver, Food Safety Laboratory and WHO Collaborating Centre for Food Virology, School of Veterinary Medicine, University of California, Davis, CA, USA
- Joseph Cotruvo, Joseph Cotruvo & Associates, Washington, DC, USA
- Gunther Craun, G.F. Craun and Associates, Staunton, VA, USA
- Michael F. Craun, G.F. Craun and Associates, Staunton, VA, USA
- John Cross, Division of Tropical Public Health, Department of Preventive Medicine and Biometrics, Uniformed Services University, Bethesda, MD, USA
- Friederike Dangendorf, Institute of Hygiene and Public Health, University of Bonn, Bonn, Germany
- Alfred Dufour, Office of Research and Development, US Environmental Protection Agency, Cincinnati, OH, USA
- Andrea Ellis, WHO, Geneva, Switzerland
- Takuro Endo, Department of Parasitology, National Institute of Infectious Diseases, Tokyo, Japan
- Ronald Fayer, Agricultural Research Service, US Department of Agriculture, Beltsville, MD, USA
- Kate Field, Department of Microbiology, Oregon State University, Corvallis, Oregon, USA
- Daniel Y.C. Fung, Department of Animal Science and Industry, Kansas State University, Manhattan, KS, USA
- Victor P.J. Gannon, Public Health Branch, Animal Diseases Research Institute, Health Canada, Lethbridge, Alberta, Canada
- Frank Humenik, College of Agricultural and Life Sciences, Animal Waste Management Program, North Carolina State University, Raleigh, NC, USA
- Sasitorn Kanarat, Hygiene and Microbiology, Ministry of Agriculture, Bangkok, Thailand
- Diane Lightfoot, Microbiological Diagnostic Unit, Public Health Laboratory, University of Melbourne, Victoria, Melbourne, Australia
- Santiago Mas-Coma, Department of Parasitology, Faculty of Pharmacy, University of Valencia, Burjassot, Valencia, Spain
- Graham McBride, National Institute of Water and Atmospheric Research, Hamilton, New Zealand
- Francois-Xavier Meslin, WHO, Geneva, Switzerland
- Christine Moe, Department of International Health, Rollins School of Public Health, Emory University, Atlanta, GA, USA
- Kåre Mølbak, Statens Serum Institut, Copenhagen, Denmark
- Yasuyuki Morishima, Department of Parasitology, National Institute of Infectious Diseases, Tokyo, Japan
- Rosa Gabriella Ramírez-Porras, Department of Veterinary Epidemiology and Public Health, Veterinary Faculty, Yucatan, Mexico

Gareth Rees, Askham-Bryan College, Askham-Bryan, York, North Yorkshire, UK
William Reilly, Scottish Centre for Infection and Environmental Health, Glasgow, Scotland
Mark Rice, College of Agricultural and Life Sciences, Animal Waste Management Program, North Carolina State University, Raleigh, NC, USA
Joan Rose, Michigan State University, East Lansing, MI, USA
Stephen Schaub, Office of Water, Office of Science and Technology, US Environmental Protection Agency, Washington, DC, USA
Flemming Scheutz, Statens Serum Institut, Copenhagen, Denmark
Jeevan B. Sherchand, Tribhuvan University Teaching Hospital, Kathmandu, Nepal
Huw V. Smith, Scottish Parasite Diagnostic Laboratory, Glasgow, Scotland
James E. Smith, Jr., Office of Research and Development, US Environmental Protection Agency, Cincinnati, OH, USA
Mark Sobsey, University of North Carolina, Chapel Hill, NC, USA
K. Suresh, Department of Parasitology, Faculty of Medicine, University of Malaya, Kuala Lumpur, Malaysia
Desmond Till, Public Health Microbiologist Consultant, Wellington, New Zealand
Jose Williams, Department of Veterinary Epidemiology and Public Health, Veterinary Faculty, Yucatan, Mexico

Special thanks are due to Penny Ward, Water, Sanitation and Health Programme, WHO, Geneva, who provided administrative support for the meeting and to the development of this book, and Marla Sheffer of Ottawa, Canada, who edited the final document.

We would like to express our gratitude to the US Environmental Protection Agency Office of Research and Development for sponsoring the initiative on Emerging Issues in Water and Infectious Disease and providing financial support for this workshop and publication. We would also like to thank the US Environmental Protection Agency Office of Water for further support to this workshop.

List of acronyms and abbreviations

A/EEC	attaching and effacing <i>E. coli</i>
AFLP	amplified fragment length polymorphism
AFO	animal feeding operation
AGI	acute gastrointestinal illness of unknown origin
AIDS	acquired immunodeficiency syndrome
ARCC	average rate of correct classification
ATP	adenosine triphosphate
BFP	bundle-forming pilus
BSE	bovine spongiform encephalopathy
CAFO	concentrated animal feeding operation
CDSC	Communicable Disease Surveillance Centre (England and Wales)
CFU	colony-forming unit
CI	confidence interval
CJD	Creutzfeldt-Jakob disease
CUP	carbon-source utilization
CWD	chronic wasting disease
DAEC	diffuse adherent <i>E. coli</i>
DALY	disability-adjusted life year

DBP	disinfection by-product
DEC	diarrhoeagenic <i>E. coli</i>
DNA	deoxyribonucleic acid
DT	definitive phage type
EAEC	enteroadherent <i>E. coli</i>
EAggEC	enteroaggregative <i>E. coli</i>
EHEC	enterohaemorrhagic <i>E. coli</i>
EIEC	enteroinvasive <i>E. coli</i>
EPA	Environmental Protection Agency (USA)
EPEC	enteropathogenic <i>E. coli</i>
epg	eggs per gram of faeces
ESWTR	Enhanced Surface Water Treatment Rule (USA)
ETEC	enterotoxigenic <i>E. coli</i>
HACCP	hazard analysis and critical control points
HAV	hepatitis A virus
HBV	hepatitis B virus
HEV	hepatitis E virus
HIV	human immunodeficiency virus
HUS	haemolytic uraemic syndrome
ID	infective dose
ID ₅₀	median infective dose
Ig	immunoglobulin
IID	infectious intestinal disease
IPCC	Intergovernmental Panel on Climate Change
LEE	locus of enterocyte effacement
LH-PCR	length heterogeneity polymerase chain reaction
LT	heat-labile enterotoxin
LU	livestock unit
MAP	<i>Mycobacterium avium</i> (ssp. <i>paratuberculosis</i>)
MAR	multiple antibiotic resistance
MBM	meat and bone meal
MCL	Maximum Contaminant Level (USA)
MCLG	Maximum Contaminant Level Goal (USA)
MOR	matched odds ratio
MPN	most probable number
mRNA	messenger ribonucleic acid
MST	microbiological source tracking
NASBA	nucleic acid sequence-based amplification
NPDES	National Pollutant Discharge Elimination System (USA)
NTU	nephelometric turbidity unit

OIE	Office International des Epizooties (World Organization for Animal Health)
PCR	polymerase chain reaction
PEAS	possible estuary-associated syndrome
PFGE	pulsed-field gel electrophoresis
PT	phage type
QMRA	quantitative microbial risk assessment
QRA	quantitative risk assessment
rDNA	ribosomal deoxyribonucleic acid
REP-PCR	repetitive extragenic palindromic polymerase chain reaction
RFLP	restriction fragment length polymorphism
RNA	ribonucleic acid
rRNA	ribosomal ribonucleic acid
SARS	severe acute respiratory syndrome
SCCWRP	Southern California Coastal Water Research Project (USA)
SMX	sulfamethoxazole
STEC	Shiga toxin-producing <i>E. coli</i>
STh	heat-stable enterotoxin (human)
STp	heat-stable enterotoxin (porcine)
TMDL	total maximum daily load
TMP	trimethoprim
T-RFLP	terminal restriction fragment length polymorphism
TSE	transmissible spongiform encephalopathy
UDG	uracil-D-glycosylase
USA	United States of America
US EPA	United States Environmental Protection Agency
UV	ultraviolet
VBNC	viable but non-culturable
vCJD	variant Creutzfeldt-Jakob disease
VTEC	verocytotoxin-producing <i>E. coli</i>
WHO	World Health Organization
WSP	water safety plan
YLD	years lived with a disability
YLL	years of life lost to premature death

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. Published by IWA Publishing, London, UK. ISBN: 1 84339 058 2.Â them and other potentially infected animals of the same and also of other species, and 3) to provide clean housing, food, and water. Other tactics, such as selective breeding for disease resistance in animals, competitive exclusion, bacteriophage therapy, use of antimicrobials, and active and passive immunization, may also be helpful in controlling specific zoonotic pathogens in animal reservoirs. Control of zoonotic diseases in wild animal populations presents an even greater challenge than their control in domestic animal species. An introduction to emerging waterborne zoonoses and general control principles. section III. Water-related zoonosis disease impacts-- geographical prevalence. section IV. Epidemiological data, case-studies and outbreaks. section V. Categories of waterborne disease organisms. section VI. Analysis of zoonotic microorganisms. section VII. Prevention and control of waterborne zoonoses. section VIII. Risk assessment and regulation. section IX. Future emerging waterborne zoonoses.