

Guidelines for Drinking-water Quality

FIRST ADDENDUM TO THE
FOURTH EDITION



World Health
Organization

Guidelines for Drinking-water Quality

FIRST ADDENDUM TO THE
FOURTH EDITION

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Preface

Access to safe drinking-water is essential to health, a basic human right and a component of effective policy for health protection.

The primary goal of the *Guidelines for drinking-water* quality is to protect public health associated with drinking-water quality. The overall objectives of the Guidelines are to:

- provide an authoritative basis for the effective consideration of public health in setting national or regional drinking-water policies and actions;
- provide a comprehensive preventive risk management framework for health protection from catchment to consumer, covering policy formulation and standard setting, risk-based management approaches and surveillance;
- emphasize achievable practices and the formulation of sound regulations, applicable to low-income, middle-income and industrialized countries alike;
- summarize the health implications associated with contaminants in drinking-water, and the role of risk assessment and risk management in disease prevention and control;
- summarize effective options for drinking-water management; and
- provide guidance on hazard identification and risk assessment.

The objectives of the first addendum are to ensure that the fourth edition of the Guidelines is updated to reflect new evidence and to provide additional explanations to support better understanding of the document. In particular, efforts were made to:

- update or develop chemical threshold values (guideline and health-based values) where new evidence has emerged through high-quality reviews of the literature; for example, through evaluations from the Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Meeting on Pesticide Residue (JMPR) and the Joint FAO/WHO Expert Committee on Food Additives (JECFA);

- respond to requests from Member States for specific guidance (e.g. guidance on pesticides in drinking-water); and
- clarify known misunderstandings about some concepts and terminology included in the fourth edition.

The key changes in the first addendum include:

- new risk assessments and guideline values or health-based values for dichlorvos, dicofol, and perchlorate;
- revised risk assessments and guideline values or health-based values for barium, bentazone, diquat, and MCPA;
- revised risk assessments for chlorine dioxide, chlorate and chlorite, and nitrate and nitrite;
- additional guidance on risk management considerations and monitoring of lead;
- additional guidance on microbial risk assessment, aggregating multiple barriers for overall water treatment performance and microbial detection methods; and
- inclusion of references to supporting documents published after the fourth edition of the Guidelines.

The Guidelines are addressed primarily to water and health regulators, policy-makers and their advisors, to assist in the development of national policies and regulations. Together with associated documents, the Guidelines are also used by many others as a source of information on water quality and health, and on effective management approaches.

Acknowledgements

The preparation of the first addendum to the fourth edition of the *Guidelines for drinking-water quality* and supporting documentation covered a period of more than 5 years, and involved the participation of hundreds of experts from a wide range of developing and developed countries. The contributions of all who participated in the preparation and finalization of the fourth edition and this first addendum to that edition – including those individuals listed in “Changes to Annex 7” – are gratefully acknowledged.

The work of the following individuals within the microbial, chemical and protection and control working groups (WGs) were crucial in the development of this first addendum to the fourth edition: Dr M. Asami, Dr R.J. Bevan, Mr E. Calderon, Dr J. Cotruvo, Dr D. Cunliffe, Dr L. D’Anglada, Dr A.M. de Roda Husman, Dr A. Eckhardt, Professor J.K. Fawell, Ms M. Giddings, Dr A. Hirose, Dr P. Hunter, Dr P. Marsden, Dr G. Medema, Professor Y. Matsui, Dr M.E. Meek, Dr E. Ohanian, Professor C.N. Ong, Dr S. Ramasamy, Professor S. Snyder and Professor M. Sobsey (see Annex 8 for affiliations and Annex 9 for a summary of conflict of interest [COI] management).

The Guideline Development Group oversaw finalization of this addendum: Dr D. Cunliffe (chair), Dr S. Hamid Abdelrahman, Dr R. Bevan, Mrs J. Brown, Mr E. Calderon, Dr I. Chorus, Dr L. D’Anglada, Dr A. M. de Roda Husman, Professor J. Fawell, Ms M. Giddings, Dr A. Hirose, Dr P. Hunter, Dr P. Labhasetwar, Professor K. Linden, Dr P. Marsden, Dr Y. Matsui, Professor C. N. Ong, Dr S. Ramasamy, Professor S. Snyder and Professor M. Sobsey (see Annex 8 for affiliations and Annex 9 for a summary of COI management).

The WHO Steering Group included the following: Mr H. Bakir, Mr R. Brown, Ms J. De France, Mr B. Gordon, Ms Payden, Dr M. Perez, Dr A. Pruss-Ustun, Mr O. Schmoll, Dr J. Simon, Dr P. Verger and Dr R. Yadav. The contributions from additional WHO staff are also acknowledged: Dr M. Bagayoko, Dr S. Boisson, Dr N. Hassan, Dr T. Monteiro, Dr A. Tritscher and Ms C. Vickers (see Annex 8 for affiliations).

The coordinator was Ms J. De France, WHO Headquarters, with support from Mr P. Callan, Australia. Strategic direction was provided by Mr B. Gordon, WHO Headquarters.

Ms P. Ward, Ms L. Robinson and Mr E. Johnson provided invaluable administrative support for the various WG meetings, and throughout the review and publication process. Ms M. Sheffer of Canada and Dr H. Cadman of Australia were responsible for the scientific editing of the document.

Many individuals from various countries contributed to the development of the Guidelines. The efforts of all who contributed to the preparation of this document – in particular those who provided peer or public domain review comment – are greatly appreciated.

The generous financial support of the following is gratefully acknowledged: the Australian Department of Foreign Affairs and Trade, the Ministry of Environment and Water Resources of Singapore, the Ministry of Health, Labour and Welfare of Japan; the United Kingdom Department for International Development and the United States Environmental Protection Agency.

Abbreviations used in the first addendum

2,4,5-T	2,4,5-trichlorophenoxyacetic acid
ADI	acceptable daily intake
AES	atomic emission spectrometry
AIDS	acquired immunodeficiency syndrome
AMPA	aminomethylphosphonic acid
ARfD	acute reference dose
BMDL _x	lower 95% confidence limit on the benchmark dose for an x% response
Bw	body weight
CAS	Chemical Abstracts Service
COI	conflict of interest
DBP	disinfection by-product
DDT	dichlorodiphenyltrichloroethane
DNA	deoxyribonucleic acid
DPD	N,N-diethyl-1,4-phenylenediamine sulfate
ECD	electron capture detection
ELISA	enzyme-linked immunosorbent assay
F ₀	parental generation
F ₁	first filial generation
FAO	Food and Agriculture Organization of the United Nations
GC	gas chromatography
HPLC	high-performance liquid chromatography
IARC	International Agency for Research on Cancer
ICP	inductively coupled plasma
JECFA	Joint FAO/WHO Expert Committee on Food Additives
JMPR	Joint FAO/WHO Meeting on Pesticide Residues
LC	liquid chromatography
LOAEL	lowest-observed-adverse-effect level
LRV	log ₁₀ reduction value
MCPA	(2-methyl-4-chlorophenoxy)acetic acid

MDL	method detection limit
MS	mass spectrometry
MS/MS	tandem mass spectrometry
NOAEL	no-observed-adverse-effect level
NTU	nephelometric turbidity units
PCR	polymerase chain reaction
PMTDI	provisional maximum tolerable daily intake
QMRA	quantitative microbial risk assessment
RNA	ribonucleic acid
SARS	severe acute respiratory syndrome
TDI	tolerable daily intake
UN	United Nations
USA	United States of America
UV	ultraviolet
WHO	World Health Organization
WHOPES	World Health Organization Pesticide Evaluation Scheme
WSP	water safety plan

Changes to title page and back of title page

Title page

- Change FOURTH EDITION to read as follows:

FOURTH EDITION INCORPORATING THE FIRST ADDENDUM

Back of title page

- Replace the page with the following:

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Changes to “Contents”

Page iii

- Replace “Acronyms and abbreviations used in text” with the following:

Abbreviations used in text

Page vi

- Replace “8.2 Derivation of chemical guideline values” with the following:

8.2 Derivation of chemical guideline values and health-based values

Page x

- Replace “Chlorite and chlorate” with the following:

Chlorine dioxide, chlorate and chlorite

Page xi

- Insert the following below Dichlorprop:

Dichlorvos

Dicofol

Page xii

- Insert the following below Pentachlorophenol:

Perchlorate

Page xiii

- Change **Annex 7** Contributors to the development of the fourth edition of the *Guidelines for drinking-water quality* to:

Annex 7 Contributors to the development of the *Guidelines for drinking-water quality*: fourth edition incorporating the first addendum

Changes to “Preface”

Page xv-xvii

- Replace with the following:

Access to safe drinking-water is essential to health, a basic human right and a component of effective policy for health protection.

The importance of water, sanitation and hygiene for health and development has been reflected in the outcomes of a series of international policy forums. This includes, most recently, the adoption of the Sustainable Development Goals by countries, in 2015, which include a target and indicator on safe drinking-water. Further, the United Nations (UN) General Assembly declared in 2010 that safe and clean drinking-water and sanitation is a human right, essential to the full enjoyment of life and all other human rights. These commitments build on a long history of support including the UN General Assembly adopting the Millennium Development Goals in 2000 and declaring the period 2005–2015 as the International Decade for Action, “Water for Life”.

Access to safe drinking-water is important as a health and development issue at national, regional and local levels. In some regions, it has been shown that investments in water supply and sanitation can yield a net economic benefit, because the reductions in adverse health effects and health-care costs outweigh the costs of undertaking the interventions. This is true for investments ranging from major water supply infrastructure through to water treatment in the home. Experience has also shown that interventions in improving access to safe water favour the poor in particular, whether in rural or urban areas, and can be an effective part of poverty alleviation strategies.

The World Health Organization (WHO) published four editions of the *Guidelines for drinking-water quality* (in 1983–1984, 1993–1997, 2004 and 2011), as successors to the previous WHO *International standards for drinking water*, which were published in 1958, 1963 and 1971. Since 1995, the Guidelines have been kept up to date through a process of rolling revision, which leads to the regular publication of addenda that may add to or supersede information in previous volumes, as well as expert reviews on key issues in preparation for the revision of the Guidelines.

Leading the process of the development of the fourth edition was the Water, Sanitation, Hygiene and Health Unit within WHO Headquarters. The Chemical Safety Unit and the Risk Assessment and Management Unit provided input on chemical hazards, and the Radiation Programme provided input on radiological hazards. All six WHO regional offices participated in the process, in consultation with Member States.

This version of the Guidelines integrates the fourth edition, which was published in 2011, with the first addendum to the fourth edition, published in 2016. It supersedes previous editions of the Guidelines and previous International Standards.

The primary goal of the Guidelines is to protect public health associated with drinking-water quality. The overall objectives of the Guidelines are to:

- provide an authoritative basis for the effective consideration of public health in setting national or regional drinking-water policies and actions;
- provide a comprehensive preventive risk management framework for health protection, from catchment to consumer, that covers policy formulation and standard setting, risk-based management approaches and surveillance;
- emphasize achievable practices and the formulation of sound regulations that are applicable to low-income, middle-income and industrialized countries alike;
- summarize the health implications associated with contaminants in drinking-water, and the role of risk assessment and risk management in disease prevention and control;
- summarize effective options for drinking-water management; and
- provide guidance on hazard identification and risk assessment.

This edition of the Guidelines, incorporating the first addendum, further develops concepts, approaches and information introduced in previous editions, including the comprehensive preventive risk management approach for ensuring drinking-water quality that was introduced in the third edition. This edition considers:

- drinking-water safety, including minimum procedures and specific guideline values, and how these are intended to be used;
- approaches used in deriving the Guidelines, including guideline values;
- microbial hazards, which continue to be the primary concern in both developing and developed countries. Experience has shown the value of a systematic approach to securing microbial safety. This edition builds on the preventive principles introduced in the third edition on ensuring the microbial safety of drinking-water through a multiple-barrier approach, highlighting the importance of source water protection;
- climate change, which results in changing water temperature and rainfall patterns, severe and prolonged drought or increased flooding, and its implications for water quality and water scarcity, recognizing the importance of managing these impacts as part of water management strategies;

- chemical contaminants in drinking-water, including information on chemicals not considered previously (e.g. pesticides used for vector control in drinking-water); revisions of existing chemical fact sheets, taking into account new scientific information; and reduced coverage in the Guidelines in cases where new information suggests a lesser priority;
- key chemicals responsible for large-scale health effects through drinking-water exposure (e.g. arsenic, fluoride, lead, nitrate, selenium and uranium), with the Guidelines providing guidance on identifying local priorities and on management;
- the important roles of many different stakeholders in ensuring drinking-water safety; this edition furthers the discussion introduced in the third edition of the roles and responsibilities of key stakeholders in ensuring drinking-water safety; and
- guidance in situations other than traditional community supplies or managed utilities, such as rainwater harvesting and other non-piped supplies or dual-piped systems.

The Guidelines are accompanied by a series of supporting publications. These include internationally peer-reviewed risk assessments for specific chemicals (see list of chapter 12 background documents in Annex 2) and other publications explaining the scientific basis of the development of the Guidelines and providing guidance on good practice in their implementation (see Annex 1). The publication *Guidelines for drinking-water quality Volume 3—Surveillance and control of community supplies* (1997, revision forthcoming) provides guidance on good practice in surveillance, monitoring and assessment of drinking-water quality in community supplies.

The Guidelines are addressed primarily to water and health regulators, policy-makers and their advisors, to assist in the development of national policies and regulations. The Guidelines and associated documents are also used by many others as a source of information on water quality and health, and on effective management approaches.

The Guidelines are recognized as representing the position of the UN system on issues of drinking-water quality and health by “UN-Water”, the body that coordinates among the 24 UN agencies and programmes concerned with water issues.

Changes to “Acknowledgements”

- Replace the first full paragraph with the following

The preparation of the fourth edition of the *Guidelines for drinking-water quality*, the first addendum to the fourth edition and supporting documentation covered a period of more than 10 years. It involved the participation of hundreds of experts from a wide range of developing and developed countries. The contributions of all who participated in the preparation and finalization of the fourth edition and the first addendum to the fourth edition, including those individuals listed in Annex 7, are gratefully acknowledged.

- Add the following information after the paragraph starting with: “Ms P. Ward”

With reference to the addendum, the following experts contributed in the Guideline Development Group or chemical, microbial or protection and control working groups, supporting the development and finalization of this addendum: Dr D. Cunliffe (Chair), Dr S.H. Abdelrahman, Dr R. Bevan, Mrs J. Brown, Mr E. Calderon, Dr I. Chorus, Dr J. Cotruvo, Dr. D'Anglada, Dr A.M. de Roda Husman, Dr A. Eckhardt, Professor J. Fawell, Ms M. Giddings, Dr A. Hirose, Dr P. Hunter, Dr P. Labhasetwar, Professor K. Linden, Dr P. Marsden, Dr Y. Matsui, Dr G. Medema, Dr M.E. Meek, Dr E. Ohanian, Professor C.N. Ong, Dr S. Ramasamy, Professor S. Snyder and Professor M. Sobsey.

The WHO Steering Group for the addendum included: Mr H. Bakir, Mr R. Brown, Ms J. De France, Mr B. Gordon, Ms Payden, Dr M. Perez, Dr A. Pruss-Ustun, Mr O. Schmoll, Dr J. Simon, Dr P. Verger and Dr R. Yadav. The contributions from additional WHO staff are also acknowledged: Dr M. Bagayoko, Dr S. Boisson, Dr N. Hassan, Dr T. Monteiro, Dr A. Tritscher and Ms C. Vickers

The coordinator for the addendum was Ms J. De France, WHO Headquarters, with support from Mr P. Callan, Australia. Strategic direction was provided by Mr B. Gordon, WHO Headquarters.

Ms P. Ward, Ms L. Robinson and Mr E. Johnson provided administrative support, and Ms M. Sheffer of Canada and Dr H. Cadman of Australia were responsible for the scientific editing of the document.

- Change “Australian Agency for International Development” to” “Australian Department of Foreign Affairs and Trade”
- Add “the United Kingdom Department for International Development” before “and the United States Environmental Agency”

Changes to “Acronyms and abbreviations used in text”

Page xx

- Replace “Acronyms and abbreviations used in text” with the following:

Abbreviations used in text

- Insert the following below BMDL:

BMDL_x lower 95% confidence limit on the benchmark dose for an x% response

Page xxi

- Replace page header with the following:

ABBREVIATIONS USED IN TEXT

- Insert the following below the DNA entry:

DPD *N,N*-diethyl-1,4-phenylenediamine sulfate

- Insert the following below the ETEC entry:

F₀ parental generation

F₁ first filial generation

Page xxii

- Insert the following below the MCPPE entry:

MDL method detection limit

- Insert the following below the MS entry:

MS/MS tandem mass spectrometry

Page xxiii

- Replace page header with the following:

ABBREVIATIONS USED IN TEXT

Changes to “Chapter 1: Introduction”

Page 13

- Replace the last sentence of the paragraph preceding section 1.2.5 with the following:

For further information, see the supporting documents *Protecting groundwater for health* and *Protecting surface water for health* (see Annex 1).

Page 18

- Replace the URL with http://www.who.int/water_sanitation_health/water-quality/en/

Changes to “Chapter 4: Water safety plans”

Page 45

- In the last line, change ‘document’ to ‘documents’ and add the following after “*Water safety plan manual*”
and *Water safety planning for small community water supplies*

Page 46

- Remove italics from “3)”

Page 54

- Replace the last line preceding “Control measures” with the following:
manual and the supporting documents *Protecting groundwater for health* and *Protecting surface water for health* (Annex 1).

Page 55

- Replace the first sentence of the paragraph preceding section 4.1.4 with the following:

For examples of control measures for effective protection of source water and catchments and of water extraction and storage systems, see Module 4 in the supporting document *Water safety plan manual* and the supporting document *Protecting surface water for health* (Annex 1).

Page 58

- In the section Hazard identification, second paragraph, change ‘document’ to ‘documents’ and add the following after “*Water safety plan manual*”:

and *Water safety planning for small community water supplies*

- In the section Control measures, second paragraph, change ‘document’ to ‘documents’ and add the following after “*Water safety plan manual*”:

and *Water safety planning for small community water supplies*

Page 62

- Replace the last line of the first bullet point under section 4.2.2 with the following:

(see the supporting documents *Protecting groundwater for health* and *Protecting surface water for health*; Annex 1).

Page 63

- Replace the first full bullet point with the following:

— *Pressure measurement* and *turbidity* are also useful operational monitoring parameters in piped distribution systems (see the supporting document *Turbidity: information for regulators and operators of water supplies*; Annex 1).

Page 69

- At the end of section 4.3.7, add the following after the last sentence

Further information can be found in the supporting document *A practical guide to auditing water safety plans* (Annex 1)

Changes to “Chapter 6: Application of the Guidelines in specific circumstances”

Page 93

- On line 10 of the first paragraph, correct the spelling of Guidelines

Page 101

- Insert the following sentence at the end of the bullet that starts “*The need for disinfection*”:

The information in Table 6.1 in section 6.11, on drinking-water disinfection methods that can be used by travellers, may be applied to temporary uses in emergency situations.

Changes to “Chapter 7: Microbial aspects”

Page 118

- Insert the following new paragraph after the first paragraph:

Waterborne outbreaks have been associated with inadequate treatment of water supplies and unsatisfactory management of drinking-water distribution. For example, in distribution systems, such outbreaks have been linked to cross-connections, contamination during storage, low water pressure and intermittent supply. Waterborne outbreaks are preventable if an integrated risk management framework based on a multiple-barrier approach from catchment to consumer is applied. Implementing an integrated risk management framework to keep the water safe from contamination in distribution systems includes the protection of water sources, the proper selection and operation of drinking-water treatment processes, and the correct management of risks within the distribution systems (for further information, see the supporting document *Water safety in distribution systems*; Annex 1).

- In section 7.1.1, replace the sentence starting “Table 7.2 provides information” with the following:

Table 7.2 provides information on organisms that have been suggested as possible causes of waterborne disease but where evidence is inconclusive or lacking.

Page 119

- Replace Table 7.1 with the following table:

Editorial note:

- Type species/genus/group column added to Table 7.1
- Superscript b added after type species/genus/group, along with a corresponding note, and each of the subsequent superscripts letters amended
- *Escherichia coli* – Pathogenic changed to *Escherichia coli* – Diarrhoeagenic
- *Escherichia coli* – Enterohaemorrhagic changed to *E. coli* – Enterohaemorrhagic
- *E. coli* O157, *L. pneumophila*, *Mycobacterium avium* complex, *S. enterica*, *S. bongori*, *S. dysenteriae*, *V. cholerae* O1 and O139 and *A. culbertsoni* added to the type species/genus/group column
- *Leptospira* and *Schistosoma* moved to Table 7.2
- Adenoviridae added to the pathogen column and adenoviruses moved to the type species/genus/group column
- Astroviridae added to the pathogen column and astroviruses moved to the type species/genus/group column
- Caliciviridae added to the pathogen column, and noroviruses and sapoviruses moved to the type species/genus/group column
- Superscript i added after low in resistance to chlorine column for Calciviridae, along with a corresponding note, and subsequent superscript amended
- Hepeviridae added to the pathogen column, and hepatitis E virus moved to the type species/genus/group column
- Picornaviridae added to the pathogen column, enteroviruses and hepatitis A virus moved to the type species/genus/group column, and parechoviruses added to the type species/genus/group column
- Reoviridae added to the pathogen column and rotoviruses moved to the type species/genus/group column
- Text relating to definitions of low, moderate and high for note relating to resistance to chlorine column amended

Table 7.1 Pathogens transmitted through drinking-water^a

Pathogen	Type species/ genus/group^b	Health significance^c	Persistence in water supplies^d	Resistance to chlorine^e	Relative infectivity^f	Important animal source
Bacteria						
<i>Burkholderia</i>	<i>B. pseudomallei</i>	High	May multiply	Low	Low	No
<i>Campylobacter</i>	<i>C. coli</i> <i>C. jejuni</i>	High	Moderate	Low	Moderate	Yes
<i>Escherichia coli</i> – Diarrhoeagenic ^g		High	Moderate	Low	Low	Yes
<i>E. coli</i> – Enterohaemorrhagic	<i>E. coli</i> O157	High	Moderate	Low	High	Yes
<i>Francisella</i>	<i>F. tularensis</i>	High	Long	Moderate	High	Yes
<i>Legionella</i>	<i>L. pneumophila</i>	High	May multiply	Low	Moderate	No
Mycobacteria (non- tuberculous)	<i>Mycobacterium avium</i> complex	Low	May multiply	High	Low	No
<i>Salmonella typhi</i>		High	Moderate	Low	Low	No
Other salmonellae	<i>S. enterica</i> <i>S. bongori</i>	High	May multiply	Low	Low	Yes
<i>Shigella</i>	<i>S. dysenteriae</i>	High	Short	Low	High	No
<i>Vibrio</i>	<i>V. cholerae</i> O1 and O139	High	Short to long ^h	Low	Low	No
Viruses						
Adenoviridae	Adenoviruses	Moderate	Long	Moderate	High	No
Astroviridae	Astroviruses	Moderate	Long	Moderate	High	No
Caliciviridae	Noroviruses, Sapoviruses	High	Long	Moderate	High	Potentially
Hepeviridae	Hepatitis E virus	High	Long	Moderate	High	Potentially
Picornaviridae	Enteroviruses, Parechoviruses, Hepatitis A virus	High	Long	Moderate	High	No
Reoviridae	Rotaviruses	High	Long	Moderate	High	No

Pathogen	Type species/ genus/group ^b	Health significance ^c	Persistence in water supplies ^d	Resistance to chlorine ^e	Relative infectivity ^f	Important animal source
Protozoa						
<i>Acanthamoeba</i>	<i>A. culbertsoni</i>	High	May multiply	High	High	No
<i>Cryptosporidium</i>	<i>C. hominis/parvum</i>	High	Long	High	High	Yes
<i>Cyclospora</i>	<i>C. cayetanensis</i>	High	Long	High	High	No
<i>Entamoeba</i>	<i>E. histolytica</i>	High	Moderate	High	High	No
<i>Giardia</i>	<i>G. intestinalis</i>	High	Moderate	High	High	Yes
<i>Naegleria</i>	<i>N. fowleri</i>	High	May multiply	Low	Moderate	No
Helminths						
<i>Dracunculus</i>	<i>D. medinensis</i>	High	Moderate	Moderate	High	No

^a This table contains pathogens for which there is some evidence of health significance related to their occurrence in drinking-water supplies. More information on these and other pathogens is presented in Chapter 11.

^b The type species listed (e.g. *L. pneumophila*) are those most commonly linked to waterborne transmission but other species may also cause disease.

^c Health significance relates to the incidence and severity of disease, including association with outbreaks.

^d Detection period for infective stage in water at 20 °C: short, up to 1 week; moderate, 1 week to 1 month; long, over 1 month.

^e Within pathogen species and groups, there are likely to be variations in resistance, which could be further impacted by characteristics of the water supply and operating conditions. Resistance is based on 99% inactivation at 20 °C where, generally, low represents a Ct_{99} of < 1 min.mg/L, moderate 1–30 min.mg/L and high > 30 min.mg/L (where C = the concentration of free chlorine in mg/L and t = contact time in minutes) under the following conditions: the infective stage is freely suspended in water treated at conventional doses and contact times, and the pH is between 7 and 8. It should be noted that organisms that survive and grow in biofilms, such as *Legionella* and mycobacteria, will be protected from chlorination.

^f From experiments with human volunteers, from epidemiological evidence and from experimental animal studies. High means infective doses can be 1–10² organisms or particles, moderate 10²–10⁴ and low > 10⁴.

^g Includes enteropathogenic, enterotoxigenic, enteroinvasive, diffusely adherent and enteroaggregative.

^h *Vibrio cholerae* may persist for long periods in association with copepods and other aquatic organisms.

Page 121

➤ Replace Table 7.2 with the following table:

Editorial note:

- Table 7.2 heading changed: 1) Organism changed to Microorganism
- Table 7.2 column headings changed: 1) Pathogen changed to Microorganism, 2) Type species/genus/group column added, 3) Level of evidence changed to Waterborne transmission evidence (or epidemiological features), 4) Presence in water supplies changed to Presence and behaviour in water supplies
- Superscript b added after type species/genus/group, along with a corresponding note, and each of the subsequent superscripts letters amended
- *A. calcoaceticus baumannii* complex, *A. hydrophila*, *K. pneumonia*, *T. paurometabola*, *F. hepatica* and *F. gigantea* added to the type species/genus/group column
- *Leptospira*, and *Schistosoma* moved from Table 7.1 to Table 7.2 with corresponding information on waterborne transmission evidence, presence and behaviour in water supplies, and resistance to chlorine
- Orthomyxoviridae added to the microorganism column and influenza viruses moved to the type species/genus/group column
- Coronaviridae added to the microorganism column and severe acute respiratory syndrome (SARS) coronaviruses moved to the type species/genus/group column
- Filoviridae (Ebola virus) and Picornaviridae/Kobuvirus (Aichivirus) added to the microorganism column, with corresponding information on type species/genus/group, waterborne transmission evidence, presence and behaviour in water supplies, and resistance to chlorine
- Text relating to definitions of low, moderate and high for note relating to resistance to chlorine column amended

Table 7.2 Microorganisms for which transmission through drinking-water has been proposed but for which evidence is inconclusive or lacking^a

Microorganism	Type species/ genus/group^b	Waterborne transmission evidence (or epidemiological features)	Presence and behaviour in water supplies	Resistance to chlorine^c
Bacteria				
<i>Acinetobacter</i>	<i>A. calcoaceticus baumannii complex</i>	Possible issue in health-care facilities (non-gastrointestinal)	Common and can multiply	Low
<i>Aeromonas</i>	<i>A. hydrophila</i>	Clinical isolates do not match environmental isolates	Common and can multiply	Low
<i>Enterobacter</i>	<i>E. sakazakii</i>	Infection associated with infant formula; no evidence of waterborne transmission	Unlikely	Low

Microorganism	Type species/ genus/group^b	Waterborne transmission evidence (or epidemiological features)	Presence and behaviour in water supplies	Resistance to chlorine^c
<i>Helicobacter</i>	<i>H. pylori</i>	Suggested, but no direct evidence; familial transmission primary route	Detected, survives for limited time	Low
<i>Klebsiella</i>	<i>K. pneumoniae</i>	Possible issue in health-care facilities (non-gastrointestinal)	Can multiply	Low
<i>Leptospira</i>	<i>L. interrogans</i>	No evidence of transmission through drinking-water ingestion. Primarily spread by contact with contaminated surface water; outbreaks associated with flooding	Can survive for months in water	Low
<i>Pseudomonas</i>	<i>P. aeruginosa</i>	Possible issue in health-care facilities (non-gastrointestinal)	Common and can multiply	Moderate
<i>Staphylococcus</i>	<i>S. aureus</i>	No evidence of transmission through drinking-water; hands are the most important source	Common and can multiply	Moderate
<i>Tsukamurella</i>	<i>T. paurometabola</i>	Possible issue in health-care facilities (non-gastrointestinal)	Common and can multiply	Unknown
<i>Yersinia</i>	<i>Y. enterocolitica</i>	Species detected in water probably non-pathogenic; food is the primary source	Common and can multiply	Low
Viruses				
Filoviridae	Ebola virus	No evidence of transmission through drinking-water	Unlikely	Low
Orthomyxoviridae	Influenza viruses	No evidence for waterborne transmission	Unlikely	Low
Coronaviridae	Severe acute respiratory syndrome (SARS) coronaviruses	Some evidence for transmission via inhalation of droplets	Unlikely	Unknown
Picornaviridae/ Kobuvirus	Aichivirus	Present in fecal wastes, wastewater and sometimes contaminated drinking water	Likely present in faecally contaminated water	Moderate

Microorganism	Type species/ genus/group^b	Waterborne transmission evidence (or epidemiological features)	Presence and behaviour in water supplies	Resistance to chlorine^c
Protozoa				
<i>Balantidium</i>	<i>B. coli</i>	One outbreak reported in 1971	Detected	High
<i>Blastocystis</i>	<i>B. hominis</i>	Plausible, but limited evidence	Unknown, persistence ^d likely	High
<i>Isospora</i>	<i>I. belli</i>	Plausible, but no evidence	Unknown	High
Microsporidia	–	Plausible, but limited evidence; infections predominantly in persons with acquired immunodeficiency syndrome (AIDS)	Detected, persistence likely	Moderate
<i>Toxoplasma</i>	<i>T. gondii</i>	One outbreak reported in 1995	Long	High
Helminths				
<i>Fasciola</i>	<i>F. hepatica</i> <i>F. gigantica</i>	Plausible, detected in water in hyperendemic regions	Detected	High
Free-living nematodes (other than <i>Dracunculus medinensis</i>)	–	Plausible, but transmission primarily associated with food or soil	Detected and can multiply	High
<i>Schistosoma</i>	<i>S. mansoni</i> <i>S. japonicum</i> <i>S. mekongi</i> <i>S. intercalatum</i> <i>S. haematobium</i>	No evidence of transmission through drinking-water ingestion. Primarily spread by contact with contaminated surface water in communities with inadequate access to safe drinking-water	Life cycle involves animal and snail hosts; can be released into water following reproduction in freshwater snails	Moderate

^a More information on these and other pathogens is presented in Chapter 11.

^b The type species listed (e.g. *H. pylori*) are those most commonly linked to waterborne transmission but other species may also cause disease.

^c Resistance is based on 99% inactivation at 20 °C where, generally, low represents a Ct₉₉ of < 1 min.mg/L, moderate 1–30 min.mg/L and high > 30 min.mg/L (where C = the concentration of free chlorine in mg/L and t = contact time in minutes) under the following conditions: the infective stage is freely suspended in water treated at conventional doses and contact times, and the pH is between 7 and 8. It should be noted that organisms that survive and grow in biofilms, such as *Pseudomonas aeruginosa*, will be protected from chlorination.

^d Persistence means survival for 1 month or more.

Page 123

- The following changes need to be made to Figure 7.1:
 - Change *Campylobacter* spp. to *Campylobacter jejuni/coli*
 - Change *E. coli* pathogenic to *E. coli* – Diarrhoeagenic
 - Add *E. coli* – Enterohaemorrhagic below *E. coli* – Diarrhoeagenic
 - Change *Salmonella* spp. including *S. Typhi* to *Salmonella enterica*, *S. bongori* and *S. Typhi*
 - Change *Shigella* spp. to *Shigella dysenteriae*
 - Add “O1 and O139” after *Vibrio cholerae*
 - Add Parechoviruses below Enteroviruses (in two locations)
 - Change Mycobacteria (non-tuberculous) to *Mycobacterium avium* complex (in two locations)
 - Change *Acanthamoeba* spp. to *Acanthamoeba culbertsoni*
 - Change *Leptospira* spp. to *Leptospira interrogans*

Page 128

- In section 7.2.3, add the following sentence at the end of the paragraph preceding “Problem formulation and hazard identification”

For more detailed information on QMRA in the context of drinking-water safety, see the supporting document *Quantitative microbial risk assessment: application for water safety management*; Annex 1).

Page 131

- Insert the following paragraph at the end of section 7.2.3:

Emergencies such as major storms and floods can lead to substantial deteriorations in source water quality, including large short-term increases in pathogen concentrations. These should not be included in calculations of arithmetic means. Inclusion will lead to higher levels of treatment being applied on a continuous basis, with substantial cost implications. It is more efficient to develop specific plans to deal with the events and emergencies (see section 4.4). Such plans can include enhanced treatment or (if possible) selection of alternative sources of water during an emergency.

Page 138

- Insert the following paragraph at the bottom of the page:

Treatment efficacy for microbial reduction can also differ when aggregating different treatment processes. Applying multiple barriers in treatment, for example

in drinking-water treatment plants, may strengthen performance, as failure of one process does not result in failure of the entire treatment. However, both positive and negative interactions can occur between multiple treatment steps, and how these interactions affect the overall water quality and water treatment performance is not yet completely understood. In positive interactions, the inactivation of a contaminant is higher when two steps are occurring together than when each of the steps occurs separately – as happens, for example, when coagulation and sedimentation are operating under optimal conditions, and there is an increase in performance of rapid sand filters. In contrast, negative interactions can occur when failure in the first step of the treatment process could lead to a failure of the next process – for example, if coagulation fails to remove organic material, this could lead to a reduced efficacy of subsequent disinfection and a potential increase in DBPs. An overall assessment of the drinking-water treatment performance, as part of the implementation of the WSP, will assist in understanding the efficacy of the multiple treatment processes to ensure the safety of the drinking-water supply.

Page 139

➤ Make the following changes in Table 7.7:

- In the Notes column next to Granular high-rate filtration, add the following at the end of the text:

; filtered water turbidity of ≤ 0.3 NTU in 95% of samples (and none to exceed 1 NTU) associated with 1–2 log reduction of viruses and 3 log reduction of *Cryptosporidium*^a

- In the Notes column next to Slow sand filtration, add the following at the end of the text:

; filtered water turbidity of ≤ 1 NTU in 95% of samples (and none to exceed 5 NTU) associated with 1–2 log reduction of viruses and 2.5–3 log reduction of *Cryptosporidium*^a

- Under “Membrane filtration:”, add a comma after nanofiltration
- In the Notes column next to “Membrane filtration: microfiltration, ultrafiltration, nanofiltration, reverse osmosis”, add the following at the end of the text:

; maximum reductions associated with filtered water turbidity of < 0.1 NTU^a

Page 140

➤ Delete column headings “Minimum removal (LRV)” and “Maximum removal (LRV)” and replace with a single heading “Reduction” that is centred over the two columns (on this page of the table only)

- Replace superscripts “a,b” on bold heading “Primary disinfection” with the following superscripted text:

b,c

- In the Notes column opposite Chlorine, replace the first sentence with the following:

Free chlorine × contact time predicts efficacy; not effective against *Cryptosporidium* oocysts. Turbidity and chlorine-demanding solutes inhibit this process; hence, turbidity should be kept below 1 NTU to support effective disinfection. Where this is not practical, turbidities should be kept below 5 NTU with higher chlorine doses or contact times.^a

- In the Notes column opposite UV, replace the current text with the following:

Effectiveness of disinfection depends on delivered fluence (dose), which varies with intensity, exposure time and UV wavelength. Excessive turbidity and certain dissolved species inhibit this process; hence, turbidity should be kept below 1 NTU to support effective disinfection. Where this is not practical, turbidities should be kept below 5 NTU with higher fluences^a

- Insert the following new footnote “a” below the table:

See *Turbidity: information for regulators and operators of water supplies* (Annex 1).

- Change footnotes “a” and “b” below the table to footnotes “b” and “c”, respectively

Page 143

- In the Thermal (heat) technologies bullet, add the following at the end of the sentence starting “The recommended procedure for water treatment: ...”

(see the supporting document *Boil water*; Annex 1)

Page 145

- Make the following changes to Table 7.8:

- In the Notes column opposite Free chlorine disinfection, replace the current text with the following:

Free chlorine x contact time predicts efficacy; not effective against *Cryptosporidium* oocysts. Turbidity and chlorine-demanding solutes inhibit this process; hence, turbidity should be kept below 1 NTU to support effective disinfection. Where this is not practical, the aim should be to keep turbidities below 5 NTU, although

disinfection should still be practiced if 5 NTU cannot be achieved. At turbidities of more than 1 NTU, higher chlorine doses or contact times will be required^a

- In the Notes column opposite Membrane filtration (microfiltration, ultrafiltration, nanofiltration, reverse osmosis), insert the following at the end of the text:

; maximum reductions associated with filtered water turbidity of < 0.1 NTU^a

Page 146

➤ Make the following changes to Table 7.8:

- In the Notes column opposite UV irradiation, replace the current text with the following:

Effectiveness of disinfection depends on delivered fluence (dose), which varies with intensity, exposure time and UV wavelength. Excessive turbidity and certain dissolved species inhibit this process; hence, turbidity should be kept below 1 NTU to support effective disinfection. Where this is not practical, turbidities should be kept below 5 NTU with higher fluences^a

- Insert new footnote below the definitions under the table:

^a See *Turbidity: information for regulators and operators of water supplies* (Annex 1).

Page 147

- In section 7.4, change “2.3.1” in the third dot point to “2.4.1”
- In section 7.4, replace the final bullet point with the following:

Editorial note:

- Bullet point modified to reference the recently published QMRA guide

- collecting data for QMRA (see also section 7.2.3 and the supporting document *Quantitative microbial risk assessment: application to water safety management*, Annex 1).
- Replace the paragraph beginning “It is important to recognize that different methods” with the following:

Different methods can be employed for the detection of bacteria, viruses, protozoan parasites and helminths in water. The use of some methods, such as microscopy, relies

on detection of the whole particle or organism. Other methods, such as molecular amplification using polymerase chain reaction (PCR), target the genomic material, deoxyribonucleic acid (DNA) or ribonucleic acid (RNA). Still other methods, such as immunological detection methods (e.g. enzyme-linked immunosorbent assay [ELISA]), target proteins. Culture-based methods, such as broth cultures or agar-based bacterial media and cell cultures for viruses and phages, detect organisms by infection or growth.

Culture in broth or on solid media is largely applied to determine the number of viable bacteria in water. The best known examples are culture-based methods for indicators such as *E. coli*. Viruses can be detected by several methods. Using cell culture, the number of infectious viruses in water can be determined. Alternatively, viral genomes can be detected by use of PCR. Protozoan parasites are often detected by immunomagnetic separation in combination with immunofluorescence microscopy. PCR can also be applied. Helminths are generally detected using microscopy.

In source investigation associated with waterborne infectious disease outbreaks, microbial hazards are generally typed by use of PCR, which can be followed by sequencing analysis to improve the precision of identification. One innovative approach is metagenome analysis (i.e. sequencing nucleic acid obtained directly from environmental samples). This can detect a multitude of microbial hazards in a water sample.

It is important to recognize that the different methods measure different properties of microorganisms. Culture-based methods detect living organisms, whereas microscopy, detection of nucleic acid and immunological assays measure the physical presence of microorganisms or components of them, and do not necessarily determine if what is detected is alive or infectious. This creates greater uncertainty regarding the significance of the human health risk compared with detection by culture-based methods. When using non-culture methods that do not measure in units indicative of culturability or infectivity, assumptions are often made about the fraction of pathogens or components detected that represent viable and infectious organisms.

Changes to “Chapter 8: Chemical aspects”

Page 156

- Replace the URL with http://www.who.int/water_sanitation_health/water-quality/guidelines/chemicals/en/

Page 158

- Replace “8.2 Derivation of chemical guideline values” with the following:

8.2 Derivation of chemical guideline values and health-based values

Pages 158–9

Editorial note:

- Clarified first sentence
- Addition of last paragraph

- Replace the first two paragraphs of section 8.2 with the following:

In order for a particular chemical constituent to be evaluated to determine whether a guideline value or health-based value should be derived, one of the following criteria must be satisfied:

- There is credible evidence of occurrence of the chemical in drinking-water, combined with evidence of actual or potential toxicity.
- The chemical is of significant international concern.
- The chemical is being considered for inclusion or is included in the WHO Pesticide Evaluation Scheme (WHOPES), which coordinates the testing and evaluation of

pesticides for public health, including those applied directly to drinking-water for control of insect vectors of disease.

Guideline values are derived for many chemical constituents of drinking-water. A guideline value normally represents the concentration of a constituent that does not result in any significant risk to health over a lifetime of consumption. A number of provisional guideline values have been established at concentrations that are reasonably achievable through practical treatment approaches or in analytical laboratories; in these cases, the guideline value is above the concentration that would normally represent the calculated health-based value. Guideline values are also designated as provisional when there is a high degree of uncertainty in the toxicological and health data (see also section 8.2.5).

For some chemicals, no formal guideline value is proposed, on the grounds that occurrence is only at concentrations well below those that would be of concern for health. Establishing a formal guideline value for such substances could encourage some Member States to incorporate the value into their national standards when this is neither necessary nor appropriate. However, to provide guidance for Member States should the chemical be found in drinking-water or in source water in the hazard identification phase of developing a WSP, a health-based value has been determined.

In addition, health-based values for acute exposures are now being developed for a small number of substances that may be implicated in emergency situations as a result of a spill, usually to surface water sources. The derivation of these acute health-based values is explained in section 8.7.5.

Pages 163–4

Editorial note:

- Text has been updated to reflect Krishnan & Carrier article

- Replace the second and third paragraphs under the heading “Relative source allocation” with the following:

Wherever possible or in an ideal situation, derivation of guideline values uses data on the proportion of total daily intake normally ingested in drinking-water (based on mean levels in food, drinking-water, consumer products, soil and air), or data on intakes estimated on the basis of physical and chemical properties of the substances of concern. As the primary sources of exposure to chemicals are generally food (e.g. pesticide residues) and water, it is important to quantify, whenever possible, the exposures from both sources. To inform this process, it is desirable to collect as much high-quality data as possible on food intake in different parts of the world as possible.

The data collected can then be used to estimate the proportion of the intake that comes from food and the proportion that comes from drinking-water. However, for most contaminants, data from the various exposure sources, most notably food and drinking-water, are available only from developed countries.

In the absence of adequate exposure data or where documented evidence is available regarding widespread presence in one or more of the other media (i.e. air, food, soil or consumer products), the normal allocation of the total daily intake to drinking-water is 20% (floor value), which reflects a reasonable level of exposure based on broad experience, while still being protective (Krishnan & Carrier, 2013). This value reflects a change from the previous allocation of 10%, which was found to be excessively conservative. As chemicals are progressively reassessed, overall exposure will be reconsidered, and a change in the default allocation factor from 10% to 20% will be made, if appropriate. Therefore, not all older guideline values reflect this change. In some circumstances, there is clear evidence that water is the main (and possibly only) source of exposure, such as for some of the DBPs; the allocation in such cases may be as high as 80% (ceiling value), which still allows for some exposure from other sources (Krishnan & Carrier, 2013). Where chemical and context-specific allocation factors can be developed using exposure data or models, the allocation factor applied should still be bounded by the floor and ceiling values (i.e. 20–80%).

For pesticides, even when available food exposure data suggest that exposure via this route is minimal, the default allocation factor of 20% is used to account for the fact that available food exposure data do not generally include information from developing countries, where exposure via this route may be higher.

Pages 164

Editorial note:

- First sentence has been updated to reflect that the ADI (in addition to the TDI) can be used as the point of departure for deriving a guideline value
- Second sentence replaces the sentence: In some instances, ADI values with only one significant figure set by JECFA or JMPR were used to calculate the guideline value
- New paragraph to start with third sentence

- Replace the first paragraph under the subsection “Significant figures” in section 8.2.2 with the following:

The calculated ADI or TDI is used to derive the guideline value, which is usually rounded to one significant figure. In calculating the guideline value, the unrounded ADI or TDI value should be used.

The guideline value is generally rounded to one significant figure to reflect the uncertainty in, for example, experimental animal toxicity data, exposure assumptions

made and the uncertainty factors selected. In a few cases, rounding to two significant figures is appropriate because the practical impact of rounding depends on the units; for example, rounding from 1.5 to 2.0 µg/L has less influence on treatment requirements than rounding from 1.5 to 2.0 mg/L. These are considered on a case-by-case basis.

Page 166

- Replace the text in the first cell of the bottom row of Table 8.3, for designation D, with the following:

Calculated guideline value may be exceeded as a result of disinfection procedures

- Replace the text in the last cell of the bottom row of Table 8.3, for designation D, with the following:

(Guideline value is set considering possible health effects and the need to maintain adequate disinfection. Adequate disinfection of drinking-water remains paramount)

Page 177

- Replace the text in the first column next to Manganese in Table 8.7 with the following:

Not of health concern at levels normally causing acceptability problems in drinking-water. However, there are circumstances where manganese may remain in solution at higher concentrations in some acidic or anaerobic waters, particularly groundwater

Page 178

- In Table 8.8, replace the “Barium” entry with the following:

Barium	1300	1.3
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Page 181

- On the last line, insert the following before the sentence “Fact sheets for each are included in chapter 12”:

However, health-based values and, in some cases, acute health-based values have been developed for a number of these pesticides in order to provide guidance to Member States when there is a reason for local concern such as an emergency or spill situation (for further information on guideline values and health-based values, see section 8.2).

Page 182

➤ In Table 8.12:

- For Bentazone, change the text in the second column to read as follows: “Occurs in drinking-water or drinking-water sources at concentrations well below those of health concern”
- Below 1,3-Dichloropropane, insert “Dichlorvos” in the first column and “Occurs in drinking-water or drinking-water sources at concentrations well below those of health concern” in the second column
- Below Dichlorvos, insert “Dicofol” in the first column and “Unlikely to occur in drinking-water or drinking-water sources^a” in the second column
- For Diquat, change the text in the second column to read as follows: “Occurs in drinking-water or drinking-water sources at concentrations well below those of health concern”
- Below Malathion, insert “MCPA” in the first column and “Occurs in drinking-water or drinking-water sources at concentrations well below those of health concern” in the second column
- Change superscript “a” on AMPA to superscript “b”
- Insert a new footnote “a” below the table, which reads as follows: Although dicofol does not fulfil one of the three criteria for evaluation in the Guidelines, a background document has been prepared, and a health-based value has been established, in response to a request from Member States for guidance.
- Change the existing footnote “a” to footnote “b”
- Insert a new footnote “c” below the table, which reads as follows: (2-Methyl-4-chlorophenoxy)acetic acid.

➤ Replace the paragraph below Table 8.12 with the following:

Editorial note:

- In the first paragraph, added “(see section 8.2)”
- Paragraphs 2–4 are new

Guideline values have been established for the chemicals listed in Table 8.13, which meet the criteria for inclusion (see section 8.2). Fact sheets for each of these chemicals are included in Chapter 12.

Guideline values and health-based values are protective against health effects resulting from lifetime exposure. Small exceedances for short periods would not normally constitute a health emergency. In the event of a spill, a higher allocation

of the ADI to drinking-water could be justified. Alternatively, in cases where acute health-based values have been derived, normally based on JMPR evaluations, these may provide useful guidance (for further information, see section 8.7.5).

Routine monitoring of pesticides is generally not considered necessary. Member States should consider local usage and potential situations such as spills in deciding whether and where to monitor. In the event that monitoring results show levels above the guideline value or health-based value on a regular basis, it is advisable that a plan be developed and implemented to address the situation.

As a general principle, efforts should be made to keep the concentration of pesticides in water as low as possible, and to not allow concentrations to increase up to the guideline value or health-based value.

Page 183

- Make the following changes to Table 8.13:
 - In the Remarks column opposite “Nitrate”, replace the text with “Based on short-term effects, but protective for long-term effects”
 - In the Remarks column opposite “Nitrite”, replace the text with “Based on short-term effects, but protective for long-term effects”
 - Delete the row “MCPA^d / 2 / 0.002”

Page 184

- Make the following changes to Table 8.13:
 - Change the superscript “e” after 2,4,5-T to superscript “d”
 - Below the table, delete footnote “d”
 - Below the table, change footnote “e” to footnote “d”

Page 186

- In Table 8.15, replace the text in the column opposite “Chlorine dioxide” with the following:

Reduced primarily to chlorite, chlorate and chloride in drinking-water, and to chlorite and chloride upon ingestion; the provisional guideline values for chlorite and chlorate are protective for potential toxicity from chlorine dioxide

Page 190

- Replace the first full paragraph (starting “Effective treatment of pharmaceuticals”) with the following:

Effective treatment of pharmaceuticals depends on the physicochemical properties of the specific compounds. Typically, conventional treatment processes are less effective than advanced treatment processes for the removal of many organic compounds, particularly those that are more water soluble.

- At the end of section 8.5.5, add the following:

Further information is available in *Pharmaceuticals in drinking-water* (see Annex 1).

Page 195

- Replace the URL with http://www.who.int/water_sanitation_health/water-quality/guidelines/chemicals/en/

Page 196

- Replace the first bullet point with the following:
 - The guideline value for nitrate is 50 mg/L, (as nitrate ion), to be protective of the health of the most sensitive subpopulation, bottle-fed infants. This guideline value is based on the absence of adverse health effects (methaemoglobinaemia and thyroid effects) at concentrations below 50 mg/L in epidemiological studies. Although the guideline value is based on short-term effects, it is protective for long-term effects and in other population groups, such as older children and adults. Methaemoglobinaemia is complicated by the presence of microbial contamination and subsequent gastrointestinal infection, which can increase the risk for this group significantly. Authorities should therefore be all the more vigilant that water to be used for bottle-fed infants is microbiologically safe when nitrate is present at concentrations near or above the guideline value. It is also particularly important to ensure that these infants are not currently exhibiting symptoms of gastrointestinal infection (diarrhoea). In addition, because excessive boiling of water to ensure microbiological safety can concentrate levels of nitrate in the water, care should be taken to ensure that water is heated only until the water reaches a rolling boil. In extreme situations, alternative sources of water (e.g. bottled water) can be used.

Pages 197

- Replace page 197 with the following:

Editorial note:

- Added last two sentences in second paragraph
- Added information on how to calculate the acute health-based value

Health-based values for use in emergencies

Health-based values for acute and short-term exposures (called acute and short-term health-based values) can be derived for any chemicals that are used in significant quantities and are involved in an emergency, such as a spill into surface water sources.

JMPR has provided guidance on the setting of acute reference doses (ARfDs) for pesticides (Solecki et al., 2005). These ARfDs can be used as a basis for deriving acute health-based values for pesticides in drinking-water, and the general guidance can also be applied to derive ARfDs for other chemicals. The JMPR ARfD is usually established to cover the whole population, and must be adequate to protect the embryo or fetus from possible in utero effects. An ARfD based on developmental (embryo/fetal) effects, which applies to women of childbearing age only, may be conservative and not relevant to other population subgroups.¹

The ARfD can be defined as the amount of a chemical, normally expressed on a body weight basis, that can be ingested in a period of 24 hours or less without appreciable health risk to the consumer. Most of the scientific concepts applicable to the setting of ADIs or TDIs for chronic exposure apply equally to the setting of ARfDs. The toxicological end-points most relevant for a single or 1-day exposure should be selected. For ARfDs for pesticides, possible relevant end-points include haematotoxicity (including methaemoglobin formation), immunotoxicity, acute neurotoxicity, liver and kidney toxicity (observed in single-dose studies or early in repeated-dose studies), endocrine effects and developmental effects. The most relevant or adequate study in which these end-points have been determined (in the most sensitive species or most vulnerable subgroup) is selected, and NOAELs are established. The most relevant end-point providing the lowest NOAEL is then used in the derivation of the ARfD. Uncertainty factors are used to extrapolate from experimental animal data to the average human and to allow for variation in sensitivity within the human population. An ARfD derived in such a manner can then be used

¹ ARfDs established for pesticides by JMPR may be found at <http://apps.who.int/pesticide-residues-jmpr-database>.

to establish an acute health-based value by allocating 100% of the ARfD to drinking-water, as follows:

$$\text{Acute health-based value} = \frac{\text{ARfD} \times \text{bw} \times \text{P}}{\text{C}}$$

where:

- bw = body weight (60 kg for adult, 10 kg for children, 5 kg for infants)
- P = fraction of the ARfD allocated to drinking-water (100%)
- C = daily drinking-water consumption (2 L for adults, 1 L for children, 0.75 L for bottle-fed infants)

However, available data sets do not allow the accurate evaluation of the acute toxicity for a number of compounds of interest. If appropriate single-dose or short-term data are lacking, an end-point from a repeated-dose toxicity study can be used. This is likely to be a more conservative approach, and this should be clearly stated in the health-based value derivation.

When a substance has been spilt into a drinking-water source, contamination may be present for a period longer than 24 hours, but is not usually present for longer than a few days. Under these circumstances, the use of data from repeated-dose toxicity studies is appropriate to derive a short-term health-based value (using the approach outlined in section 8.2.2). As the period of exposure used in these studies will often be much longer than a few days, this, too, is likely to be a conservative approach.

Where there is a need for a rapid response, and suitable data are not available to establish an ARfD but a guideline value or health-based value is available for the chemical of concern, a pragmatic approach would be to allocate a higher proportion of the ADI or TDI to drinking-water. As the ADI or TDI is intended to be protective of lifetime exposure, small exceedances of the ADI or TDI for short periods will not be of significant concern for health. In these circumstances, it would be reasonable to allow 100% of the ADI or TDI to come from drinking-water for a short period.

Changes to “Chapter 9: Radiological aspects”

Page 211

- Delete “for members of the public” from the Table 9.2 caption.
- Below Table 9.2, replace footnote “b” with the following:

Guidance levels were rounded to the nearest order of magnitude by averaging the log scale values (to 10^n if the calculated value was below 3×10^n and to 10^{n+1} if value was 3×10^n or above). For example, if the calculated value was 2 Bq/L (i.e. 2×10^0), the guidance level was rounded to 10^0 (i.e. = 1) whereas, if the calculated value was 3 Bq /L, (i.e. 3×10^0 or above) the guidance level was rounded to 10^1 (i.e. = 10).

Page 215

- Below Table 9.4, delete “(some removal by aeration of water, not quantified)” from the last row.

Changes to “Chapter 10: Acceptability aspects: taste, odour and appearance”

Page 226

➤ Under “Manganese”:

- In the first line, replace “causes” with “may cause”.
- At the end of the paragraph, add the following:

However, under some conditions, manganese can be at concentrations above 0.1 mg/L and may remain in solution for a longer period compared with its usual solubility in most drinking-water.

Page 228

➤ Replace the text under “Turbidity” with the following

Editorial note:

- Text revised so that it focused on aesthetic aspects of turbidity only

Turbidity, typically expressed as nephelometric turbidity units (NTU), describes the cloudiness of water caused by suspended particles (e.g. clay and silts), chemical precipitates (e.g. manganese and iron), organic particles (e.g. plant debris) and organisms. Turbidity can be caused by poor source water quality, poor treatment and, within distribution systems, disturbance of sediments and biofilms or the ingress of dirty water through main breaks and other faults. At high levels, turbidity can lead to staining of materials, fittings and clothes exposed during washing, in addition to interfering with the effectiveness of treatment processes (see Tables 7.7 and 7.8 in chapter 7).

Increasing turbidity reduces the clarity of water to transmitted light. Below 4 NTU, turbidity can be detected only using instruments, but at 4 NTU and above, a milky-white, muddy, red-brown or black suspension can be visible. Large municipal supplies should consistently produce water with no visible turbidity (and should be able to achieve 0.5 NTU before disinfection at all times and average 0.2 NTU or less). However, small supplies, particularly those where resources are limited, may not be able to achieve such levels.

Visible turbidity reduces the acceptability of drinking-water. Although most particles that contribute to turbidity have no health significance (even though they may indicate the presence of hazardous chemical and microbial contaminants), many consumers associate turbidity with safety and consider turbid water as being unsafe to drink. This response is exacerbated when consumers have been used to receiving high-quality filtered water. If consumers lose confidence in a drinking-water supply, they may drink less water or use lower turbidity alternatives that may not be safe. Any complaints about unexpected turbidity should always be investigated because they could reflect significant faults or breaches in distribution systems.

Further information is available in *Turbidity: information for regulators and operators of water supplies* (see Annex 1).

Changes to “Chapter 11: Microbial fact sheets”

Pages 231

- Delete the following from dot point 1:

“, with the exception of *Schistosoma*, which is primarily spread by contact with contaminated surface water during bathing and washing;”

- Delete dot point 3.

Pages 235–6

- Delete the *Bacillus* fact sheet.

Page 293

- In Table 11.1, replace the row “*Cylindrospermum* spp.” with the following:

<i>Cylindrospermum</i> spp.	Anatoxin-a
<i>Cylindrospermopsis</i> spp.	Cylindrospermopsins, saxitoxins

Changes to “Chapter 12: Chemical fact sheets”

Page 307

- Replace the URL with http://www.who.int/water_sanitation_health/water-quality/guidelines/chemicals/en/

Pages 320–1

- Replace the fact sheet on “Barium” with the following:

Editorial note:

- Text revised to address new evidence
- Guideline value changed from 0.7 mg/l to 1.3 mg/l

Barium

Barium compounds are present in nature as ore deposits and in igneous and sedimentary rocks, and are used in a variety of industrial applications. Barium in water comes primarily from natural sources, although barium also enters the environment from industrial emissions and anthropogenic uses. Food is the primary source of intake for the non-occupationally exposed population. However, where barium concentrations in water are high, drinking-water may contribute significantly to total intake.

Guideline value	1.3 mg/l (1300 µg/l)
Occurrence	Concentrations in drinking-water are generally below 100 µg/l, although concentrations above 1 mg/l have been measured in drinking-water derived from groundwater

TDI	0.21 mg/kg bw per day, derived by applying an uncertainty factor of 300 to account for intraspecies variation (10), interspecies variation (10) and database deficiencies (3 for the lack of a developmental toxicity study) to a BMDL ₀₅ of 63 mg/kg bw per day for nephropathy in mice in a 2-year study
Limit of detection	0.004–0.8 µg/l by ICP-MS; 1.0 µg/l by ICP-AES
Treatment performance	Ion exchange, lime softening or direct filtration with chemical precipitation may be able to remove barium to below 1 mg/l
Guideline value derivation	
• allocation to water	20% of TDI
• weight	60 kg adult
• consumption	2 litres/day
Additional comments	As rounding can have significant practical implications at milligram per litre levels, it was concluded that a guideline value with two significant figures was reasonable in this case. The guideline value derived based on the long-term mouse study is not inconsistent with health-based values that could be derived from limited human studies.
Assessment date	2016
Principal references	IPCS (2001). <i>Barium and barium compounds</i> USEPA (2005). Toxicological review of barium and compounds. In support of summary information on the Integrated Risk Information System (IRIS). WHO (2016). <i>Barium in drinking-water</i>

There is no evidence that barium is carcinogenic or genotoxic. Acute hypertension has been observed in case reports, but the effects may be secondary to hypokalaemia. The critical study that had been identified previously for deriving the guideline value has several limitations (e.g. no effect observed at the single dose evaluated, limitations in the exposure methodology and design, no control for important risk factors for hypertension). Another human study that reported no effects on hypertension at 10 mg/L is limited by the small study size and short exposure duration. Barium has been shown to cause nephropathy in laboratory animals, and this was selected as the toxicological end-point of concern for the current guideline.

Pages 321–2

- Replace the fact sheet on “Bentazone” with the following:

Editorial note:

- Text revised to address new evidence
- New health-based value

Bentazone

Bentazone (CAS No. 25057-89-0) is a post-emergence herbicide used for selective control of broadleaf weeds and sedges occurring among a variety of crops. It is highly soluble in water and very resistant to hydrolysis; it is also very mobile in soil. However, photodegradation occurs in both soil and water. Bentazone may leach from soil into groundwater, particularly during heavy rainfall, and may contaminate surface water through effluents from production plants, drainage waters and actual use in the water (rice fields). Exposure from food is likely to be low.

Reason for not establishing a guideline value	Occurs in drinking-water or drinking-water sources at concentrations well below those of health concern
Health-based value*	0.5 mg/l
Acute health-based value**	Unnecessary, as no ARfD established
Occurrence	Concentrations up to 120 µg/l in groundwater and up to 14 µg/l in surface water have been measured
ADI	0–0.09 mg/kg bw, based on a NOAEL of 9 mg/kg bw per day for prolonged blood coagulation and clinical chemistry changes indicative of effects on liver and kidney from a 2-year toxicity and carcinogenicity study in rats and application of a safety factor of 100
ARfD	Unnecessary, as no effects observed that could be due to a single dose
Limit of detection	0.1 µg/l by GC with ECD after liquid–liquid extraction; limit of quantification of 0.01 µg/l by LC-MS/MS
Treatment performance	Conventional treatment, including coagulation and filtration, not effective; activated carbon may be effective under certain circumstances
Health-based value derivation	
• allocation to water	20% of upper bound of ADI
• weight	60 kg adult
• consumption	2 litres/day
Additional comments	The default allocation factor of 20% has been used to account for the fact that the available food exposure data, which suggest that exposure via this route is low, do not generally include information from developing countries, where exposure via this route may be higher.
	Guidance on interpreting the health-based value and deciding when to monitor can be found in section 8.5.3.
Assessment date	2016
Principal references	WHO (2013). <i>Pesticide residues in food – 2012 evaluations</i> WHO (2016). <i>Bentazone in drinking-water</i>

* When a formal guideline value is not established, a “health-based value” may be determined in order to provide guidance to Member States when there is reason for local concern. Establishing a formal guideline value for such substances may encourage Member States to incorporate a value into their national standards when this may be unnecessary.

** For more information on acute health-based values, see section 8.7.5.

Bentazone is not carcinogenic in rats or mice, and showed no evidence of genotoxicity in a range of in vitro and in vivo assays. Consistent observations in repeated-dose toxicity studies in mice, rats and dogs are effects on haematology and blood coagulation (e.g. prolongation of prothrombin time and partial thromboplastin time).

Page 326

- Under “Brominated acetic acids”, Principal references, change WHO (2003) to WHO (2004).

Page 329

- Under “Carbofuran”, Principal references, change WHO (2003) to WHO (2004).

Page 330

- Under “Carbon tetrachloride”, Principal references, change WHO (2003) to WHO (2004).

Page 332

- Under “Chloramines”, Principal references, change WHO (2003) to WHO (2004).

Pages 335–6

- Replace the fact sheet on “Chlorite and chlorate” with the following:

Editorial note:

- Text revised to address new evidence
- No change to the guideline value

Chlorine dioxide, chlorite and chlorate

Chlorite and chlorate are DBPs resulting from the use of chlorine dioxide as a disinfectant and for odour and taste control in water. Sodium chlorite and sodium chlorate are both used in the production of chlorine dioxide as well as for other commercial purposes. Chlorite and chlorate are also formed during the decomposition of hypochlorite solutions that are stored for long periods, particularly at warm temperatures. Where hypochlorite or chlorine dioxide is used as a disinfectant, the major route of environmental exposure to chlorite and chlorate is expected to be through drinking-water.

Provisional guideline values	<p><i>Chlorite</i>: 0.7 mg/l (700 µg/l)</p> <p><i>Chlorate</i>: 0.7 mg/l (700 µg/l)</p> <p>The guideline values for chlorite and chlorate are designated as provisional because use of aged hypochlorite or of chlorine dioxide as disinfectants may result in the chlorite and chlorate guideline values being exceeded, and difficulties in meeting the guideline values must never be a reason for compromising adequate disinfection.</p>
Occurrence	<p>When chlorine dioxide is used as the final disinfectant at typical doses, the resulting chlorite concentration would normally be less than 0.2 mg/l. Chlorate concentrations above 1 mg/l have been reported when hypochlorite was used, but such high concentrations would be unusual unless hypochlorite is stored under adverse conditions.</p>
ADIs	<p><i>Chlorite</i>: 0–0.03 mg/kg bw based on a NOEL of 3 mg/kg bw per day for reduced liver weight of F₀ females and F₁ males and females in a two-generation reproductive toxicity study in rats and using a safety factor of 100 (10 each for interspecies and intraspecies variability)</p> <p><i>Chlorate</i>: 0–0.01 mg/kg bw based on a BMDL₁₀ of 1.1 mg/kg bw per day for non-neoplastic effects on the thyroid of male rats in a carcinogenicity study and using a safety factor of 100 (10 to allow for intraspecies variability and an additional factor of 10 to allow for the deficiencies in the database; a safety factor for interspecies variation was not considered necessary because humans are likely to be less sensitive than rats to these effects)</p>
Limit of detection	<p>MDLs as low as 0.45 µg/l for chlorite and 0.78 µg/l for chlorate (IC with conductivity detection) and 78 µg/l for chlorine dioxide (UV/visible spectrophotometric method)</p>
Prevention and treatment	<p>When using hypochlorite, the following control approach is recommended to minimize formation of chlorite and chlorate: purchase fresh solutions that are of an appropriate quality, store them in a cool place and out of direct sunlight, and use the hypochlorite as soon as possible after purchase (e.g. within a month, if possible). Further, new hypochlorite solutions should not be added to containers containing old hypochlorite solutions, as this will accelerate chlorate formation.</p> <p>It is possible to reduce the concentration of chlorine dioxide and chlorite effectively to zero (<0.1 mg/l) by reduction; however, it is normal practice to supply water with a chlorine dioxide residual of a few tenths of a milligram per litre to provide some protection against microbial regrowth during distribution. With chlorine dioxide disinfection, the concentrations of chlorate and chlorite depend on process conditions (in both the chlorine dioxide generator and the water treatment plant) and applied dose of chlorine dioxide. As there is no low-cost option for reducing concentrations of chlorate once it is formed, control of chlorate concentration must rely on preventing its addition (from sodium hypochlorite) or formation (from chlorine dioxide). If chlorine dioxide is used as a pre-oxidant, the resulting chlorite concentration may need to be reduced using ferrous iron, sulfur reducing agents or activated carbon.</p>

Guideline value derivation	
• allocation to water	80% of ADI
• weight	60 kg adult
• consumption	2 litres/day
Additional comments	Concentrations should be maintained as low as reasonably practical, without compromising adequate disinfection. Although a health-based value of 0.3 mg/l could be derived from the ADI for chlorate, in some circumstances, it may not be possible to adequately disinfect potable water and maintain chlorate concentrations at or below the health-based value as chlorate is a byproduct of hypochlorite. Therefore, the previous provisional guideline value is retained. Moreover, even this provisional guideline value may be exceeded when aged hypochlorite is used and difficulties in meeting the guideline value must never be a reason for compromising adequate disinfection.
Assessment date	2016
Principal references	IPCS (2000). <i>Disinfectants and disinfectant by-products</i> WHO (2008). <i>Acidified sodium chlorite</i> WHO (2016). <i>Chlorine dioxide, chlorate and chlorite in drinking-water</i>

Chlorine dioxide

Any chlorine dioxide remaining at the consumer's tap will be reduced to chlorite and chloride upon ingestion. Consequently, a guideline value for chlorine dioxide has not been established. The provisional guideline values for chlorite and chlorate are adequately protective for potential toxicity from chlorine dioxide. The taste and odour threshold for chlorine dioxide is 0.2–0.4 mg/L.

Chlorite

IARC has concluded that chlorite is not classifiable as to its carcinogenicity to humans. The primary and most consistent finding arising from exposure to chlorite in a number of species was oxidative stress resulting in changes in the red blood cells. This observation was supported by a number of biochemical studies conducted in vitro. Studies with human volunteers for up to 12 weeks did not identify any effect on blood parameters at the highest dose tested, 36 µg/kg bw per day.

Chlorate

Although chlorate has also been reported to have effects on red blood cells, the most sensitive effects observed in rats administered sodium chlorate in drinking-water for 21 or 90 days were changes in thyroid histology (e.g. colloid depletion, hypertrophy, incidence and severity of hyperplasia) and in thyroid hormones. As with chlorite, a chlorate dose of 36 µg/kg bw per day for 12 weeks did not result in any adverse effects in human volunteers.

Page 341

- Under “Copper”, Principal references, change WHO (2003) to WHO (2004).

Page 345

- Insert the following at the end of the “Prevention and treatment” row (before the closing period):

(see the supporting document *Management of cyanobacteria in drinking-water supplies*; Annex 1)

Page 350

- Under “DDT and metabolites”, Principal references, change WHO (2003) to WHO (2004).
- Under “Dialkyltins”, Principal references, change WHO (2003) to WHO (2004).

Page 361

- After the fact sheet on “Dichlorprop”, insert the following new fact sheets:

Dichlorvos

Dichlorvos (CAS No. 62-73-7) is a broad-spectrum organophosphorus insecticide used primarily for controlling household pests and for protecting stored products from insects. It is no longer approved for use in some jurisdictions because of concerns over its acute toxicity. Dichlorvos is expected to be very mobile in soils. It is rapidly degraded by microbial activity and hydrolysis in soil, and does not adsorb to sediments. Degradation in water occurs primarily through hydrolysis. There are relatively few studies on its occurrence in source waters. Exposure from food varies widely, depending on local circumstances and usage. Dichlorvos can be inhaled from its use as a domestic insecticide.

Reason for not establishing a guideline value	Occurs in drinking-water or drinking-water sources at concentrations well below those of health concern
Health-based value*	0.02 mg/l
Acute health-based value**	3 mg/l
Occurrence	Concentrations in surface water in the range 10–50 ng/l, but sometimes as high as 1500 ng/l, have been measured

ADI	0–0.004 mg/kg bw, based on a NOAEL of 0.04 mg/kg bw per day for the inhibition of erythrocyte acetylcholinesterase activity in a 21-day study in male volunteers and application of a safety factor of 10
ARfD	0.1 mg/kg bw, based on a NOAEL of 1 mg/kg bw for erythrocyte acetylcholinesterase inhibition in an acute oral study in male volunteers and application of a safety factor of 10
Limit of detection	0.01 µg/l (limit of quantification) based on solvent extraction and GC analysis; 0.1 µg/l (reporting limit) based on GC-MS
Treatment performance	Conventional treatment, including coagulation, filtration and chlorination, not effective; removal by membranes depends on membrane type and operational conditions. Removal by nanofiltration membranes has variable effectiveness (removal rates from 4 to 60%). Reverse osmosis would be expected to be effective (removal rates > 85%) based on removal studies and predictions.
Health-based value derivation	
• allocation to water	20% of upper bound of ADI
• weight	60 kg adult
• consumption	2 litres/day
Acute health-based value derivation	
• allocation to water	100% of ARfD
• weight	60 kg adult
• consumption	2 litres/day
Additional comments	The default allocation factor of 20% has been used to account for the fact that the available food exposure data, which suggest that exposure via this route is low, do not generally include information from developing countries, where exposure via this route may be higher, and as potential exposure via inhalation from indoor air resulting from use of dichlorvos as a domestic insecticide is unknown. Guidance on interpreting the health-based value and deciding when to monitor can be found in section 8.5.3.
Assessment date	2016
Principal references	WHO (2012). <i>Pesticide residues in food – 2011 evaluations</i> WHO (2016). <i>Dichlorvos in drinking-water</i>

* When a formal guideline value is not established, a “health-based value” may be determined in order to provide guidance to Member States when there is reason for local concern. Establishing a formal guideline value for such substances may encourage Member States to incorporate a value into their national standards when this may be unnecessary.

** For more information on acute health-based values, see section 8.7.5.

As with other organophosphorus insecticides, the inhibition of cholinesterase activity, causing neurotoxicity, is the most sensitive toxicological end-point following acute or repeated exposures to dichlorvos. Dichlorvos is unlikely to be genotoxic in vivo or to pose a carcinogenic risk to humans. Some reproductive toxicity has been observed in rats, but dichlorvos was not found to cause developmental toxicity or to be teratogenic.

Dicofol

Dicofol (CAS No. 115-32-2) is an organochlorine acaricide that has been registered for broad-spectrum contact, non-systemic control of plant-eating mites in cotton, tea and a wide variety of fruit, vegetable and ornamental crops. Products containing dicofol, which is manufactured from DDT, are being phased out in the USA and are no longer approved for use in the European Union. Dicofol is unlikely to reach water, but may do so if bound to particulate matter subject to runoff. Dicofol is only slightly soluble in water and binds strongly to soil. There are few data on the occurrence of dicofol in water. Exposure from food varies widely, depending on local circumstances and usage. Dicofol has been proposed as a persistent organic pollutant under the Stockholm Convention.

Reason for not establishing a guideline value	Unlikely to be found in drinking-water or drinking-water sources*
Health-based value**	0.01 mg/l
Acute health-based value***	6 mg/l
Occurrence	Not detected in limited groundwater monitoring
ADI	0–0.002 mg/kg bw, based on a NOAEL of 0.22 mg/kg bw per day for histopathological changes in the liver and adrenal gland in a 2-year toxicity and carcinogenicity study in rats and application of a safety factor of 100
ARfD	0.2 mg/kg bw, based on a NOAEL of 15 mg/kg bw for decreased body weight and decreased feed intake in an acute neurotoxicity study in rats and application of a safety factor of 100
Limit of detection	Solvent extraction followed by GC-ECD may be effective (limit of quantification 5 ng/l)
Treatment performance	Should be removed by adsorption onto activated carbon, and any dicofol adsorbed onto particulate matter would likely be removed during coagulation
Health-based value derivation	
• allocation to water	20% of the upper bound of the ADI
• weight	60 kg adult
• consumption	2 litres/day
Acute health-based value derivation	
• allocation to water	100% of the ARfD
• weight	60 kg adult
• consumption	2 litres/day

Additional comments	The default allocation factor of 20% has been used to account for the fact that the available food exposure data, which suggest that exposure via this route is low, do not generally include information from developing countries, where exposure via this route may be higher.
	Guidance on interpreting the health-based value and deciding when to monitor can be found in section 8.5.3.
Assessment date	2016
Principal references	WHO (2012). <i>Pesticide residues in food – 2011 evaluations</i> WHO (2016). <i>Dicofol in drinking-water</i>

* Although dicofol does not fulfil one of the three criteria for evaluation in the Guidelines, a background document has been prepared, and a health-based value has been established, in response to a request from Member States for guidance.

** When a formal guideline value is not established, a “health-based value” may be determined in order to provide guidance to Member States when there is reason for local concern. Establishing a formal guideline value for such substances may encourage Member States to incorporate a value into their national standards when this may be unnecessary.

*** For more information on acute health-based values, see section 8.7.5.

The primary effects of dicofol after short- or long-term exposure of experimental animals were body weight reduction associated with decreased feed intake, and increased liver weight accompanied by changes in liver enzyme activities. Dicofol caused liver tumours in male mice at doses associated with significant enzyme induction and liver hypertrophy. However, on the basis of the absence of genotoxicity in an adequate range of in vitro genotoxicity and in vivo chromosomal aberration tests, the absence of carcinogenic effects in rats and the expectation that the adenomas present in mice will exhibit a threshold, dicofol is unlikely to pose a carcinogenic risk to humans at anticipated dietary exposure levels. There is a margin of 20 000 between the upper bound of the ADI and the LOAEL for liver adenomas in the male mouse.

Page 363

➤ Under “Dimethoate”, Principal references, change WHO (2003) to WHO (2004).

Page 364

➤ Replace the fact sheet on “Diquat” with the following:

Editorial note:

- Text revised to address new evidence
- New health-based value
- New acute health-based value

Diquat

Diquat (CAS No. 85-00-7; CAS No. 2764-72-9 for diquat ion) is a non-selective, quick-acting contact herbicide that is used for weed control on several food crops, for residential weed control on lawns and ornamental plants, and as an aquatic herbicide for the control of free-floating and submerged aquatic weeds in ponds and irrigation ditches. It is highly soluble in water but is strongly adsorbed to soil and is resistant to degradation in the sorbed state. Photochemical degradation in soil and water occurs in the presence of sunlight. Exposure from food is likely to be low.

Reason for not establishing a guideline value	Occurs in drinking-water or drinking-water sources at concentrations well below those of health concern
Health-based value*	0.03 mg/l
Acute health-based value**	20 mg/l
Occurrence	Rarely detected in surface water
ADI	0–0.006 mg/kg bw (expressed as the diquat ion), based on a NOAEL of 0.58 mg/kg bw per day for cataracts in a 2-year toxicity and carcinogenicity study in rats and application of a safety factor of 100
ARfD	0.8 mg/kg bw (expressed as the diquat ion), based on a NOAEL of 75 mg/kg bw for clinical signs and decreased body weight gain in the 1st week and decreased feed consumption in a neurotoxicity study in rats and application of a safety factor of 100
Limit of detection	1 µg/l using HPLC with UV absorbance detection after solid sorbent cartridge extraction; practical quantification limit of 1 µg/l using LC-MS analysis after solid-phase extraction
Treatment performance	Conventional treatment, including coagulation and filtration, not effective; activated carbon may be effective
Health-based value derivation	<ul style="list-style-type: none"> • allocation to water 20% of upper bound of unrounded ADI (0.0058 mg/kg bw) • weight 60 kg adult • consumption 2 litres/day
Acute health-based value derivation	<ul style="list-style-type: none"> • allocation to water 100% of unrounded ARfD (0.75 mg/kg bw) • weight 60 kg adult • consumption 2 litres/day
Additional comments	<p>The default allocation factor of 20% has been used to account for the fact that the available food exposure data, which suggest that exposure via this route is low, do not generally include information from developing countries, where exposure via this route may be higher.</p> <p>Guidance on interpreting the health-based value and deciding when to monitor can be found in section 8.5.3.</p>

Assessment date	2016
Principal references	WHO (2014). <i>Pesticide residues in food – 2013 evaluations</i> WHO (2016). <i>Diquat in drinking-water</i>

* When a formal guideline value is not established, a “health-based value” may be determined in order to provide guidance to Member States when there is reason for local concern. Establishing a formal guideline value for such substances may encourage Member States to incorporate a value into their national standards when this may be unnecessary.

** For more information on acute health-based values, see section 8.7.5.

The eye is the main target organ following short-term repeated exposure in rats and dogs. Effects on kidney, liver and haematological parameters are also observed. Diquat is not carcinogenic in mice or rats. In tests for genotoxicity, diquat gave equivocal or positive responses in the mammalian cell cytogenetic assay, but was negative in the in vivo mouse micronucleus assay and dominant lethal assay. No reproductive effects were observed in a two-generation reproductive toxicity study in rats, and diquat was not teratogenic in rats or rabbits.

Page 366

- Under “Endosulfan”, Principal references, change WHO (2003) to WHO (2004).

Page 367

- Under “Endrin”, Principal references, change WHO (2003) to WHO (2004).
- Under “Epichlorohydrin”, Principal references, change WHO (2003) to WHO (2004).

Page 369

- Under “Fenitrothion”, Principal references, change WHO (2003) to WHO (2004).

Page 371

- Under “Fluoride”, Principal references, change WHO (2003) to WHO (2004).

Page 374

- Under “Glyphosate and AMPA”, Principal references, change WHO (2003) to WHO (2005).

Page 375

- Under “Halogenated acetonitriles”, Principal references, change WHO (2003) to WHO (2004) (twice).

Page 378

- Under “Hexachlorobenzene”, Principal references, change WHO (2003) to WHO (2004).

Page 380

- Under “Inorganic tin”, Principal references, change WHO (2003) to WHO (2004).

Pages 383–44

- Replace the fact sheet on “Lead” with the following:

Editorial note:

- Additional explanation regarding the provisional guideline value added after the first sentence in the section, “Provisional guideline value”
- New text added on preventing lead contamination and sampling in the additional comments section and at the end of the fact sheet

Lead is used principally in the production of lead-acid batteries, solder and alloys. The organolead compounds tetraethyl and tetramethyl lead have also been used extensively as antiknock and lubricating agents in petrol, although their use for these purposes in many countries has largely been phased out. Owing to the decreasing use of lead-containing additives in petrol and of lead-containing solder in the food processing industry, concentrations in air and food are declining; in most countries, lead levels in blood are also declining unless there are specific sources, such as dust from leaded paint or occupational/household recycling of lead-containing materials. Lead is rarely present in tap water as a result of its dissolution from natural sources; rather, its presence is primarily from corrosive water effects on household plumbing systems containing lead in pipes, solder or fittings (including alloy fittings with high lead content), or from the service connections to homes. The amount of lead dissolved from the plumbing system depends on several factors, including pH, temperature, alkalinity, scale in pipes and standing time of the water, with soft, acidic water being the most plumbosolvent. Free chlorine residuals in drinking-water tend to form more insoluble lead-containing deposits, whereas chloramine residuals may form more soluble deposits in lead pipe. Accordingly, significant changes in the water quality of

a supply, resulting from, for example, changes in treatment or changes of source, can result in changes in plumbosolvency or solubilization of lead deposits, or both.

Provisional guideline value	0.01 mg/l (10 µg/l)
	The guideline value is designated as provisional on the basis of treatment performance and analytical achievability. As this is no longer a health-based guideline value, concentrations should be maintained as low as reasonably practical. New sources of lead, such as service connections and lead solder, should not be introduced into any system, and low lead alloy fittings should be used in repairs and new installations.
Occurrence	Concentrations in drinking-water are generally below 5 µg/l, although much higher concentrations (above 100 µg/l) have been measured where lead service connections or fittings are present. The primary source of lead is from service connections and plumbing in buildings; therefore, lead should be measured at the tap. Lead concentrations can also vary according to the period in which the water has been in contact with the lead-containing materials.
Basis of guideline derivation	The guideline value was previously based on a JECFA PTWI, which has since been withdrawn, and no new PTWI has been established, on the basis that there does not appear to be a threshold for the key effects of lead. However, substantial efforts have been made to reduce lead exposure from a range of sources, including drinking-water. The guideline value is maintained at 10 µg/l but is designated as provisional on the basis of treatment performance and analytical achievability because it is extremely difficult to achieve a lower concentration than this by central conditioning, such as phosphate dosing.
Limit of detection	1 µg/l by AAS; practical quantification limit in the region of 1–10 µg/l
Treatment performance	Not a raw water contaminant; treatment not applicable
Additional comments	<p>Infants and children are considered to be the most sensitive subgroups of the population.</p> <p>Lead is exceptional compared with other chemical hazards, in that most lead in drinking-water arises from lead service connections and plumbing in buildings, and the remedy consists principally of removing service connections, plumbing and fittings containing lead. This requires much time and money, and it is recognized that not all water will meet the guideline value immediately. Meanwhile, all other practical measures to reduce total exposure to lead, including corrosion control, should be implemented. In new installations or repairs, lead-free service connections and solder and lowlead alloy fittings should be used to prevent the introduction of contamination.</p> <p>The sampling protocol adopted – e.g. first draw, random daytime sampling or flushed – will depend on the objective of taking the samples. Where there is a need to verify that lead solder and/or high-lead fittings have not been installed in new or repaired systems, the approach used is to take a worst-case sample that reflects an extended period of stagnation, to maximize the chance of identifying the presence of lead.</p>

Assessment date	2011, revised 2016
Principal references	FAO/WHO (2011) <i>Evaluation of certain food additives and contaminants</i> WHO (2016) <i>Lead in drinking-water</i>

Exposure to lead is associated with a wide range of effects, including various neurodevelopmental effects, mortality (mainly due to cardiovascular diseases), impaired renal function, hypertension, impaired fertility and adverse pregnancy outcomes. Impaired neurodevelopment in children is generally associated with lower blood lead concentrations than the other effects; the weight of evidence is greater for neurodevelopmental effects than for other health effects and the results across studies are more consistent than those for other effects. For adults, the adverse effect associated with the lowest blood lead concentrations for which the weight of evidence is greatest and most consistent is a lead-associated increase in systolic blood pressure. JECFA concluded that the effects on neurodevelopment and systolic blood pressure provided the appropriate bases for dose–response analyses.

Based on the dose–response analyses, JECFA estimated that the previously established PTWI of 25 µg/kg body weight is associated with a decrease of at least 3 intelligence quotient (IQ) points in children and an increase in systolic blood pressure of approximately 3 mmHg (0.4 kPa) in adults. These changes are important when viewed as a shift in the distribution of IQ or blood pressure within a population. JECFA therefore concluded that the PTWI could no longer be considered health protective, and it was withdrawn.

Because the dose–response analyses do not provide any indication of a threshold for the key effects of lead, JECFA concluded that it was not possible to establish a new PTWI that would be considered to be health protective. JECFA reaffirmed that because of the neurodevelopmental effects, fetuses, infants and children are the subgroups that are most sensitive to lead.

It needs to be recognized that lead is exceptional compared with other chemical hazards, in that most lead in drinking-water arises from lead service connections and plumbing in buildings, and the remedy consists principally of removing plumbing and fittings containing lead, which requires much time and money. It is therefore emphasized that all other practical measures to reduce total exposure to lead, including corrosion control, should be implemented. New sources of lead, such as lead service connections and solder, should not be introduced into any system, and low lead alloy fittings should be used in repairs and new installations.

In terms of monitoring, if the monitoring objective is to identify the presence of lead in the internal plumbing of a building, then the sample should be from the tap. The sampling protocols also depend on the objective of taking the samples. First-draw samples typically will have the highest lead concentrations, but this may not be reflected in normal use if the same system provides water for toilet flushing, etc. Flushed samples, in contrast, give consistent values, but reflect the minimum contact

time between the water and the lead-containing material. The random daytime samples, although most truly reflecting the water that the consumer drinks, give the most variable levels; hence, it is necessary to collect more samples to determine the mean level of exposure. Where there is a need to verify that lead service connections, lead solder and/or high-lead fittings have not been installed in new or repaired systems, the approach used is to take a worst-case sample that reflects an extended period of stagnation and to maximize the chance of identifying the presence of lead. Extended stagnation with sequential volume can also be used to identify sources or locations of lead as an investigative activity.

Page 387

- Within the fact sheet on “Manganese”, make the following changes:

Editorial note:

- Reason for not establishing a guideline value clarified
- Updated text on epidemiological evidence

- Within the table, in the row “Reason for not establishing a guideline value”, replace the text “Not of health concern at levels found in drinking-water” with the following:

Not of health concern at levels normally causing acceptability problems in drinking-water. However, there are circumstances where manganese can remain in solution at higher concentrations in some acidic or anaerobic waters, particularly groundwater.

- Within the table, delete the “Additional comments” row:
- Under the table, replace the text with the following:

Manganese is an essential element for humans and other animals. Several epidemiological studies have suggested that soluble manganese in drinking-water is associated with adverse effects on learning in children. These findings remain to be confirmed, and the association has yet to be demonstrated as causal. Experimental animal data, especially rodent data, are not appropriate for human risk assessment because the physiological requirements for manganese vary among different species. Further, rodents are of limited value in assessing neurobehavioural effects, because the neurological effects (e.g. tremor, gait disorders) seen in primates are often preceded or accompanied by psychological symptoms (e.g. irritability, emotional lability) that are not apparent in rodents. The only primate study is of limited use in a quantitative risk

assessment because only one dose group was studied in a small number of animals and the manganese content in the basal diet was not provided.

A health-based value of 0.4 mg/l can be derived for manganese based on the upper range value of manganese intake of 11 mg/day, identified using dietary surveys, at which there are no observed adverse effects, using an uncertainty factor of 3 to take into consideration the possible increased bioavailability of manganese from water, allocating 20% of the TDI to drinking-water and assuming the consumption of 2 litres of water per day by a 60 kg adult. As this health-based value is well above concentrations of manganese normally causing acceptability problems in drinking-water (see chapter 10), it is not considered necessary to derive a formal guideline value. Accordingly, aesthetic as well as health aspects should be considered when setting national standards and regulations, and confirming the acceptability of drinking-water. There are circumstances, however, where manganese can remain in solution at higher concentrations in some acidic or anaerobic waters, particularly groundwater.

Pages 387–8

- Replace the fact sheet on “MCPA” with the following:

Editorial note:

- Text revised to address new evidence
- New health-based value
- New acute health-based value

MCPA

MCPA is a phenoxyacetic acid herbicide that is found in various formulations: as the free acid (CAS No. 94-74-6), as a dimethylamine salt (CAS No. 2039-46-5), as a sodium salt (CAS No. 3653-48-3) and as a 2-ethylhexyl ester (CAS No. 29450-45-1). It is a post-emergence herbicide that is widely used against broadleaf weeds in agriculture and horticulture and on grassland and lawns. All forms of MCPA will dissociate in water to the acid (anion) form. MCPA is highly soluble in water. Biological degradation is an important process in determining MCPA's environmental fate. Chlorophenols and chlorocresols are potential soil metabolites and may, if present in water, give rise to unacceptable tastes. Surface water may be contaminated via spray drift and runoff, whereas groundwater may be contaminated via leaching from soil. Exposure from food is likely to be low.

GUIDELINES FOR DRINKING-WATER QUALITY: FIRST ADDENDUM TO THE FOURTH EDITION

Reason for not establishing a guideline value	Occurs in drinking-water or drinking-water sources at concentrations well below those of health concern
Health-based value*	0.7 mg/l
Acute health-based value**	20 mg/l
Occurrence	Concentrations in surface water usually less than 1 µg/l; concentrations in drinking-water usually below 0.1 µg/l
ADI	0–0.1 mg/kg bw for MCPA ion, based on an overall NOAEL of 12 mg/kg bw per day for changes in clinical chemistry parameters indicative of effects on the kidneys from four subchronic studies in rats and application of a safety factor of 100 ADI established for the sum of MCPA and its salts and esters, expressed as MCPA acid equivalents
ARfD	0.6 mg/kg bw for MCPA ion, based on the overall NOAEL of 60 mg/kg bw for maternal and developmental toxicity in rats and application of a safety factor of 100 ARfD established for the sum of MCPA and its salts and esters, expressed as MCPA acid equivalents
Limit of detection	0.8 µg/l using HPLC with a photodiode array UV detector; 0.09 µg/l using derivatization and GC with ECD; limit of quantification of 0.0005 µg/l for LC-MS/MS
Treatment performance	Conventional treatment not effective; activated carbon adsorption and/or ozonation and advanced oxidation processes (e.g. UV with hydrogen peroxide) are effective; membrane filtration processes (e.g. reverse osmosis) may be effective
Health-based value derivation	<ul style="list-style-type: none"> • allocation to water 20% of upper bound of unrounded ADI (0.12 mg/kg bw) • weight 60 kg adult • consumption 2 litres/day
Acute health-based value derivation	<ul style="list-style-type: none"> • allocation to water 100% of ARfD • weight 60 kg adult • consumption 2 litres/day
Additional comments	<p>The default allocation factor of 20% has been used to account for the fact that the available food exposure data, which suggest that exposure via this route is low, do not generally include information from developing countries, where exposure via this route may be higher.</p> <p>Guidance on interpreting the health-based value and deciding when to monitor can be found in section 8.5.3.</p>
Assessment date	2016
Principal references	WHO (2013). <i>Pesticide residues in food – 2012 evaluations</i> WHO (2016). <i>MCPA in drinking-water</i>

* When a formal guideline value is not established, a “health-based value” may be determined in order to provide guidance to Member States when there is reason for local concern. Establishing a formal guideline value for such substances may encourage Member States to incorporate a value into their national standards when this may be unnecessary.

** For more information on acute health-based values, see section 8.7.5.

The target organs for the MCPA ion are the kidney, liver and blood. MCPA is not carcinogenic in mice or rats, and the MCPA ion exhibits no genotoxic potential. In multigeneration studies in rats, there was no evidence of reproductive toxicity up to the highest dose tested. The MCPA ion was not teratogenic in rats or rabbits.

Page 391

- Under “Methoxychlor”, Principal references, change WHO (2003) to WHO (2004).
- Under “Methyl parathion”, Principal references, change WHO (2003) to WHO (2004).

Page 395

- Under “Monochloroacetic acid”, Principal references, change WHO (2003) to WHO (2004).
- Under “Monochlorobenzene”, Principal references, change WHO (2003) to WHO (2004).

Pages 398–403

- Replace the fact sheet on “Nitrate and nitrite” with the following:

Editorial note:

- Text revised to address new evidence
- No change to the guideline value

Nitrate and nitrite¹

Nitrate (NO_3^-) is found naturally in the environment and is an important plant nutrient. It is present at varying concentrations in all plants and is a part of the nitrogen cycle. Nitrite (NO_2^-) is not usually present in significant concentrations except in a reducing environment, because nitrate is the more stable oxidation state. It can be formed by the microbial reduction of nitrate and in vivo by reduction from ingested nitrate. Nitrite can also be formed chemically in distribution pipes by *Nitrosomonas* bacteria during stagnation of nitrate-containing and oxygen-poor

¹ As nitrate and nitrite are chemicals of significant concern in some natural waters, the chemical fact sheet on nitrate and nitrite has been expanded.

drinking-water in galvanized steel pipes, or if chloramination is used to provide a residual disinfectant. An excess of free ammonia entering the distribution system can lead to nitrification and the potential increase of nitrate and nitrite in drinking-water. Nitrate can reach both surface water and groundwater as a consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), from wastewater disposal and from oxidation of nitrogenous waste products in human and other animal excreta, including septic tanks. Nitrate can also occasionally reach groundwater as a consequence of natural vegetation. Surface water nitrate concentrations can change rapidly owing to surface runoff of fertilizer, uptake by phytoplankton and denitrification by bacteria, but groundwater concentrations generally show relatively slow changes. Nitrate and nitrite can also be produced as a result of nitrification in source water or distribution systems.

In general, the most important source of human exposure to nitrate and nitrite is through vegetables (nitrate and nitrite) and through meat in the diet (nitrite is used as a preservative in many cured meats). In some circumstances, however, drinking-water can make a significant contribution to nitrate and, occasionally, nitrite intake. In the case of bottle-fed infants, drinking-water can be the major external source of exposure to nitrate and nitrite.

Guideline values ¹	<p><i>Nitrate</i>: 50 mg/l as nitrate ion, to be protective against methaemoglobinaemia and thyroid effects in the most sensitive subpopulation, bottle-fed infants, and, consequently, other population subgroups</p>
	<p><i>Nitrite</i>: 3 mg/l as nitrite ion, to be protective against methaemoglobinaemia induced by nitrite from both endogenous and exogenous sources in bottle-fed infants, the most sensitive subpopulation, and, consequently, the general population</p>
	<p><i>Combined nitrate plus nitrite</i>: The sum of the ratios of the concentrations of each of nitrate and nitrite to its guideline value should not exceed 1</p>
Occurrence	<p>Nitrate levels vary significantly, but levels in well water are often higher than those in surface water and, unless heavily influenced by surface water, are less likely to fluctuate. Concentrations often approach or exceed 50 mg/l where there are significant sources of contamination. Nitrite levels are normally lower, less than a few milligrams per litre.</p>
Basis of guideline value derivation	<p><i>Nitrate (bottle-fed infants)</i>: In epidemiological studies, no adverse health effects (methaemoglobinaemia or thyroid effects) were reported in infants in areas where drinking-water consistently contained nitrate at concentrations below 50 mg/l.</p>

¹ Conversion factors: 1 mg/l as nitrate = 0.226 mg/l as nitrate-nitrogen; 1 mg/l as nitrite = 0.304 mg/l as nitrite-nitrogen.

	<p><i>Nitrite (bottle-fed infants):</i> Based on: 1) no incidence of methaemoglobinaemia at nitrate concentrations below 50 mg/l (as nitrate ion) in drinking-water for bottle-fed infants less than 6 months of age (assuming body weight of 2 kg); 2) converting 50 mg/l as nitrate to corresponding molar concentration for nitrite; 3) multiplying by a factor of 0.1 to account for the estimated conversion rate of nitrate to nitrite in infants where nitrite is formed endogenously from nitrate at a rate of 5–10%; and 4) multiplying by a source allocation factor for drinking-water of 100% or 1, as a bottle-fed infant’s primary exposure to nitrite is through consumption of formula reconstituted with drinking-water that contains nitrate or nitrite. As the guideline value is based on the most sensitive subgroup of the population (bottle-fed infants less than 6 months of age), application of an uncertainty factor is not deemed necessary.</p> <p><i>Combined nitrate plus nitrite:</i> To account for the possibility of the simultaneous occurrence of nitrate and nitrite in drinking-water</p>
Limit of detection	MDLs of 0.009 mg/l as nitrate ion and 0.013 mg/l as nitrite ion by IC; MDL of 0.04–4.4 mg/l as nitrate ion by automated cadmium reduction with colorimetry (recommended for the analysis of nitrate at concentrations below 0.4 mg/l)
Treatment performance	<p><i>Nitrate:</i> Effective central treatment technologies involve the physical/chemical and biological removal of nitrate and include ion exchange, reverse osmosis, biological denitrification and electrodialysis, which are capable of removing over 80% of nitrate from water to achieve effluent nitrate concentrations as low as 13 mg/l; conventional treatment processes (coagulation, sedimentation, filtration and chlorination) are not effective</p> <p><i>Nitrite:</i> Treatment usually focuses on nitrate, because nitrite is readily converted to nitrate by many disinfectants</p>
Additional comments	<p>The guideline values for both nitrate and nitrite are based on short-term effects; however, they are also considered protective for any possible long-term effects.</p> <p>Methaemoglobinaemia is complicated by the presence of microbial contamination and subsequent gastrointestinal infection, which can increase the risk for bottle-fed infants significantly. Authorities should therefore be all the more vigilant that water to be used for bottle-fed infants is microbiologically safe when nitrate is present at concentrations near or above the guideline value. It is particularly important to ensure that these infants are not currently exhibiting symptoms of gastrointestinal infection (diarrhoea). Also, as excessive boiling of water to ensure microbiological safety can concentrate levels of nitrate in the water, care should be taken to ensure that water is heated only until it reaches a rolling boil. In extreme situations, alternative sources of water (e.g. bottled water) can be used.</p> <p>Nitrite is relatively unstable and can be rapidly oxidized to nitrate. Nitrite can occur in the distribution system at higher concentrations when chloramination is used, but the occurrence is almost invariably intermittent. Methaemoglobinaemia is therefore the most important consideration, and the guideline value derived for protection against methaemoglobinaemia would be the most appropriate under these circumstances, allowing for any nitrate that may also be present.</p>

All water systems that practise chloramination should closely and regularly monitor their systems to verify disinfectant levels, microbiological quality and nitrite levels. If nitrification is detected (e.g. reduced disinfectant residuals and increased nitrite levels), steps can be taken to modify the treatment train or water chemistry in order to minimize nitrite formation. Effective disinfection must never be compromised. Excessively high levels may occur in small supplies; where this is suspected from the risk assessment, testing may be appropriate.

Assessment date 2016

Principal references Health Canada (2013). *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Nitrate and nitrite*
 WHO (2016). *Nitrate and nitrite in drinking-water*

Absorption of nitrate ingested from vegetables, meat or water is rapid and in excess of 90%; final excretion is in the urine. In humans, about 25% of ingested nitrate is recirculated in saliva, of which about 20% is converted to nitrite by the action of bacteria in the mouth. There is also endogenous formation of nitrate from nitric oxide and protein breakdown as part of normal metabolism. In normal healthy adults, this endogenous synthesis leads to the excretion of about 62 mg of nitrate ion per day in the urine. Endogenous formation of nitrate or nitrite can be significantly increased in the presence of infections, particularly gastrointestinal infections. When nitrate intake is low, endogenous formation may be the major source of nitrate in the body. Nitrate metabolism is different in humans and rats, as rats may not actively secrete nitrate in their saliva.

Nitrate probably has a role in protecting the gastrointestinal tract against a variety of gastrointestinal pathogens, as nitrous oxide and acidified nitrite have antibacterial properties. It may have other beneficial physiological roles. Hence, there may be a benefit from exogenous nitrate uptake, and there remains a need to balance the potential risks with the potential benefits.

Significant bacterial reduction of nitrate to nitrite does not normally take place in the stomach, except in individuals with low gastric acidity or with gastrointestinal infections. These may include individuals using antacids, particularly those that block acid secretion. In humans, methaemoglobinaemia is a consequence of the reaction of nitrite with haemoglobin in the red blood cells to form methaemoglobin, which binds oxygen tightly and does not release it, thus blocking oxygen transport. Although most absorbed nitrite is oxidized to nitrate in the blood, residual nitrite can react with haemoglobin. High levels of methaemoglobin (>10%) formation in infants can give rise to cyanosis, referred to as blue-baby syndrome. Although clinically significant methaemoglobinaemia can occur as a result of extremely high nitrate intake in adults and children, the most familiar situation is its occurrence in bottle-fed infants. This was considered to be primarily a consequence of high levels of nitrate in water, although there have been cases of methaemoglobinaemia in weaned infants, associated with high nitrate intake from vegetables. Bottle-fed infants are considered to be at greater

risk because the intake of water in relation to body weight is high and, in infants, the development of repair enzymes is limited. In clinical epidemiological studies of methaemoglobinaemia and subclinical increases in methaemoglobin levels associated with drinking-water nitrate, 97% of cases occurred at concentrations in excess of 44.3 mg/l, with clinical symptoms associated with the higher concentrations. The affected individuals were almost exclusively under 3 months of age.

Although drinking-water nitrate may be an important risk factor for methaemoglobinaemia in bottle-fed infants, there is compelling evidence that the risk of methaemoglobinaemia is primarily increased in the presence of simultaneous gastrointestinal infections, which increase endogenous nitrite formation, may increase reduction of nitrate to nitrite and may also increase the intake of water in combatting dehydration. Cases have been described in which gastrointestinal infection seems to have been the primary cause of methaemoglobinaemia. Most cases of methaemoglobinaemia reported in the literature are associated with contaminated private wells (predominantly when the drinking-water is anaerobic) that also have a high probability of microbial contamination, which should not occur if it is properly disinfected.

Although numerous epidemiological studies have investigated the relationship between exposure to nitrate or nitrite in drinking-water and cancer occurrence, the weight of evidence does not support an association between cancer and exposure to nitrate or nitrite per se. Nitrite can react with nitrosatable compounds, primarily secondary amines, in the body to form *N*-nitroso compounds. A number of these are considered to be carcinogenic to humans, whereas others, such as *N*-nitrosoproline, are not. Several studies have been carried out on the formation of *N*-nitroso compounds in relation to nitrate intake in humans, but there is large variation in the intake of nitrosatable compounds and in gastric physiology. Higher mean levels of *N*-nitroso compounds, along with high nitrate levels, have been found in the gastric juice of individuals who are achlorhydric (i.e. have very low levels of hydrochloric acid in the stomach). However, other studies have been largely inconclusive, and there appears to be no clear relationship with drinking-water nitrate compared with overall nitrate intake in relation to formation of *N*-nitroso compounds. Moderate consumption of a number of dietary antioxidant components, such as ascorbic acid and green tea, appears to reduce endogenous *N*-nitrosamine formation.

A significant number of epidemiological studies have been carried out on the association of nitrate intake with primarily gastric cancers. Although the epidemiological data are considered to be inadequate to allow definitive conclusions to be drawn regarding all cancers, there is no convincing evidence of a causal association with any cancer site. The weight of evidence indicates that there is unlikely to be a causal association between gastric cancer and nitrate in drinking-water. This is consistent with the conclusion by IARC that ingested nitrate or nitrite under conditions that result in endogenous nitrosation is probably carcinogenic to humans (Group 2A), but not nitrate alone.

There have been suggestions that nitrate in drinking-water could be associated with congenital malformations, but the overall weight of evidence does not support this.

Nitrate appears to competitively inhibit iodine uptake, with the potential for an adverse effect on the thyroid. Current evidence also suggests that exposure to nitrate in drinking-water may alter human thyroid gland function by competitively inhibiting thyroidal iodide uptake, leading to altered thyroid hormone concentrations and functions. Although studies found that exposure to nitrate concentrations above 50 mg/l are weakly associated with altered thyroid function, the evidence is limited, conflicting and based on studies with important methodological limitations. Mode of action data suggest that pregnant women and infants are the most sensitive populations, owing primarily to the importance of adequate thyroid hormones for normal neurodevelopment in the fetus and infant, but also to increased thyroid hormone turnover and low intrathyroidal stores in fetal and early life.

There have been suggestions of an association between nitrate in drinking-water and the incidence of childhood diabetes mellitus. However, subsequent studies have not found a significant relationship, and no mechanism has been identified.

In some studies on rats treated with high doses of nitrite, a dose-related hypertrophy of the zona glomerulosa of the adrenal was seen; one strain of rats appeared to be more sensitive than others. However, this minimal hyperplasia was considered to be due to physiological adaptation to small fluctuations in blood pressure in response to high nitrite doses.

Nitrate is not carcinogenic in laboratory animals. Nitrite has been frequently studied, and there have been suggestions of carcinogenic activity, but only at very high doses. The most recent long-term studies have shown only equivocal evidence of carcinogenicity in the forestomach of female mice, but not in rats or male mice. In view of the lack of evidence for genotoxicity, this led to the conclusion that sodium nitrite was not carcinogenic in mice and rats. In addition, as humans do not possess a forestomach and the doses were high, the significance of these data for humans is very doubtful.

The guideline value for nitrate of 50 mg/l, as nitrate ion, is based on an absence of health effects (methaemoglobinaemia and thyroid effects) in epidemiological studies and is protective for bottle-fed infants and, consequently, other parts of the population. Methaemoglobinaemia is complicated by the presence of microbial contamination and subsequent gastrointestinal infection, which can increase the risk for this group significantly. Authorities should therefore be all the more vigilant that water to be used for bottle-fed infants is microbiologically safe when nitrate is present at concentrations near the guideline value. It is particularly important to ensure that these infants are not currently exhibiting symptoms of significant gastrointestinal infection (diarrhoea). Also, as excessive boiling of water to ensure microbiological safety can concentrate levels of nitrate in the water, care should be taken to ensure that water is heated only until it reaches a rolling boil. In extreme situations, alternative sources of water (e.g. bottled water) can be used.

The guideline for nitrite of 3 mg/l, as nitrite ion, is based on: 1) no incidence of methaemoglobinaemia at nitrate concentrations below 50 mg/l in drinking-water for bottle-fed infants less than 6 months of age (assuming body weight of 2 kg), 2) converting 50 mg/l nitrate to the corresponding molar concentration for nitrite, 3) multiplying by a factor of 0.1 to account for the estimated conversion rate of nitrate to nitrite in infants where nitrite is formed endogenously from nitrate at a rate of 5–10% and 4) multiplying by a source allocation factor for drinking water of 100% or 1, as a bottle-fed infant's primary exposure to nitrite is through consumption of formula reconstituted with nitrate- or nitrite-containing drinking-water. As the health-based value is based on the most sensitive subgroup of the population (bottle-fed infants less than 6 months of age), application of an uncertainty factor is not deemed necessary.

Because of the possibility of the simultaneous occurrence of nitrate and nitrite in drinking-water, the sum of the ratios of the concentration (C) of each to its guideline value (GV) should not exceed 1:

$$\frac{C_{\text{nitrate}}}{GV_{\text{nitrate}}} + \frac{C_{\text{nitrite}}}{GV_{\text{nitrite}}} \leq 1$$

The guideline values are based on short-term effects; however, they are also considered protective for long-term effects.

Practical considerations

The most appropriate means of controlling nitrate concentrations, particularly in groundwater, is the prevention of contamination. This may take the form of appropriate management of agricultural practices (e.g. management of fertilizer and manure application and storage of animal manures) and sanitation practices (e.g. the careful siting of pit latrines and septic tanks, sewer leakage control).

Methaemoglobinaemia has most frequently been associated with private wells. It is particularly important to ensure that septic tanks and pit latrines are not sited near a well or where a well is to be dug and to ensure that animal manure is kept at a sufficient distance to ensure that runoff cannot enter the well or the ground near the well. It is particularly important that the household use of manures and fertilizers on small plots near wells should be managed with care to avoid potential contamination. The well should be sufficiently protected to prevent runoff from entering the well. Where there are elevated concentrations of nitrate or where inspection of the well indicated that there are sources of nitrate close by that could be causing contamination, particularly where there are also indications that microbiological quality might also be poor, a number of actions can be taken. As noted above, water should be heated only until the water reaches a rolling boil or disinfected by an appropriate means before consumption. Where alternative supplies are available for bottle-fed infants, these can be used, taking care to ensure that they are microbiologically safe. Steps should then

be taken to protect the well and ensure that sources of both nitrate and microbial contamination are removed from the vicinity of the well.

In areas where household wells are common, health authorities may wish to take a number of steps to ensure that nitrate contamination is not or does not become a problem. Such steps could include targeting mothers, particularly expectant mothers, with appropriate information about water safety, assisting with visual inspection of wells to determine whether a problem may exist, providing testing facilities where a problem is suspected, providing guidance on disinfecting water or, where nitrate levels are particularly high, providing bottled water from safe sources or providing advice as to where such water can be obtained.

With regard to piped supplies, where nitrate is present, the first potential approach to treatment of drinking-water supplies, if source substitution is not feasible, is to dilute the contaminated water with a low-nitrate source. Where blending is not feasible, a number of treatment techniques are available for drinking-water. The first is disinfection, which may serve to oxidize nitrite to the less toxic nitrate as well as minimize the pathogenic and non-pathogenic reducing bacterial population in the water. Nitrate removal methods include ion exchange, biological denitrification, reverse osmosis and electrodialysis. However, there are disadvantages associated with all of these approaches, including cost, operational complexities and the need for disposal of resin, brine or reject water. Conventional municipal water treatment processes (coagulation, sedimentation, filtration and chlorination) are not effective for nitrate removal, as nitrate is a stable and highly soluble ion with low potential for co-precipitation and adsorption.

In systems with a water source containing naturally occurring ammonia or that add ammonia for chloramination, free ammonia entering the distribution system can be one of the causative factors of nitrification and the potential increase of nitrate and nitrite in the distribution system. Care should be taken with the use of chloramination for providing a residual disinfectant in the distribution system. It is important to manage this to minimize nitrite formation, either in the main distribution system or in the distribution systems of buildings.

Page 406

- Under “Parathion”, Principal references, change WHO (2003) to WHO (2004).

Page 408

- Insert the following new fact sheet on “Perchlorate” above the fact sheet on “Petroleum products”:

Editorial note:

- New fact sheet

Perchlorate

Perchlorate is a naturally occurring anion that is frequently detected in the environment. It is used primarily as an oxidizer for solid rocket fuels, automotive airbags, fireworks and road flares. Perchlorate is found in water due to contamination from perchlorate manufacturing or use, natural deposits of perchlorate, use of fertilizers containing natural deposits of perchlorate, and natural formation of perchlorate in the atmosphere and its deposition during rain or snow events. It also forms in hypochlorite solutions to varying degrees, depending on the hypochlorite concentration, age and storage conditions.

Guideline value	0.07 mg/l (70 µg/l)
Occurrence	Generally found in drinking-water at concentrations below 10 µg/l, although concentrations above 40 µg/l have been measured
PMTDI	0.01 mg/kg bw, based on a BMDL ₅₀ of 0.11 mg/kg bw per day for 50% inhibition of iodide uptake, derived from a human clinical study on healthy adult volunteers administered perchlorate in drinking-water, and using an uncertainty factor of 10 to account for inter-individual differences
Limit of detection	20–50 ng/l (method reporting limits) by LC-MS; 4 µg/l (method reporting limit) by IC with suppressed conductivity detection
Treatment performance	The perchlorate anion is highly stable in water and is difficult to remove using conventional water treatment technologies. Treatment technologies that have been shown to effectively remove perchlorate from water include nanofiltration and reverse osmosis membranes, anaerobic biodegradation and ion exchange.
Guideline value derivation	
• allocation to water	20% of unrounded PMTDI (0.011 mg/kg bw)
• weight	60 kg adult
• consumption	2 litres/day
Assessment date	2016
Principal references	EFSA (2014). Scientific opinion on the risks to public health related to the presence of perchlorate in food, in particular fruits and vegetables FAO/WHO (2011). Safety evaluation of certain contaminants in food WHO (2016). Perchlorate in drinking-water

The primary effect of perchlorate is its ability to competitively inhibit uptake of iodide by the thyroid gland. Inhibition of iodide uptake by perchlorate reduces the amount of iodide available for the synthesis of thyroid hormones. Sustained reduction in iodide uptake by the thyroid may result in hypothyroidism, which has adverse implications for structural and functional brain development in the fetus, infant and child, and for metabolism and the functioning of the cardiovascular, gastrointestinal, skeletal, neuromuscular and reproductive systems in adults. As the rat is not a good model for humans for substances known to affect the thyroid and having a mode of action involving inhibition of the uptake of iodide, the guideline value was derived from human studies.

- Under “Petroleum products”, Principal reference, change WHO (2005) to WHO (2008).

Page 419

- Under “Sulfate”, Principal references, change WHO (2003) to WHO (2004).

Page 429

- Under Principal references, insert the following reference below the IPCS (2004) reference:

USNTP (1987). Toxicology and carcinogenesis studies of bromodichloromethane in F344/N rats and B6C3F1 mice (gavage studies)

Page 431

- Under “Uranium”, Principal reference, change WHO (2011) to WHO (2012).

Page 432

- Under “Vinyl chloride”, Principal references, change WHO (2003) to WHO (2004).

Page 440

- In the last line of the table, replace “WHO (2010)” with “WHO (2008)”

Changes to “Annex 1: Supporting documentation to the Guidelines”

Page 443

- In the first paragraph, change the first URL to: http://www.who.int/water_sanitation_health/water-quality/guidelines/drinking-water-guidelines-publications/en/
- Insert the following before “*Assessing microbial safety of drinking-water*”

A practical guide to auditing water safety plans

Published in 2015 by the World Health Organization

Provides guidance on developing and implementing a WSP auditing scheme, including examples, case studies and tools from more than a dozen low-, middle- and high-income countries with WSP auditing experience

http://www.who.int/water_sanitation_health/publications/auditing-water-safety-plans/en/

- Below “*Assessing microbial safety of drinking-water*”, change the URL to: http://www.who.int/water_sanitation_health/publications/assessing-microbial-safety-of-drinking-water/en/
- Insert the following below “*Assessing microbial safety of drinking-water*”:

Boil water

Published in 2015 by the World Health Organization

Provides the scientific basis for the efficacy of boiling water

http://www.who.int/water_sanitation_health/publications/boiling-water/en/

- Below “*Calcium and magnesium in drinking-water: Public health significance*”, change the URL to: http://www.who.int/water_sanitation_health/publications/publication_9789241563550/en/

- Below “*Chemical safety of drinking-water: Assessing priorities for risk management*”, change the URL to: http://www.who.int/water_sanitation_health/publications/dwchem_safety/en/

Page 444

- Below “*Domestic water quantity, service level and health*”, change the URL to: http://www.who.int/water_sanitation_health/publications/wsh0302/en/
- Below “*Evaluating household water treatment options*”, change the URL to: http://www.who.int/water_sanitation_health/publications/household_water/en/
- Below “*Evaluation of the H2S method for detection of fecal contamination of drinking water*”, change the URL to: http://www.who.int/water_sanitation_health/publications/h2s-method-for-detection-of-fecal-contamination/en/
- Below “*Fluoride in drinking-water*”, change the URL to: http://www.who.int/water_sanitation_health/publications/fluoride-in-drinking-water/en/
- Below “*Guide to hygiene and sanitation in aviation*”, change the URL to: http://www.who.int/water_sanitation_health/publications/aviation_guide/en/
- Below “*Guide to ship sanitation*”, change the URL to: http://www.who.int/water_sanitation_health/publications/ship_sanitation_guide/en/
- Below “*Hazard characterization for pathogens in food and water*”, change the URL to: http://www.who.int/water_sanitation_health/publications/hazard-characterization-for-pathogens/en/

Page 445

- Below “*Health aspects of plumbing*”, change the URL to: http://www.who.int/water_sanitation_health/publications/plumbing-health-aspects/en/
- Below “*Heterotrophic plate counts and drinking-water safety*”, change the URL to: http://www.who.int/water_sanitation_health/publications/hpc/en/
- Below “*Legionella and the prevention of legionellosis*”, change the URL to: http://www.who.int/water_sanitation_health/publications/legionella/en/

- Insert the following below “*Legionella and the prevention of legionellosis*”:

Management of cyanobacteria in drinking-water supplies: information for regulators and water suppliers

Published in 2015 by the World Health Organization

Guidance for regulators and water suppliers to prevent and manage cyanobacterial blooms

http://www.who.int/water_sanitation_health/publications/cyanobacteria_in_drinking-water/en/

- Below “*Managing water in the home*”, change the URL to: http://www.who.int/water_sanitation_health/publications/wsh0207/en/
- Below “*Pathogenic mycobacteria in water*”, change the URL to: http://www.who.int/water_sanitation_health/publications/pathogenic-mycobacteria-in-water/en/
- Insert the following below “*Pathogenic mycobacteria in water*”:

Pharmaceuticals in drinking-water

Published in 2012 by the World Health Organization

Provides evidence-based, practical guidance and recommendations for managing pharmaceuticals in drinking-water.

http://www.who.int/water_sanitation_health/publications/pharmaceuticals-in-drinking-water/en/

- Insert the following below “*Protecting groundwater for health*”:

Protecting surface water for health: identifying, assessing and managing drinking-water quality risks in surface water catchments

Published in 2016 by the World Health Organization

Provides a structured approach to understanding surface waters and their catchments to support the identification, assessment and prioritization of the risks, and the development of management strategies for their control, as a basis for providing safe drinking-water

http://www.who.int/water_sanitation_health/publications/pswh/en

- Below “*Quantifying public health risk in the WHO Guidelines*”, change the URL to: http://www.who.int/water_sanitation_health/publications/quantifyinghealthrisks/en/

Page 446

- Insert the following above “*Rapid assessment of drinking-water quality*”:

Quantitative microbial risk assessment: application for water safety management

Published in 2016 by the World Health Organization

Synthesizes the current knowledge on quantitative microbial risk assessment (QMRA) to facilitate its application in the practice of water supply, water reuse and water recreation to support the management of risks associated with faecal pathogens in the water-related context. http://www.who.int/water_sanitation_health/publications/qmra/en

- Below “*Rapid assessment of drinking-water quality*”, change the URL to: http://www.who.int/water_sanitation_health/publications/rapid_assessment/en/
- Below “*Review of latest available evidence on potential transmission of avian influenza*”, change the URL to: http://www.who.int/water_sanitation_health/publications/potential-transmission-of-avian-influenza/en/
- Below “*Risk assessment of Cryptosporidium in drinking water*”, change the URL to: http://www.who.int/water_sanitation_health/publications/cryptoRA/en/
- Below “*Safe drinking-water from desalination*”, change the URL to: http://www.who.int/water_sanitation_health/publications/desalination_guidance/en/
- Below “*Safe piped water*”, change the URL to: http://www.who.int/water_sanitation_health/publications/safe-piped-water/en/
- Below “*Scaling up household water treatment among low-income populations*”, change the URL to: http://www.who.int/water_sanitation_health/publications/household_water_treatment/en/

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- Below “*Toxic cyanobacteria in water*”, change the URL to: http://www.who.int/water_sanitation_health/publications/toxiccyanobact/en/
- Insert the following below “*Toxic cyanobacteria in water*”:

Turbidity: information for regulators and operators of water supplies

Published in 2017 by the World Health Organization

Provides information on the uses and significance of turbidity, and is intended for regulators and operators of drinking-water supplies.

- Below “*Upgrading water treatment plants*”, change the URL to: http://www.who.int/water_sanitation_health/publications/treatplants/en/

- Below “*Water quality—Guidelines, standards and health*”, change the URL to: http://www.who.int/water_sanitation_health/publications/whoiwa/en/
- Insert the following below “Edited by D. Cunliffe et al” in the “*Water Safety in Buildings*” entry:

Published in 2011 by the World Health Organization

- Below “*Water safety in buildings*”, change the URL to: http://www.who.int/water_sanitation_health/publications/9789241548106/en/
- Insert the following below “*Water safety in buildings*”

Water safety in distribution systems

Published in 2014 by the World Health Organization

A reference tool to help water suppliers and regulators who are familiar with the water safety plan approach to enhance risk assessment and management and investment planning for their water distribution systems.

http://www.who.int/water_sanitation_health/publications/water-safety-in-distribution-system/en/

- Insert the following below “*Water safety in distribution systems*”

Water safety plan: a field guide to improving drinking-water safety in small communities

Published in 2014 by the World Health Organization Regional Office for Europe
Contains short explanations of the water safety planning process (including practical templates and tips) that support WSP development and implementation in small communities

<http://www.euro.who.int/en/health-topics/environment-and-health/water-and-sanitation/publications/2014/water-safety-plan-a-field-guide-to-improving-drinking-water-safety-in-small-communities>

- Below “*Water safety plan manual*”, change the URL to: http://www.who.int/water_sanitation_health/publications/publication_9789241562638/en/
- Below “*Water safety planning for small community water supplies*”, change the URL to: http://www.who.int/water_sanitation_health/publications/small-comm-water_supplies/en/
- Under “*Water safety planning for small community water supplies*”:
 - Replace the first line with “Published in 2012 by the World Health Organization”
 - Replace the last line with “http://www.who.int/water_sanitation_health/publications/small-comm-water_supplies/en/”

Page 448

- Above “*Water treatment and pathogen control*”, change the URL to:
http://who.int/water_sanitation_health/publications/wsp0506/en
- Below “*Water treatment and pathogen control*”, change the URL to: http://www.who.int/water_sanitation_health/publications/water-treatment-and-pathogen-control/en/
- Below “*Waterborne zoonoses*”, change the URL to: http://www.who.int/water_sanitation_health/publications/waterborne-zoonoses/en/

Changes to “Annex 2: References cited”

Page 449

Chapter 1

- Below “Brikké F”, change the URL to: http://www.who.int/water_sanitation_health/publications/omruralsystems/en/
- Below “Sawyer R, Simpson-Hébert M, Wood S”, change the URL to: http://www.who.int/water_sanitation_health/publications/phastep/en/
- Below “Simpson-Hébert M, Sawyer R, Clarke L”, change the URL to: <http://apps.who.int/iris/handle/10665/63260>
- Below “WHO (1997) *Guidelines for drinking-water quality, 2nd ed. Vol. 3*”, change the URL to: http://www.who.int/water_sanitation_health/publications/small-water-supplies-guidelines/en/

Chapter 3

- Below “Howard G et al. (2002)”, change the URL to: http://www.who.int/water_sanitation_health/publications/healthvillages/en/

Page 450

Chapter 4

- Below “WHO (1997) *Guidelines for drinking-water quality, 2nd ed. Vol. 3. Surveillance and control of community supplies*”, change the URL to: http://www.who.int/water_sanitation_health/publications/small-water-supplies-guidelines/en/

Chapter 5

- Below “WHO (1997) *Guidelines for drinking-water quality, 2nd ed. Vol. 3. Surveillance and control of community supplies*”, change the URL to: http://www.who.int/water_sanitation_health/publications/small-water-supplies-guidelines/en/

Chapter 6

- Below “WHO (1997) *Guidelines for drinking-water quality, 2nd ed. Vol. 3. Surveillance and control of community supplies*”, change the URL to: http://www.who.int/water_sanitation_health/publications/small-water-supplies-guidelines/en/
- Below “WHO (2005b) *Nutrients in drinking water*”, change the URL to: http://www.who.int/water_sanitation_health/publications/nutrients-in-dw/en/
- Below “Wisner B, Adams J (2003) *Environmental health in emergencies and disasters: a practical guide*”, change the URL to: http://www.who.int/water_sanitation_health/publications/emergencies2002/en/

Page 452

Top section (continuation of chapter 7)

- Below “WHO (2003) *Emerging issues in water and infectious disease*”, change the URL to: http://www.who.int/water_sanitation_health/publications/emergingissues/en/
- Below “WHO (2005) *Preventing travellers’ diarrhoea: How to make drinking water safe*”, change the URL to: http://www.who.int/water_sanitation_health/publications/traveldiarrh/en/

Chapter 8

- Below “FAO/WHO (2009) *Principles and methods for the risk assessment of chemicals in food*” change the URL to: <http://www.who.int/foodsafety/publications/chemical-food/en/>
- Under Chapter 8, insert the following reference below the “IPCS (2009)” reference:
Krishnan K, Carrier R (2013). The use of exposure source allocation factor in the risk assessment of drinking-water contaminants. *J Toxicol Environ Health B*. 16(1):39–51.
- Below “Solecki R et al. (2005)”, change the URL to: <https://www.ncbi.nlm.nih.gov/pubmed/16040182>

- Below “WHO (2006) *Guidelines for safe recreational water environments*”, change the URL to: http://www.who.int/water_sanitation_health/publications/safe-recreational-water-guidelines-2/en/

Page 453

Chapter 9

- Below “European Commission (2001)”, change the URL to: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2001.344.01.0085.01.ENG&toc=OJ:L:2001:344:TOC

Page 454

Chapter 11

- Below “WHO (2003) *Emerging issues in water and infectious disease*”, change the URL to: http://www.who.int/water_sanitation_health/publications/emergingissues/en/

Page 455

- For footnote 2, change the URL to: http://www.who.int/water_sanitation_health/water-quality/guidelines/chemicals/en/

Page 456

- Delete the following references:

WHO (2003) *Barium in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality*. Geneva, World Health Organization (WHO/SDE/WSH/03.04/76).

WHO (2003) *Bentazone in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality*. Geneva, World Health Organization (WHO/SDE/WSH/03.04/77).

WHO (2003) *Bromate in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality*. Geneva, World Health Organization (WHO/SDE/WSH/03.04/78).

- Change “WHO (2003)” to “WHO (2004)” for the Brominated acetic acids, Carbofuran and Carbon tetrachloride references, and move the references to page 460, as indicated below.

Page 457

- Change “WHO (2003)” to “WHO (2004)” for the Copper, DDT and its derivatives, Dialkyltins, Dimethoate and Endosulfan references, and move the references to page 460, as indicated below.
- Delete the following reference:

WHO (2003) *Diquat in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality*. Geneva, World Health Organization (WHO/SDE/WSH/03.04/91).

Page 458

- Change “WHO (2003)” to “WHO (2004)” for the Endrin, Epichlorohydrin, Fenitrothion, Fluoride, Halogenated acetonitriles, Hexachlorobenzene and Inorganic tin references, and move the references to page 460, as indicated below.
- Change “WHO (2003)” to “WHO (2005)” for the Glyphosate and AMPA reference, and move the reference to page 461 to follow the Formaldehyde reference.

Page 459

- Delete the following reference:

WHO (2003) *MCPA in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality*. Geneva, World Health Organization (WHO/SDE/WSH/03.04/38).

- Change “WHO (2003)” to “WHO (2004)” for the Methoxychlor, Methyl parathion, Monochloramine, Monochloroacetic acid, Monochlorobenzene and Parathion references, and move the references to page 460, as indicated below.

Page 460

- Change “WHO (2003)” to “WHO (2004)” for the Sulfate and Vinyl chloride references, and move the references as indicated below.
- Insert all WHO (2004) references below the “WHO (2003) *Zinc in drinking-water*” reference, in alphabetical order.
- Insert the following reference below the “WHO (2005) *1,4-Dioxane in drinking-water*” reference:

WHO (2005) *Bromate in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality*. Geneva, World Health Organization (WHO/SDE/WSH/05.08/78).

- Delete the following reference:

WHO (2005) *Chlorite and chlorate in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality*. Geneva, World Health Organization (WHO/SDE/WSH/05.08/86).

Page 461

- Delete the following reference:

WHO (2005) *Nickel in drinking-water. Background document for development of WHO Guidelines for drinking-water quality*. Geneva, World Health Organization (WHO/SDE/WSH/05.08/55).

- Insert the following reference below the “WHO (2005) *Trihalomethanes in drinking-water*” reference:

WHO (2007) *Nickel in drinking-water. Background document for development of WHO Guidelines for drinking-water quality*. Geneva, World Health Organization (WHO/SDE/WSH/07.08/55).

- Change “WHO (2005)” to “WHO (2008)” for the Petroleum products reference, and move the reference below the “WHO (2008) *Novaluron in drinking-water*” reference.

- Insert the following reference below the “WHO (2008) *Pirimiphos-methyl in drinking-water*” reference:

WHO (2008). *Pyriproxyfen in drinking-water: Use for vector control in drinking-water sources and containers. Background document for development of WHO Guidelines for drinking-water quality*. Geneva: World Health Organization (WHO/HSE/AMR/08.03/9).

Page 462

- Delete the following reference:

WHO (2010) *Pyriproxyfen in drinking-water: Use for vector control in drinking-water sources and containers. Background document for development of WHO Guidelines for drinking-water quality*. Geneva, World Health Organization (WHO/HSE/AMR/08.03/9).

Page 463

- Delete the following references:

WHO (2011) *Lead in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality*. Geneva, World Health Organization (WHO/SDE/WSH/03.04/9/Rev/1).

WHO (2011) *Nitrate and nitrite in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality*. Geneva, World Health Organization (WHO/HSE/AMR/07.01/16/Rev/1).

- Change “WHO (2011)” to “WHO (2012)” for the “*Uranium in drinking-water*” reference.

- Insert the following above “Other references cited”:

WHO (2016). Barium in drinking-water. Background document for development of WHO Guidelines for drinking-water quality. Geneva: World Health Organization (WHO/FWC/WSH/16.48).

WHO (2016). Bentazone in drinking-water. Background document for development of WHO Guidelines for drinking-water quality. Geneva: World Health Organization (WHO/FWC/WSH/16.47).

WHO (2016). Chlorine dioxide, chlorate and chlorite in drinking-water. Background document for development of WHO Guidelines for drinking-water quality. Geneva: World Health Organization (WHO/FWC/WSH/16.49).

WHO (2016). Dichlorvos in drinking-water. Background document for development of WHO Guidelines for drinking-water quality. Geneva: World Health Organization (WHO/FWC/WSH/16.44).

WHO (2016). Dicofol in drinking-water. Background document for development of WHO Guidelines for drinking-water quality. Geneva: World Health Organization (WHO/FWC/WSH/16.45).

WHO (2016). Diquat in drinking-water. Background document for development of WHO Guidelines for drinking-water quality. Geneva: World Health Organization (WHO/FWC/WSH/16.50).

WHO (2016). Lead in drinking-water. Background document for development of WHO Guidelines for drinking-water quality. Geneva: World Health Organization (WHO WHO/FWC/WSH/16.53)

WHO (2016). MCPA in drinking-water. Background document for development of WHO Guidelines for drinking-water quality. Geneva: World Health Organization (WHO/SDE/FWC/16.51).

WHO (2016). Nitrate and nitrite in drinking-water. Background document for development of WHO Guidelines for drinking-water quality. Geneva: World Health Organization (WHO/SDE/FWC/16.52).

WHO (2016). Perchlorate in drinking-water. Background document for development of WHO Guidelines for drinking-water quality. Geneva: World Health Organization (WHO/SDE/FWC/16.46).

- for “Chorus I, Bartram J, eds (1999) *Toxic cyanobacteria in water*” change the URL to: http://www.who.int/water_sanitation_health/publications/toxiccyanobact/en/
- Insert the following references below the “Chorus I, Bartram J, eds (1999)” reference:

EFSA (2014). Scientific opinion on the risks to public health related to the presence of perchlorate in food, in particular fruits and vegetables. EFSA J. 12(10):3869 (<http://www.efsa.europa.eu/en/efsajournal/pub/3869.htm>, accessed 7 January 2014).

- Delete the following reference:

FAO/WHO (1994) *Pesticide residues in food—1993 evaluations. Part II—Toxicology*. Geneva, World Health Organization, Joint FAO/WHO Meeting on Pesticide Residues (WHO/PCS/94.4).

Page 464

- Delete the following reference:

FAO/WHO (2002) *Evaluation of certain food additives. Fifty-ninth report of the Joint FAO/WHO Expert Committee on Food Additives*. Geneva, World Health Organization (WHO Technical Report Series, No. 913).

- Delete the following reference:

FAO/WHO (2003) Nitrate (and potential endogenous formation of N-nitrosos compounds). In: *Safety evaluation of certain food additives and contaminants*. Geneva, World Health Organization, Joint FAO/WHO Expert Committee on Food Additives (WHO Food Additives Series, No. 50).

- Insert the following reference below the “FAO/WHO (2011) *Evaluation of certain contaminants in food*” reference:

FAO/WHO (2011). Safety evaluation of certain contaminants in food. Prepared by the seventy-second meeting of the Joint FAO/WHO Expert Committee on Food Additives. Geneva: World Health Organization; 685–762 (WHO Food Additives Series 63; FAO JECFA Monographs 8).

Page 465

- At top of page, under “*Fluoride in drinking-water*”, change the URL to: http://www.who.int/water_sanitation_health/publications/fluoride-in-drinking-water/en/

- Insert the following reference below the “Fawell J et al. (2006)” reference:

Health Canada (2013). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Nitrate and nitrite. Ottawa (ON): Health Canada, Healthy Environments and Consumer Safety Branch, Water and Air Quality Bureau (http://hc-sc.gc.ca/ewh-semtpubs/water-eau/nitrate_nitrite/index-eng.php).

Page 466

- Delete the following reference:

Schmoll O et al. (2006) *Protecting groundwater for health: Managing the quality of drinking-water sources*. London, IWA Publishing on behalf of the World Health Organization (http://www.who.int/water_sanitation_health/publications/protecting_groundwater/en/).

- Insert the following reference after ISO (1982) (at bottom of page):

USEPA (2005). Toxicological review of barium and compounds (CAS No. 7440-39-3): in support of summary information on the Integrated Risk Information System (IRIS). Washington (DC): United States Environmental Protection Agency; (https://cfpub.epa.gov/ncea/iris/iris_documents/documents/toxreviews/0010tr.pdf).

Page 467

- Insert the following reference at the top of the page:

USNTP (1987). Toxicology and carcinogenesis studies of bromodichloromethane (CAS No. 75-27-4) in F344/N rats and B6C3F1 mice (gavage studies). Research Triangle Park (NC): United States Department of Health and Human Services, Public Health Service, National Toxicology Program (NTP TR 321).

- Insert the following references below the “WHO (2007)” reference:

WHO (2008). Acidified sodium chlorite. In: Safety evaluation of certain food additives and contaminants. Prepared by the sixty-eighth meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA). Geneva: World Health Organization; 3–54 (Food Additives Series, No. 59; http://whqlibdoc.who.int/publications/2008/9789241660594_eng.pdf?ua=1).

- WHO (2012). Pesticide residues in food – 2011 evaluations. Part II. Toxicological. Geneva: World Health Organization.
- WHO (2013). Pesticide residues in food – 2012 evaluations. Part II. Toxicological. Geneva: World Health Organization.
- WHO (2014). Pesticide residues in food – 2013 evaluations. Part II – Toxicological. Geneva: World Health Organization.

Changes to “Annex 3: Chemical summary tables”

Page 469

- For Bentazone, change the text in the second column to read as follows: “Occurs in drinking-water or drinking-water sources at concentrations well below those of health concern”

- Replace the “Chlorine dioxide” entry with the following:

Chlorine dioxide	Reduced primarily to chlorite, chlorate and chloride in drinking-water, and to chlorite and chloride upon ingestion; the provisional guideline values for chlorite and chlorate are protective for potential toxicity from chlorine dioxide
------------------	---

Page 470

- Insert the following below the “1,3-Dichloropropane” entry:

Dichlorvos	Occurs in drinking-water or drinking-water sources at concentrations well below those of health concern
Dicofol	Unlikely to occur in drinking-water or drinking-water sources ^b

- Replace the “Diquat” entry with the following:

Diquat	Occurs in drinking-water or drinking-water sources at concentrations well below those of health concern
--------	---

- Change the superscript “b” on “Glyphosate and AMPA” to superscript “c”

Page 471

- Replace the text in the first column next to “Manganese” with the following:

Not of health concern at levels normally causing acceptability problems in drinking-water. However, there are circumstances where manganese can remain in solution at higher concentrations in some acidic or anaerobic waters, particularly groundwater.

- Insert the following below the “Manganese” entry:

MCPA ^d		Occurs in drinking-water or drinking-water sources at concentrations well below those of health concern
-------------------	--	---

- Change the superscript “c” on pH / Not of health concern at levels found in drinking-water to superscript “e”

Page 472

- Insert a new footnote “b” as follows:

^b Although dicofol does not fulfil one of the three criteria for evaluation in the Guidelines, a background document has been prepared and a health-based value has been established, in response to a request from Member States for guidance.

- Change footnote “b” to footnote “c”

- Insert a new footnote “d”:

^d (2-Methyl-4-chlorophenoxy)acetic acid.

- Change footnote “c” to footnote “e”

Page 472

- Replace the “Barium” entry with the following:

Barium	1.3	1 300
--------	-----	-------

Page 474

- Delete the following row:

MCPA ^e	0.002	2
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- For the “Nitrate” entry, replace Short-term exposure with the following:

Based on short-term effects, but protective for long-term effects

- For the “Nitrite” entry, replace Short-term exposure with the following:

Based on short-term effects, but protective for long-term effects

- Insert the following below Pentachlorophenol:

Perchlorate	0.07	70
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- Change the superscript on 2,4,5-T from “f” to “e”

Page 475

- For the “Uranium” entry, replace 0.30 (P) with 0.03 (P)
- In the footnote, change the description associated with “D” to: provisional guideline value because effective disinfection may result in the guideline value being exceeded
- Delete footnote “e” below the table
- Change footnote “f” to footnote “e” below the table

Changes to “Annex 4: Analytical methods and achievability”

Page 480

- Insert the following after “Pentachlorophenol”:

	IC-SCD	LC-MS
Perchlorate	++	+++

Page 481

- Delete the following row:

MCPA	+++	+++	+
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Page 484

- Insert “IC-SCD Ion chromatography-suppressed conductivity detection” between “IC-FD” and “ICP”

Changes to “Annex 5: Treatment methods and performance”

Page 496

- Insert the following after “Pentachlorophenol”:

	Ion Exchange	Membranes	Biological Treatment
Perchlorate	Yes ^d	Yes ^d	Yes ^d

Page 498

- Delete the following row:

MCPA	+++ <0.0001	+++ <0.0001	yes ^d
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Changes to “Annex 6: Supporting information on radionuclides”

Page 505

➤ Change footnote ‘a’ under Table 6.1 to read as follows:

Guidance levels were rounded to the nearest order of magnitude by averaging the log scale values (to 10^n if the calculated value was below 3×10^n and to 10^{n+1} if the value was 3×10^n or above). For example, if the calculated value was 2 Bq/L (i.e. 2×10^0), the guidance level was rounded to 10^0 (i.e. = 1) whereas, if the calculated value was 3 Bq/L (i.e. 3×10^0 or above), the guidance level was rounded to 10^1 (i.e. = 10).

Changes to “Annex 7: Contributors to the development of the fourth edition of the *Guidelines for drinking-water quality*”

Page 509

- Change the title of Annex 7 to read as follows:

Annex 7: Contributors to the development of the *Guidelines for drinking-water quality*: fourth edition incorporating the first addendum

- Replace the first sentence of Annex 7 with the following:

This annex lists the names of those who have contributed to the development of the fourth edition of the *Guidelines for drinking-water quality* and to the first addendum to the fourth edition, through participation at relevant meetings, authorship or peer review of text in the Guidelines themselves or its supporting documents, or through provision of intellectual advice.

Pages 509–517

- On Page 509, change the URL to: <http://apps.who.int/iris/handle/10665/204411>
- Replace the list of contributors with the following:

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- Change the page header to read as follows:

ANNEX 7. CONTRIBUTORS TO FOURTH EDITION INCORPORATING FIRST ADDENDUM

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Page 515

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Page 517

- Change the page header to read as follows:

ANNEX 7. CONTRIBUTORS TO FOURTH EDITION INCORPORATING FIRST ADDENDUM

Changes to “Index”

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- Under “Page numbers in bold indicate main discussions” add:

This index has not been updated to reflect any new entries or changes that result from the incorporation of the first addendum into the fourth edition of the *Guidelines for Drinking-water Quality*.

Annex I. Summary of process for developing the Guidelines, and information on steering, guideline development and working groups, and other contributors

Methods used to develop the guideline

The publication *Policies and procedures used in updating the WHO guidelines for drinking-water quality*¹ guides the development of the Guidelines.

Updating of the guidance in the Guidelines is based on assessment of the highest quality scientific reviews as they become available, and of new reviews specifically commissioned as necessary by WHO.

For this addendum, existing high-quality literature reviews informed the chemical risk assessments and update of chemical guideline or health-based values.

Decision-making

The publication *Policies and procedure for updating the guidelines for drinking-water quality* is used by the GDG and working group (WG) experts as a formal guide to the process by which the guidelines are revised, how decisions are made, how data are interpreted and applied in establishing recommendations and guidance, and secretariat procedures associated with meetings.

Amendments to the Guidelines are agreed by consensus. Where a consensus cannot be achieved and the issue is not urgent, the amendments can be re-reviewed before publication in the second addendum.

Special provisions have been made for issues that are considered urgent but for which a consensus cannot be achieved. Decisions can be made based on a majority vote, where at least half the total members of the GDG plus one support the amendment. No urgent issues were addressed as part of the first addendum.

¹ http://www.who.int/water_sanitation_health/publications/guideline-policy-procedure/en/

Table A1: Members of the WHO Guidelines for drinking-water quality Steering Group

Name	Location	Department/unit	Role
Hamed Bakir	EMRO	Environmental Health Interventions Unit	Regional advisor, environmental health
Richard Brown	HQ	PHE/Chemical Safety	Ensure linkage with chemical risk assessment programmes (International Programme on Chemical Safety)
Jennifer De France	HQ	Department of Public Health, Environmental and Social Determinants of Health (PHE)/Water, Sanitation, Hygiene and Health	Management and coordination
Bruce Gordon	HQ	Department of Public Health, Environmental and Social Determinants of Health (PHE)/ Water, Sanitation, Hygiene and Health	Strategic and technical oversight
Payden	SEARO	Water, Sanitation and Health Unit	Regional advisor, environmental health
Maria Perez	HQ	Department of Public Health, Environmental and Social Determinants of Health (PHE)/Radiation Programme	Ensure linkage with radiation protection
Annette Pruss-Ustun	HQ	Department of Public Health, Environmental and Social Determinants of Health (PHE)/Assessment of Environmental Health Impacts	Ensure linkage with burden of diseases estimates
Oliver Schmoll	EURO	Water and Sanitation Unit	Regional advisor, environmental health
Jonathon Simon	HQ	Department of Maternal, Newborn, Child and Adolescent Health (MCA)/ MCA Research and Development Unit	Ensure linkage with waterborne infectious diseases (focus on childhood diarrhoea and interventions combined with WASH)
Philippe Verger	HQ	Department of Food Safety and Zoonosis (FOS)/ Risk Assessment and Management	Ensure linkage with chemical risk assessment programmes (FAO/WHO JECFA, JMPR)
Rajpal Yadav	HQ	Department of Control of Neglected Tropical Diseases/ Vector Ecology & Management	Ensure linkage with WHO Pesticide Evaluation Scheme (WHOPES)

Table A2: Members of the WHO Guidelines for drinking-water quality Guideline Development Group (GDG) and of the microbial and chemical working groups (WGs)

Name	Affiliation	Country of origin	Sex	WHO region	Area of expertise	GDG, WGs
Dr Samira Hamid Abdelrahman	University of Gezira	Sudan	F	EMRO	Health promotion	GDG, Protection & Control WG
Dr Mari Asami	National Institute of Public Health	Japan	F	WPRO	Naturally occurring contaminants; radiological	Chemical WG
Dr Ruth Bevan	IEH Consulting Ltd. (formerly of Cranfield University)	United Kingdom	F	EURO	Toxicology	GDG, Chemical WG
Mrs Joanne Brown	Environmental Radioactivity Consultancy (formerly of Public Health England)	United Kingdom	F	EURO	Radiological aspects	GDG
Mr Enrique Calderon	Buenos Aires University	Argentina	M	AMRO	Regulations	GDG, Protection & Control, Microbial WGs
Dr Ingrid Chorus	Umweltbundesamt (Federal Environment Agency)	Germany	F	EURO	Resource and source protection	GDG, Protection & Control, WG
Dr Joseph Cotruvo	Joseph Cotruvo and Associates	USA	M	AMRO	Materials and chemicals used in the production and distribution of drinking-water	Chemical WG
Dr David Cunliffe	South Australia Health	Australia	M	WPRO	Public Health; Bacteria	GDG (Chair), Microbial WG
Dr Lesley D'Anglada	US Environmental Protection Agency	USA	F	AMRO	Microbial indicators	GDG, Microbial WG
Dr Ana Maria de Roda Husman	National Institute of Public Health and the Environment	The Netherlands	F	EURO	Viruses	GDG, Microbial WG

Name	Affiliation	Country of origin	Sex	WHO region	Area of expertise	GDG, WGs
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Ms Michèle Giddings	Health Canada	Canada	F	AMRO	Disinfectants and DBPs	GDG, Chemical WG
Dr Akihiko Hirose	National Institutes of Health Sciences	Japan	M	WPRO	Industrial contaminants; Toxicology	GDG, Chemical WG
Dr Paul Hunter	University of East Anglia	United Kingdom	M	EURO	Environmental epidemiology/ Methodologist	GDG, Microbial WG, Protection & Control WG
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Dr Peter Marsden	Drinking Water Inspectorate	United Kingdom	M	EURO	Pesticides	GDG, Chemical WG
Dr Yoshihiko Matsui	Hokkaido University	Japan	M	WPRO	Water Treatment including treatment achievability	GDG, Chemical WG
Dr Gertjan Medema	Delft University of Technology / KWR Watercycle Research Institute	The Netherlands	M	EURO	Microbial Risk Assessment	Microbial WG
Dr Bette Meek	University of Ottawa	Canada	F	AMRO	Chemical mixtures, toxicology	Chemical WG

Name	Affiliation	Country of origin	Sex	WHO region	Area of expertise	GDG, WGs
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Prof Shane Snyder	University of Arizona	USA	M	AMRO	Materials and additive chemicals; Analytical aspects	GDG, Chemical WG, Protection & Control WG
Prof Mark Sobsey	University of North Carolina	USA	M	AMRO	Protozoa and parasites	GDG, Microbial WG

External peer and public reviewers

The key revisions for the first addendum are an update of some chemical guideline values; therefore, peer and public review was undertaken as part of the revision processes for the chemical background documents, following the procedures outlined in the *Policies and procedures for updating the guidelines for drinking-water quality*. These reviewers and others who contributed to the development of the first addendum to the fourth edition, through participation at relevant meetings, authorship or peer review of text in the Guidelines themselves or its supporting documents, or through provision of intellectual advice are listed below.

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Managing conflicts of interest and confidentiality

All members of the GDG and of the chemical and microbial working groups (WGs) completed WHO declaration of interest forms, which were reviewed by the secretariat for potential conflicts of interest (COI) (see Tables A4 and A5). A number of COI were declared, but none required any member of the GDG or WG to be excluded from their respective role.

Annex II. Summary of conflicts of interest management

Table A3. Summary of conflicts of interest (COI) management – members of the Guideline Development Group (GDG) and the microbial and chemical working groups (WGs)

Name	COI declared Yes or No	Details of conflicts	How managed	GDG, WG
Samira Hamid Abdelrahman	No	N/A	N/A	GDG, Protection & Control WG
Mari Asami	No	N/A	N/A	Chemical WG
Ruth Bevan	No	N/A	N/A	GDG, Chemical WG
Joanne Brown	Yes	Technical lead on radioactivity in drinking-water and remediation of drinking-water supplies in the event of a radiological incident within CRCE and PHE. Technical support to WHO on radiological aspects of drinking-water quality	Reviewed by WHO Secretariat: no action required	GDG
Enrique Calderon	No	N/A	N/A	GDG, Microbial WG, Protection & Control WG
Ingrid Chorus	Yes	Research grant from German Technical and Scientific Association for Gas and Water for investigating chemicals released into drinking water from plastic pipes.	Reviewed by WHO Secretariat: no action required	Protection & Control WG
Joseph Cotruvo	Yes	Personal consulting services to Coca Cola Ltd, American Chemistry Council and Liquitech.	Reviewed by WHO Secretariat: no action required	Chemical WG

GUIDELINES FOR DRINKING-WATER QUALITY: FIRST ADDENDUM TO THE FOURTH EDITION

Name	COI declared Yes or No	Details of conflicts	How managed	GDG, WG
David Cunliffe	Yes	Employed by a government agency that uses the WHO Guidelines as a reference Member of the PUB (Singapore) Expert Advisory Panel reviewing drinking-water quality with reference to the WHO Guidelines	Reviewed by WHO Secretariat: no action required	GDG, Microbial WG
Lesley D'Anglada	No	N/A	N/A	GDG, Microbial WG
Ana Maria de Roda Husman	No	N/A	N/A	GDG, Microbial WG
Alexander Eckhardt	No	N/A	N/A	Chemical WG
John Fawell	Yes	Provision of advice to Coca Cola Co until 2014 on water quality standards and on water safety planning. Provision of advice to Jersey and Guernsey Water on water quality and water safety planning Expert witness to Commission of Inquiry on lead in drinking-water for Government of Hong Kong. Government departments and building contractors	Reviewed by WHO Secretariat: no action required	GDG, Chemical WG
Michèle Giddings	Yes	Employer, Health Canada, contributes some travel-related expenses in order to attend these meetings.	Reviewed by WHO Secretariat: no action required	GDG, Chemical WG
Akihiko Hirose	No	N/A	N/A	GDG, Chemical WG
Paul Hunter	Yes	Honorarium in 2014 from Unilever for attending a workshop on wastewater re-use Accommodation and travel costs from Suez Environment, and from Danone to attend conferences. Various drinking-water related research grants including from EU 7 th Framework, Wellcome Trust, DEFRA, MRC, National Institute for Health Research	Reviewed by WHO Secretariat: no action required	GDG, Microbial WG, Protection & Control WG

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Pawan Kumar Labhassetwat	Yes	Various drinking-water related research grants including from WHO, PHED, NMCG, MoWR, WSSO, GOM Member of committee to prepare Uniform Drinking-water Quality Monitoring Protocol for India. Coordinator, Key Resource Centre (KRC) of Ministry of Drinking Water and Sanitation, Government of India for training of chemists and microbiologists on water quality monitoring	Reviewed by WHO Secretariat: no action required	GDG, Protection & Control WG
Karl Linden	No	President of the International Ultraviolet Association from 2013 to 2015 (identified by secretariat)	Reviewed by WHO Secretariat: no action required	GDG, Protection & Control WG
Peter Marsden	Yes	Employment at the United Kingdom Drinking Water Inspectorate	Reviewed by WHO Secretariat: no action required	GDG, Chemical WG
Yoshihiko Matsui	Yes	University of Hokkaido may cover airfares to attend WHO meetings.	Reviewed by WHO Secretariat: no action required	GDG, Chemical WG
Gertjan Medema	No	N/A	N/A	Microbial WG
Bette Meek	No	N/A	N/A	Chemical WG
Choon Nam Ong	No	N/A	N/A	GDG, Chemical WG
Edward Ohanian	No	N/A	N/A	Chemical WG
Santhini Ramasamy	No	N/A	N/A	GDG, Chemical WG

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Shane Snyder	Yes	<p>Expert Witness for DuPont in PFOA litigation</p> <p>Expert Panel member for water reuse for State of Texas via Allen Plummer Ass.</p> <p>Principal Investigator, WaterReuse Research Foundation</p> <p>Visiting Professor, National University of Singapore</p> <p>Identified equipment donated by Xylem Inc, Agilent Technologies and Trojan UV to University research programme</p>	<p>Reviewed by WHO</p> <p>Secretariat: no action required</p>	<p>GDG, Chemical WG, Protection & Control WG</p>
Mark Sobsey	Yes	<p>Founder and co-owner of a company that makes and sells a test to detect and quantify <i>E. coli</i> bacteria in drinking-water by a culture based, chromogenic MPN method. There is proprietary information associated with this culture test for <i>E. coli</i> in water.</p> <p>Principal investigator of a research grant from Unilever United Kingdom to the University of North Carolina for research on performance evaluation test conditions to disinfect water with free chlorine</p>	<p>Reviewed by WHO</p> <p>Secretariat: no action required</p>	<p>GDG, Microbial WG</p>



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