Guidelines for Drinking-water Quality

SECOND ADDENDUM TO THIRD EDITION

Volume 1
Recommendations

World Health Organization

Guidelines for Drinking-water Quality

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World Health Organization

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Contents

Preface

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. These have included health-oriented conferences such as the International Conference on Primary Health Care, held in Alma-Ata, Kazakhstan (former Soviet Union), in 1978. They have also included water-oriented conferences such as the 1977 World Water Conference in Mar del Plata, Argentina, which launched the water supply and sanitation decade of 1981–1990, as well as the Millennium Development Goals adopted by the General Assembly of the United Nations (UN) in 2000 and the outcome of the Johannesburg World Summit for Sustainable Development in 2002. Most recently, the UN General Assembly declared the period from 2005 to 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, since the reductions in adverse health effects and health care costs outweigh the costs of undertaking the interventions. This is true for major water supply infrastructure investments 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.

In 1983–1984 and in 1993–1997, the World Health Organization (WHO) published the first and second editions of the *Guidelines for Drinking-water Quality* in three volumes as successors to previous WHO International Standards. In 1995, the decision was made to pursue the further development of the Guidelines through a process of rolling revision. This led to the publication of addenda to the second edition of the Guidelines, on chemical and microbial aspects, in 1998, 1999 and 2002; the publication of a text on *Toxic Cyanobacteria in Water*; and the preparation of expert reviews on key issues preparatory to the development of a third edition of the Guidelines.

In 2000, a detailed plan of work was agreed upon for development of the third edition of the Guidelines. As with previous editions, this work was shared between WHO Headquarters and the WHO Regional Office for Europe (EURO). Leading the process of the development of the third edition were the Programme on Water, Sanitation and Health within Headquarters and the European Centre for Environment and Health, Rome, within EURO. Within WHO Headquarters, the Programme on Chemical Safety provided inputs on some chemical hazards, and the Programme on Radiological Safety contributed to the section dealing with radiological aspects. All six WHO Regional Offices participated in the process.

The revised Volume 1 of the Guidelines, published in 2004, is accompanied by a series of publications providing information on the assessment and management of risks associated with microbial hazards and by internationally peer-reviewed risk assessments for specific chemicals. These replace the corresponding parts of the previous Volume 2. Volume 3 provides guidance on good practice in surveillance, monitoring and assessment of drinking-water quality in community supplies. The Guidelines are also accompanied by other publications explaining the scientific basis of their development and providing guidance on good practice in implementation.

Volume 1 of the *Guidelines for Drinking-water Quality* explains requirements to ensure drinking-water safety, including minimum procedures and specific guideline values, and how those requirements are intended to be used. It also describes the approaches used in deriving the guidelines, including guideline values. It includes fact sheets on significant microbial and

chemical hazards. The development of the third edition of the *Guidelines for Drinking-water Quality* includes a substantive revision of approaches to ensuring microbial safety. This takes account of important developments in microbial risk assessment and its linkages to risk management. The development of this orientation and content was led over an extended period by Dr Arie Havelaar (RIVM, Netherlands) and Dr Jamie Bartram (WHO).

The contents of this second addendum to Volume 1 of the Guidelines amend and supersede the corresponding sections of Volume 1 of the Guidelines.

The third edition of these Guidelines, including these amendments, supersedes previous editions (1983–1984, 1993–1997 and addenda in 1998, 1999, 2002 and 2005) and previous International Standards (1958, 1963 and 1971). 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.

The *Guidelines for Drinking-water Quality* are kept up to date through a process of rolling revision, which leads to periodic release of documents that may add to or supersede information in this volume.

The Guidelines are addressed primarily to water and health regulators, policy-makers and their advisors, to assist in the development of national standards. 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.

Acknowledgements

The preparation of the third edition of the *Guidelines for Drinking-water Quality* and supporting documentation covered a period of more than 10 years and involved the participation of over 490 experts from 90 developing and developed countries. The contributions of all who participated in the preparation and finalization of the third edition and the two addenda to that edition – including those individuals listed in Annex 2 of the third edition and in Changes to "Annex 2" in the first and second addenda – are gratefully acknowledged.

The work of the following working group coordinators was crucial in the development of this second addendum to the third edition:

Dr I. Chorus, Federal Environment Agency, Germany (*Resource and source protection*)

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Dr D. Cunliffe, Environmental Health Service, Australia (*Public health aspects*)

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Mr J.K. Fawell, United Kingdom (*Naturally occurring and industrial contaminants*)

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Dr S. Kumar, University of Malaya, Malaysia (*Parasitological aspects*)

Dr J. Latorre Montero, Universidad del Valle, Colombia (*Microbial treatment*)

Professor Y. Magara, Hokkaido University, Japan (*Analytical achievability*)

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Dr E. Ohanian, Environmental Protection Agency, USA (*Disinfectants and disinfection by-products*)

Professor M. Sobsey, University of North Carolina, USA (*Risk management*)

Acronyms and abbreviations used in the second addendum

AAS	atomic absorption spectrometry
ADI	acceptable daily intake
ARfD	acute reference dose
CAS	Chemical Abstracts Service
cfu	colony-forming unit
DALY	disability-adjusted life-year
DDT	dichlorodiphenyltrichloroethane
DNA	deoxyribonucleic acid
ELISA	enzyme-linked immunosorbent assay
EURO	WHO Regional Office for Europe
FAAS	flame atomic absorption spectrometry
FAO	Food and Agriculture Organization of the United Nations
FD	fluorescence detector
GAC	granular activated carbon
GC	gas chromatography
HPLC	high-performance liquid chromatography
HWT	household water treatment
IARC	International Agency for Research on Cancer
IC	ion chromatography
ICP	inductively coupled plasma
JECFA	Joint FAO/WHO Expert Committee on Food Additives
JMPR	Joint FAO/WHO Meeting on Pesticide Residues
K_{ow}	octanol/water partition coefficient
LC	liquid chromatography
LOAEL	lowest-observed-adverse-effect level
LRV	$\log_{10}$ reduction value
MS	mass spectrometry
NDMA	*N*-nitrosodimethylamine
NOAEL	no-observed-adverse-effect level
NOEL	no-observed-effect level
PAC	powdered activated carbon
PAH	polynuclear aromatic hydrocarbon
PPA	protein phosphatase assay
PTWI	provisional tolerable weekly intake
RIVM	Rijksinstituut voor Volksgenzondheid en Milieu (Dutch National Institute of Public Health and Environmental Protection)
SODIS	solar water disinfection

SPADNS	sulfo phenyl azo dihydroxy naphthalene disulfonic acid
TDI	tolerable daily intake
THM	trihalomethane
UN	United Nations
USA	United States of America
UV	ultraviolet
UVPAD	ultraviolet photodiode array detector
WHO	World Health Organization
WSP	water safety plan

Changes to "Contents"

Page vi

➢ Insert the following below section 6.8.5:

6.9   Temporary water supplies
     6.9.1   Planning and design
     6.9.2   Operation and maintenance
     6.9.3   Monitoring, sanitary inspection and surveillance
6.10   Vended water
     6.10.1 System risk assessment
     6.10.2 Operational monitoring
     6.10.3 Management
     6.10.4 Surveillance
6.11   Rainwater harvesting
     6.11.1 Water quality and health risk
     6.11.2 System risk assessment
     6.11.3 Operational monitoring
     6.11.4 Verification
     6.11.5 Management
     6.11.6 Surveillance
6.12   Non-piped water supplies

➢ Replace section 7.3.2 with the following:

7.3.2   Central treatment

➢ Insert the following below section 7.3.2:

7.3.3   Household treatment

Page vii

➢ Insert the following below section 8.2.9:

8.2.10   Guidance values for use in emergencies

➢ Insert the following below section 8.4.13:

8.4.14   Household treatment

Page viii

➢ Insert the following below section 9.5.3:

9.5.4   Treatment and control methods and technical achievability

➢ Insert the following below section 11.1.5:

11.1.5(a)   *Enterobacter sakazakii*

➢ Insert the following below section 11.1.9:

11.1.9(a)   *Leptospira*

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➢ Insert the following below section 11.3.2:

11.3.2(a)   *Blastocystis*

➢ Insert the following below section 11.4.2:

11.4.2(a)   Free-living nematodes

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➢ Insert the following below section 12.17:

12.17(a)   Carbaryl

Page xii

➢ Insert the following below section 12.95:

12.95(a)   *N*-Nitrosodimethylamine (NDMA)

➢ Insert the following below section 12.108:

12.108(a) Sodium dichloroisocyanurate

➢ Insert the following below section 12.125:

12.126   Pesticides used for vector control in drinking-water sources and containers
          12.126.1   Diflubenzuron
          12.126.2   Methoprene
          12.126.3   Novaluron
          12.126.4   Pirimiphos-methyl
          12.126.5   Pyriproxyfen

Changes to "Preface"

Page xvii

➢ Replace the last sentence at the end of the second last paragraph with the following:

This version of the Guidelines integrates the third edition, which was published in 2004, with both the first addendum to the third edition, published in 2005, and the second addendum to the third edition, published in 2008.

Changes to "Acronyms and abbreviations used in text"

Page xx

➢ Insert below AMPA:

ARfD   acute reference dose

➢ Insert below CAS:

cfu   colony-forming unit

Page xxi

➢ Insert below HUS:

HWT   household water treatment

Page xxii

➢ Insert above LI:

LC   liquid chromatography

➢ Insert below LOAEL:

LRV $\log_{10}$ reduction value

➢ Insert below NAS:

NDMA   *N*-nitrosodimethylamine

➢ Insert below PMTDI:

PPA   protein phosphatase assay

Changes to "Chapter 1: Introduction"

Page 15

➢ Replace the last two paragraphs of section 1.2.7 with the following:

More detailed information on treatment of vended water, undertaking a risk assessment of vended water supplies, operational monitoring of control measures, management plans and independent surveillance is included in section 6.10.

Page 18

➢ Insert the following new paragraph at the end of section 1.2.10:

For more information on the essential roles of proper drinking-water system and waste system plumbing in public health, see the supporting document *Health Aspects of Plumbing* (section 1.3).

➢ Insert the following below the text on *Assessing Microbial Safety of Drinking Water*:

Calcium and Magnesium in Drinking-water: Public Health Significance
Many fresh waters are naturally low in minerals, and water softening and desalination technologies remove minerals from water. This monograph reviews the possible contribution of drinking-water to total daily intake of calcium and magnesium and examines the case that drinking-water could provide important health benefits, including reducing cardiovascular disease mortality (magnesium) and reducing osteoporosis (calcium), at least for many people whose dietary intake is deficient in either of those nutrients.

Page 19

➢ Insert the following below the text on *Hazard Characterization for Pathogens in Food and Water*:

Health Aspects of Plumbing
This publication describes the processes involved in the design, installation and maintenance of effective plumbing systems and recommends effective design and installation specifications as well as a model plumbing code of practice. It also examines microbial, chemical, physical and financial concerns associated with plumbing and outlines major risk management strategies that have been employed, as well as the importance of measures to conserve supplies of safe drinking-water.

➢ Insert the following below the text on *Heterotrophic Plate Counts and Drinking-water Safety*:

Legionella and the Prevention of Legionellosis
This book provides a comprehensive overview on the sources, ecology and laboratory detection of *Legionella* bacteria. Guidance is provided on risk assessment and risk management of susceptible environments. The necessary measures to prevent or adequately control the risk from exposure to *Legionella* are identified for each natural and

artificial aquatic environment where they are found. The policies and practices for outbreak management and the institutional roles and responsibilities of an outbreak control team are reviewed. This book will be useful to all those concerned with *Legionella* and health, including environmental and public health officers, health care workers, the travel industry, researchers and special interest groups.

➢ Insert the following below the text on *Pathogenic Mycobacteria in Water*:

Protecting Groundwater for Health: Managing the Quality of Drinking-water Sources
This monograph describes a structured approach to analysing hazards to groundwater quality, assessing the risk they may cause for a specific supply, setting priorities in addressing these hazards and developing management strategies for their control. The book presents tools for developing strategies to protect groundwater for health by managing the quality of drinking-water sources. For health professionals, it provides access to necessary environmental information; for professionals from other sectors, it gives a point of entry for understanding health aspects of groundwater management.

Page 20

➢ Under "Texts in preparation or in revision," delete the following:

Health Aspects of Plumbing (in preparation)
Legionella and the Prevention of Legionellosis (in finalization)
Protecting Groundwater for Health – Managing the Quality of Drinking-water Sources (in preparation)

➢ Under *Guide to Ship Sanitation*, insert the following:

Guidelines for the Microbiological Performance Evaluation of Point-of-Use Drinking-water Technologies (in preparation)

Changes to "Chapter 3: Health-based targets"

Page 47

➢ Insert the following after the first paragraph:

The reference level of tolerable disease burden or risk employed in these Guidelines may not be achievable or realistic in some locations and circumstances in the near term. Where the overall burden of disease from microbial, chemical or natural radiological exposures by multiple exposure routes (water, food, air, direct personal contact, etc.) is very high, setting a 10^{-6} DALY per person per year level of disease burden from waterborne exposure alone will have little impact on the overall disease burden; it is also not consistent with the public health objective of reducing overall levels of risk from all sources of exposure to environmental hazards (Prüss et al., 2002; Prüss & Corvalan, 2006). Setting a less stringent level of acceptable risk, such as 10^{-5} or 10^{-4} DALY per person per year, from waterborne exposure may be more realistic, yet still consistent with the goals of providing high-quality, safer water and encouraging incremental improvement of water quality.

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

Page 105

➢ Insert the following bullet below the bullet beginning "The treatment processes required for rapidly providing a sufficient quantity of potable water":

- *The availability of bottled or packaged water* – The provision of bottled or packaged water from a reliable source is often an effective way to quickly provide safe, potable water in emergencies and disasters. However, getting bottled or packaged water to the area and people in need may be a significant challenge. In such circumstances, one approach to providing bottled water is through the use of local small treatment plants. Care should be taken to protect bottled water from recontamination during its storage, distribution and use. See section 6.5 for further details on sources, safety and certification of packaged drinking-water.

Page 109

➢ Insert the following text at the end of section 6.2.5:

There are occasions when chemicals may be a threat to drinking-water for short periods following unusual circumstances, such as a spill of a chemical to a surface water source. Under these circumstances, guidance will be sought as to whether water is safe to drink or use for other domestic purposes, such as showering or bathing. These Guidelines can be used to support an initial evaluation of the situation, assuming that guidance is given on the chemical of concern. This is described in detail in section 8.6.5. It is important to seek specialist advice if the guideline value is exceeded by a significant amount or if the period for which it is exceeded is more than a few days. It is important to take local circumstances into account, including the availability of alternative water supplies and exposure to the contaminant from other sources, such as food. It is also important to consider what water treatment is available and whether this will reduce the concentration of the substance. For example, substances that are of low solubility in water and that tend to partition out of the water will tend to adsorb to particles and may be removed by treatment processes that are designed to remove particles, including coagulation, flocculation, filtration and adsorption by powdered (PAC) and granular activated carbon (GAC).

Short-term exposure guidance values are developed for key substances – for example, chemicals that are used in significant quantities and that may be more prone than others to be implicated in the contamination of a surface water source. The methods used to derive such guidance values are outlined in section 8.2.10.

Pages 109–111

➢ Replace section 6.3 with the following:

6.3 Safe drinking-water for travellers

The most common source of exposure to disease-causing organisms for travellers is ingestion of contaminated drinking-water and food. Diarrhoea is the most common symptom of waterborne infection, affecting 20–50% of all travellers or about 10 million people per year. Cases can occur even among people staying in high-quality resorts and hotels. In some parts

of the world, tap or bottled water that has not been produced under proper conditions may not be safe, even if it is clear and colourless.

No vaccine is capable of conferring general protection against infectious diarrhoea, which is caused by many different pathogens. It is important that travellers be aware of the possibility of illness and take appropriate steps to minimize the risks.

Preventive measures while living or travelling in areas with questionable drinking-water quality include the following:

- Drink only bottled water or other beverages (carbonated beverages, pasteurized juices and milk) provided in sealed tamper-proof containers and bottled/canned by known manufacturers (preferably certified by responsible authorities). Hotel personnel or local hosts are often good sources of information about which local brands are safe.
- Drink water that has been treated effectively at point of use (e.g., through boiling, filtration or chemical disinfection) and stored in clean containers.
- Drink hot beverages such as coffee and tea that are made with boiled water and are kept hot and stored in clean containers.
- Avoid brushing the teeth with unsafe water.
- Avoid consumption of homemade or unpasteurized juices and unpasteurized milk.
- Avoid ice unless it has been made from safe water.
- Avoid salads or other uncooked foods that may have been washed or prepared with unsafe water.

Water can be treated in small quantities by travellers to significantly improve its safety. Numerous simple treatment approaches and commercially available technologies are available to travellers to disinfect drinking-water for single-person or family use. Travellers should select a water treatment approach that removes or inactivates all classes of pathogens. Technologies should be certified by a credible organization, and manufacturer's instructions should be followed carefully.

Bringing water to a rolling boil is the simplest and most effective way to kill all disease-causing pathogens, even in turbid water and at high altitudes. The hot water should be allowed to cool without the addition of ice. If the water is turbid and needs to be clarified for aesthetic reasons, this should be done before boiling.

If it is not possible to boil water, chemical disinfection of clear, non-turbid water is effective for killing bacteria and most viruses and protozoa (but not, for example, *Cryptosporidium* oocysts). Certain chlorine- or iodine-based compounds are most widely used for disinfection of drinking-water by travellers. Silver is sometimes promoted as a disinfectant, but its efficacy is uncertain, and it requires lengthy contact periods. It is not recommended for treating contaminated drinking-water. Following chlorination or iodination, an activated carbon (charcoal) filter may be used to remove excess taste and odour from the water.

While iodine deficiency is a significant public health issue in many parts of the world, excess iodine may interfere with the functioning of the thyroid gland. Therefore, the use of iodine as a disinfectant is not recommended for infants, pregnant women, those with a history of thyroid disease and those with known hypersensitivity to iodine, unless treatment includes an effective post-disinfection iodine removal device, such as activated carbon. Travellers intending to use iodine treatment daily for all water consumed for more than 3–4 weeks should consult their physician beforehand and not use it in excessive amounts.

Suspended particles in water reduce the effectiveness of disinfectants. Turbid water (i.e., containing suspended particles) should be clarified or filtered before disinfection. Chemical

products that combine clarification (coagulation and flocculation to remove particles) with chlorine disinfection are available.

Portable point-of-use filtration devices tested and rated to remove protozoa and some bacteria are also available; ceramic, membrane (mainly reverse osmosis) and activated carbon block filters are the most common types. A pore size rating of 1 μm or less is recommended to ensure removal of *Cryptosporidium* oocysts. These filters may require a pre-filter to remove suspended particles in order to avoid clogging the final filter.

Unless water is boiled, a combination of techniques (e.g., clarification and/or filtration followed by chemical disinfection) is recommended. This combination provides a multiple treatment barrier that removes significant numbers of protozoa in addition to killing bacteria and viruses.

For people with weakened immune systems, pregnant women and infants, extra precautions are recommended to reduce the risk of infection from contaminated water. *Cryptosporidium*, for example, is a special danger. Boiling and storing water in a protected container are recommended, although internationally or nationally certified bottled or mineral water may also be acceptable.

The treatment methods described here will generally not reduce levels of most chemical contaminants in drinking-water, with the possible exception of carbon filtration and reverse osmosis. However, in most cases, levels of chemicals in drinking-water are not of health concern in the short term.

Further information on household water treatment of microbial and chemical contaminants of water can be found in sections 7.3.3 and 8.4.14, respectively.

Table 6.1 provides a summary of drinking-water disinfection methods that can be used by travellers.

Table 6.1 Drinking-water disinfection methods for use by travellers

Method	Recommendation	What it does	What it does *not* do
Boiling	• Bring water to a rolling boil and allow to cool	• Kills all pathogens	• Does not remove turbidity/cloudiness • Does not provide residual chemical disinfectant, such as chlorine, to protect against contamination

Method	Recommendation	What it does	What it does *not* do

Chlorine compounds:
 	
1. Unscented household bleach (sodium hypo-chlorite)
 	
2. Sodium dichloroiso-cyanurate tablet
 	
3. Calcium hypochlorite
	• For typical room temperature and water temperature of 25 °C, minimum contact time should be 30 min; increase contact time for colder water – e.g., double time for each 10 °C less than 25 °C
	
	• Prepare according to instructions
	
	• Should be added to clear water or after settling or clarification to be most effective
	
	• Type and typical dosage:
	  1. Household bleach (5%) – 4 drops per litre
	  2. Sodium dichloroiso-cyanurate – 1 tablet (per package directions)
	  3. Calcium hypochlorite (1% stock solution)[a] – 4 drops per litre
		• Effective for killing most bacteria and viruses
		
		• Longer contact time required to kill *Giardia* cysts, especially when water is cold
			• Not effective against *Cryptosporidium*; not as effective as iodine when using turbid water

Flocculant-chlorine tablet or sachet	• Dose per package directions	• Effective for killing or removing most waterborne pathogens (coagulant-flocculants partially remove *Cryptosporidium*)	• Flocculated water must be decanted into a clean container, preferably through a clean fabric filter

Iodine:
 	
1. Tincture of iodine (2% solution)
 	
2. Iodine (10% solution)
 	
3. Iodine tablet
 	
4. Iodinated (triiodide or pentaiodide) resin
	• 25 °C – minimum contact for 30 min; increase contact time for colder water
	
	• Prepare according to package instructions
	
	• Type and typical dosage:
	  1. Tincture of iodine (2% solution) – 5 drops per litre
	  2. Iodine (10% solution) – 8 drops per litre
	  3. Iodine tablet – 1 or 2 tablets per litre
	  4. Iodinated (triiodide or pentaiodide) resin – room temperature according to directions and stay within rated capacity
	
	• *Caution*: Not recommended for pregnant women, for people with thyroid problems or for more than a few months' time. For pregnant women who may be more sensitive, a carbon filter or other effective process should be used to remove excess iodine after iodine treatment.
		• Kills most pathogens
		
		• Longer contact time is required to kill *Giardia* cysts, especially when water is cold
		
		• Carbon filtration after an iodine resin will remove excess iodine from the water; replace the carbon filter regularly
			• Not effective against *Cryptosporidium*

Method	Recommendation	What it does	What it does *not* do
Portable filtering devices: 1. Ceramic filters 2. Carbon filters; some carbon block filters will remove *Cryptosporidium* – only if tested and certified for oocyst removal 3. Membrane filter (microfilter, ultra-filter, nanofilter and reverse osmosis) type devices	• Check pore size rating and reported removal efficiencies for different pathogens (viruses, bacteria and protozoa) provided by manufacturer and certified by a national or international certification agency. Filter media pore size must be rated at 1 μm (absolute) or less. Note that water must be clear to prevent clogging of pores. • Filtration or settling of turbid water to clarify it is recommended before disinfection with chlorine or iodine if water is not boiled	• 1 μm or less filter pore size will remove *Giardia*, *Cryptosporidium* and other protozoa • Approved reverse osmosis device can remove almost all pathogens • Some filters include a chemical disin-fectant such as iodine or chlorine to kill microbes; check for manufacturer's claim and docu-mentation from an independent national or inter-national certification agency	• Most bacteria and viruses will not be removed by filters with a pore size larger than 1 μm • Microfilters may not remove viruses, especially from clear waters; additional treatment such as chemical disinfection or boiling/pasteurization may be needed to reduce viruses • Most carbon block filters do not remove pathogens, other than possibly protozoa, even if carbon is impregnated with silver, because pore size is too large (>1 μm)

a   To make a 1% stock solution of calcium hypochlorite, add (to 1 litre of water) 28 g if chlorine content is 35%, 15.4 g if chlorine content is 65% or 14.3 g if chlorine content is 70%.

Page 114

➢ Insert the following new paragraph above section 6.5.2:

Ozone is sometimes used as an oxidant before bottling to prevent precipitation of iron and manganese, including natural mineral water. Where the water contains naturally occurring bromide, this can lead to the formation of high levels of bromate unless care is taken to minimize its formation. When ozone is used after the addition of the minerals to demineralized water, the presence of bromide in the additives may also lead to the formation of bromate.

Page 120

➢ Insert the following below section 6.8.5:

6.9 Temporary water supplies
Temporary water supply systems may transmit disease unless they are properly designed and managed. "Temporary water supplies" in these Guidelines refers to water supplies for planned seasonal or time-limited events (e.g., festivals, markets and summer camps). Water supplies for holiday towns are not covered because they are not truly "temporary" supplies, although substantial seasonal variations in demand will bring specific problems.

A systematic approach to drinking-water safety is needed for temporary water supplies, as for permanent ones. Chapter 4 (Water safety plans), along with sections 6.2 (Emergencies and disasters) and 6.3 (Safe drinking-water for travellers), also provide useful information. It is also important to ensure that adequate water supplies are available.

A temporary water supply may be independent – i.e., not connected with any other water supply system and with its own facilities from source to taps; or dependent – i.e., receiving treated water from an existing water supply system but with independent distribution

facilities. The risk of drinking-water contamination is usually lower in dependent systems, if there is access to the technologies, expertise and management of the permanent system.

For temporary water supplies, a contract is often made between the organizer of an event (e.g., a festival) and a water supply entity. The most important issues that should be included in such a contract are water quantity supplied by the entity, the roles and responsibilities of each party (i.e., the event organizer and the entity) in water quality management, and the locations and frequency of water quality monitoring. Coordination among an event organizer, a water supply entity and the relevant health authority is also very important for ensuring drinking-water safety. It is recommended that sanitary inspection and surveillance by a health authority be included in the contract.

6.9.1 Planning and design

Temporary water supply systems can vary in terms of their scale, period of operation, water use, time-dependent water demand and dependence on an existing permanent water supply system. These factors should be taken into consideration during the planning and design stages. In the case of an independent system, adequate consideration should be given to the selection of a water source and treatment processes. The plan and design of a temporary water supply system should be agreed with the appropriate local authority before construction begins.

A temporary water supply system should be planned and designed so as to meet potentially large and frequent fluctuations in water demand without compromising water quality (e.g., intrusion of contaminated water from outside the system in response to a pressure drop). To this end, distribution reservoirs and booster pumps with adequate capacities should be installed. Where a temporary system is directly connected to a mains water supply, it is important to prevent the accidental contamination of the mains water supply through backflow during construction and operation of the temporary system. If necessary, drinking-water supply can be increased through the use of mobile tanker trucks or the provision of bottled water.

Water consumption for fire-fighting, hand-washing and toilet flushing should be taken into account in estimating total water demand where there are no other water sources available for such a purpose.

Water quality targets for temporary supplies should be the same as those for permanent water supplies. Disinfection should be considered indispensable in a temporary supply, and it is preferable to maintain a certain level of disinfectant residual (e.g., chlorine residual) at service taps. If the supply is not for potable uses, then appropriate action should be taken to ensure that it is not taken for drinking.

If a temporary water supply is used recurringly, it is essential to fully flush the entire system with water containing a disinfectant residual before the start of operation. When planning installation on site, positioning of pipes, hoses and particularly connections should take risks of contamination into account – for example, avoiding the placement of hosing and fittings on the ground near sites of potential faecal contamination or storage tanks in direct sunlight where rising temperatures support microbial growth. It is also important to ensure that the facility has no defects, including leakage, that could cause the deterioration of water quality and that water quality at every service tap satisfies the required quality target. Important control measures during dismantling and transport of installations include emptying hoses, preferably drying them and storing them so that ingress of contamination is avoided.

Care should be taken in planning and designing wastewater management and disposal facilities, particularly to ensure that lavatories and disposal facilities are located so as to avoid any risk of adversely affecting source water quality. The source, treatment facilities and

distribution reservoirs should also be well protected from access by humans and animals (e.g., bird faeces) by covers or roofs.

6.9.2 Operation and maintenance

A temporary system is usually more vulnerable to accidental and deliberate contamination than an existing permanent water supply system; therefore, attention needs to be paid to security, ensuring the primary importance of adequate disinfection and other protective measures. To this end, an operation and maintenance manual should be prepared before the temporary water supply system begins operation. All water treatment facilities should be thoroughly inspected at least every day.

Signboards should be installed beside each service tap with instructions on the purposes for which the water can and cannot be used, along with additional instructions when warranted – for example, on hand-washing before preparing foods and beverages. Suitable signs should be installed around water sources indicating requirements for source water protection, including protection from animal and human faeces. Humans should be required to use proper sanitary facilities.

6.9.3 Monitoring, sanitary inspection and surveillance

Water quality and appearance should be routinely monitored at the service tap of a temporary water supply system. It is recommended that, at the very least, water temperature and disinfectant residual should be monitored every day as simple rapid tests that act as indicators of possible problems. Other basic parameters that should be regularly monitored include pH, conductivity, turbidity, colour and *E. coli* (or, alternatively, thermotolerant coliforms), as in an ordinary permanent water supply. Routine sanitary inspection of a temporary water supply by the appropriate health authority is very important. If any problem related to water quality arises, remedial actions should be taken promptly. If a temporary water supply system is to be used for a period of more than several weeks, regular surveillance by the appropriate health authority should be implemented.

6.10 Vended water

Vended water is common in many parts of the world where scarcity of supplies or lack of infrastructure limits access to suitable quantities of safe drinking-water. Although water vending is more common in developing countries, it also occurs in developed countries.

In the context of these Guidelines, water vending implies private vending of drinking-water (e.g., sold from kiosks, standpipes or tanker trucks, or delivered to households), not including bottled or packaged water (which is considered in section 6.5) or water sold through vending machines.

Water vending may be undertaken by formal bodies, such as water utilities or registered associations, by contracted suppliers or by informal and independent suppliers. Where formal vending is practised, the water typically comes from treated utility supplies or registered sources and is supplied in tankers or from standpipes and water kiosks. Informal suppliers tend to use a range of sources – protected as well as unprotected, including untreated surface water, dug wells and boreholes – and deliver small volumes for domestic use, often in containers loaded into donkey carts, hand carts or tanker trucks.

Both the quality and adequacy of vended supplies can vary. Vended water has been associated with outbreaks of diarrhoeal disease (Hutin et al., 2003). Water supplied to users should be suitable for drinking and comply with national or regional guidelines and regulatory requirements. The chemical and microbial quality of untreated or private sources of water should be tested to determine their suitability for use and to identify appropriate control measures, including treatment requirements. Surface water and some dug well and

borehole waters are not suitable for drinking unless subject to treatment. Disinfection is the minimum requirement, and filtration, with or without coagulation, is often required when surface water is used.

In many developing countries, consumers purchase water from kiosks and then carry the water home. Water can be transported in a variety of ways, including containers on wheelbarrows, trolleys and animal-drawn or mechanized carts. Measures should be taken to protect vended water from contamination during transport as well as storage in the home. These include transporting and storing water in enclosed containers or containers with narrow openings, ideally fitted with a dispensing device such as a spigot that prevents hand access and other sources of extraneous contamination. Good hygiene is required and should be supported by educational programmes.

In other cases, particularly in developed countries, vendors transport and deliver the water to users in tanker trucks. If large volumes are being transported in water tankers, chlorine should be added to provide a free residual chlorine concentration of at least 0.5 mg/litre at the point of delivery to users. Tankers should also be used solely for water or, if this is not possible, should be thoroughly cleaned prior to use to ensure that there is no residual contamination.

All components of systems associated with supplying and delivering vended water need to be designed and operated in a manner that protects water quality. This includes ensuring that water storages, pipework and fittings do not include defects such as structural faults that allow leakage and permit the entry of contaminants. Cleanliness of storages, standpipes, taps and hoses needs to be maintained. Hoses used to transfer water at kiosks or used on carts and tanker trucks should be protected from contamination by avoiding contact of openings with the ground. Hoses should be drained when not in use. The area around standpipes should include drainage or be constructed in a manner to prevent pooling of water. Materials used in all components, including pipework, storages, hoses and containers, need to be suitable for use in contact with drinking-water and should not result in contamination of the water with hazardous compounds or with compounds that could adversely affect the taste of the water.

All components of water vending, including sources, methods of abstraction and transport, should be incorporated within WSPs. Where vendors are registered or have a contract with a water utility, implementation and operation of the WSP should be regularly checked by the utility. WSPs and the operation of water vendors should also be subject to independent surveillance.

6.10.1 System risk assessment

In undertaking a risk assessment of vended water supplies, a range of issues should be considered, including:

— the nature and quality of source water. Sources can include surface water, dug wells, boreholes or standpipes associated with piped water supplies. The quality of these sources should be assessed and the likelihood of contamination determined.

— control measures, including protection of source waters and treatment. Where untreated sources are used, they should be protected from human and animal excreta and domestic, industrial and agricultural chemicals.

— mechanisms for abstraction and storage, including hoses, hydrants and pipework. Water should be abstracted and delivered in a manner that protects water quality and does not permit entry of contamination. Materials should be suitable for use with drinking-water. Where mains water is used, backflow prevention will ensure that abstraction does not lead to ingress of contamination.

— design and characteristics of containers used to transport and deliver water. Containers should be dedicated to transport of drinking-water and made of suitable material for contact with drinking-water. Containers should be enclosed and designed to prevent entry of contaminants.

6.10.2 Operational monitoring

Vendors have a responsibility to ensure that control measures operate effectively. Operational monitoring of control measures could include:

— sanitary surveys of source water, abstraction devices and hoses for protection from external sources of contamination;
— integrity, cleanliness and maintenance of equipment and devices such as hydrants, standpipes, backflow preventers, storages, hoses, containers and bulk water tankers;
— appropriate use of equipment, such as avoiding contact of hose outlets with the ground and draining of hoses when not in use;
— disinfectant residuals and pH;
— performance and maintenance of filters;
— integrity, cleanliness and maintenance of containers and tankers;
— chlorine residuals at point of delivery.

6.10.3 Management

Management plans should document system assessment and operational monitoring requirements associated with abstraction, transport and delivery of water. Procedures associated with performing and monitoring these tasks need to be included. For example, procedures for cleaning and disinfection of hydrants, hoses and bulk water tankers should be documented.

Supporting programmes should also be documented, including personal hygiene requirements associated with water vending and education and training programmes to support water hygiene in homes.

Volumes of vended water and customer details should be recorded.

6.10.4 Surveillance

Independent surveillance is an important element of ensuring that vended drinking-water is safe. One of the barriers to effective surveillance can be a lack of records and documentation identifying water vendors. Implementation of registration systems should be considered.

Surveillance should include:

— direct assessment of water quality;
— review of WSPs and auditing of implementation;
— sanitary surveys of source waters, abstraction and delivery systems;
— responding to, investigating and providing advice on receipt of reports of significant incidents.

Surveillance should include an assessment of household storage practices and the effectiveness of hygiene education programmes. Where consumers carry vended water home, hygienic practices associated with the collection and transport of water should be assessed.

6.11 Rainwater harvesting

6.11.1 Water quality and health risk

Rainwater is relatively free from impurities, except those picked up by the rain from the atmosphere. However, the quality of rainwater may deteriorate during harvesting, storage and household use. Wind-blown dirt, leaves, faecal droppings from birds and other animals, insects and contaminated litter on the catchment areas and in cisterns can be sources of contamination of rainwater, leading to health risks from the consumption of contaminated water from storage tanks. Poor hygiene in water storage and water abstraction from tanks or at the point of use can also represent a health concern. However, risks from these hazards can be minimized by good design and practice. Well designed rainwater harvesting systems with clean catchments, covered cisterns and storage tanks, and treatment, as appropriate, supported by good hygiene at point of use, can offer drinking-water with very low health risk. In contrast, a poorly designed and managed system can pose high health risks.

Microbial contamination of collected rainwater, indicated by *E. coli* (or, alternatively, thermotolerant coliforms), is quite common, particularly in samples collected shortly after rainfall. Pathogens such as *Cryptosporidium*, *Giardia*, *Campylobacter*, *Vibrio*, *Salmonella*, *Shigella* and *Pseudomonas* have also been detected in collected rainwater. However, the occurrence of pathogens is generally lower in rainwater than in unprotected surface waters, and the presence of non-bacterial pathogens, in particular, can be minimized. Higher microbial concentrations are generally found in the first flush of rainwater, and the level of contamination decreases as the rain continues. A significant reduction of microbial contamination can be found in rainy seasons when catchments are frequently washed with fresh rainwater. Storage tanks can present breeding sites for mosquitoes, including species that transmit dengue virus (see section 8.5.5).

Rainwater is slightly acidic and very low in dissolved minerals; as such, it is relatively aggressive and can dissolve metals and other impurities from materials of the catchment and storage tank. In most cases, chemical concentrations in rainwater are within acceptable limits; however, elevated levels of zinc and lead have sometimes been reported. This could be from leaching from metallic roofs and storage tanks or from atmospheric pollution.

Rainwater lacks minerals, but some minerals in appropriate concentrations are essential for health, such as calcium, magnesium, iron and fluoride. Although most essential nutrients are derived from food, the lack of minerals, including calcium and magnesium, in rainwater may represent a concern for those on a mineral-deficient diet (see the supporting document *Calcium and Magnesium in Drinking-water*; section 1.3). In this circumstance, the implications of using rainwater as the primary source of drinking-water should be considered. The absence of minerals also means that rainwater has a particular taste or lack of taste that may not be acceptable to people used to drinking other mineral-rich natural waters.

Water quality should be managed through the development and application of WSPs that deal with all components of the rainwater harvesting system, from catchment areas to point of supply.

6.11.2 System risk assessment

Important factors in collecting and maintaining good-quality rainwater include proper design and installation or construction of rainwater harvesting systems. Materials used in the catchment and storage tank should be specifically suitable and approved for use in contact with drinking-water and should be non-toxic to humans.

Rainwater can be harvested using roof and other above-ground catchments and stored in tanks for use. The roof catchment is connected with a gutter and down-pipe system to deliver rainwater to the storage tank. The quality of rainwater is directly related to the cleanliness of

catchments, gutters and storage tanks. Rooftop catchment surfaces may collect dust, organic matter, leaves, and bird and animal droppings, which can contaminate the stored water and cause sediment buildup in the tank. Care should also be taken to avoid materials or coatings that may cause adverse taste or odour. Most solid roof materials are suitable for collecting rainwater. However, roofs coated with bitumen-based coatings are generally not recommended, as they may leach hazardous substances or cause taste problems. Similarly, metals can leach from some roofs, resulting in high metal concentrations in the water. Care should be taken to ensure that lead-based paints are not used on roof catchments. Thatched roofs can cause discoloration or deposition of particles in collected water. Regular cleaning of catchment surfaces and gutters should be undertaken to minimize the accumulation of debris. Wire meshes or inlet filters should be placed over the top of down-pipes to prevent leaves and other debris from entering storages. These meshes and filters should be cleaned regularly to prevent clogging.

The first flush of rainwater carries most contaminants into storages. A system to divert the contaminated first flow of rainwater from roof surfaces is therefore necessary. Automatic devices that prevent the first flush of runoff from being collected in storages are recommended. If diverters are not available, a detachable down-pipe can be used manually to provide the same result. Even with these measures in place, storages will require periodic cleaning to remove sediment.

Storages without covers or with unprotected openings will encourage mosquito breeding, and sunlight reaching the water will promote algal growth. Covers should be fitted, and openings need to be protected by mosquito-proof mesh. Cracks in the tank and water withdrawal using contaminated pots can contaminate stored water. Storages should preferably be fitted with a mechanism such as a tap or outlet pipe that enables hygienic abstraction of water. Some households incorporate cartridge filters or other treatments at the point of consumption to ensure better quality of drinking-water and reduce health risk. Solar water disinfection or point-of-use chlorination are examples of low-cost disinfection options for the treatment of stored rainwater. These and other household water treatment technologies are discussed in more detail in sections 7.3.3 (microbial) and 8.4.14 (chemical).

6.11.3 Operational monitoring

Sanitary inspections should be a focus of operational monitoring. These should include checking the cleanliness of the catchment area and storage, the structural integrity of the system and the physical quality of the rainwater (turbidity, colour and smell). The pH level should be monitored frequently where new concrete, ferrocement or masonry storage tanks are being used, as leaching of carbonates will produce water with high pH.

6.11.4 Verification

The microbial quality of rainwater needs to be monitored as part of verification. Rainwater, like all water supplies, should be tested for *E. coli* or thermotolerant coliforms. The levels of lead, zinc or other heavy metals in rainwater should also be measured occasionally if the water is in contact with metallic surfaces during collection or storage.

6.11.5 Management

Management plans should document all procedures applied during normal operation as well as actions to be taken in the event of failures. Remedial actions will generally involve physical repair of faults and cleaning of catchment areas, filters or storage systems. Disinfection of rainwater should be practised when microbial contamination is detected or sanitary inspections indicate a likelihood of contamination.

6.11.6 Surveillance

Independent surveillance is desirable for ensuring the quality, safety and acceptability of water supply based on rainwater. Apart from verification of compliance, the principal focus of surveillance should be towards the evaluation of hygienic practices in collection, storage and use of rainwater in order to develop and refine requirements for improving water safety through a WSP.

6.12 Non-piped water supplies

Non-piped water supplies, such as roof catchments (rainwater harvesting), surface waters and water collected from wells or springs, can apply the same health risk-based framework of these Guidelines as is applied to piped water supplies, including use of health-based targets, use of the highest-quality water source, treatment appropriate to source water quality to achieve a tolerable level of risk, and protection of water during storage, distribution or handling. Determination of water quality is recommended in order to best implement WSPs based on this framework.

Management of non-piped water supplies at the household level is often focused on achieving microbially safe water, as waterborne pathogens are a ubiquitous global risk. Methods for the treatment of microbial contaminants at the household level are described in section 7.3.3.

Some non-piped household water supplies uniquely pose risks of chemical and radiological contamination, from chemicals such as arsenic and fluoride and radiological contaminants such as radon, especially in certain groundwater sources. Risks of excessive chemical and radiological contamination must be considered and appropriate actions taken to avoid the use of such sources or to apply effective treatment that reduces risks from these sources to tolerable levels. Methods for treatment of chemical and radiological contaminants at the household or other local level at point of use are described in section 8.4.14.

Changes to "Chapter 7: Microbial aspects"

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> ➤ Replace Table 7.1 with the following table:

Table 7.1 Waterborne pathogens and their significance in water supplies[a]

Pathogen	Health significance[b]	Persistence in water supplies[c]	Resistance to chlorine[d]	Relative infectivity[e]	Important animal source
Bacteria					
Burkholderia pseudomallei	High	May multiply	Low	Low	No
Campylobacter jejuni, C. coli	High	Moderate	Low	Moderate	Yes
Escherichia coli – Pathogenic[f]	High	Moderate	Low	Low	Yes
E. coli – Enterohaemorrhagic	High	Moderate	Low	High	Yes
Legionella spp.	High	May multiply	Low	Moderate	No
Non-tuberculous mycobacteria	Low	May multiply	High	Low	No
Pseudomonas aeruginosa[g]	Moderate	May multiply	Moderate	Low	No
Salmonella typhi	High	Moderate	Low	Low	No
Other salmonellae	High	May multiply	Low	Low	Yes
Shigella spp.	High	Short	Low	High	No
Vibrio cholerae	High	Short to long[h]	Low	Low	No
Yersinia enterocolitica	Moderate	Long	Low	Low	Yes
Viruses					
Adenoviruses	Moderate	Long	Moderate	High	No
Enteroviruses	High	Long	Moderate	High	No
Astroviruses	Moderate	Long	Moderate	High	No
Hepatitis A virus	High	Long	Moderate	High	No
Hepatitis E virus	High	Long	Moderate	High	Potentially
Noroviruses	High	Long	Moderate	High	Potentially
Sapoviruses	High	Long	Moderate	High	Potentially
Rotavirus	High	Long	Moderate	High	No
Protozoa					
Acanthamoeba spp.	High	May multiply	Low	High	No
Cryptosporidium parvum	High	Long	High	High	Yes
Cyclospora cayetanensis	High	Long	High	High	No
Entamoeba histolytica	High	Moderate	High	High	No
Giardia intestinalis	High	Moderate	High	High	Yes
Naegleria fowleri	High	May multiply[i]	Low	Moderate	No
Toxoplasma gondii	High	Long	High	High	Yes
Helminths					
Dracunculus medinensis	High	Moderate	Moderate	High	No
Schistosoma spp.	High	Short	Moderate	High	Yes

Note: Waterborne transmission of the pathogens listed has been confirmed by epidemiological studies and case histories. Part of the demonstration of pathogenicity involves reproducing the disease in suitable hosts. Experimental studies in which volunteers are exposed to known numbers of pathogens provide relative information. As most studies are done with healthy adult volunteers, such data are applicable to only a part of the exposed population, and extrapolation to more sensitive groups is an issue that remains to be studied in more detail.

[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] Health significance relates to the severity of impact, including association with outbreaks.

[c] 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.

[d] When the infective stage is freely suspended in water treated at conventional doses and contact times and pH between 7 and 8. Low means 99% inactivation at 20 °C generally in <1 min, moderate 1–30 min and high >30 min. It should be noted that organisms that survive and grow in biofilms, such as *Legionella* and mycobacteria, will be protected from chlorination.

[e] From experiments with human volunteers, from epidemiological evidence and from animal studies. High means infective doses can be $1–10^2$ organisms or particles, moderate $10^2–10^4$ and low $>10^4$.

[f] Includes enteropathogenic, enterotoxigenic and enteroinvasive.

[g] Main route of infection is by skin contact, but can infect immunosuppressed or cancer patients orally.

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

[i] In warm water.

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➢ Replace "7.3.2 Treatment" with "7.3.2 Central treatment".

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➢ Replace the last two paragraphs of section 7.3.2, beginning "Non-piped water supplies", with the following:

Further information about these water treatment processes, their operations and their performance for pathogen reduction in piped water supplies is provided in more detail in the supporting document *Water Treatment and Pathogen Control* (see section 1.3).

7.3.3 Household treatment

Non-piped water supplies, such as roof catchments (rainwater harvesting), surface waters and water collected from wells or springs, may often be contaminated with pathogens. Such sources often require treatment and protected storage to achieve safe water. Many of the processes used for water treatment in households are the same as those used for community-managed and other piped water supplies (see section 7.3.2). However, there are additional water treatment technologies recommended for use in non-piped water supplies at the household level that typically are not used for piped supplies.

Household water treatment (HWT) technologies are any of a range of devices or methods employed for the purposes of treating water in the home or at the point of use in other settings. These are also known as point-of-use or point-of-entry water treatment technologies (Cotruvo & Sobsey, 2006; Nath et al., 2006; see also the supporting document *Managing Water in the Home*, section 1.3). HWT technologies comprise a range of options that enable individuals and communities to treat collected water or contaminated piped water to remove or inactivate microbial pathogens. Many of these methods are coupled with safe storage of the treated water to preclude or minimize contamination after household treatment (Wright et al., 2003).

HWT and safe storage have been shown to significantly improve water quality and reduce waterborne infectious disease risks (Fewtrell & Colford, 2004; Clasen et al., 2006; http://www.who.int/household_water/en/). HWT technology has the potential to have rapid and significant positive health impacts in situations where piped water systems are not possible and where people rely on source water that may be contaminated, or where stored water becomes contaminated because of unhygienic handling during transport or in the home. HWT technologies can also be used to overcome the widespread problem of microbially

unsafe piped water supplies. Similar small technologies can also be used by travellers in areas where the drinking-water quality is uncertain (see also section 6.3).

Not all HWT technologies are highly effective in reducing all classes of waterborne pathogens (bacteria, viruses and protozoa). For example, chlorine is ineffective for inactivating oocysts of the waterborne protozoan *Cryptosporidium parvum*, whereas some filtration methods, such as ceramic and cloth or fibre filters, are ineffective in removing enteric viruses. Therefore, careful consideration of the health-based target microbes to control in a drinking-water source is needed when choosing among these technologies.

Definitions and descriptions of the various HWT technologies for microbial contamination follow:

- *Chemical disinfection*: Chemical disinfection of drinking-water includes any chlorine-based technology, including chlorine dioxide, as well as ozone, some other oxidants and some strong acids and bases. Chemical disinfection is most widely done with technologies using free chlorine (hypochlorous acid) and, to lesser extents, di- and trichlorocyanurates of free chlorine, chloramines, chlorine dioxide or other forms of chlorine oxidants. Except for ozone, proper dosing of these disinfectants provides the additional benefit of leaving a residual in the water that provides some protection against post-treatment contamination during storage. Disinfection of household drinking-water in developing countries is done primarily with free chlorine, commonly available as chlorine bleach. This is because it is inexpensive, effective, widely available and used globally, and easy to dose. Disinfection of drinking-water with iodine, which is also a strong oxidant, is generally not recommended for extended use unless the residual concentrations are controlled, because of concerns about adverse effects of excess intake on the thyroid gland; however, this issue is being re-examined, because dietary iodine deficiency is a serious health problem in many parts of the world (see also section 6.3 and Table 6.1). Ozone is not recommended for household water treatment because of the need for a reliable source of electricity to generate it, its complexity of generation and proper dosing in a small application, and its relatively high cost. Strong acids or bases are not recommended as chemical disinfectants for drinking-water, as they are hazardous chemicals that can alter the pH of the water to dangerously low or high levels. However, as an emergency or short-term intervention, the juices of some citrus fruits, such as limes and lemons, can be added to water to inactivate *Vibrio cholerae*, if enough is added to sufficiently lower the pH of the water (probably to pH less than 4.5).

- *Membrane, porous ceramic or composite filters*: These are filters with defined pore sizes and include carbon block filters, porous ceramics containing colloidal silver, reactive membranes, polymeric membranes and fibre/cloth filters. They rely on physical straining through a single porous surface or multiple surfaces having structured pores to physically remove and retain microbes by size exclusion. Some of these filters may also employ chemical antimicrobial or bacteriostatic surfaces or chemical modifications to cause microbes to become adsorbed to filter media surfaces, to be inactivated or at least to not multiply. Cloth filters, such as those of sari cloth, have been recommended for reducing *Vibrio cholerae* in water. However, these filters reduce only vibrios associated with copepods, other large crustaceans or other large eukaryotes retained by the cloth. These cloths will not retain dispersed vibrios or other bacteria not associated with copepods, other crustaceans, suspended sediment or large eukaryotes, because the pores of the cloth fabric are much larger than the bacteria, allowing them to pass through. Most household filter technologies operate by gravity flow or by water pressure provided from a piped

supply. However, some forms of ultrafiltration, nanofiltration and reverse osmosis filtration may require a reliable supply of electricity to operate.

- *Granular media filters*: Granular media filters include those containing sand or diatomaceous earth or others using discrete particles as packed beds or layers of surfaces over or through which water is passed. These filters retain microbes by a combination of physical and chemical processes, including physical straining, sedimentation and adsorption. Some may also employ chemically active antimicrobial or bacteriostatic surfaces or other chemical modifications. Other granular media filters are biologically active because they develop layers of microbes and their associated exopolymers on the surface of or within the granular medium matrix. This biologically active layer, called the *schmutzdecke* in conventional slow sand filters, retains microbes and often leads to their inactivation and biodegradation. A household-scale filter with a biologically active surface layer that can be dosed intermittently with water has been developed.

- *Solar disinfection*: There are a number of technologies using solar irradiation to disinfect water. Some use solar radiation to inactivate microbes in either dark or opaque containers by relying on heat from sunlight energy. Others, such as the SODIS system, use clear plastic containers penetrated by UV radiation from sunlight that rely on the combined action of the UV radiation, oxidative activity associated with dissolved oxygen and heat. Other physical forms of solar radiation exposure systems also employ combinations of these solar radiation effects in other types of containers, such as UV-penetrable plastic bags (e.g., the "solar puddle") and panels.

- *UV light technologies using lamps*: A number of drinking-water treatment technologies employ UV light radiation from UV lamps to inactivate microbes. For household- or small-scale water treatment, most employ low-pressure mercury arc lamps producing monochromatic UV radiation at a germicidal wavelength of 254 nm. Typically, these technologies allow water in a vessel or in flow-through reactors to be exposed to the UV radiation from the UV lamps at sufficient dose (fluence) to inactivate waterborne pathogens. These may have limited application in developing countries because of the need for a reliable supply of electricity, cost and maintenance requirements.

- *Thermal (heat) technologies*: Thermal technologies are those whose primary mechanism for the destruction of microbes in water is heat produced by burning fuel. These include boiling and heating to pasteurization temperatures (typically >63 °C for 30 min when applied to milk). The recommended procedure for water treatment is to raise the temperature so that a rolling boil is achieved, removing the water from the heat and allowing it to cool naturally, and then protecting it from post-treatment contamination during storage. The above-mentioned solar technologies using solar radiation for heat or for a combination of heat and UV radiation from sunlight are distinguished from this category.

- *Coagulation, precipitation and/or sedimentation*: Coagulation or precipitation is any device or method employing a natural or chemical coagulant or precipitant to coagulate or precipitate suspended particles, including microbes, to enhance their sedimentation. Sedimentation is any method for water treatment using the settling of suspended particles, including microbes, to remove them from the water. These methods may be used along with cloth or fibre media for a straining step to remove the floc (the large coagulated or precipitated particles that form in the water). This category includes simple

sedimentation, or that achieved without the use of a chemical coagulant. This method often employs a series of three pots or other water storage vessels in series, in which sedimented (settled) water is carefully transferred by decanting daily; by the third vessel, the water has been sequentially settled and stored a total of at least 2 days to reduce microbes.

- *Combination (multi-barrier) treatment approaches*: These are any of the above technologies used together, either simultaneously or sequentially, for water treatment, such as coagulation/disinfection, media filtration/disinfection or media filtration/membrane filtration. Some combination systems are commercial products in the form of granules, powders or tablets containing a chemical coagulant, such as an iron or aluminium salt, and a disinfectant, such as chlorine. When added to water, these chemicals coagulate and flocculate impurities to promote their rapid and efficient sedimentation and also deliver the chemical disinfectant (e.g., chlorine) to inactivate microbes. These combined coagulant/flocculant/disinfectant products are added to specified volumes of water, allowed to react for floc formation, usually with brief mixing to promote coagulation/flocculation, then allowed to remain unmixed for the floc to settle. The clarified supernatant water is then decanted off, usually through a cloth or other fine-mesh medium to strain out remaining particles. The recovered supernatant is stored for some period, typically several tens of minutes, to allow for additional chemical disinfection before use.

Estimated reductions of waterborne bacteria, viruses and protozoan parasites by several of the above-mentioned HWT technologies are summarized in Table 7.6a. These reductions are based on the results of studies reported in the scientific literature. Two categories of effectiveness are reported: baseline reductions and maximum reductions. Baseline reductions are those typically expected in actual field practice when done by relatively unskilled persons who apply the treatment to raw waters of average and varying quality in developing countries and where there are minimum facilities or supporting instruments to optimize treatment conditions and practices. Maximum reductions are those possible when treatment is optimized by skilled operators who are supported with instrumentation and other tools to maintain the highest level of performance in waters of predictable and unchanging quality (e.g., a test water seeded with known concentrations of specific microbes). Further details on these treatment processes, including the factors that influence their performance and the basis for the $\log_{10}$ reduction value (LRV) performance levels provided in Table 7.6a, can be found in supporting documents (*Managing Water in the Home* and *Guidelines for the Microbiological Performance Evaluation of Point-of-Use Drinking-water Technologies*; see section 1.3).

Table 7.6a Reductions of bacteria, viruses and protozoa achieved by household water treatment technologies

Treatment process	Enteric pathogen group	Baseline removal (LRV)	Maximum removal (LRV)	Notes
Chemical disinfection				
Free chlorine disinfection	Bacteria	3	6	Turbidity and chlorine-demanding solutes inhibit this process; free chlorine × time product predicts efficacy; not effective against *C. parvum* oocysts
	Viruses	3	6	
	Protozoa, non-*Cryptosporidium*	3	5	
	Cryptosporidium	0	1	

Treatment process	Enteric pathogen group	Baseline removal (LRV)	Maximum removal (LRV)	Notes
Membrane, porous ceramic or composite filters				
Porous ceramic and carbon block filtration	Bacteria	2	6	Varies with pore size, flow rate, filter medium augmentation with silver or other chemical agents
	Viruses	1	4	
	Protozoa	4	6	
Membrane filtration	Bacteria	2 MF; 3 UF, NF or RO	4 MF; 6 UF, NF or RO	Varies with membrane pore size (micro-, ultra-, nano- and reverse osmosis filters), integrity of filter medium and filter seals, and resistance to chemical and biological ("grow-through") degradation
	Viruses	0 MF; 3 UF, NF or RO	4 MF; 6 UF, NF or RO	
	Protozoa	2 MF; 3 UF, NF or RO	6 MF; 6 UF, NF or RO	
Fibre and fabric filters (e.g., sari cloth filters)	Bacteria	1	2	Particle or plankton association increases removal of microbes, notably copepod-associated guinea worm *Dracunculus medinensis* and plankton-associated *Vibrio cholerae*; larger protozoa (>20 μm) may be removed; ineffective for viruses, dispersed bacteria and small protozoa (e.g., *Giardia intestinalis*, 8–12 μm, and *Cryptosporidium parvum,* 4–6 μm)
	Viruses	0	0	
	Protozoa	0	1	
Granular media filters				
Rapid granular, diatomaceous earth, biomass and fossil fuel-based (granular and powdered carbon, wood and charcoal ash, burnt rice hulls, etc.) filters	Bacteria	1	4+	Varies considerably with media size and properties, flow rate and operating conditions; some options are more practical than others for use in developing countries
	Viruses	1	4+	
	Protozoa	1	4+	
Household-level intermittently operated slow sand filtration	Bacteria	1	3	Varies with filter maturity, operating conditions, flow rate, grain size and filter bed contact time
	Viruses	0.5	2	
	Protozoa	2	4	
Solar disinfection				
Solar disinfection (solar UV radiation + thermal effects)	Bacteria	3	5+	Varies depending on oxygenation, sunlight intensity, exposure time, temperature, turbidity and size of water vessel (depth of water)
	Viruses	2	4+	
	Protozoa	2	4+	
UV light technologies using lamps				
UV irradiation	Bacteria	3	5+	Excessive turbidity and certain dissolved species inhibit process; effectiveness depends on fluence (dose), which varies with intensity, exposure time, UV wavelength
	Viruses	2	5+	
	Protozoa	3	5+	
Thermal (heat) technologies				
Thermal (e.g., boiling)	Bacteria	6	9+	Values are based on vegetative cells; spores are more resistant to thermal inactivation than are vegetative cells; treatment to reduce spores by boiling must ensure sufficient temperature and time
	Viruses	6	9+	
	Protozoa	6	9+	

Treatment process	Enteric pathogen group	Baseline removal (LRV)	Maximum removal (LRV)	Notes
Coagulation, precipitation and/or sedimentation				
Simple sedimentation	Bacteria	0	0.5	Effective due to settling of particle-associated and large (sedimentable) microbes; varies with storage time and particulates in the water
	Viruses	0	0.5	
	Protozoa	0	1	
Combination treatment approaches				
Flocculation/ disinfection systems (e.g., commercial powder sachets or tablets)	Bacteria	7	9	Some removal of *Cryptosporidium* possible by coagulation
	Viruses	4.5	6	
	Protozoa	3	5	

LRV, $\log_{10}$ reduction values; MF, microfilter; NF, nanofilter; RO, reverse osmosis; UF, ultrafilter

The values in Table 7.6a do not account for post-treatment contamination of stored water, which may limit the effectiveness of some technologies where safe storage methods are not practised. The best options for water treatment at the household level will also employ means for safe storage, such as covered, narrow-mouthed vessels with a tap system or spout for dispensing stored water.

Non-piped water treatment technologies manufactured by or obtained from commercial or other external sources should be certified to meet performance or effectiveness requirements or guidelines, preferably by an independent, accredited certification body. If the treatment technologies are locally made and managed by the household itself, efforts to document effective construction and use and to monitor performance during use are recommended and encouraged.

Changes to "Chapter 8: Chemical aspects"

Page 147

➢ In Table 8.1, last line, change "Eutrophic lakes" to "Eutrophic water bodies".

Pages 151–152

➢ Replace the subsection "Allocation of intake" in section 8.2.2 with the following:

Allocation of intake

Drinking-water is usually not the only source of human exposure to the chemicals for which guideline values have been derived. In many cases, the intake of chemical contaminants from drinking-water is lower than that from other sources, such as food, air and consumer products. Some consideration of the proportion of the ADI or TDI that may be attributed to different sources is therefore needed in developing guidelines and risk management strategies. This approach ensures that total daily intake from all sources (including drinking-water containing concentrations of the chemical at or near the guideline value) does not exceed the ADI or TDI.

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

Where appropriate information on exposure from food and water is not available, allocation factors are applied that reflect the likely contribution of water to total daily intake for various chemicals. In the absence of adequate exposure data, the normal allocation of the total daily intake to drinking-water is 20%, which reflects a reasonable level of exposure based on broad experience, while still being protective. This value reflects a change from the previous allocation of 10%, which was found to be excessively conservative. In some circumstances, there is clear evidence that exposure from food is very low, such as for some of the disinfection by-products; the allocation in such cases may be as high as 80%, which still allows for some exposure from other sources. In the case of some pesticides, which are likely to be found as residues in food from which there will be significant exposure, the allocation for water may be as low as 1%.

As detailed an explanation as possible of the reasoning behind the choice of allocation factor is an essential component of the evaluation. This assists Member States in making appropriate decisions about incorporating guidelines into national standards where local circumstances need to be taken into account. It also provides assistance in making decisions regarding potential risks when a guideline value is exceeded. Where a high proportion of the TDI/ADI has been allocated to drinking-water but concentrations in water are generally well below the guideline value, it should be understood that it is not appropriate to allow contamination to increase up to the guideline value.

Although the values chosen are, in most cases, sufficient to account for additional routes of intake (i.e., inhalation and dermal absorption) of contaminants in water, under certain

circumstances (e.g., limited ventilation), authorities may wish to take inhalation and dermal exposure into account in adapting the guidelines to local conditions (see section 2.3.2).

Some elements are essential for human nutrition. In developing guideline values and in considering allocation factors, it is necessary to take into account the recommended minimum daily intake and exposures from food and to ensure that the allocation does not result in an apparent conflict with essentiality.

Page 154

➢ Add the following to the end of the first paragraph under section 8.2.4:

The actual cancer risks are not likely to be higher than the upper bound but could be lower and even zero. The recognition that the cancer risk may approach zero or be indistinguishable from zero stems from the uncertainties associated with mechanisms of carcinogenesis, including the role of the chemical in the cancer process and the possibility of detoxification and repair mechanisms.

Page 156

➢ Insert the following after section 8.2.9:

8.2.10 Guidance values for use in emergencies

Guidance values for short-term exposures can be derived for any chemicals that are used in significant quantities and are frequently involved in an emergency as a consequence of spills, usually to 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 short-term guidance values for pesticides in drinking-water, and the general guidance can also be applied to derive ARfDs for other chemicals.

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 h or less without appreciable health risk to the consumer. Most of the scientific concepts applicable to the setting of ADIs or TDIs (which are guidance values for chronic toxicity) 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 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 to establish a guidance value by allocating 100% of the ARfD to drinking-water.

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 guidance value derivation.

When a substance has been spilt into a drinking-water source, contamination may be present for a period longer than 24 h, but not usually longer than a few days. Under these circumstances, the use of data from repeated-dose toxicity studies is appropriate. 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 (for ARfDs established by JMPR, see http://www.who.int/ipcs/en/; for short-term drinking-water health advisories for contaminants in drinking-water produced by the US EPA, see http://www.epa.gov/waterscience/criteria/drinking/), but a guideline value is available for the chemical of concern, a simple pragmatic approach would be to allocate a higher proportion of the ADI or TDI to drinking-water. Since the ADI/TDI is intended to be protective of lifetime exposure, small exceedances of the ADI/TDI for short periods will not be of significant concern for health. It would therefore be possible to allow 100% of the ADI/TDI to come from drinking-water for a short period (see also section 8.6.5).

Guidance values for acute and short-term exposures provide a basis for deciding when water can continue to be supplied without serious risk to consumers in such an emergency situation. However, it is important to minimize exposure wherever practical. It is recognized that losing a water supply carries risks to public health and is a major challenge to maintaining proper hygiene as well as ensuring the availability of microbially safe drinking-water. The acute and short-term guidance values assist in determining the balance of risks between supplying water containing a contaminant and not supplying water in such emergencies.

Page 158

➢ In line 3 under Table 8.4, revise the sentence to read "Analytical achievabilities of the chemical guideline values based on detection limits are given in Tables 8.6–8.10a."

Page 163

➢ Below Table 8.10, change bold footnote heading to read "**Definitions to Tables 8.6–8.10a**" and add the following definitions below IC/FD:

PPA	Protein phosphatase assay
ELISA	Enzyme-linked immunosorbent assay
LC/MS	Liquid chromatography/mass spectrometry

Page 164

➢ Insert a new Table 8.10a at the top of the page:

Table 8.10a Analytical achievability for cyanobacterial toxins for which guideline values have been established

	PPA	ELISA	GC/MS	HPLC/UVPAD	LC/MS
Microcystin-LR	+	+	+	++	++

Page 184

➢ Insert the following above section 8.5:

8.4.14 Household treatment

The chemicals of greatest health concern in some natural waters are usually excess natural fluoride, nitrate/nitrite and arsenic. Their removal technologies are usually more complex and more expensive than those required for microbial control.

Some commercial water treatment technologies are available for small applications for removal of chemical contaminants. For example, anion exchange using activated alumina or iron-containing products will effectively reduce excess fluoride concentrations. Bone char has also been used to reduce fluoride. Arsenic is also removed by anion exchange processes similar to those employed for fluoride. Nitrates and nitrates, which are frequently present due to sewage contamination or agricultural runoff, are best managed by protecting the source water from contamination. They are difficult to remove, although disinfection will oxidize nitrite, the more toxic form, to nitrate. In addition, disinfection will sanitize the water and reduce the risk of gastrointestinal infection, which is a factor in the risk of methaemo-globinaemia caused by excess nitrate/nitrite exposure of infants up to approximately 3–6 months of age.

Synthetic and natural organic chemicals can be removed by GAC or carbon block technologies. The treatment systems must be well managed and replaced regularly, because their effectiveness is eventually lost, depending upon the types of contaminating chemicals and their concentrations in the water. Reverse osmosis technologies have general applicability for removal of most organic and inorganic chemicals; however, there is some selectivity, and also there is a significant amount of water wastage when low-pressure units are used in small-volume applications.

Page 186

➢ In Table 8.18 caption, change "naturally occurring chemicals" to "naturally occurring inorganic chemicals"

Page 190

➢ In Table 8.23, add the following below Bentazone:

Carbaryl	Occurs in drinking-water at concentrations well below those at which toxic effects may occur

Page 191

➢ In Table 8.24, insert the following below Chlorotoluron:

Chlorpyrifos	30	

➢ In Table 8.24, insert the following below Pendimethalin:

Permethrin	300	
Pyriproxyfen	300	This is not to be used as a guideline value where pyriproxyfen is added to water for public health purposes (see section 8.5.5).

Pages 190–192

➤ Replace the text of section 8.5.5 with the following:

8.5.5 Pesticides used in water for public health purposes

The control of insect vectors of disease (e.g., dengue fever) is vital in many countries, and there are occasions when vectors, particularly mosquitoes, breed in containers used for the storage and collection of drinking-water. While actions can be taken to prevent access of vectors to or breeding of vectors in these containers, this is not always possible or may not always be fully effective, and use of mosquito larvicides may be indicated in certain settings.

The WHO Pesticides Evaluation Scheme carries out evaluations of pesticides for public health uses. There are currently six insecticide compounds (diflubenzuron, methoprene, novaluron, pyriproxyfen, temephos and pirimiphos-methyl) and a bacterial larvicide (*Bacillus thuringiensis israelensis*) recommended by the WHO Pesticides Evaluation Scheme for the control of container-breeding mosquitoes. The safety of methoprene, pyriproxyfen, temephos and *Bacillus thuringiensis israelensis* for use in potable water has previously been assessed by the WHO Programme on Chemical Safety.

While it is not appropriate to set guideline values for pesticide use in vector control, it is valuable to provide information regarding their safety in use. Formulations of pesticides used for vector control in drinking-water should strictly follow the label recommendations and should only be those approved for such use by national authorities, taking into consideration the ingredients and formulants used in making the final product. In evaluating vector control pesticides for the Guidelines, an assessment is made of the potential exposure compared with the ADI. However, exceeding the ADI does not necessarily mean that this will result in adverse effects. The diseases spread by vectors are significant causes of morbidity and mortality. It is therefore important to achieve an appropriate balance between the intake of the pesticide from drinking-water and the control of disease-carrying insects. It is stressed that every effort should be made to keep overall exposure and the concentration of any larvicide no greater than that recommended by the WHO Pesticides Evaluation Scheme.

Member States should consider the use of larvicides within the context of their broad vector control strategy. Better than establishing a guideline value are the formulation and implementation of a comprehensive management plan for household water storage and peridomestic waste management that does not rely exclusively on larviciding by insecticides, but also includes other environmental management measures and social behaviour change. Nevertheless, it would be valuable to obtain actual data on exposure to these substances under field conditions in order to carry out a more refined assessment of margins of exposure.

As for the other groups of chemicals discussed in this chapter, this category is not clear-cut. It includes pesticides that are used for purposes other than public health protection – for example, agricultural purposes, as in the case of pyriproxyfen. Where the pesticides are applied for purposes other than public health protection, separate guideline values are derived for such uses. These guideline values are provided in the appropriate table in this chapter.

In addition to the use of larvicides approved for drinking-water application to control disease vector insects, other control measures should also be considered. For example, the stocking of fish of appropriate varieties (e.g., larvae-eating mosquitofish) in water bodies may adequately control infestations and breeding of mosquitoes in those bodies. Other mosquito breeding areas where water collects should be managed by draining, especially after rainfall.

Those pesticides used for public health purposes for which guideline values have not been derived are listed in Table 8.28. DDT has been used for public health purposes in the past. It

is being reintroduced (but not for water applications) in some areas to control malaria-carrying mosquitoes. Its guideline value is shown in Table 8.28a.

Summary statements for all larvicides considered in the Guidelines are included in chapter 12.

Page 192

➢ In Table 8.25 caption, replace (from IPCS, 2000) with (based on IPCS, 2000).

➢ In Table 8.25, in the final column of the "Chlorine/hypochlorous acid" row, add ", *N*-nitrosodimethylamine (NDMA)" after "carboxylic acids".

➢ In Table 8.25, in the final column of the "Chloramine" row, add ", NDMA" after "ketones".

Page 194

➢ In Table 8.27, add the following text at the end of the existing text in the Remarks column opposite Chlorine:

A chlorine residual should be maintained throughout the distribution system. At the point of delivery, the minimum residual concentration of free chlorine should be 0.2 mg/litre.

➢ In Table 8.27, insert the following below Monochloramine:

Sodium dichloroisocyanurate   50   As sodium dichloroisocyanurate
                                   40   As cyanuric acid

➢ In Table 8.27, insert the following below Monochloroacetate:

N-Nitrosodimethylamine (NDMA)   0.1

Page 195

➢ Replace Table 8.28 with the following:

Table 8.28   Pesticides used for public health purposes for which guideline values have not been derived

Pesticides	Reason for not establishing a guideline value
Diflubenzuron	Not considered appropriate to set guideline values for pesticides used for vector control in drinking-water
Methoprene	Not considered appropriate to set guideline values for pesticides used for vector control in drinking-water
Novaluron	Not considered appropriate to set guideline values for pesticides used for vector control in drinking-water
Pirimiphos-methyl	Not considered appropriate to set guideline values for pesticides used for vector control in drinking-water
Pyriproxyfen	Not considered appropriate to set guideline values for pesticides used for vector control in drinking-water[a]

[a] A guideline value for pyriproxyfen used for agricultural purposes is given in Table 8.24.

Table 8.28a Guideline values for pesticides that were previously used for public health purposes and are of health significance in drinking-water

Pesticides previously used for public health purposes	Guideline value (µg/litre)
DDT and metabolites	1

Page 196d

➢ Insert the following text after the paragraph beginning "In some cases, the guideline value is derived":

Guidance values for short-term exposures are now being developed for a small number of substances that are used in significant quantities and are frequently implicated in an emergency as a consequences of spills, usually to surface water sources. The methodology used in the derivation of these guidance values is described in section 8.2.10.

Changes to "Chapter 9: Radiological aspects"

Page 203

➢ In Table 9.3, the guidance level for ^{129}I should be changed from 1000 to 1.

➢ In Table 9.3, the order of several radionuclides is incorrect. The following changes should be made:
  - ^{224}Ra, ^{225}Ra, ^{226}Ra and ^{228}Ra should be moved from the bottom of the first column to below ^{223}Ra in the third column (and ^{95}Nb at the bottom of the first column should be followed by ^{93}Mo at the top of the second column)
  - ^{235}U, ^{236}U, ^{237}U and ^{238}U should be moved from the bottom of the second column to follow ^{234}U at the bottom of the first column on page 204 (and ^{140}Ba at the bottom of the second column should be followed by ^{140}La at the top of the third column)
  - ^{210}Pb should be moved up to follow ^{203}Pb in the third column
  - ^{242}Cm, ^{243}Cm, ^{244}Cm and ^{245}Cm at the bottom of the third column should be moved to follow ^{243}Am at the bottom of the second column on page 204 (and ^{223}Ra at the bottom of the third column should be followed by ^{227}Th at the top of the first column on page 204)

Page 204

➢ In Table 9.3, the guidance level for ^{234}U should be changed from 10 to 1.

Page 207

➢ Replace the first paragraph of section 9.5.2 with the following:

Large pooled studies of indoor radon and lung cancer risk have recently become available. The European pooled analysis of 13 indoor radon studies estimated a 16% risk increase per 100 Bq/m^3 (Darby et al., 2005). Based on these data, radon accounts for about 9% of all lung cancer deaths and 2% of total cancer deaths in Europe. Similar results were obtained from the joint analysis of North American radon studies (Krewski et al., 2005).

For the USA, the US EPA has estimated that radon causes about 21 000 lung cancer deaths per year (with an uncertainty range of 8000–45 000), out of about 160 000 annual lung cancer deaths (US EPA, 2003). Radon is the second leading cause of lung cancer, after smoking.

➢ In section 9.5.3, in the sentence beginning "If the radon concentration exceeds 100 Bq/litre," add the following after "treatment of the water source":

(see section 9.5.4)

➢ In section 9.5.3, after the sentence beginning "If the radon concentration exceeds 100 Bq/litre" add the following:

Appropriate treatments include air stripping, aeration systems or – for small water supplies – activated carbon adsorption.

➢ After section 9.5.3, add the following:

9.5.4 Treatment and control methods and technical achievability

Radon, being a gas, is relatively easy to remove by air stripping. Removal efficiencies of >99% were obtained with diffuse bubble and packed tower aeration at air:water ratios of 15:1 and 5:1, respectively (Kinner et al., 1990). Other investigations focusing on aeration at public waterworks have given similar results, with 67–99% efficiencies (Annanmäki & Turtiainen, 2000). This is the preferred method of treatment.

GAC is also effective in removing radon from water, with removals of 70–100% (Lykins et al., 1992). The amount of radon removed by activated carbon is effectively unlimited, because the adsorbed radon decays into other radioactive products, such as ^{210}Pb. As the adsorbed radon decays, radioactive progeny emitting gamma radiation is produced, possibly creating a disposal problem (Castle, 1988). Elevated gamma dose rates (up to 120 μSv/h) near the filter have been recorded (Annanmäki & Turtiainen, 2000). Screening of the GAC filter could be required. In some circumstances, a twin tank system, which introduces a time delay that allows the radon to decay to a significant extent, may be a low-cost option.

Changes to "Chapter 11: Microbial fact sheets"

Page 229

➢ Insert the following new section above section 11.1.6:

11.1.5(a) Enterobacter sakazakii
General description
Enterobacter sakazakii is a motile, Gram-negative, non-spore-forming, rod-shaped bacterium that has been found in infant formulas as a contaminant. *Enterobacter* species are biochemically similar to *Klebsiella*; unlike *Klebsiella*, however, *Enterobacter* is ornithine positive. *Enterobacter sakazakii* has been found to be more resistant to osmotic and dry stress than other members of the Enterobacteriaceae family.

Human health effects
Enterobacter sakazakii has been associated with sporadic cases or small outbreaks of sepsis, meningitis, cerebritis and necrotizing enterocolitis. Most of the infections are seen in low-birth-weight infants (i.e., less than 2 kg) or infants born prematurely (i.e., less than 37 weeks of gestation). Mortality has been reported to be as high as 50% but has decreased to less than 20% in recent years.

Source and occurrence
The reservoir for *E. sakazakii* is unknown. Various environmental samples (surface water, soil, mud, bird faeces) have tested negative. It has been identified in the guts of certain flies. The organism has been frequently identified in factories that produce milk powder and other food substances and in households. Commercially produced non-sterile powdered infant formula has often been implicated as the source of the bacteria during outbreaks. In a study of 141 powdered infant formulas, 20 were found to be culture-positive for *E. sakazakii*, even though the formulas complied with Codex microbial requirements for coliforms (<3 cfu/g). The bacteria have been found in samples from newly opened sealed cans. Although sources of the bacteria other than infant formula have not been identified, environmental sources probably exist.

Routes of exposure
Disease caused by *E. sakazakii* in infants has been associated with the consumption of commercially prepared non-sterile infant formula. Contamination has been linked back to either the infant formula itself or formula preparation equipment (e.g., blenders). Many of the outbreaks have occurred without identified hygienic lapses during formula preparation. The organism has not been found in drinking-water sources used to prepare the formula. There is no evidence for person-to-person or more general environmental transmission.

Significance in drinking-water
There is no evidence that these bacteria are transmitted through drinking-water, although it is plausible that the organism could be present in poor-quality water. *Enterobacter sakazakii* is sensitive to disinfectants, and its presence can be prevented by adequate treatment.

Selected bibliography

Block C et al. (2002) Cluster of neonatal infections in Jerusalem due to unusual biochemical variant of *Enterobacter sakazakii*. *European Journal of Microbiology and Infectious Disease*, 21:613–616.

Breeuwer P et al. (2003) Desiccation and heat tolerance of *Enterobacter sakazakii*. *Journal of Applied Microbiology*, 95:967–973.

Hamilton JV, Lehane MJ, Braig HR (2003) Isolation of *Enterobacter sakazakii* from midgut of *Stomoxys calcitrans* [letter to the editor]. *Emerging Infectious Diseases*, 9(10):1355–1356.

Kandhai CM et al. (2004) Occurrence of *Enterobacter sakazakii* in food production environments and households [research letters]. *Lancet*, 363:39–40.

WHO/FAO (2004) Enterobacter sakazakii *and other microorganisms in powdered infant formula, meeting report.* Geneva, World Health Organization and Food and Agriculture Organization of the United Nations (Microbiological Risk Assessment Series 6).

Page 235

> Insert the following new section above section 11.1.10:

11.1.9(a) *Leptospira*
General description
Leptospires are aerobic spirochetes that are typically 0.1 μm in diameter and 5–25 μm in length. There are two genera: *Leptospira*, which includes the pathogenic *L. interrogans*, and *Leptonoma*. *Leptospira interrogans* causes the important zoonotic and widespread disease leptospirosis. Pathogenic leptospires are maintained in host animals but, depending on conditions, can survive for days to weeks in water. More than 200 pathogenic serovars have been identified, and these have been divided into 25 serogroups based on serologic relatedness.

Human health effects
Leptospirosis occurs globally, affecting people living in temperate and tropical climates in both rural and urban areas. The severity of illness and the types of symptoms vary widely. Infections are often subclinical or so mild that medical attention is not sought. Symptoms include fever, headache, muscle pain, chills, redness in the eyes, abdominal pain, jaundice, haemorrhages in skin and mucous membranes (including pulmonary bleeding), vomiting, diarrhoea and rash. Pulmonary bleeding has been recognized as a dangerous and often fatal result of leptospirosis, but the way it develops after infection remains unclear. Long-lasting sequelae have been identified, including depression, headaches, fatigue and joint pains. Weil disease, characterized by jaundice, renal failure, haemorrhage and myocarditis, has been used as an alternative term for leptospirosis, but it represents a subset of the manifestations. Estimates of case fatalities vary from <5% to 30%, but the figures are not considered reliable owing to uncertainties over case prevalence. Fatality rates are influenced by timeliness of treatment interventions. The number of cases is not well documented as a result of lack of awareness and adequate methods of diagnosis. It has been estimated that there are about 0.1–1 cases per 100 000 persons per year in temperate climates and up to 10–100 cases per 100 000 persons per year in tropical climates.

Source and occurrence
Pathogenic *Leptospira interrogans* are maintained in the renal tubules of many animal hosts. This can take the form of chronic asymptomatic infections, with excretion persisting for very

long periods and even for life. Rats, especially the brown rat (*Rattus norvegicus*), serve as a reservoir for *Leptospira interrogans* serovars icterohaemorrhagiae and copenhageni. Cattle are the most important reservoir for serovar hardjo, and field mice (*Microtus arvalis*) and muskrats (*Ondatra zibethicus*) are the most important reservoirs for serovar grippotyphosa. Recent research has shown that the house mouse (*Crocidura russula*) may be a reservoir for serovar mozdok (type 3). Water contaminated with urine and tissues of infected animals is an established source of pathogenic leptospires. Leptospires have a relatively low resistance to adverse environmental conditions (e.g., low pH, desiccation, direct sunlight); in the right circumstances (neutral pH, moderate temperatures), however, they can survive for months in water.

Routes of exposure
Leptospira interrogans can enter the body through cuts and abrasions or via the mucous membranes of the mouth, nose and eyes. It is not transmitted by the faecal–oral route. Leptospirosis is associated with a broad range of occupational activities predominantly associated with direct contact with dead or living animals, but also indirectly via urine-contaminated environments, especially surface water, plants and mud. Ingestion of contaminated food and water or inhalation of aerosols may occasionally cause infection. Direct person-to-person transmission is rarely observed. Sexual contact, transplacental transmission and mothers' milk are potential routes of exposure. Transmission via urine of infected patients could represent a risk to those who provide medical attention. There is an increasing trend of outbreaks associated with recreational exposure to water contaminated with urine from infected animals. Outbreaks have also been associated with natural disasters involving flooding.

Significance in drinking-water
Waterborne leptospirosis is normally caused by contact with contaminated surface water. Leptospires are sensitive to disinfectants; within a WSP, control measures that should provide effective protection against this organism include application of standard disinfection processes for drinking-water together with protection of distribution systems from contamination associated with flooding events. Because leptospires are excreted in urine and persist in favourable environments, *E. coli* (or, alternatively, thermotolerant coliforms) is not a suitable index for the presence/absence of this organism.

Selected bibliography
Bharti AR et al. (2003) Leptospirosis: A zoonotic disease of global importance. *Lancet Infectious Diseases*, 3:757–771.
Pond K (2005) *Water recreation and disease. Plausibility of associated infections: Acute effects, sequelae and mortality.* IWA Publishing, London, for the World Health Organization.
WHO (2003) *Human leptospirosis: Guidance for diagnosis, surveillance and control.* Geneva, World Health Organization.

Page 262

➢ Insert the following new section above section 11.3.3:

11.3.2(a) *Blastocystis*
General description
Blastocystis is a common anaerobic intestinal parasite that was first described in the early 1900s. Despite this long history, there are large gaps in knowledge about the organism, and

the issue of pathogenicity remains a subject of some debate. *Blastocystis* spp. have been detected in a range of animal hosts, with isolates from humans identified as *Blastocystis hominis*. However, molecular studies suggest that there is considerable antigenic and genetic heterogeneity within *B. hominis* and *Blastocystis* spp. *Blastocystis hominis* lives in the colon and has several morphological forms, including a faecal cyst that is believed to be the infective form.

Human health effects

Blastocystis hominis is probably the most common protozoan detected in human faecal samples worldwide. Infection occurs in both immunocompetent and immunocompromised individuals. Reported prevalence ranges from 2% to 50%, with the highest rates reported for developing countries with poor environmental hygiene. Infection appears to be more common in adults than in children. However, one study showed that peak infection occurs at 10 years of age and then later in life. Pathogenicity of *B. hominis* is controversial because of the nonspecific symptoms and prevalence of asymptomatic infections. Some case–control studies of individuals with and without symptoms show no difference in the prevalence of *B. hominis*. Symptoms attributed to *B. hominis* include watery or loose stools, diarrhoea, abdominal pain, anal itching, weight loss and excess gas. Duration of infection is not well known; some infections can last for weeks, months or years. In some patients, the symptoms resolve, even though *Blastocystis* can still be detected in stools. It has been suggested that *B. hominis* may be a commensal organism that becomes pathogenic when the host is immunosuppressed, is malnourished or has other infections.

Source and occurrence

The source of human infectious *Blastocystis* is uncertain. *Blastocystis* occurs in many animals, including insects, reptiles, birds and mammals. Some evidence suggests that *Blastocystis* may not be host specific and that animal-to-human transmission is possible. A recent survey in Malaysia showed that animal handlers and abattoir workers were at greater risk of infection than a control group of high-rise city dwellers. *Blastocystis* is excreted as a cyst, which could be environmentally persistent, but there are no data on its survival in the environment. *Blastocystis* has been identified in sewage samples.

Routes of exposure

The routes of transmission have not been established, but the faecal–oral route is considered to be the main mode of transmission. Studies of transmission between mice indicate infection after oral inoculation of faecal cysts. Water and foodborne transmission have been suggested but not confirmed.

Significance in drinking-water

The role of drinking-water as a source of *Blastocystis* infections has not been established. However, an investigation in Thailand provided evidence of waterborne transmission, and identification in sewage samples suggests potential for this to occur. Within a WSP, control measures focused on prevention of source water contamination by human and animal waste should reduce potential risks. There is little information on the removal and/or inactivation of *Blastocystis* by water and wastewater treatment processes. The morphology of *Blastocystis* varies over a broad range, and size estimates vary. Faecal cysts can be as small as 3–10 µm in diameter, and these are likely to be removed by conventional granular media-based filtration methods in a similar manner to *Cryptosporidium* oocysts that are 4–6 µm in diameter. It has been reported that *Blastocystis* cysts are relatively resistant to chlorine. Because of this

resistance, *E. coli* (or, alternatively, thermotolerant coliforms) should not be relied upon as an index of the presence/absence of *Blastocystis* in drinking-water sources.

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Suresh K, Smith HV, Tan TC (2005) Viable *Blastocystis* cysts in Scottish and Malaysian sewage samples. *Applied and Environmental Microbiology*, 71:5619–5620.

Tan KSW, Singh M, Yap EH (2002) Recent advances in *Blastocystis hominis* research: Hot spots in terra incognita. *International Journal of Parasitology*, 32:789–804.

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➢ Insert the following new section above section 11.5:

11.4.2(a) Free-living nematodes
General description

Nematodes are the most numerous metazoan (many-celled) animals on earth. Many of them are parasites of insects, plants or animals, including humans. Free-living species are abundant in aquatic environments, both freshwater and saltwater, and soil habitats. Not only are the vast majority of species encountered poorly understood biologically, but there may be thousands more unknown species of nematodes yet to be discovered. Nematodes are structurally simple, with the digestive tract running from the mouth on the anterior end to the posterior opening near the tail, being characterized as a tube in a tube. Nematodes found in drinking-water systems range in size from 0.1 to over 0.6 mm.

About 20 different orders have been distinguished within the phylum Nematoda. Four of these orders (Rhabditida, Tylenchida, Aphelenchida and Dorylaimida) are particularly common in soil. Non-pathogenic free-living nematodes that have been found in drinking-water include *Cheilobus*, *Diplogaster*, *Tobrilus*, *Aphelenchus* and *Rhabditis*.

Human health effects

The presence of free-living nematodes in drinking-water does not necessarily indicate a direct health threat. It has largely been regarded by water suppliers as an "aesthetic" problem, either directly or through their association with discoloured water. High concentrations of nematodes in drinking-water have been reported to impart an unpleasant taste to the drinking-water. The presence of free-living nematodes in drinking-water reduces its acceptability to the consumer.

It has been suggested that free-living nematodes could carry pathogenic bacteria in their gut. Such bacteria would be protected from chlorine disinfection and might therefore present a health hazard. Enterobacteriaceae have been isolated from the microflora in the guts of nematodes taken from a treated water supply and from the raw water from which it was derived. However, they were of non-pathogenic genera. Opportunistic pathogens such as *Nocardia* and *Mycobacterium* may also be carried in the gut of the free-living nematodes. There is no reason to suppose that pathogens would be selectively favoured. The microorganisms present in the gut of the free-living nematodes are much more likely to reflect those in the sediments and biofilms where they are feeding.

In some cases, the motile larvae of pathogens such as hookworms (*Necator americanus* and *Ancylostoma duodenale*) and threadworms (*Strongyloides stercoralis*) are capable of moving themselves through sand filters or may be introduced into drinking-water during distribution as the result of faecal contamination. There are also some other species of nematodes that theoretically could infect humans through ingestion of contaminated water. Such a source of infection, however, is difficult to prove. *Dracunculus medinensis* is a noticeable parasitic nematode that may occur in drinking-water. This parasite is reported elsewhere in this section (see section 11.4.1).

Source and occurrence

Because free-living nematodes are ubiquitous, they, as an egg or free-living larval or adult form, can enter the drinking-water supply at the storage, treatment, distribution or household level. The concentration of free-living nematodes in the raw water source generally corresponds to the turbidity of the water. The higher the turbidity, the larger the concentration of free-living nematodes there will be.

In warm or even temperate weather, slow sand filters may discharge nematodes – and Origochaetes (e.g., *Aeolosoma* spp.), insect larvae (e.g., *Chironomus* spp.) and mosquitoes (*Culex* spp.) – by draw-down into the filtered water. Aquatic animals that successfully penetrate drinking-water treatment processes are largely benthic species, living on the bottoms or margins of water bodies.

Route of exposure

Potential health concerns arise from exposure to the nematodes through ingestion of drinking-water, during recreation and potentially through consumption of fresh vegetables fertilized with sewage that received non-lethal treatment. Distinguishing pathogenic larvae of the hookworm and threadworm from free-living non-pathogenic nematodes in water is difficult (and requires special knowledge of nematology).

WHO has not established guideline values for nematodes in drinking-water. If good water source protection, treatment and distribution practices are followed, as outlined elsewhere in these Guidelines, then these organisms should be absent or present in very low numbers in the drinking-water.

Significance in drinking-water

Large numbers of nematodes are not normally found in well maintained, piped drinking-water systems. Eggs or infective larvae from species parasitic to humans (*Ascaris*, *Trichuris*, *Ancylostoma*, *Necator* and *Strongyloides*) and the many non-pathogenic nematodes are not usually present in protected groundwater sources or are generally removed during treatment processes.

In some circumstances, when the water contains a high nutrient or organic content and the ambient temperatures are appropriate, it may be possible for free-living nematodes to feed on microbial growth in the biofilms or slimes in treatment processes or in water mains and thus multiply within the system. This is particularly true if drinking-water sources have not been adequately protected, treatment systems are not adequate or not operated and maintained properly, the distribution system is leaking or there are many stagnant areas or "dead zones" in the distribution system. It may be feasible to assume that if large numbers of nematodes (live and dead) are detected in drinking-water, then there is a problem that needs to be resolved, without necessarily implying a direct health risk.

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Changes to "Chapter 12: Chemical fact sheets"

Pages 306–308

➢ Replace section 12.8 with the following:

12.8 Arsenic[1]

Arsenic is found widely in the earth's crust in oxidation states of –3, 0, +3 and +5, often as sulfides or metal arsenides or arsenates. In water, it is mostly present as arsenate (+5), but in anaerobic conditions, it is likely to be present as arsenite (+3). It is usually present in natural waters at concentrations of less than 1–2 µg/litre. However, in waters, particularly groundwaters, where there are sulfide mineral deposits and sedimentary deposits deriving from volcanic rocks, the concentrations can be significantly elevated.

Arsenic is found in the diet, particularly in fish and shellfish, in which it is found mainly in the less toxic organic form. There are only limited data on the proportion of inorganic arsenic in food, but these indicate that approximately 25% is present in the inorganic form, depending on the type of food. Apart from occupational exposure, the most important routes of exposure are through food and drinking-water, including beverages that are made from drinking-water. Where the concentration of arsenic in drinking-water is 10 µg/litre or greater, this will be the dominant source of intake. In circumstances where soups or similar dishes are a staple part of the diet, the drinking-water contribution through preparation of food will be even greater.

Provisional guideline value	0.01 mg/litre The guideline value is designated as provisional in view of the scientific uncertainties.
Occurrence	Levels in natural waters generally range between 1 and 2 µg/litre, although concentrations may be elevated (up to 12 mg/litre) in areas containing natural sources.
Basis of guideline derivation	There remains considerable uncertainty over the actual risks at low concentrations, and available data on mode of action do not provide a biological basis for using either linear or non-linear extrapolation. In view of the significant uncertainties surrounding the risk assessment for arsenic carcinogenicity, the practical quantification limit in the region of 1–10 µg/litre and the practical difficulties in removing arsenic from drinking-water, the guideline value of 10 µg/litre is retained. In view of the scientific uncertainties, the guideline value is designated as provisional.
Limit of detection	0.1 µg/litre by ICP/MS; 2 µg/litre by hydride generation AAS or FAAS
Treatment achievability	It is technically feasible to achieve arsenic concentrations of 5 µg/litre or lower using any of several possible treatment methods. However, this requires careful process optimization and control, and a more reasonable expectation is that 10 µg/litre should be achievable by conventional treatment, e.g., coagulation.
Additional comments	• A management guidance document on arsenic is in preparation. • The guideline value is supported by the JECFA PTWI of 15 µg/kg of body weight, if a 20% allocation to drinking-water is assumed. • In many countries, this guideline value may not be attainable. Where this is the case, every effort should be made to keep concentrations as low as possible.

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[1] As arsenic is one of the chemicals of greatest health concern in some natural waters, its chemical fact sheet has been expanded.

Toxicological review

Both pentavalent and trivalent soluble arsenic compounds are rapidly and extensively absorbed from the gastrointestinal tract. Metabolism is characterized by 1) reduction of pentavalent to trivalent arsenic and 2) oxidative methylation of trivalent arsenic to form mono-, di- and trimethylated products. Methylation of inorganic arsenic facilitates the excretion of inorganic arsenic from the body, as the end-products monomethylarsonic acid and dimethylarsinic acid are readily excreted in urine. There are major qualitative and quantitative interspecies differences in methylation, but in humans and most common laboratory animals, inorganic arsenic is extensively methylated, and the metabolites are excreted primarily in the urine. There is large interindividual variation in arsenic methylation in humans, probably due to a wide difference in the activity of methyltransferases and possible polymorphism. Ingested organoarsenicals are much less extensively metabolized and more rapidly eliminated in urine than inorganic arsenic.

Arsenic has not been demonstrated to be essential in humans. The acute toxicity of arsenic compounds in humans is predominantly a function of their rate of removal from the body. Arsine is considered to be the most toxic form, followed by the arsenites, the arsenates and organic arsenic compounds. Acute arsenic intoxication associated with the ingestion of well water containing very high concentrations (21.0 mg/litre) of arsenic has been reported.

Signs of chronic arsenicism, including dermal lesions such as hyper- and hypo-pigmentation, peripheral neuropathy, skin cancer, bladder and lung cancers and peripheral vascular disease, have been observed in populations ingesting arsenic-contaminated drinking-water. Dermal lesions were the most commonly observed symptom, occurring after minimum exposure periods of approximately 5 years. Effects on the cardiovascular system were observed in children consuming arsenic-contaminated water (mean concentration 0.6 mg/litre) for an average of 7 years.

Numerous epidemiological studies have examined the risk of cancers associated with arsenic ingestion through drinking-water. Many are ecological-type studies, and many suffer from methodological flaws, particularly in the measurement of exposure. However, there is overwhelming evidence that consumption of elevated levels of arsenic through drinking-water is causally related to the development of cancer at several sites. Nevertheless, there remain considerable uncertainty and controversy over both the mechanism of carcinogenicity and the shape of the dose–response curve at low intakes. IPCS (2001) concluded that long-term exposure to arsenic in drinking-water is causally related to increased risks of cancer in the skin, lungs, bladder and kidney, as well as other skin changes, such as hyperkeratosis and pigmentation changes. These effects have been demonstrated in many studies using different study designs. Exposure–response relationships and high risks have been observed for each of these end-points. The effects have been most thoroughly studied in Taiwan, China, but there is considerable evidence from studies on populations in other countries as well. Increased risks of lung and bladder cancer and of arsenic-associated skin lesions have been reported to be associated with ingestion of drinking-water at concentrations of ≤50 µg of arsenic per litre. There is a need for more analytical epidemiological studies to determine the dose–time response for skin lesions, as well as cancer, in order to assist in developing suitable interventions and determining practical intervention policies.

Inorganic arsenic compounds are classified by IARC (1987) in Group 1 (carcinogenic to humans) on the basis of sufficient evidence for carcinogenicity in humans and limited evidence for carcinogenicity in animals. Although there is a substantial database on the association between both internal and skin cancers and the consumption of arsenic in drinking-water, there remains considerable uncertainty over the actual risks at low concentrations. USNRC (2001), in its updated evaluation, concluded that "the available mode-of-action data on arsenic do not provide a biological basis for using either a linear or

nonlinear extrapolation." The maximum likelihood estimates, using a linear extrapolation, for bladder and lung cancer for populations in the United States exposed to 10 µg of arsenic per litre in drinking-water are, respectively, 12 and 18 per 10 000 population for females and 23 and 14 per 10 000 population for males. The actual numbers indicated by these estimated risks would be very difficult to detect by current epidemiological methods. There is also uncertainty over the contribution of arsenic in food – a higher intake of inorganic arsenic from food would lead to a lower risk estimate for water – and the impact of factors such as variation in the metabolism of arsenic and nutritional status. Some studies in areas with arsenic concentrations somewhat above 50 µg/litre have not detected arsenic-related adverse effects in the residents. It remains possible that the estimates of cancer risk associated with various arsenic intakes are overestimates. The concentration of arsenic in drinking-water below which no effects can be observed remains to be determined, and there is an urgent need for identification of the mechanism by which arsenic causes cancer, which appears to be the most sensitive toxicity end-point.

The practical quantification limit for arsenic is in the region of 1–10 µg/litre, and removal of arsenic to concentrations below 10 µg/litre is difficult in many circumstances. In view of the significant uncertainties surrounding the risk assessment for arsenic carcinogenicity and the practical difficulties in removing arsenic from drinking-water, the guideline value of 10 µg/litre is retained as a goal. In view of the scientific uncertainties, the guideline value is designated as provisional. In many countries, this guideline value may not be attainable; where this is the case, every effort should be made to keep concentrations as low as possible.

Practical considerations
A silver diethyldithiocarbamate spectrophotometric method is available for the determination of arsenic; the detection limit is about 1 µg/litre (ISO, 1982). Graphite furnace AAS, hydride generation AAS and ICP/MS are more sensitive. HPLC in combination with ICP/MS can also be used to determine various arsenic species.

It is technically feasible to achieve arsenic concentrations of 5 µg/litre or lower using any of several possible treatment methods. However, this requires careful process optimization and control, and a more reasonable expectation is that 10 µg/litre should be achievable by conventional treatment, e.g., coagulation (WHO, 2001). For local non-piped water supplies, the first option is often substitution by, or dilution with, microbiologically safe low-arsenic sources. It may also be appropriate to use alternative sources for drinking and cooking but to use the contaminated sources for purposes such as washing and laundry. There are also an increasing number of effective small-scale treatment techniques, usually based around coagulation and precipitation or adsorption, available at relatively low cost for removal of arsenic from small supplies.

History of guideline development
The 1958 WHO *International Standards for Drinking-water* recommended a maximum allowable concentration of 0.2 mg/litre for arsenic, based on health concerns. In the 1963 International Standards, this value was lowered to 0.05 mg/litre, which was retained as a tentative upper concentration limit in the 1971 International Standards. The guideline value of 0.05 mg/litre was also retained in the first edition of the *Guidelines for Drinking-water Quality*, published in 1984. A provisional guideline value for arsenic was set at the practical quantification limit of 0.01 mg/litre in the 1993 Guidelines, based on concern regarding its carcinogenicity in humans.

Assessment date
The risk assessment was conducted in 2003 for the third edition. An expanded summary statement based on the risk assessment was prepared in 2007 for the second addendum to the third edition.

Principal references
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ISO (1982) *Water quality – determination of total arsenic*. Geneva, International Organization for Standardization (ISO 6595-1982).

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➢ Insert the following new section above section 12.18:

12.17(a) Carbaryl

Carbaryl (CAS No. 63-25-2) is a broad-spectrum carbamate insecticide that is used to control insect pests in crops, trees and ornamental plants. It also has some uses in public health and veterinary practice. Carbaryl has not been reported in drinking-water; however, it could occur following overspraying or spillage into surface water. Exposure through drinking-water is, therefore, considered to be low unless in exceptional circumstances. The major route of carbaryl intake for the general population is food, but residues are considered to be relatively low.

Carbaryl acts through inhibition of brain cholinesterase, and this is also its primary mode of toxicity. However, carbaryl is also considered to be a non-genotoxic carcinogen in mice, in which it causes vascular tumours in males. On this basis, JMPR established an ADI of 0–0.008 mg/kg of body weight. This was based on a LOAEL of 15 mg/kg of body weight per day and application of a safety factor of 2000 ($\times$10 for interspecies variation, $\times$10 for intraspecies variation and $\times$20 to reflect the occurrence of the rare and malignant tumour for which a no-effect level could not be identified).

A health-based value of 50 µg/litre (rounded value) can be determined from the JMPR ADI of 0–0.008 mg/kg of body weight, assuming a 60-kg adult drinking 2 litres of water per day and allowing 20% of the ADI from drinking-water. However, carbaryl does not appear to be found in drinking-water at significant concentrations, and so it is not considered necessary to propose a formal guideline value.

History of guideline development
Carbaryl was not evaluated in the WHO *International Standards for Drinking-water* or in the first or second editions of the WHO *Guidelines for Drinking-water Quality*.

Assessment date
The risk assessment was conducted in 2006.

Principal references
FAO/WHO (2002) *Pesticide residues in food – 2001. Toxicological evaluations. Carbaryl (addendum).* Geneva, World Health Organization, Joint FAO/WHO Meeting on Pesticide Residues (http://www.inchem.org/documents/jmpr/jmpmono/2001pr02.htm).

WHO (2008) *Carbaryl in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality.* Geneva, World Health Organization (WHO/HSE/AMR/08.03/5).

Pages 375–377

➢ Replace section 12.63 with the following:

12.63 Fluoride[1]

Fluorine is a common element that is widely distributed in the earth's crust and exists in the form of fluorides in a number of minerals, such as fluorspar, cryolite and fluorapatite. Traces of fluorides are present in many waters, with higher concentrations often associated with underground sources. In areas rich in fluoride-containing minerals, well water may contain up to about 10 mg of fluoride per litre, although much higher concentrations can be found. High fluoride concentrations can be found in many parts of the world, particularly in parts of India, China, Central Africa and South America, but high concentrations can be encountered locally in most parts of the world. Virtually all foodstuffs contain at least traces of fluorine. All vegetation contains some fluoride, which is absorbed from soil and water. Tea in particular can contain high fluoride concentrations, and levels in dry tea are on average 100 mg/kg.

Fluoride is widely used in dental preparations to combat dental caries, particularly in areas of high sugar intake. These can be in the form of tablets, mouthwashes, toothpaste, varnishes and gels for local application. In some countries, fluoride may also be added to table salt or drinking-water in order to provide protection against dental caries. The amounts added to drinking-water are such that final concentrations are between 0.5 and 1 mg/litre. The fluoride in final water is always present as fluoride ions, whether from natural sources or from artificial fluoridation.

Total daily fluoride exposure can vary markedly from one region to another. This will depend on the concentration of fluoride in drinking-water and the amount drunk, levels in foodstuffs and the use of fluoridated dental preparations. In addition, fluoride exposure in some areas is considerably higher as a consequence of a range of practices, including the consumption of brick tea and the cooking and drying of food with high-fluoride coal.

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[1] As fluoride is one of the chemicals of greatest health concern in some natural waters, its chemical fact sheet has been expanded.

Guideline value	1.5 mg/litre
Occurrence	In groundwater, concentrations vary with the type of rock the water flows through but do not usually exceed 10 mg/litre; the highest natural level reported is 2800 mg/litre.
Basis of guideline derivation	Epidemiological evidence that concentrations above this value carry an increasing risk of dental fluorosis, and progressively higher concentrations lead to increasing risks of skeletal fluorosis. The value is higher than that recommended for artificial fluoridation of water supplies, which is usually 0.5–1.0 mg/litre.
Limit of detection	0.01 mg/litre by IC; 0.1 mg/litre by ion-selective electrodes or the sulfo phenyl azo dihydroxy naphthalene disulfonic acid (SPADNS) colorimetric method
Treatment achievability	1 mg/litre should be achievable using activated alumina (not a "conventional" treatment process, but relatively simple to install filters)
Additional comments	• A management guidance document on fluoride is available (Fawell et al., 2006).
	• In setting national standards for fluoride or in evaluating the possible health consequences of exposure to fluoride, it is essential to consider the intake of water by the population of interest and the intake of fluoride from other sources (e.g., from food, air and dental preparations). Where the intakes from other sources are likely to approach, or be greater than, 6 mg/day, it would be appropriate to consider setting standards at a lower concentration than the guideline value.
	• In areas with high natural fluoride levels in drinking-water, the guideline value may be difficult to achieve, in some circumstances, with the treatment technology available.

Toxicological review

After oral uptake, water-soluble fluorides are rapidly and almost completely absorbed from the gastrointestinal tract, although this may be reduced by complex formation with aluminium, phosphorus, magnesium or calcium. There is no difference in absorption between natural or added fluoride in drinking-water. Fluoride in inhaled particles, for example, from high-fluoride coal, is also absorbed, depending on particle size and solubility of fluoride compounds present. Absorbed fluoride is rapidly distributed through the body, where it is incorporated into teeth and bones, with virtually no storage in soft tissues. Fluoride in teeth and bone can be mobilized after external exposure has ceased or been reduced. Fluoride is excreted via urine, faeces and sweat.

Fluoride may be an essential element for humans; however, essentiality has not been demonstrated unequivocally. Meanwhile, there is evidence of fluoride being a beneficial element with regard to the prevention of dental caries.

To produce signs of acute fluoride intoxication, minimum oral doses of about 1 mg of fluoride per kilogram of body weight were required. Many epidemiological studies of possible adverse effects of the long-term ingestion of fluoride via drinking-water have been carried out. These studies clearly establish that high fluoride intakes primarily produce effects on skeletal tissues (bones and teeth). Low concentrations provide protection against dental caries, both in children and in adults. The protective effects of fluoride increase with concentration up to about 2 mg of fluoride per litre of drinking-water; the minimum concentration of fluoride in drinking-water required to produce it is approximately 0.5 mg/litre. However, fluoride can also have an adverse effect on tooth enamel and may give rise to mild dental fluorosis (prevalence: 12–33%) at drinking-water concentrations between 0.9 and 1.2 mg/litre, depending on drinking-water intake and exposure to fluoride from other sources. Mild dental fluorosis may not be detectable except by specialist examination. The

risk of dental fluorosis will depend on the total intake of fluoride from all sources and not just the concentration in drinking-water.

Elevated fluoride intakes can have more serious effects on skeletal tissues. Skeletal fluorosis (with adverse changes in bone structure) may be observed when drinking-water contains 3–6 mg of fluoride per litre, particularly with high water consumption. Crippling skeletal fluorosis usually develops only where drinking-water contains over 10 mg of fluoride per litre. IPCS (2002) concluded that there is clear evidence from India and China that skeletal fluorosis and an increased risk of bone fractures occur at a total intake of 14 mg of fluoride per day. This conclusion was supported by a review by the United States National Research Council in 2006 (US NRC, 2006). The relation between exposure and response for adverse effects in bone is frequently difficult to ascertain because of inadequacies in most of the epidemiological studies. IPCS (2002) concluded from estimates based on studies from China and India that for a total intake of 14 mg/day, there is a clear excess risk of skeletal adverse effects; and there is suggestive evidence of an increased risk of effects on the skeleton at total fluoride intakes above about 6 mg/day.

Several epidemiological studies are available on the possible association between fluoride in drinking-water and cancer. IPCS (2002) evaluated these studies and concluded that overall the evidence of carcinogenicity in laboratory animals is inconclusive and that the available evidence does not support the hypothesis that fluoride causes cancer in humans; however, the data on bone cancer are relatively limited. The results of several epidemiological studies on the possible adverse effects of fluoride in drinking-water on pregnancy outcome indicate that there is no relationship between the rates of Down syndrome or congenital malformation and the consumption of fluoridated drinking-water.

There is no evidence to suggest that the guideline value of 1.5 mg/litre set in 1984 and reaffirmed in 1993 needs to be revised. Concentrations above this value carry an increasing risk of dental fluorosis, and much higher concentrations lead to skeletal fluorosis. The value is higher than that recommended for artificial fluoridation of water supplies, which is usually 0.5–1.0 mg/litre.

In setting national standards or local guidelines for fluoride or in evaluating the possible health consequences of exposure to fluoride, it is essential to consider the average daily intake of water by the population of interest and the intake of fluoride from other sources (e.g., from food and air). Where the intakes are likely to approach, or be greater than, 6 mg/day, it would be appropriate to consider setting a standard or local guideline at a concentration lower than 1.5 mg/litre.

Practical considerations

Fluoride is usually determined by means of an ion-selective electrode, which makes it possible to measure the total amount of free and complex-bound fluoride dissolved in water. The method can detect fluoride concentrations in water well below the guideline value. However, appropriate sample preparation is a critical step in the accurate quantification of fluoride, especially where only the free fluoride ion is measured (Fawell et al., 2006).

A range of treatment technologies are available for both large and small supplies. Different methods for small supplies are favoured in different countries; these are based on bone charcoal, contact precipitation, activated alumina and clay (Fawell et al., 2006). However, in some areas with high natural fluoride levels in drinking-water, the guideline value may be difficult to achieve in some circumstances with the treatment technology available. Large supplies tend to rely on activated alumina or advanced treatment processes such as reverse osmosis.

History of guideline development

The 1958 and 1963 WHO *International Standards for Drinking-water* referred to fluoride, stating that concentrations in drinking-water in excess of 1.0–1.5 mg of fluorine per litre may give rise to dental fluorosis in some children, and much higher concentrations may eventually result in skeletal damage in both children and adults. To prevent the development of dental caries in children, a number of communal water supplies are fluoridated to bring the fluorine concentration to 1.0 mg/litre. The 1971 International Standards recommended control limits for fluorides in drinking-water for various ranges of the annual average of maximum daily air temperatures; control limits ranged from 0.6–0.8 mg/litre for temperatures of 26.3–32.6 °C to 0.9–1.7 mg/litre for temperatures of 10–12 °C. In the first edition of the *Guidelines for Drinking-water Quality*, published in 1984, a guideline value of 1.5 mg/litre was established for fluoride, as mottling of teeth has been reported very occasionally at higher levels. It was also noted that local application of the guideline value must take into account climatic conditions and higher levels of water intake. The 1993 Guidelines concluded that there was no evidence to suggest that the guideline value of 1.5 mg/litre set in 1984 needed to be revised. It was also recognized that in areas with high natural fluoride levels, the guideline value may be difficult to achieve in some circumstances with the treatment technology available. It was emphasized that in setting national standards for fluoride, it is particularly important to consider climatic conditions, volume of water intake and intake of fluoride from other sources.

Assessment date

The risk assessment was conducted in 2003 for the third edition. An expanded summary statement based on the risk assessment was prepared for the second addendum to the third edition.

Principal references

Fawell J et al. (2006) *Fluoride in drinking-water*. London, IWA Publishing, on behalf of the World Health Organization (WHO Drinking-water Quality Series).

IPCS (2002) *Fluorides*. Geneva, World Health Organization, International Programme on Chemical Safety (Environmental Health Criteria 227).

US NRC (2006) *Fluoride in drinking water: A scientific review of EPA's standards*. Washington, DC, United States National Research Council, National Academies Press.

WHO (2003) *Fluoride in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality*. Geneva, World Health Organization (WHO/SDE/WSH/03.04/96).

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➢ In the second paragraph of section 12.64, replace "Group 2A (probably carcinogenic to humans)" with "Group 1 (carcinogenic to humans)."

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➢ Replace section 12.94 with the following:

12.94 Nitrate and nitrite[1]

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[1] As nitrate is one of the chemicals of greatest health concern in some natural waters, the chemical fact sheet on nitrate and nitrite has been expanded.

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, since nitrate is the most stable oxidation state. It can be formed by the microbial reduction of nitrate. Nitrite can also be formed chemically in distribution pipes by *Nitrosomonas* bacteria during stagnation of nitrate-containing and oxygen-poor drinking-water in galvanized steel pipes or if chloramination is used to provide a residual disinfectant.

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 animal excreta, including septic tanks. 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. Some groundwaters may also have nitrate contamination as a consequence of leaching from natural vegetation.

In general, the most important source of human exposure to nitrate and nitrite is through vegetables (nitrite and nitrate) 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 value for nitrate	50 mg/litre to protect against methaemoglobinaemia in bottle-fed infants (short-term exposure)
Guideline value / Provisional guideline value for nitrite	• 3 mg/litre for methaemoglobinaemia in infants (short-term exposure) • 0.2 mg/litre (provisional) (long-term exposure) The guideline value for chronic effects of nitrite is considered provisional owing to uncertainty surrounding the susceptibility of humans compared with animals.
Guideline value for combined nitrate plus nitrite	The sum of the ratios of the concentrations of each to its guideline value should not exceed 1.
Occurrence	In most countries, nitrate levels in drinking-water derived from surface water do not exceed 10 mg/litre, although nitrate levels in well water often exceed 50 mg/litre; nitrite levels are normally lower, less than a few milligrams per litre.
Basis of guideline derivation	• Nitrate (bottle-fed infants): in epidemiological studies, methaemoglobinaemia was not reported in infants in areas where drinking-water consistently contained less than 50 mg of nitrate per litre • Nitrite (bottle-fed infants): application of body weight of 5 kg for an infant and drinking-water consumption of 0.75 litre to lowest level of toxic dose range, 0.4 mg/kg of body weight • Nitrite (long-term exposure): based on allocation to drinking-water of 10% of JECFA ADI of 0.07 mg/kg of body weight per day, based on nitrite-induced morphological changes in the adrenals, heart and lungs in laboratory animal studies
Limit of detection	0.1 mg/litre (nitrate) and 0.05 mg/litre (nitrite) by LC; 0.01–1 mg/litre (nitrate) by spectrometric techniques; 0.005–0.01 mg/litre (nitrite) by a molecular absorption spectrometric method; 22 µg/litre (nitrate) and 35 µg/litre (nitrite) by IC
Treatment achievability	• Nitrate: 5 mg/litre or lower should be achievable using biological denitrification (surface waters) or ion exchange (groundwaters) • Nitrite: 0.1 mg/litre should be achievable using chlorination (to form nitrate)

Additional comments	• Nitrite can occur in distribution at higher concentrations when chloramination is used, but the occurrence is almost invariably sporadic. Methaemo-globinaemia is therefore the most important consideration, and the guideline derived for protection against methaemoglobinaemia would be the most appropriate under these circumstances, allowing for any nitrate that may also be present.
	• Methaemoglobinaemia in infants appears to be associated with simultaneous exposure to microbial contaminants. 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
	• 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 should be taken to modify the treatment train or water chemistry in order to maintain a safe water quality. Efficient disinfection must never be compromised.
	• The occurrence of nitrite in distribution as a consequence of chloramine use will be intermittent, and average exposures over time should not exceed the provisional guideline value.

Toxicological review

Absorption of nitrate ingested from vegetables, meat or water is rapid and in excess of 90%, and 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 the potential for endogenous formation of nitrate from nitric oxide and protein breakdown. 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 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, since rats actively secrete virtually no nitrate in their saliva.

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 can include individuals using antacids, particularly those that block acid secretion, and potentially bottle-fed infants (due to relatively higher stomach pH), although there is some uncertainty regarding the latter.

In humans, methaemoglobinaemia forms as 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, so blocking oxygen transport. Although most absorbed nitrite is oxidized to nitrate in the blood, residual nitrite can react with haemoglobin. High levels of methaemoglobin (greater than 10%) formation 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 associated with drinking-water nitrate, 97% of cases occurred at concentrations in excess of 44.3 mg/litre, with clinical symptoms associated with the higher concentrations. The affected individuals were almost exclusively under 3 months of age.

While drinking-water nitrate may be an important risk factor for bottle-fed infants, there is good evidence that the risk of methaemoglobinaemia is primarily increased in the presence of simultaneous gastrointestinal infections, which increase endogenous nitrate formation, may increase nitrate reduction 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 that also have a high probability of microbial contamination and predominantly when the drinking-water is anaerobic, which should not occur if it is properly disinfected.

Nitrite can react with nitrosatable compounds, primarily 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 (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. A number of dietary antioxidant components, such as moderate consumption of ascorbic acid and green tea, appear 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.

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; however, this would be an issue only under circumstances of very high nitrate intake and simultaneous iodine deficiency, which appears to be the most important factor.

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 was identified.

Nitrate may have a role in protecting the gastrointestinal tract against a variety of gastrointestinal pathogens, since nitrous oxide and acidified nitrite have antibacterial properties. There may, therefore, be a benefit from nitrate uptake, but endogenous synthesis probably provides sufficiently high levels of nitrate for biocidal activity, and there remains a need to balance the potential risks with the potential benefits.

In some studies in 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. Results from some carcinogenicity bioassays with nitrite were not conclusive. 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, since 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/litre as nitrate is based on epidemiological evidence for methaemoglobinaemia in infants, which results from short-term exposure and is protective for bottle-fed infants and, consequently, other parts of the population. This outcome 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 However, the water must also be known to be microbiologically safe. The latter is a minor modification of previous guidance to give greater emphasis to the role of microbiological quality.

The guideline for nitrite of 3 mg/litre is based on human data showing that doses of nitrite that cause methaemoglobinaemia in infants range from 0.4 to more than 200 mg/kg of body weight. By applying the lowest level of the range (0.4 mg/kg of body weight), a body weight of 5 kg for an infant and a drinking-water consumption of 0.75 litre, a guideline value of 3 mg/litre (rounded figure) can be derived.

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 one, i.e.,

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

For chronic exposure, JECFA has proposed an ADI for nitrate of 0–3.7 mg/kg of body weight and an ADI of 0–0.07 mg/kg of body weight for nitrite, expressed as nitrite ion. The value for nitrate is based on a NOEL of 370 mg/kg of body weight per day in laboratory animal studies; in view of the known interspecies variation in nitrate/nitrite metabolism, however, it was not considered appropriate at this time to use this in the risk assessment for humans. The ADI for nitrite is based on effects on heart and lung in a 2-year study in rats with a safety factor of 100. In view of the unusual findings in animals following chronic exposure to nitrite, it was considered prudent to also consider a guideline value for nitrite associated with chronic exposure. Using JECFA's ADI of 0–0.07 mg/kg of body weight, assuming a 60-kg adult ingesting 2 litres of drinking-water per day, and allocating 10% of the ADI to drinking-water, a guideline value of 0.2 mg of nitrite ion per litre (rounded figure) can be calculated. However, owing to the uncertainty surrounding the susceptibility of humans compared with animals, this guideline value should be considered provisional.

Practical considerations

The most appropriate means of controlling nitrate concentrations, particularly in groundwater, is the prevention of contamination (Schmoll et al., 2006). This may take the form of appropriate management of agricultural practices, the careful siting of pit latrines and septic tanks, sewer leakage control, as well as management of fertilizer and manure application and storage of animal manures. It may also take the form of denitrification of wastewater effluents.

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. Water should be boiled 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 (normally for groundwaters) and biological denitrification (normally for surface waters). However, there are disadvantages associated with both approaches, including the need for regeneration and disposal of spent regenerant with ion exchange, the complexities of operation and the potential for microbial and carbon feed contamination of the final water with biological denitrification.

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 where chloramines are used to control *Legionella*.

History of guideline development

The 1958 WHO *International Standards for Drinking-water* referred to nitrates, stating that the ingestion of water containing nitrates in excess of 50–100 mg/litre (as nitrate) may give rise to methaemoglobinaemia in infants under 1 year of age. In the 1963 International Standards, this value was lowered to 45 mg/litre (as nitrate), which was retained in the 1971 International Standards. The 1971 International Standards first mentioned concern over the possibility of nitrosamine formation *in vivo*; as nitrosamines are a possible hazard to human health, the 1971 Standards stated that it may eventually become necessary to reduce the level of nitrates in water if it is found that this source makes a significant contribution to the hazard to human health arising from nitrosamines. In the first edition of the *Guidelines for Drinking-water Quality*, published in 1984, a guideline value of 10 mg/litre for nitrate-nitrogen was recommended. It was also recommended that the guideline value for nitrite must be correspondingly lower than that for nitrate, and it was noted that the nitrite-nitrogen level should be considerably lower than 1 mg/litre where drinking-water is correctly treated. The 1993 Guidelines concluded that extensive epidemiological data support the current guideline value for nitrate-nitrogen of 10 mg/litre, but stated that this value should be expressed not on the basis of nitrate-nitrogen but on the basis of nitrate itself, which is the chemical entity of

concern to health. The guideline value for nitrate is therefore 50 mg/litre. This guideline value for methaemoglobinaemia in infants, an acute effect, was confirmed in the addendum to the Guidelines, published in 1998. It was also concluded in the 1993 Guidelines that a guideline value for nitrite should be proposed, although no suitable animal studies of methaemoglobinaemia were available. A provisional guideline value for nitrite of 3 mg/litre was therefore proposed by accepting a relative potency for nitrite and nitrate with respect to methaemoglobin formation of 10:1 (on a molar basis). In the addendum to the Guidelines, published in 1998, it was concluded that human data on nitrite reviewed by JECFA supported the guideline value of 3 mg/litre, based on induction of methaemoglobinaemia in infants, and the guideline value was no longer designated as provisional. In addition, a guideline value of 0.2 mg/litre for nitrate ion associated with long-term exposure was derived in the addendum to the Guidelines, based on JECFA's ADI. However, because of the uncertainty surrounding the relevance of the observed adverse health effects for humans and the susceptibility of humans compared with animals, this guideline value was considered provisional. Because of the possibility of simultaneous occurrence of nitrite and nitrate in drinking-water, it was recommended in the 1993 and 1998 Guidelines that the sum of the ratios of the concentration of each to its guideline value should not exceed 1. These guideline values were retained in the third edition of the Guidelines, published in 2004.

Assessment date

The risk assessment was originally conducted in 1998. The Final Task Force Meeting in 2003 agreed that this risk assessment be brought forward to the third edition of the *Guidelines for Drinking-water Quality*, published in 2004. An expanded summary statement based on the risk assessment was prepared for the second addendum to the third edition, published in 2007.

Principal references

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; http://whqlibdoc.who.int/trs/WHO_TRS_913.pdf).

FAO/WHO (2003) Nitrite (and potential endogenous formation of *N*-nitroso 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; http://www.inchem.org/documents/jecfa/jecmono/v50je05.htm).

FAO/WHO (2003) Nitrate (and potential endogenous formation of *N*-nitroso 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; http://www.inchem.org/documents/jecfa/jecmono/v50je06.htm).

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.

WHO (2007) *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).

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➢ Insert the following above section 12.96:

12.95(a) *N*-Nitrosodimethylamine (NDMA)

N-Nitrosodimethylamine, or NDMA, can occur in drinking-water through the degradation of dimethylhydrazine (a component of rocket fuel) as well as from several other industrial processes. It is also a contaminant of certain pesticides. NDMA has recently been identified as a disinfection by-product of chloramination (by the reaction of monochloramine with dimethylamine, a ubiquitous component of waters impacted by wastewater discharges) and, to some extent, chlorination. NDMA can also be formed as a by-product of anion-exchange treatment of water.

Guideline value	0.0001 mg/litre (0.1 µg/litre)
Occurrence	Where chloramination is used, distribution system samples can have much higher levels of NDMA than the finished water at the treatment plant. Levels as high as 0.16 µg/litre have been measured in the distribution system, but concentrations in water at the treatment plant are generally less than 0.01 µg/litre.
Basis of guideline derivation	Hepatic biliary cystadenomas in female rats, the most sensitive carcinogenic end-point, observed in a drinking-water study, using a multistage model
Limit of detection	0.028 ng/litre by capillary column GC and chemical ionization tandem MS; 0.4 ng/litre by capillary column GC and high-resolution MS; 0.7–1.6 ng/litre by GC/MS and ammonia positive chemical ionization detection
Treatment achievability	The most common process for NDMA removal is UV irradiation. A concentration below 0.005 µg/litre should be achievable by UV irradiation provided that the water is not grossly contaminated. NDMA is not removable by air stripping, activated carbon adsorption, reverse osmosis or biodegradation.
Additional comments	Potential methods for reducing the formation of NDMA during disinfection include avoiding the use of chloramination, use of breakpoint chlorination and removal of ammonia prior to chlorination.

Toxicological review

There is conclusive evidence that NDMA is a potent carcinogen in experimental animals by several routes of exposure, including through ingestion of drinking-water. NDMA has been classified by IARC as probably carcinogenic to humans. The mechanism by which NDMA produces cancer is well understood to involve biotransformation by liver microsomal enzymes, generating the methyldiazonium ion. This reactive metabolite forms DNA adducts, with most evidence pointing to O^6-methylguanine as the likely proximal carcinogenic agent. As a consequence of the clear evidence of carcinogenicity, there have been few studies of other possible toxic end-points.

There is also ample evidence that NDMA is genotoxic both *in vivo* and *in vitro*. Activation by liver microsomal S9 fractions is necessary for a positive *in vitro* result. The recent observation that human S9 fractions are much more active in promoting genotoxicity in the Ames test than rat S9 fractions suggests that humans may be especially sensitive to the carcinogenicity of NDMA.

Although there have been several case–control studies and one cohort study of NDMA in humans, none of them can be used to derive a quantitative risk of cancer. The results are supportive of the assumption that NDMA consumption is positively associated with either gastric or colorectal cancer. However, none of the studies focused on drinking-water as the route of exposure; instead, they used estimations of total dietary intake of NDMA.

History of guideline development

N-Nitrosodimethylamine was not considered in the WHO *International Standards for Drinking-water* or in the first or second editions of the WHO *Guidelines for Drinking-water Quality*.

Assessment date
The risk assessment was conducted in 2006.

Principal references
WHO (2002) N-*Nitrosodimethylamine.* Geneva, World Health Organization, International Programme on Chemical Safety (Concise International Chemical Assessment Document No. 38).

WHO (2008) N-*Nitrosodimethylamine in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality.* Geneva, World Health Organization (WHO/HSE/AMR/08.03/8).

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➢ Replace the "Principal reference" for section 12.100 with the following:

WHO (2007) *pH in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality.* Geneva, World Health Organization (WHO/SDE/WSH/07.01/1).

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➢ In first paragraph of section 12.102, replace "The use of open fires for heating and cooking may increase PAH exposure, especially in developing countries" with "The use of open fires for heating and cooking, which is common especially in developing countries, may increase PAH exposure."

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➢ Replace section 12.104 with the following:

12.104 Pyriproxyfen
Pyriproxyfen (CAS No. 95737-68-1) is a broad-spectrum insect growth regulator with insecticidal activity against public health insect pests: houseflies, mosquitoes and cockroaches. In agriculture and horticulture, pyriproxyfen has registered uses for the control of scale, whitefly, bollworm, jassids, aphids and cutworms. Pyriproxyfen is used on citrus fruit in Israel, South Africa, Spain and Italy. Pyriproxyfen is one of several insecticides used for the control of the red imported fire ant (*Solenopsis invicta*) in California, USA. Pyriproxyfen has also been considered by WHO for vector control under its Pesticides Evaluation Scheme.

Pyriproxyfen degrades rapidly in soil under aerobic conditions, with a half-life of 6.4–36 days. Pyriproxyfen disappeared from aerobic lake water–sediment systems with half-lives ranging from 16 to 21 days. As pyriproxyfen is a relatively new pesticide, few environmental data have been collected. Intake of pyriproxyfen from all sources is generally low and below the ADI.

Guideline value	0.3 mg/litre
	This guideline value is not intended for pyriproxyfen used as a vector control agent in drinking-water (see section 12.126.5).
Occurrence	No detectable concentrations found in surface water in the USA
ADI	0–0.1 mg/kg of body weight based on an overall NOAEL of 10 mg/kg of body weight per day for increased relative liver weight and increased total plasma cholesterol concentration in male dogs in two 1-year toxicity studies, using an uncertainty factor of 100
Limit of detection	0.1 µg/litre by organic solvent extraction followed by HPLC/UV detection; 0.02 mg/kg by gas–liquid chromatography with NPD
Treatment achievability	No data available; 1 µg/litre should be achievable using GAC
Guideline derivation	
• allocation to water	10% of ADI (to account for exposure through food)
• weight	60-kg adult
• consumption	2 litres/day

Toxicological review

JMPR concluded that pyriproxyfen was not carcinogenic or genotoxic. In short- and long-term studies of the effects of pyriproxyfen in mice, rats and dogs, the liver (increases in liver weight and changes in plasma lipid concentrations, particularly cholesterol) was the main toxicological target. Young animals do not appear to be significantly more sensitive than adults.

History of guideline development

The 1958 and 1963 WHO *International Standards for Drinking-water* did not refer to pyriproxyfen, but the 1971 International Standards suggested that pesticide residues that may occur in community water supplies make only a minimal contribution to the total daily intake of pesticides for the population served. Pyriproxyfen was not evaluated in the first edition of the *Guidelines for Drinking-water Quality*, published in 1984, in the second edition, published in 1993, or in the addendum to the second edition, published in 1998. In the third edition of the Guidelines, a guideline value of 0.3 mg/litre was established for pyriproxyfen in drinking-water.

Assessment date

The risk assessment was conducted in 2004. The background document was revised in 2008 based on FAO/WHO (2000).

Principal references

FAO/WHO (2000) *Pesticide residues in food – 1999 evaluations. Part II – Toxicological.* Geneva, World Health Organization, Joint FAO/WHO Meeting on Pesticide Residues (WHO/PCS/00.4).

WHO (2008) *Pyriproxyfen in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality.* Geneva, World Health Organization (WHO/HSE/AMR/08.03/10).

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➢ Insert the following new section above section 12.109:

12.108(a) Sodium dichloroisocyanurate

Sodium dichloroisocyanurate is the sodium salt of a chlorinated hydroxytriazine and is used as a source of free available chlorine, in the form of hypochlorous acid, for the disinfection of water. It is widely used as a stable source of chlorine for the disinfection of swimming pools and in the food industry. It is also used as a means of disinfecting drinking-water, primarily in emergencies, when it provides an easy-to-use source of free chlorine, and, more recently, as the form of chlorine for household point-of-use water treatment.

Guideline values	50 mg/litre (as sodium dichloroisocyanurate)
	40 mg/litre (as cyanuric acid)
Occurrence	Where sodium dichloroisocyanurate is used for the disinfection of drinking-water, exposure will be to both the chlorinated species and residual cyanuric acid. The concentrations will relate directly to the quantities added to achieve adequate disinfection.
TDI	2.2 mg/kg of body weight for anhydrous sodium dichloroisocyanurate and 1.54 mg/kg of body weight for cyanuric acid, based on a NOEL of 154 mg/kg of body weight per day (equivalent to 220 mg/kg of body weight per day as anhydrous sodium dichloroisocyanurate) for urinary tract and cardiac lesions from a 2-year study on exposure of rats to sodium cyanurate and using an uncertainty factor of 100
Limit of detection	0.001 mg/litre by GC with flame thermionic specific detection; 0.05 mg/litre by reverse-phase LC with UV detection; 0.09 mg/litre by GC with MS selective ion monitoring
Treatment achievability	At very high chlorine doses (up to 10 mg/litre), the sodium cyanurate concentration would be below 11 mg/litre. In emergency situations, "topping up" might be done in an attempt to maintain a free chlorine residual, but this practice should be discouraged. In this case, it would be possible for the sodium cyanurate concentration to build up to undesirable levels. In such cases, it would be very desirable to monitor the concentration of sodium cyanurate.
Guideline derivation	
• allocation to water	80% of TDI
• weight	60-kg adult
• consumption	2 litres/day
Additional considerations	• The controlling factors are the level of free chlorine and the residue of cyanuric acid, particularly if there is topping up of chlorine in a static system under emergency conditions. The concentration of free chlorine should normally be such that it should not give rise to unacceptable tastes and should not normally exceed the guideline value of 5 mg/litre for free chlorine.
	• Sodium dichloroisocyanurate used for disinfecting drinking-water should be of adequate purity so that there is no increase in any inorganic or organic contaminants in the drinking-water. The amounts of sodium dichloroisocyanurate used should be the lowest consistent with adequate disinfection, and the concentrations of cyanuric acid should be managed to be kept as low as is reasonably possible.

Toxicological review

Studies of the toxicity of sodium cyanurate are appropriate for assessing the safety of sodium dichloroisocyanurate, because any residues of intact sodium dichloroisocyanurate in drinking-water would be rapidly converted to cyanuric acid on contact with saliva. Both sodium dichloroisocyanurate and sodium cyanurate have low acute oral toxicity. Sodium cyanurate does not induce any genotoxic, carcinogenic or teratogenic effects. The NOEL from which the guideline value was derived was based on multiple lesions of the urinary tract (calculi and hyperplasia, bleeding and inflammation of the bladder epithelium, dilated and

inflamed ureters and renal tubular nephrosis) and cardiac lesions (acute myocarditis, necrosis and vascular mineralization) in male rats exposed at the next higher dose.

History of guideline development
Sodium dichloroisocyanurate was not considered in the WHO *International Standards for Drinking-water* or in the first or second editions of the WHO *Guidelines for Drinking-water Quality.*

Assessment date
The risk assessment was conducted in 2007.

Principal references
WHO (2004) *Evaluation of certain food additives and contaminants*. Sixty-first report of the Joint FAO/WHO Committee on Food Additives. Geneva, World Health Organization (WHO Technical Report Series No. 922; http://whqlibdoc.who.int/trs/WHO_TRS_922.pdf).

WHO (2008) *Sodium dichloroisocyanurate in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality*. Geneva, World Health Organization (WHO/HSE/AMR/08.03/3).

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➢ In the "Additional comments" row of the table in section 12.121, add the following sentence before the sentence "It is emphasized that adequate disinfection should never be compromised in attempting to meet guidelines for THMs":

Authorities wishing to use a guideline value for total THMs should not simply add up the guideline values for the individual compounds in order to arrive at a standard, because the four compounds are basically similar.

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➢ Insert the following sections at the end of the page:

12.126 Pesticides used for vector control in drinking-water sources and containers
In setting local guidelines or standards in the context of local storage practices and realistic insecticide application regimes, health authorities should take into consideration the potential for higher rates of water consumption in the area or region under consideration. However, exceeding the ADIs will not necessarily result in adverse effects. The diseases spread by vectors are significant causes of morbidity and mortality. It is therefore important to achieve an appropriate balance between the intake of the pesticides from drinking-water and the control of disease-carrying insects. Better than establishing guideline values are the formulation and implementation of a comprehensive management plan for household water storage and peridomestic waste management that does not rely exclusively on larviciding by insecticides, but also includes other environmental management measures and social behavioural changes.

Formulations of pesticides used for vector control in drinking-water should strictly follow the label recommendations and should only be those approved for such a use by national authorities, taking into consideration the ingredients and formulants used in making the final

product. National authorities should note that these assessments refer only to the active ingredients and do not consider the additives in different formulations.

12.126.1 Diflubenzuron

Diflubenzuron is a direct-acting insecticide normally applied directly to plants or water. It is used in public health applications against mosquito and noxious fly larvae. WHO is considering diflubenzuron for use as a mosquito larvicide in drinking-water in containers, particularly to control dengue fever. The recommended dosage of diflubenzuron in potable water in containers should not exceed 0.25 mg/litre under the WHO Pesticides Evaluation Scheme.

It is reported that public exposure to diflubenzuron through either food or drinking-water is negligible. However, there is a potential for direct exposure through drinking-water when diflubenzuron is directly applied to drinking-water storage containers.

Diflubenzuron is considered to be of very low acute toxicity. The primary target for toxicity is the erythrocytes, although the mechanism of haematotoxicity is uncertain. There is no evidence that diflubenzuron is either genotoxic or carcinogenic. It also does not appear to be fetotoxic or teratogenic and does not show significant signs of reproductive toxicity. There is evidence that young animals are not significantly more sensitive than adults to the effects of diflubenzuron.

It is not considered appropriate to set a formal guideline value for diflubenzuron used as a vector control agent in drinking-water. Where diflubenzuron is used for vector control in potable water, this will involve considerably less than lifetime exposure. The ADI determined by JMPR in 2001 was 0.02 mg/kg of body weight. The maximum dosage in drinking-water of 0.25 mg/litre would be equivalent to approximately 40% of the ADI allocated to drinking-water for a 60-kg adult drinking 2 litres of water per day. For a 10-kg child drinking 1 litre of water, the exposure would be 0.25 mg, compared with an exposure of 0.2 mg at the ADI. For a 5-kg bottle-fed infant drinking 0.75 litre per day, the exposure would be 0.19 mg, compared with an exposure of 0.1 mg at the ADI. Diflubenzuron is unlikely to remain in solution at the maximum recommended applied dose, and the actual levels of exposure are likely to be much lower than those calculated.

Consideration should be given to using alternative sources of water for bottle-fed infants for a period after an application of diflubenzuron, where this is practical. However, exceeding the ADI will not necessarily result in adverse effects.

History of guideline development

Diflubenzuron was not evaluated in the WHO *International Standards for Drinking-water* or in the first or second editions of the WHO *Guidelines for Drinking-water Quality*.

Assessment date

The risk assessment was conducted in 2007.

Principal references

FAO/WHO (2002) Diflubenzuron. In: *Pesticide residues in food – 2001 evaluations. Part II – Toxicological*. Geneva, World Health Organization, Joint FAO/WHO Meeting on Pesticide Residues (WHO/PCS/02.1; http://www.inchem.org/documents/jmpr/jmpmono/2001pr04.htm).

WHO (2008) *Diflubenzuron in drinking-water: Use for vector control in drinking-water sources and containers. Background document for preparation of WHO Guidelines for drinking-water quality*. Geneva, World Health Organization (WHO/HSE/AMR/08.03/6).

12.126.2 Methoprene

WHO has assessed methoprene for use as a mosquito larvicide in drinking-water in containers, particularly to control dengue fever. The recommended dosage of methoprene in potable water in containers should not exceed 1 mg/litre under the WHO Pesticides Evaluation Scheme.

In 2001, JMPR reaffirmed the basis of the ADI for racemic methoprene established in 1987, but lowered the value to 0–0.09 mg/kg of body weight to correct for the purity of the racemate tested. The basis for the ADI was the NOAEL of 500 mg/kg, equivalent to 8.6 mg/kg of body weight per day (corrected for purity), in a 90-day study in dogs (the main effect was increased relative liver weight) and a safety factor of 100. Young animals do not appear to be significantly more sensitive than adults. As no bridging studies with repeated doses were available for (*S*)-methoprene, JMPR made the conservative assumption that, in the absence of any information to the contrary, all the toxicity of the racemate was due to the S enantiomer. On this basis, JMPR established an ADI for (*S*)-methoprene of 0–0.05 mg/kg of body weight, equal to one-half the ADI for the racemate (which is a 1:1 mixture of the R and S enantiomers).

It is not considered appropriate to set a formal guideline value for methoprene used as a vector control agent in drinking-water. Where methoprene is used for vector control in potable water, this will involve less than lifetime exposure. The maximum dosage in drinking-water of 1 mg/litre would be equivalent to approximately 66% of the ADI (0.033 mg/kg of body weight) for a 60-kg adult drinking 2 litres of water per day. The exposure for a 10-kg child drinking 1 litre of water would be approximately 0.1 mg/kg of body weight, and for a 5-kg bottle-fed infant, the exposure would be approximately 0.15 mg/kg of body weight, compared with the ADI of 0–0.05 mg/kg of body weight. However, the low solubility and the high log K_{ow} of methoprene indicate that it is unlikely to remain in solution at the maximum recommended applied dose, and the actual levels of exposure are likely to be much lower than those calculated. Exposure from food is considered to be low.

Consideration should be given to using alternative sources of water for small children and bottle-fed infants for a period after an application of methoprene, where this is practical. However, exceeding the ADI will not necessarily result in adverse effects.

History of guideline development

Methoprene was not considered in the WHO *International Standards for Drinking-water* or in the first or second editions of the WHO *Guidelines for Drinking-water Quality*.

Assessment date

The risk assessment was conducted in 2007.

Principal references

FAO/WHO (2002) Methoprene and *S*-methoprene. In: *Pesticide residues in food – 2001 evaluations. Part II – Toxicological.* Geneva, World Health Organization, Joint FAO/WHO Meeting on Pesticide Residues (WHO/PCS/02.1; http://www.inchem.org/documents/jmpr/jmpmono/2001pr09.htm).

WHO (2008) *Methoprene in drinking-water: Use for vector control in drinking-water sources and containers. Background document for preparation of WHO Guidelines for drinking-water quality.* Geneva, World Health Organization (WHO/HSE/AMR/08.03/14).

12.126.3 Novaluron

Novaluron has been registered as an insecticide for food crops and ornamentals in a number of countries. WHO has assessed novaluron for use as a mosquito larvicide in drinking-water

in containers, particularly to control dengue fever. The recommended dosage of novaluron in potable water in containers should not exceed 0.05 mg/litre under the WHO Pesticides Evaluation Scheme.

In view of the absence of a carcinogenic potential in rodents and the lack of genotoxic potential *in vitro* and *in vivo*, JMPR concluded that novaluron is unlikely to pose a carcinogenic risk to humans. JMPR also concluded that novaluron is not a developmental toxicant.

JMPR established an ADI of 0–0.01 mg/kg of body weight on the basis of the NOAEL of 1.1 mg/kg of body weight per day for erythrocyte damage and secondary splenic and liver changes in a 2-year dietary study in rats, and a safety factor of 100.

It is not considered appropriate to set a formal guideline value for novaluron as a vector control agent in drinking-water. At the maximum recommended dosage for drinking-water of 0.05 mg/litre, the intake of a 60-kg adult drinking 2 litres of water would represent only 17% of the ADI. Similarly, the intake for a 10-kg child drinking 1 litre of water would be 50% of the ADI, whereas a 5-kg bottle-fed infant drinking 0.75 litre of water would receive an intake of 75% of the ADI.

The high log K_{ow} of 4.3 indicates that novaluron is likely to adsorb to the sides of containers, and so the actual concentration is likely to be less than the recommended dose. Exposure to novaluron through food is not expected to be significant.

History of guideline development
Novaluron was not considered in the WHO *International Standards for Drinking-water* or in the first or second editions of the WHO *Guidelines for Drinking-water Quality*.

Assessment date
The risk assessment was conducted in 2007.

Principal references
FAO/WHO (2005) Novaluron. In: *Pesticide residues in food – 2005*. Rome, Food and Agriculture Organization of the United Nations, Joint FAO/WHO Meeting on Pesticide Residues (FAO Plant Production and Protection Paper 183; http://www.fao.org/ag/AGP/AGPP/Pesticid/JMPR/DOWNLOAD/2005_rep/report2005jmpr.pdf).

WHO (2008) *Novaluron in drinking-water: Use for vector control in drinking-water sources and containers. Background document for preparation of WHO Guidelines for drinking-water quality.* Geneva, World Health Organization (WHO/HSE/AMR/08.03/11).

12.126.4 Pirimiphos-methyl
Pirimiphos-methyl is an organophosphorus compound that is used in a wide range of pesticidal applications. Pirimiphos-methyl is being considered by WHO for addition to potable water in containers as a mosquito larvicide treatment, particularly to control dengue fever. The manufacturer recommends the direct addition of 1 mg/litre to water.

The only biochemical effect consistently observed with pirimiphos-methyl in acute, short-term or long-term studies is cholinesterase inhibition. Studies with mice, rats and dogs showed NOAELs of 0.5 mg/kg of body weight per day and above. Young animals do not appear to be significantly more sensitive than adults. In human studies, no cholinesterase inhibition was seen at 0.25 mg/kg of body weight per day (the highest dose tested). On this basis, JMPR revised the ADI to 0–0.03 mg/kg of body weight by applying a 10-fold safety factor to the NOAEL in the human studies.

At the maximum recommended dosage for drinking-water of 1 mg/litre, a 60-kg adult drinking 2 litres of water would have an intake of 0.033 mg/kg of body weight, compared

with the ADI of 0–0.03 mg/kg of body weight. The intake for a 10-kg child drinking 1 litre of water would be 0.1 mg/kg of body weight; for a 5-kg bottle-fed infant drinking 0.75 litre, it would be 0.15 mg/kg of body weight. There is uncertainty regarding the level that would cause effects in humans, since the NOAEL on which the ADI is based was the highest dose tested, and so the ADI may be more conservative than is at first apparent. These intake figures are all below the ARfD of 0.2 mg/kg of body weight and would not result in an acute exposure risk from the initial application of pirimiphos-methyl to drinking-water containers at the recommended dose. In addition, the low solubility and the high log K_{ow} of pirimiphos-methyl indicate that it is very unlikely to remain in solution at the maximum recommended applied dose, so the actual levels of exposure are expected to be lower than those calculated. Exposure from food is generally considered to be low, but occasional high exposures can be experienced.

Based on the above calculations, pirimiphos-methyl is not recommended for direct application to drinking-water unless no other effective and safe treatments are available. If pirimiphos-methyl is applied directly to drinking-water, consideration should be given to using alternative sources of water for bottle-fed infants and small children for a period after its application, where this is practical. However, it is noted that exceeding the ADI will not necessarily result in adverse effects.

History of guideline development
Pirimiphos-methyl was not considered in the WHO *International Standards for Drinking-water* or in the first or second editions of the WHO *Guidelines for Drinking-water Quality*.

Assessment date
The risk assessment was conducted in 2007.

Principal references
FAO/WHO (1993) Pirimiphos-methyl. In: *Pesticide residues in food – 1992 evaluations. Part II – Toxicological.* Geneva, World Health Organization, Joint FAO/WHO Meeting on Pesticide Residues (WHO/PCS/93.34; http://www.inchem.org/documents/jmpr/jmpmono/v92pr16.htm).

FAO/WHO (2006) Pirimiphos-methyl. In: *Pesticide residues in food 2006.* Rome, Food and Agriculture Organization of the United, Joint FAO/WHO Meeting on Pesticide Residues, pp. 178–179 (FAO Plant Production and Protection Paper 187; http://www.fao.org/ag/AGP/AGPP/Pesticid/JMPR/DOWNLOAD/2006_rep/report2006jmpr.pdf).

WHO (2008) *Pirimiphos-methyl in drinking-water: Use for vector control in drinking-water sources and containers. Background document for preparation of WHO Guidelines for drinking-water quality.* Geneva, World Health Organization (WHO/HSE/AMR/08.03/15).

12.126.5 Pyriproxyfen
Pyriproxyfen is a broad-spectrum insect growth regulator with insecticidal activity against public health insect pests, including mosquitoes. WHO has assessed pyriproxyfen for use as a mosquito larvicide in drinking-water in containers, particularly to control dengue fever. The recommended dosage of pyriproxyfen in potable water in containers should not exceed 0.01 mg/litre under the WHO Pesticides Evaluation Scheme.

JMPR evaluated pyriproxyfen and concluded that it was not genotoxic and does not pose a carcinogenic risk to humans. Young animals do not appear to be significantly more sensitive than adults.

JMPR established an ADI of 0–0.1 mg/kg of body weight on the basis of an overall NOAEL of 10 mg/kg of body weight per day, based on increased relative liver weight and increased total plasma cholesterol concentration in male dogs in two 1-year studies of toxicity and a safety factor of 100.

It is not considered appropriate to set a formal guideline value for pyriproxyfen used for vector control in drinking-water. The maximum recommended dosage in drinking-water of 0.01 mg/litre would be equivalent to less than 1% of the ADI allocated to drinking-water for a 60-kg adult drinking 2 litres of water per day. For a 10-kg child drinking 1 litre of water, the exposure would be 0.01 mg, compared with an exposure of 1 mg at the ADI. For a 5-kg bottle-fed infant drinking 0.75 litre per day, the exposure would be 0.0075 mg, compared with an exposure of 0.5 mg at the ADI. The low solubility and the high log K_{ow} of pyriproxyfen indicate that it is unlikely to remain in solution at the maximum recommended applied dose, and the actual levels of exposure are likely to be even lower than those calculated.

A guideline value for pyriproxyfen used for agriculture purposes is described in section 12.104.

History of guideline development
The 1958 and 1963 WHO *International Standards for Drinking-water* did not refer to pyriproxyfen, but the 1971 International Standards suggested that pesticide residues that may occur in community water supplies make only a minimal contribution to the total daily intake of pesticides for the population served. Pyriproxyfen was not evaluated in the first edition of the *Guidelines for Drinking-water Quality*, published in 1984, in the second edition, published in 1993, or in the addendum to the second edition, published in 1998. A guideline value for pyriproxyfen was published in the third edition. It was subsequently decided to evaluate pyriproxyfen as a vector control larvicide separately from its other uses.

Assessment date
The risk assessment was conducted in 2007.

Principal references
FAO/WHO (2000) Pyriproxyfen. In: *Pesticide residues in food – 1999 evaluations. Part II – Toxicological*. Geneva, World Health Organization, Joint FAO/WHO Meeting on Pesticide Residues (WHO/PCS/00.4; http://www.inchem.org/documents/jmpr/jmpmono/v99pr12.htm).

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

Changes to "Annex 1: Bibliography"

Page 461

➢ Insert the following below Bartram J et al., eds. (2004):

Bartram J et al., eds. (2007) *Legionella and the prevention of legionellosis*. Geneva, World Health Organization. Available at http://www.who.int/water_sanitation_health/emerging/legionella.pdf.

➢ Insert the following below Chorus I, Bartram J, eds. (1999):

Cotruvo J, Bartram J, eds. (2007) *Calcium and magnesium in drinking-water: Public health significance*. Geneva, World Health Organization.

➢ Insert the following below FAO/WHO (2003):

Fawell J et al. (2006) *Fluoride in drinking-water*. London, IWA Publishing, on behalf of the World Health Organization (WHO Drinking-water Quality Series). Available at http://www.who.int/water_sanitation_health/publications/fluoride_drinking_water/en/index.html.

➢ Insert the following below LeChevallier MW, Au K-K (2004):

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. Available at http://www.who.int/water_sanitation_health/publications/protecting_groundwater/en/index.html.

Page 462

➢ Below WHO (in revision) *Guide to ship sanitation*, insert the following:

WHO (in preparation) *Guidelines for the microbiological performance evaluation of point-of-use drinking-water technologies*. Geneva, World Health Organization.

➢ Replace the WHO *Health aspects of plumbing* reference with the following:

WHO (2006) *Health aspects of plumbing*. Geneva, World Health Organization and World Plumbing Council. Available at http://www.who.int/water_sanitation_health/publications/plumbinghealthasp/en/.

➢ Delete the WHO *Legionella and the prevention of legionellosis* reference.

➢ Delete WHO (in preparation) *Protecting groundwaters for health – Managing the quality of drinking-water sources*. Geneva, World Health Organization.

➢ Insert the following above APHA (1998):

Annanmäki M, Turtiainen T, eds. (2000) *Treatment techniques for removing natural radionuclides from drinking water*. Helsinki, Radiation and Nuclear Safety Authority (STUK-A169).

Page 463

> ➢ Insert the following below Brikké F (2000):

Castle RG (1988) Radioactivity in water supplies. *Journal of the Institution of Water and Environmental Management*, 2(3):275–284.
Clasen T et al. (2006) Interventions to improve water quality for preventing diarrhoea (Cochrane Review). In: *The Cochrane Library*, Issue 3. Oxford, Update Software (CD004794).

> ➢ Insert the following below Codex Alimentarius Commission (2001):

Cotruvo JA, Sobsey M (2006) Point-of-use water treatment for home and travel. In: Grabow W, ed. *UNESCO encyclopedia of life support systems*. Paris, United Nations Educational, Scientific and Cultural Organization. Available at http://www.eolss.net.

> ➢ Insert the following below Dangendorf et al. (2003):

Darby S et al. (2005) Radon in homes and risk of lung cancer: Collaborative analysis of individual data from 13 European case–control studies. *BMJ (British Medical Journal)*, 330(7485):223.

> ➢ Insert the following below Farland W, Dourson ML (1992):

Fewtrell L, Colford J (2004) *Water, sanitation and hygiene: Interventions and diarrhoea – A systematic review and meta-analysis.* Health, Nutrition, and Population Family of the World Bank Human Development Network. Available at http://siteresources.worldbank.org/HEALTHNUTRITIONANDPOPULATION/Resources/281627-1095698140167/Fewtrell&ColfordJuly2004.pdf.

Page 464

> ➢ Insert the following below Howard G et al. (2002):

Hutin Y, Luby S, Paquet C (2003) A large cholera outbreak in Kano City, Nigeria: The importance of hand washing with soap and the danger of street-vended water. *Journal of Water and Health*, 1:45–52.

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> ➢ Insert the following below Jochimsen EM et al. (1998):

Kinner NE et al. (1990) Treatment technology for removing radon from small community water supplies. In: Cothern CR, Rebers PA, eds. *Radon, radium and uranium in drinking water.* Chelsea, MI, Lewis Publishers.

Krewski D et al. (2005) Residential radon and risk of lung cancer: a combined analysis of 7 North American case–control studies. *Epidemiology*, 16(2):137–145.

➢ Insert the following below Lloyd B, Bartram J (1991):

Lykins BW, Clark RM, Goodrich JA (1992) *Point-of-use/point-of-entry for drinking water treatment*. Chelsea, MI, Lewis Publishers.

Nath KJ, Bloomfield S, Jones M (2006) *Household water storage, handling and point-of-use treatment*. A review commissioned by the International Scientific Forum on Home Hygiene. Available at http://www.ifh-homehygiene.org/2003/2library/low_res_water_paper.pdf.

➢ Insert the following below Pouria S et al. (1998):

Prüss A, Corvalan C (2006) *Preventing disease through healthy environments. Towards an estimate of the environmental burden of disease*. Geneva, World Health Organization.

Prüss A et al. (2002) Estimating the burden of disease from water, sanitation, and hygiene at a global level. *Environmental Health Perspectives*, 110:537–542.

➢ Insert the following below Simpson-Hébert M, Sawyer R, Clarke L (1996):

Solecki R et al. (2005) Guidance on setting of acute reference dose (ARfD) for pesticides. *Food and Chemical Toxicology*, 43:1569–1593. Available at http://www.who.int/ipcs/food/jmpr/arfd/en/index.html.

➢ Insert the following below UNSCEAR (2000):

US EPA (2003) *EPA assessment of risks from radon in homes*. Washington, DC, United States Environmental Protection Agency, Office of Radiation and Indoor Air (EPA 402-R-03-003).

➢ Delete the US NRC (1999) reference.

Page 466

➢ Replace the reference below WHO (2003b) with the following:

WHO (2006) *Guidelines for safe recreational water environments.* Vol. 2. *Swimming pools and similar environments*. Geneva, World Health Organization, Water, Sanitation and Health.

➢ Insert the following below World Health Assembly (1991):

Wright J, Gundry S, Conroy R (2003) Household drinking water in developing countries: A systematic review of microbiological contamination between source and point-of-use. *Tropical Medicine & International Health*, 9(1):106–117.

Changes to "Annex 2: Contributors to the development of the third edition of the *Guidelines for drinking-water quality*"

Page 467

➢ For Dr H. Abouzaid, replace the parenthetical material as follows:

(1, 7, 9, 15, 23, 25, 27, 32, 47)

➢ Insert the following below Dr R. Abrams:

Dr L. Achene, (49), Istituto Superiore di Sanita, Rome, Italy

➢ Insert the following below Dr Z. Adeel:

Professor A. Adin, (47), Hebrew University of Jerusalem, Rehovot, Israel

➢ Insert the following below Mr M. Adriaanse:

Dr S. Adrian, (25), US Environmental Protection Agency, Washington, DC, USA

➢ For Mr R. Aertgeerts, replace the parenthetical material as follows:

(7, 15, 23, 24, 27, 32, 48, 49, 51)

➢ For Dr F. Ahmed, replace the parenthetical material as follows:

(30, 32, 33, 38, 39, 50, 51)

➢ For Dr A. Aitio, replace the parenthetical material as follows:

(26, 30, 32)

➢ Insert the following below Dr M. Allen:

Dr F. Allerberger, (41), Institut für Medizinische Mikrobiologie und Hygiene, Vienna, Austria

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➢ Insert the following below Dr M. Al Sulaiti:

Dr B.M. Altura, (40), New York Downstate Medical Center, Brooklyn, NY, USA
Dr B.T. Altura, (40), New York Downstate Medical Center, Brooklyn, NY, USA
Mr M. Amazonas, (25), The Coca-Cola Company, Atlanta, GA, USA

➢ Insert the following below Dr L.K. Andersen:

Mrs R. Anderson, (46, 52), WHO, Geneva, Switzerland

➢ Insert the following below Dr M. Ando:

Ms K. Andrus, (46), Air Transport Association of America, Washington, DC, USA

➢ Insert the following below Ms K. Asora:

Professor S. Atkinson, (40, 47), McMaster University, Hamilton, Canada

➢ For Dr K. Bailey, replace the parenthetical material as follows:

(5, 37)

➢ Insert the following below Dr M. Baril:

Dr J. Barot, (33), WHO, New Delhi, India
Dr H. Bartel, (51), Federal Environment Agency, Berlin, Germany

➢ For Dr J. Bartram, replace the parenthetical material as follows:

(1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13, 14, 15, 16, 18, 19: xiii–lii, liv–lxviii, 21: i–v, 22, 23, 24, 25, 29, 30, 32, 33, 37, 38, 40, 41, 46, 47, 51, 52)

➢ For Dr H. Bates, replace the parenthetical material as follows:

(31: vii, 34: iii)

➢ For Dr A. Bathija, replace the parenthetical material as follows:

(19: xxvi, 30, 32, 33, 34: ii–v, 39)

➢ Insert the following below Dr A. Bathija:

Dr J. Baumgartner, (39), University of Wisconsin, Madison, WI, USA

➢ Insert the following below Dr R. Belmar:

Dr D. Bennitz, (52), Health Canada, Ottawa, Canada

➢ For Dr R. Bentham, replace the parenthetical material as follows:

(16, 41)

Page 468a

➢ Insert the following below Dr P. Berger:

Dr M. Berglund, (34: iii), Karolinska Institute, Stockholm, Sweden

➢ Insert the following below Dr A. Boehncke:

Mr N. Bogatz, (38), International Association of Plumbing and Mechanical Officials, Ontario, CA, USA

➢ For Dr L. Bonadonna, replace the parenthetical material as follows:

(14, 21: i, 49)

Page 469

➢ Insert "(deceased)" after Dr X. Bonnefoy.

➢ Insert the following below Dr X. Bonnefoy:

Mr C. Bonnici, (48), Environment and Health Unit, Civic Centre, Zabbar, Malta

➢ For Mr R. Bos, replace the parenthetical material as follows:

(30, 31: xiii, 33, 38)

➢ For Professor K. Botzenhart, replace the parenthetical material as follows:

(5, 16, 21: iii, 41)

➢ Insert the following below Professor K. Botzenhart:

Mr M. Bower, (49), Scottish Executive, Edinburgh, UK

➢ Insert the following below Dr L. Bowling:

Mr R. Brannon Davis, (25), Centers for Disease Control and Prevention, Atlanta, GA, USA

➢ For Dr E. Briand, replace entry as follows:

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➢ Insert the following below Dr E. Briand:

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Ms T. Brooks, (39), Health Canada, Ottawa, Canada
Mr G. Brundrett, (41), Brundrett Associates, Kingsley, UK

➢ Insert the following below Mr M. Burch:

Mr R.D. Burgon, (38), Scottish and Northern Ireland Plumbing Employers Federation, Edinburgh, Scotland

➢ For Dr P. Byleveld, replace the parenthetical material as follows:

(10, 25)

➢ Insert the following below Dr P. Byleveld:

Mr P.A. Cabanes, (41), Electricité de France, Service des Etudes Médicales, Paris, France
Mr E. Calderon, (49), Tripartite Body for Sanitation Works and Services (ETOSS), Buenos Aires, Argentina
Dr R. Calderon, (40, 47), US Environmental Protection Agency, Durham, NC, USA

➢ For Mr P. Callan, replace the parenthetical material as follows:

(7, 8, 13, 15, 17, 19: xiii–lii, liv–lxviii, 22, 25, 41)

➢ For Mr R. Carr, replace the parenthetical material as follows:

(23, 38, 42)

➢ For Dr C. Castell-Exner, replace the parenthetical material as follows:

(25, 27)

➢ Insert the following below Dr M. Cavalieri:

Mr S. Cavanaugh, (38), United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry of the United States and Canada

➢ For Dr D. Chapman, replace the parenthetical material as follows:

(29, 37)

➢ Move Mr S. Chantaphone and Dr D. Chapman below Ms L. Channan

➢ Insert the following below Dr D. Chapman:

Mr Y. Chartier, (32, 33, 41, 49), WHO, Geneva, Switzerland

➢ Insert the following below Professor W. Chee Woon:

Dr B. Chen, (37), Fudan University, Shanghai, China
Mr P.F. Chevet, (41), Direction Régionale de l'Industrie, de la Recherche et de l'Environnement, Douai, France

Page 469a

➢ Insert the following below Dr T. Chi Ho:

Dr J. Chilton, (37), British Geological Survey, Wallingford, UK

➢ Insert the following below Dr N. Chiu:

Mr T. Cho, (52), Airports Council International Headquarters, Geneva, Switzerland

Page 470

➢ For Dr I. Chorus, replace the parenthetical material as follows:

(2, 5, 7, 8, 15, 20, 22, 25, 27, 29, 32, 33, 50, 51)

➢ Insert the following below Dr J. Clark-Curtiss:

Dr T. Clasen, (39), London School of Hygiene & Tropical Medicine, London, UK

➢ Insert the following below Dr E. Clayton:

Dr L. Coccagna, (49), independent consultant, Castel Maggiore, Italy

➢ Insert the following below Professor G. Codd:

Mr S. Cole, (41), Wessex Water, Bristol, UK
Dr G. Combs, (40, 47), Grand Forks Human Nutrition Research Center, Grand Forks, ND, USA

➢ Insert the following below Dr M. Cooper:

Dr J. Cortvriend, (48, 51), European Commission, Brussels, Belgium

➢ Insert the following below Dr A.L. Corwin:

Dr R. Costello, (40, 47), National Institutes of Health, Bethesda, MD, USA

➢ For Dr J. Cotruvo, replace the parenthetical material as follows:

(3, 5, 7, 9, 14, 18, 22, 23, 25, 30, 32, 33, 34: ii, 37, 38, 39, 40, 46, 47, 50, 51)

➢ Insert the following below Dr J. Cotruvo:

Professor J. Colbourne, (49), Drinking Water Inspectorate, London, UK
Mr D. Courtman, (38), Institute of Plumbing and Heating Engineering, Essex, UK

➢ For Dr S. Crespi, replace the parenthetical material as follows:

(16, 41)

➢ For Dr C. Cunliffe, replace the parenthetical material as follows:

(8, 13, 19, 20, 21: iv, 22, 23, 25, 27, 30, 32, 33, 39, 41, 42, 43, 44, 50, 51)

➢ For Dr F. Dagendorf, replace the entire entry as follows:

Dr F. Dangendorf (deceased), (16, 41), University of Bonn, Bonn, Germany

➢ Insert the following below Dr F. Dangendorf:

Professor E. Dahi, (37), Environmental Development Cooperation Group, Soborg, Denmark

➢ Insert the following below Dr H. Darpito:

Dr D. Davidson, (46, 52), US Food and Drug Administration, College Park, MD, USA
Mrs G. Davis, (38), International Association of Plumbing and Mechanical Officials, Ontario, CA, USA

➢ For Dr A. Davison, replace the parenthetical material as follows:

(13, 25, 41)

➢ Insert the following below Dr A. Davison:

Dr B. de Benoist, (33), WHO, Geneva, Switzerland

➢ For Dr D. Deere, replace the parenthetical material as follows:

(6, 8, 12, 13, 23, 25, 27, 41)

➢ Insert the following below Dr D. Deere:

Dr B. de Jong, (41), Swedish Institute for Infectious Disease Control, Solna, Sweden

➢ Insert the following below Dr J.M. Delattre:

Dr J. Dennis, (41), Thames Water Utilities, Reading, UK

➢ For Dr A.M. de Roda Husman, replace the parenthetical material as follows:

(30, 32, 51)

➢ Insert the following below Professor B. De Villiers:

Mr T. Devin, (41), Institute of Engineers of Ireland, Dublin, Ireland

Page 470a

➢ For Professor H. Dieter, replace the parenthetical material as follows:

(19: xxii, 39, 51)

➢ Insert the following below Dr P. Dillon:

Mrs V. Djudemisheva, (51), Rural Water Supply and Sanitation Project WB/DFID, Bishkek, Kyrgyzstan

➢ Insert the following below Dr B.A. Dmytrasz:

Mr P. Donlon, (25), Water Services Association of Australia, Victoria, Australia

Page 471

➢ For Dr J. Donohue, replace the parenthetical material as follows:

(7, 19: xxxvi, 31: iii, 40, 47)

➢ For Dr V. Drasar, replace the parenthetical material as follows:

(16, 41)

➢ Insert the following below Dr M. Drikas:

Mrs I. Drulyte, (48, 51), State Public Health Service, Ministry of Health, Vilinius, Lithuania
Dr D. Drury, (25, 48, 50, 51), Drinking Water Inspectorate, London, UK

➢ Insert the following below Dr S. Edberg:

Professor P. Edelstein, (41), University of Pennsylvania Medical Center, Philadelphia, PA, USA

➢ Insert the following below Dr N. Edmonds:

Mr P. Edmondson, (34: vi), Medentech Ltd, Wexford, Ireland

➢ Insert the following below Dr H. El Habr:

Dr R.J. Elin, (40, 47), University of Louisville, Louisville, KY, USA

➢ Insert the following below Mr P. Emile:

Dr J. Emmanuel, (52), WHO, Geneva, Switzerland

➢ For Dr T. Endo, replace the parenthetical material as follows:

(5, 7, 14, 15, 19, 22, 30, 32, 33, 45, 51)

➢ Insert the following below Mr G. Ethier:

Dr A. Evans, (46, 52), International Civil Aviation Organization, Montreal, Canada

➢ Insert the following below Dr C. Evins:

Dr S. Ewig, (41), DGI Umweltmedizin, Bonn, Germany

➢ For Dr M. Exner, replace the parenthetical material as follows:

(14, 16, 22, 41, 49)

➢ For Dr J. Fastner, replace the parenthetical material as follows:

(15, 29, 51)

➢ For Mr J. Fawell, replace the parenthetical material as follows:

(4, 5, 7, 15, 17, 19: vi, xii–lxix, 20, 22, 29, 30, 31: iv–vii, xii, 32, 33, 34: i, iii–vi, 37, 39, 40, 47, 50, 51)

➢ Insert the following below Mr J. Fawell:

Dr D. Fayzieva, (49), Uzbekistan Academy of Sciences, Taskent, Uzbekistan

➢ Insert the following below Dr T. Fengthong:

Mr B. Ferguson, (46), NSF International, Ann Arbor, MI, USA
Dr E. Ferretti, Istituto Superiore di Sanita, Rome, Italy

Page 472

➢ For Dr L. Fewtrell, replace the parenthetical material as follows:

(6, 12, 37, 41)

➢ For Dr B. Fields, replace the parenthetical material as follows:

(16, 41)

➢ For Dr J. Fitzgerald, replace the parenthetical material as follows:

(29, 37)

➢ Insert the following below Dr T. Ford:

Dr P. Fourrier, (41), Direction Générale de la Santé, Paris, France

➢ Insert the following below Dr A. Friday:

Mr A. Frost, (40), Aqua Europa, Brussels, Belgium
Mr T. Frost, (40), Aqua Focus Ltd, Newport, UK
Dr N.K. Fry, (41), Health Protection Agency, London, UK

➢ For Dr E. Funari, replace the parenthetical material as follows:

(7, 51)

➢ Insert the following below Dr E. Funari:

Dr V.Gaia, (41), Istituto Cantonale Microbiologia, Bellinzona, Switzerland

➤ Insert the following below Dr Luiz Augusto Galvao:

Mr D. Gamper, (52), Airports Council International Headquarters, Geneva, Switzerland

➤ Insert the following below Dr A.E.H. Gassim:

Mr D. Gatel, (48), EUREAU, Brussels, Belgium

➤ For Ms M. Giddings, replace the parenthetical material as follows:

(15, 19: xiii–lii, liv–lxviii, 20, 22, 29, 30, 31: ii, viii, ix, xi, 32, 33, 51, 53)

➤ For Mr B. Gordon, replace the parenthetical material as follows:

(30, 32, 33, 38, 50, 51, 52)

➤ For Ms F. Gore, replace the parenthetical material as follows:

(22, 30, 32, 33)

Page 472a

➤ Insert the following below Mr S. Godfrey:

Dr S. Godfrey, (25), UNICEF, Bhopal, India

Page 473

➤ For Professor W. Grabow, replace the parenthetical material as follows:

(5, 6, 8, 13, 19, 20, 21: ii, 22, 25, 42, 43, 44)

➤ Insert the following below Professor W. Grabow:

Dr J. Grace, (52), Association of Flight Attendants, Washington, DC, USA

➤ Insert the following below Mr W. Graham:

Dr A.C. Grandjean, (40, 47), Center for Human Nutrition, Omaha, NE, USA

➤ Insert the following below Dr R. Gregory:

Dr E. Griswold, (40), International Council of Bottled Water Associations, Richmond Hill, Canada

➤ Insert the following below Professor A. Grohmann:

Dr H.-J. Grummt, (51), Federal Environment Agency, Bad Elster, Germany
Dr T. Grummt, (51), Federal Environment Agency, Bad Elster, Germany

➢ Insert the following below Dr S. Gupta:

Mr B. Guthrie, (41), Pool Water Treatment Advisory Group, Thrandeston, Diss, Norfolk, UK

➢ Insert the following below Ms L. Haller:

Mr J. Halliwill, (38), International Association of Plumbing & Mechanical Officials, Ontario, CA, USA

➢ Insert the following below Dr M. Hardiman:

Dr S. Harris, (47), International Life Sciences Institute, Washington, DC, USA
Dr J. Harrison, (40), Water Quality Association, Lisle, IL, USA
Professor P. Hartemann, (41, 49), University of Nancy, Vandoeuvre, France

➢ For Mr J. Hayes, replace the parenthetical material as follows:

(16, 41)

➢ Insert the following below Mr J. Hayes:

Mr S. Hazen, (46), NSF International, Ann Arbor, MI, USA
Dr R.P. Heaney, (40), Creighton University, Omaha, NE, USA

➢ For Mr H. Heijnen, replace the parenthetical material as follows:

(30, 32, 33, 51)

➢ Insert the following below Dr N. Hepworth:

Dr S. Herbst, (49), Institute for Hygiene and Public Health, Bonn, Germany

➢ Insert the following below Mr A. Hicking:

Dr L. Hicks, (41), Centers for Disease Control and Prevention, Atlanta, GA, USA

➢ Insert the following below Dr R. Hilton:

Dr A. Hirose, (33, 51), National Institute of Health Sciences, Tokyo, Japan
Dr E. Hoekstra, (34: iii), Institute for Health and Consumer Protection, Rome, Italy

Page 473a

➢ Insert the following below Dr D. Holt:

Ms L. Hope, (52), WHO, Geneva, Switzerland

➢ Insert the following below Professor H. Höring:

Dr B. Hornei, (41), Hygiene Institute, University of Bonn, Bonn, Germany

Page 474

➢ For Dr G. Howard, replace the parenthetical material as follows:

(2, 5, 7, 8, 12, 13, 15, 19, 20, 22, 23, 25, 30, 32, 33, 37, 51)

➢ Insert the following below Professor S. Hrudey:

Dr S. Huda, (32), WHO, New Delhi, India

➢ For Mr J. Hueb, replace the parenthetical material as follows:

(20, 21: v, 23, 30, 32, 33, 38)

➢ For Dr P. Hunter, replace the parenthetical material as follows:

(14, 23, 40, 47)

➢ For Dr M. Ince, replace the parenthetical material as follows:

(12, 25, 26, 53)

➢ Insert the following below Dr M. Ince:

Councillor L. Intemann, (40), Wauchope, Australia

➢ Insert the following below Mr J. Ishiwata:

Dr M. Itoh, (33, 49), National Institute of Public Health, Saitama, Japan (formerly WHO, Geneva, Switzerland)

➢ For Mr P. Jackson, replace the parenthetical material as follows:

(2, 5, 7, 15, 19: xiii–lii, liv–lxviii, 22, 25, 30, 31: i, xiv, 32, 33, 37, 39, 51)

➢ For Dr C. Joseph, replace the parenthetical material as follows:

(16, 41)

➢ Insert the following below Mr I. Karnjanareka:

Dr G. Karthikeyan, (37), The Gandhigram Rural Institute, Tamilnadu, India

➢ Insert the following below Dr D. Kay:

Mr D. Keenan, (38), Master Plumbers, Gasfitters and Drainlayers New Zealand, Inc., Wellington, New Zealand

➢ Insert the following below Dr H. Kerndorff:

Dr R. Kfir, (37), Water Research Commission, Pretoria, South Africa

Page 475

➢ Insert the following below Dr G. Klein:

Mrs K. Knufmann-Happe, (51), Ministry of Health, Berlin, Germany

➢ Insert the following below Dr M. Koopmans:

Professor R. Kopschitz Xavier Bastos, (25), Federal University of Viçosa, Viçosa, Brazil

➢ For Dr F. Kozisek, replace the parenthetical material as follows:

(19, 47, 48)

➢ Insert the following below Dr A. Kozma-Törökne:

Dr W. Krüger, (51), Ministry of Health, Bonn, Germany

➢ For Dr S. Kumar, replace the parenthetical material as follows:

(30, 32, 33, 39, 45, 50, 51, 53)

➢ For Dr S. Kunikane, replace the parenthetical material as follows:

(7, 15, 17, 22, 30, 32, 33, 51)

➢ Insert the following below Mr P. Lafitaga:

Ms H. Lahav, (34: iv), Makhteshim Chemical Works Ltd, Beer-Sheva, Israel
Dr L. Lajoie, (41), University of Bonn, Bonn, Germany

➢ For Dr J. Latorre Monterro, replace the parenthetical material as follows:

(25, 30, 32, 33, 39)

➢ Replace the entry for Dr J. Lee with the following:

Dr J.V. Lee, (5, 16, 21: iii, 41, 49), Health Protection Agency, London, UK

➢ Insert the following below Mr F. Leitz:

Professor M. Lennon, (37), University of Liverpool, Liverpool, UK

➢ Insert the following below Dr N. Lightfoot:

Dr P. Lindgaard-Jørgensen, (36, 53), DHI Water and Environment, Horsholm, Denmark

➢ Insert the following below Mr S. Loau:

Mr J.F. Loret, (41), Centre International de Recherche sur l'Eau et l'Environnement, Paris, France
Dr L. Lucentini, (49), Istituto Superiore di Sanita, Rome, Italy

➢ For Dr Y. Magara, replace the parenthetical material as follows:

(1, 4, 5, 7, 14, 15, 19: xiii–lii, liv–lxviii, 21: iv, 22, 30, 31: x, 32, 33, 37, 51)

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➢ For Dr B. Magtibay, replace the parenthetical material as follows:

(11, 22, 25, 32)

➢ Insert the following below Professor M. Martin:

Mr R.T. Martin, (38), The Institute of Plumbing Australia Inc., Marmion, Australia

➢ Insert the following below Dr R. Mascarenhas:

Professor Y. Matsui, (51), Hokkaido University, Sapporo, Japan
Ms A. May, (25, 49), Drinking Water Inspectorate, London, UK
Dr W. McCoy, (41), Phigenics, Chicago, IL, USA
Mr D. McRae, (40), Water Quality Australia (Inc.), Melbourne, Australia

➢ For Dr D. Medeiros, replace the parenthetical material as follows:

(26, 39)

➢ For Dr G. Medema, replace the parenthetical material as follows:

(5, 7, 8, 21: iv, 51)

➢ Insert the following below Dr J.M. Melse:

Mr S.R. Mendonca, (38), WHO, Lima, Peru
Dr D. Menucci, (52), WHO, Lyon, France

➢ Insert the following below Dr E. Meyer:

Mr T. Michelon, (41), Direction Générale de la Santé, Paris, France

➢ For Ms M.N. Mons, replace the parenthetical material as follows:

(7, 47)

➢ Insert the following below Ms M.N. Mons:

Dr M. Moore, (41), Centers for Disease Control and Prevention, Atlanta, GA, USA

➢ Insert the following below Dr R. Morris:

Dr. R.W. Morris, (47), University College London, London, UK

➢ Insert the following below Ms G. Motturi:

Mr S.J. Movley, (38), The Institute of Plumbing Australia Inc., Marmion, Australia

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➢ Insert the following below Dr G. Moy:

Professor U. Müller-Wegener, (51), Federal Environment Agency, Berlin, Germany

Page 477

➢ Insert the following below Mr M.W. Muru:

Mr L. Muthumariappan, (40), Tamilnadu Water Supply and Drainage Board, Tamilnadu, India

➢ Replace the entry for Pr. K. Nath with the following:

Professor K. Nath, (19, 48), Institution of Public Health Engineers, Calcutta, India

➢ Insert the following below Professor K. Nath:

Dr M. Nathan, (33), WHO, Geneva, Switzerland

➢ Insert the following below Mr P. Navuth:

Dr R. Naylor, (46, 52), US Environmental Protection Agency, Washington, DC, USA

➢ Insert the following below Mr M. Neal:

Dr A. Nejjar, (51), WHO Regional Office for Africa, Libreville, Gabon

➢ For Mr J. Newbold, replace the parenthetical material as follows:

(16, 41)

➢ Insert the following below Dr E. Ngoni Mudege:

Dr A.V.F. Ngowi, (32, 33, 37, 51), Tropical Pesticides Research Institute, Arusha, United Republic of Tanzania

➢ Insert the following below Dr G. Nichols:

Dr C. Nicholson, (25), Sydney Water, Sydney, Australia
Dr F.H. Nielsen, (40), US Department of Agriculture, Grand Forks, ND, USA
Dr J.W. Nieves, (40), Columbia University, West Haverstraw, NY, USA

➢ For Dr E. Ohanian, replace the parenthetical material as follows:

(4, 7, 19: i–lii; liv–lxviii, 22, 51)

➢ Insert the following below Dr Y. Okumura:

Professor C.N. Ong, (40, 47, 51), University of Singapore, Singapore
Ms L. Onyon, (33), WHO, Geneva, Switzerland

➢ Insert the following below Ms J. Orme-Zavaleta:

Dr J-N. Ormsby, (41), Direction Générale de la Santé, Paris, France

➢ Insert the following below Dr Y. Ortega:

Dr M. Ottaviani, (49), Istituto Superiore di Sanita, Rome, Italy

➢ Insert the following below Dr J. Padisák:

Dr I. Pallet, (40), British Water, London, UK

➢ Insert the following below Dr F. Pamminger:

Mr G. Panié, (41), Direction Régionale de l'Industrie, de la Recherche et de l'Environnement, Douai, France

➢ Insert the following below Mr R. Paramasivan:

Dr M. Pardon, (32, 51), WHO, Lima, Peru

Page 478

➢ Insert the following below Dr S. Pedley:

Mr F. Penfold, (38), Ontario Plumbing Inspectors Association, Toronto, Canada

➢ Insert the following below Mr A. Percival:

Professor J.M. Pereira Vieira, (25), University of Minho, Braga, Portugal
Dr P.E. Petersen, (32, 33, 37), WHO, Geneva, Switzerland

➢ Insert the following below Dr J. Plouffe:

Plumbing-Heating-Cooling Contractors National Association, (38), Falls Church, VA, USA
Plumbing Industry Commission, (38), Victoria, Australia
Mr T. Pohle, (52), Air Transport Association, Washington, DC, USA

Dr K. Pond, (41), University of Surrey, Guildford, UK
Dr K.L. Porter, (46, 52), US Environmental Protection Agency, Washington, DC, USA
Dr R.C. Portero, (41), Instituto de Salud Carlos III, Madrid, Spain

➢ For Mr F. Properzi, replace the parenthetical material as follows:

(22, 30, 32, 33, 38)

➢ Insert the following below Dr P.P. Raingsey:

Mr H. Ramanathan, (38), International Association of Plumbing and Mechanical Officials, Ontario, CA, USA

➢ Insert the following below Dr C. Ramsay:

Dr T. Rapp, (49, 51), Federal Environment Agency, Bad Elster, Germany

➢ Insert the following below Dr S. Regli:

Dr P. Regunathan, (40, 47), Regunathan & Associates, Inc., Wheaton, IL, USA

➢ For Mr M. Repacholi, replace the parenthetical material as follows:

(20, 22, 33)

➢ Insert the following below Ms J. Riego de Dios:

Ms A. Rinehold, (25), Centers for Disease Control and Prevention, Atlanta, GA, USA

➢ For Mr W. Robertson, replace the parenthetical material as follows:

(3, 7, 8, 14, 23, 26, 42, 43, 44)

➢ Insert the following below Mr W. Robertson:

Mr A. Robin, (48), Ministry of Health, Paris, France

➢ Insert the following below Dr J. Rocourt:

Dr J. Roig, (41), Hospital Nostra Senyora de Meritxell, Andorra, Spain
Mr R. Rojas Vargas, (32, 33, 36, 38, 53), WHO, Lima, Peru

Page 479

➢ For Ms R. Rooney, replace the entry with the following:

Dr R. Rooney, (12, 16, 41), WHO, Delhi, India

➢ Insert the following below Mr A. Salem:

Mr E. Saltzberg, (38), Edward Saltzberg & Associates, Van Nuys, CA, USA

➢ For Mr D. Sartory, replace the parenthetical material as follows:

(5, 21: i, 35)

➢ Insert the following below Dr M. Savkin:

Dr B. Schaefer, (49), Umweltbundesamt, Bad Elster, Germany

➢ For Dr S. Schaub, replace the parenthetical material as follows:

(6, 16, 21: iv, 28, 51)

➢ Insert the following below Mrs G. Schlag:

Dr D. Schmid, (41), Institut für Medizinische Mikrobiologie und Hygiene, Vienna, Austria

➢ For Mr O. Schmoll, replace the parenthetical material as follows:

(8, 15, 27, 32, 33, 48, 50, 51)

➢ Insert the following below Mr O. Schmoll:

Dr J. Schoeman, (37), Council for Scientific and Industrial Research, Pretoria, South Africa

➢ Insert the following below Ms S. Shaw:

Dr D. Sheehan, (25), Drinking Water Regulation Department of Human Services, Melbourne, Australia
Mr R. Shepherd, (38), International Association of Plumbing and Mechanical Officials, Ontario, CA, USA
Ms E. Sheward, (52), independent consultant, Washington, DC, USA

➢ For Ms J. Sims, replace the parenthetical material as follows:

(30, 32, 33)

➢ For Dr M. Sinclair, replace the parenthetical material as follows:

(8, 42, 43, 44, 47)

Page 480

➢ Insert the following above Professor H.V. Smith:

Mr D. Smith, (25), Melbourne Water, Victoria, Australia

➢ For Professor M. Sobsey, replace the parenthetical material as follows:

(7, 8, 12, 13, 20, 22, 25, 28, 30, 32, 33, 39, 51)

➢ Insert the following below Professor M. Sobsey:

Dr O. Soetens, (41), University of Brussels, Brussels, Belgium

➢ Insert the following below Dr F. Solsona:

Dr B. Sontia, (40), University of Ottawa, Ottawa, Canada

➢ Insert the following below Dr M. Storey:

Dr J. Stout, (41), University of Pittsburgh, Pittsburgh, PA, USA

➢ Insert the following below Dr K. Subramanian:

Mr S. Subramanian, (40), Tamilnadu Water Supply and Drainage Board, Tamilnadu, India
Dr N. Sunna, (36, 53), independent consultant, Water & Environment, Amman, Jordan (formerly of Ministry of Water and Irrigation, Jordan)

➢ For Dr S. Surman, replace the entry with the following:

Dr S. Surman-Lee, (16, 41, 49), Health Protection Agency, London, UK

➢ For Mr B. Tanner, replace the parenthetical material as follows:

(2, 49)

➢ For Professor I. Tartakovsky, replace the entry with the following:

Professor I. Tartakovsky, (16, 41), National Reference Centre on Legionellosis of the Russian Ministry of Health, Moscow, Russian Federation

➢ Insert the following below Mr J. Teio:

Mr J. Tester, (38), Schweizerischer Spenglermeister und Installateur-Verband, Switzerland

Page 480a

➢ Insert the following below Dr P.F.M. Teunis:

Dr C. Thibeault, (46, 52), International Air Transport Association, Montreal, Canada

Page 481

➢ For Dr B.H. Thomas, replace the parenthetical material as follows:

(4, 31: xi, 34: ii)

➢ Insert the following below Dr B.H. Thomas:

Mr M. Thomas, (38), PPTC Skills, Maylands, WA, Australia

➢ For Mr T. Thompson, replace the parenthetical material as follows:

(7, 12, 15, 17, 22, 23, 25, 27, 30, 32, 33)

➢ Insert the following below Dr P. Toft:

Mr R. Torres, (33, 50, 51), WHO, Lima, Peru
Dr R.M. Touyz, (40), University of Ottawa, Ottawa, Canada

➢ Insert the following below Mr V. Tovu:

Dr D.M. Trindade, (52), Núcleo de Planeamento da Saúde, Macau, People's Republic of China

➢ For Dr A. Tritscher, replace the parenthetical material as follows:

(30, 32, 33)

➢ Insert the following below Dr A. Tritscher:

Mr T. Trouvé, (41), Ministère de l'Écologie et du Développement, Paris, France

➢ Insert the following below Dr H. Utkilen:

Professor S. Vajpeyee, (47), Government Medical College and New Civil Hospital, Gujarat, India

➢ Insert the following below Dr J. van Den Berg:

Dr J.P. van der Hoek, (47), Amsterdam Water Supply, Amsterdam, Netherlands

➢ For Dr D. van der Kooij, replace the parenthetical material as follows:

(14, 21: i, 23, 41)

➢ For Dr A. Versteegh, replace the parenthetical material as follows:

(16, 41)

➢ For Ms C. Vickers, replace the parenthetical material as follows:

(15, 19: xiii–lii, liv–lxviii, 30, 32, 33)

➢ Insert the following below Ms C. Vickers:

Mr L. Vijselaar, (39), DACAAR, Kabul, Afghanistan

Page 482

➤ Insert the following below Dr I. Wagner:

Mr R. Wagner, (38), Environmental Engineering, USA

➤ Insert the following below Dr G.Wallace:

Dr F. Wallet, (41), Electricité de France, Service des Etudes Médicales, Paris, France

➤ Insert the following below Mr M.Waring:

Mr C. Watson, (38), Curtin University of Technology, Perth, WA, Australia
Mr A. Watts, (38), Institute of Plumbing and Heating Engineering, Essex, UK
Professor C.M. Weaver, (40, 47), Purdue University, West Lafayette, IN, USA
Dr W. Weglicki, (40, 47), George Washington University Medical Center, Washington, DC, USA
Dr G. Wewalka, (41), Institut für Medizinische Mikrobiologie und Hygiene, Vienna, Austria

➤ Insert the following below Dr C. Willert:

Mr T. Williams, (32, 33, 51), IWA Publishing, London, UK
Mr D. Wilson, (40), Octo Marine, Biot, France

➤ Insert the following below Dr A.Wrixon:

Dr Q. Xiang, (37), School of Public Health, Fudan University, Shanghai, People's Republic of China

➤ Insert the following below Dr Z. Yinfa:

Dr R. Yoder, (40), Water Quality Association, Lisle, IL, USA

➤ Insert the following below Professor Z. Yuhui:

Dr M. Zaim, (32, 33), WHO, Geneva, Switzerland

➤ Insert the following below Mrs N. Zainuddin:

Mr S. Zhao, (38), Building Design Institute, Ministry of Construction, People's Republic of China

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➤ Add the following text at the bottom of the page:

32. *Participant in the Expert Consultation for Updating the Third Edition of the Guidelines for Drinking-water Quality, Geneva, Switzerland, 9–13 May 2005*
33. *Participant in the Expert Consultation for the Second Addendum to the Third Edition of the Guidelines for Drinking-water Quality, Geneva, Switzerland, 15–19 May 2006*

34. *Contributor to the chemical background document on:*
    i.   *Carbaryl*
    ii.   *Diflubenzuron*
    iii.   *Methoprene*
    iv.   *NDMA*
    v.   *Novaluron*
    vi.   *Pirimiphos-methyl*
    vii.   *Pyriproxyfen*
    viii.   *Sodium dichloroisocyanurate*
35. *Contributor to the microbial background document on Aeromonas*
36. *Contributor to the background document "Field Guide to Water Supply Surveillance"*
37. *Contributor to the background document "Fluoride in Drinking-water"*
38. *Contributor to the background document "Health Aspects of Plumbing"*
39. *Contributor to the second addendum of the third edition of the Guidelines for Drinking-water Quality*
40. *Contributor to the background document "Calcium and Magnesium in Drinking-water: Public Health Significance"*
41. *Contributor to the background document "Legionella and the Prevention of Legionellosis"*
42. *Contributor to the microbial background document on Enterobacter*
43. *Contributor to the microbial background document on Blastocystis*
44. *Contributor to the microbial background document on Leptospira*
45. *Contributor to the microbial background document on Nematodes*
46. *Participant in the informal meeting on aircraft water and sanitation to inform the WHO revised Guide to Hygiene and Sanitation in Aviation, Baltimore, MD, USA, 25 April 2006*
47. *Participant in the Expert Meeting on the possible relationship between hard water and cardiovascular disease, Washington, DC, USA, 27–28 April 2006*
48. *Participant in the Second Expert Group Meeting on EU/WHO Project on Water Safety Plans, Rome, Italy, 14–15 November 2006*
49. *Participant in the Third Expert Meeting on Water Safety in Buildings, Rome, Italy, 8–9 February 2007*
50. *Participant in the meeting to discuss the draft guidance document on developing national standards and regulations based on the drinking-water guidelines, Berlin, Germany, 5 May 2007*
51. *Participant in the Expert Consultation for the Fourth Edition of the Guidelines for Drinking-water Quality, Berlin, Germany, 7–11 May 2007*
52. *Participant in the Informal Meeting of Experts to discuss the WHO Guide to Hygiene and Sanitation in Aviation, Geneva, Switzerland, 7–8 June 2007*
53. *Contributor to the background document "GDWQ training package"*

Changes to "Annex 4: Chemical summary tables"

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➤ In Table A4.2, Chemicals for which guideline values have not been established, insert the following below Bromochloroacetonitrile:

Carbaryl	Generally occurs in drinking-water at concentrations well below those at which toxic effects may occur

➤ In Table A4.2, Chemicals for which guideline values have not been established, insert the following below Di(2-ethylhexyl)adipate:

Diflubenzuron	Not considered appropriate to set guideline values for pesticides used for vector control in drinking-water

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➤ In Table A4.2, Chemicals for which guideline values have not been established, insert the following below Malathion:

Methoprene	Not considered appropriate to set guideline values for pesticides used for vector control in drinking-water

➤ In Table A4.2, Chemicals for which guideline values have not been established, insert the following below MX:

Novaluron	Not considered appropriate to set guideline values for pesticides used for vector control in drinking-water

➤ In Table A4.2, Chemicals for which guideline values have not been established, insert the following below Phenylphenol, 2- and its sodium salt:

Pirimiphos-methyl	Not recommended for direct application to drinking-water unless no other effective and safe treatments are available

➤ In Table A4.2, Chemicals for which guideline values have not been established, insert the following below Propanil:

Pyriproxyfen	Not considered appropriate to set guideline values for pesticides used for vector control in drinking-water[c]

➤ At the bottom of Table A4.2, insert the following footnote:

[c] A guideline value for pyriproxyfen used for agricultural purposes is given in Table A4.3.

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➤ In Table A4.3, insert the following below Nitrite:

N-Nitrosodimethylamine (NDMA)	0.1

> ➤ In Table A4.3, replace the Pyriproxyfen entry with the following:

Pyriproxyfen	0.3	This is not to be used as a guideline value where pyriproxyfen is added to water for public health purposes.

> ➤ In Table A4.3, insert the following below Simazine:

Sodium dichloroisocyanurate	50	As sodium dichloroisocyanurate
	40	As cyanuric acid
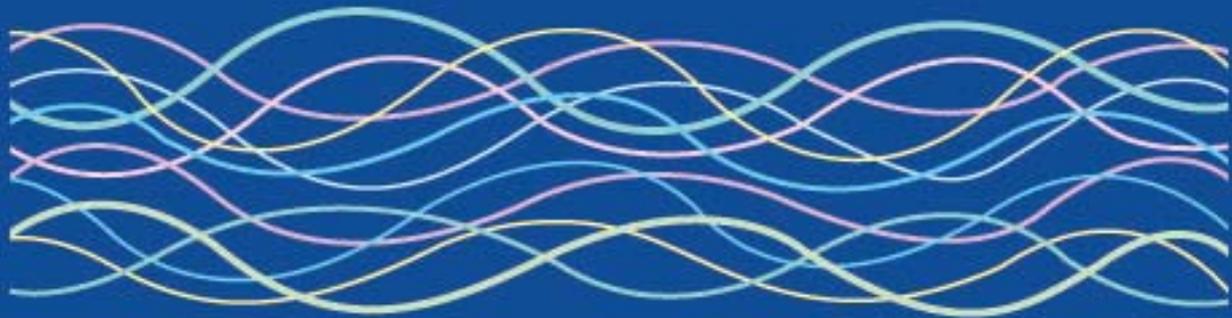
The first and second editions of the *Guidelines for Drinking-water Quality* were used by developing and developed countries worldwide as the basis of regulation and standard setting to ensure the safety of drinking-water. They recognized the priority that should be given to ensuring microbial safety and provided guidelines values for a large number of chemical hazards.

The third edition of the Guidelines was comprehensively updated to take account of developments in risk assessment and risk management. This edition was subsequently updated through a first addendum.

This second addendum further updates the third edition. It includes more guidance on household water management, rainwater harvesting, vended water, temporary water supplies, and pesticides used for vector control in drinking-water sources. It also includes a series of new microbial and chemical fact sheets. Moreover, "expanded" fact sheets are included for key chemical risks such as arsenic, fluoride and nitrate/nitrite.