

Guidelines for Drinking-water Quality

FIRST ADDENDUM TO THIRD EDITION

Volume 1

Recommendations



World Health
Organization

WHO Library Cataloguing-in-Publication Data

World Health Organization.

**Guidelines for drinking-water quality [electronic resource] :
incorporating first addendum. Vol. 1, Recommendations. – 3rd ed.**

Electronic version for the Web.

1.Potable water – standards. 2.Water – standards. 3.Water quality –
standards. 4.Guidelines. I. Title.

ISBN 92 4 154696 4

(NLM classification: WA 675)

© World Health Organization 2006

All rights reserved. Publications of the World Health Organization can be obtained from WHO Press, World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland (tel: +41 22 791 3264; fax: +41 22 791 4857; email: bookorders@who.int). Requests for permission to reproduce or translate WHO publications – whether for sale or for noncommercial distribution – should be addressed to WHO Press, at the above address (fax: +41 22 791 4806; email: permissions@who.int).

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

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

All reasonable precautions have been taken by WHO to verify the information contained in this publication. However, the published material is being distributed without warranty of any kind, either expressed or implied. The responsibility for the interpretation and use of the material lies with the reader. In no event shall the World Health Organization be liable for damages arising from its use.

Contents

Preface	xv
Acknowledgements	xviii
Acronyms and abbreviations used in text	xx
1. Introduction	1
I 1.1 General considerations and principles	1
1.1.1 Microbial aspects	3
1.1.2 Disinfection	5
1.1.3 Chemical aspects	6
1.1.4 Radiological aspects	7
1.1.5 Acceptability aspects	7
1.2 Roles and responsibilities in drinking-water safety management	8
1.2.1 Surveillance and quality control	8
1.2.2 Public health authorities	10
1.2.3 Local authorities	11
1.2.4 Water resource management	12
1.2.5 Drinking-water supply agencies	13
1.2.6 Community management	14
1.2.7 Water vendors	15
1.2.8 Individual consumers	15
1.2.9 Certification agencies	16
1.2.10 Plumbing	17
1.3 Supporting documentation to the Guidelines	18
2. The Guidelines: a framework for safe drinking-water	22
2.1 Framework for safe drinking-water: requirements	22
2.1.1 Health-based targets	24
2.1.2 System assessment and design	25
2.1.3 Operational monitoring	26
2.1.4 Management plans, documentation and communication	27
2.1.5 Surveillance of drinking-water quality	28

2.2	Guidelines for verification	29
2.2.1	Microbial water quality	29
2.2.2	Chemical water quality	30
2.3	National drinking-water policy	31
2.3.1	Laws, regulations and standards	31
2.3.2	Setting national standards	32
2.4	Identifying priority drinking-water quality concerns	34
2.4.1	Assessing microbial priorities	35
2.4.2	Assessing chemical priorities	35
3.	Health-based targets	37
3.1	Role and purpose of health-based targets	37
3.2	Types of health-based targets	39
3.2.1	Specified technology targets	41
3.2.2	Performance targets	41
3.2.3	Water quality targets	42
3.2.4	Health outcome targets	43
3.3	General considerations in establishing health-based targets	43
3.3.1	Assessment of risk in the framework for safe drinking-water	44
3.3.2	Reference level of risk	44
3.3.3	Disability-adjusted life-years (DALYs)	45
4.	Water safety plans	48
4.1	System assessment and design	51
4.1.1	New systems	52
4.1.2	Collecting and evaluating available data	53
4.1.3	Resource and source protection	56
4.1.4	Treatment	59
4.1.5	Piped distribution systems	61
4.1.6	Non-piped, community and household systems	64
4.1.7	Validation	67
4.1.8	Upgrade and improvement	67
4.2	Operational monitoring and maintaining control	68
4.2.1	Determining system control measures	68
4.2.2	Selecting operational monitoring parameters	68
4.2.3	Establishing operational and critical limits	70
4.2.4	Non-piped, community and household systems	71
4.3	Verification	71
4.3.1	Verification of microbial quality	72
4.3.2	Verification of chemical quality	73
4.3.3	Water sources	73
4.3.4	Piped distribution systems	74

CONTENTS

4.3.5	Verification for community-managed supplies	74
4.3.6	Quality assurance and quality control	75
4.4	Management procedures for piped distribution systems	76
4.4.1	Predictable incidents (“deviations”)	77
4.4.2	Unforeseen events	77
4.4.3	Emergencies	78
	[4.4.4 Deleted in first addendum to third edition]	
4.4.5	Preparing a monitoring plan	80
4.4.6	Supporting programmes	80
4.5	Management of community and household water supplies	81
4.6	Documentation and communication	82
5.	Surveillance	84
5.1	Types of approaches	85
5.1.1	Audit	86
5.1.2	Direct assessment	87
5.2	Adapting approaches to specific circumstances	88
5.2.1	Urban areas in developing countries	88
5.2.2	Surveillance of community drinking-water supplies	88
5.2.3	Surveillance of household treatment and storage systems	89
5.3	Adequacy of supply	90
5.3.1	Quantity (service level)	90
5.3.2	Accessibility	91
5.3.3	Affordability	92
5.3.4	Continuity	92
5.4	Planning and implementation	93
5.5	Reporting and communicating	95
5.5.1	Interaction with community and consumers	96
5.5.2	Regional use of data	96
6.	Application of the Guidelines in specific circumstances	99
6.1	Large buildings	99
6.1.1	Health risk assessment	100
6.1.2	System assessment	100
6.1.3	Management	101
6.1.4	Monitoring	101
6.1.5	Independent surveillance and supporting programmes	102
6.1.6	Drinking-water quality in health care facilities	102
6.1.7	Drinking-water quality in schools and day care centres	103
6.2	Emergencies and disasters	104
6.2.1	Practical considerations	105
6.2.2	Monitoring	106
6.2.3	Microbial guidelines	107

GUIDELINES FOR DRINKING-WATER QUALITY

6.2.4	Sanitary inspections and catchment mapping	108
6.2.5	Chemical and radiological guidelines	108
6.2.6	Testing kits and laboratories	109
6.3	Safe drinking-water for travellers	109
6.4	Desalination systems	111
6.5	Packaged drinking-water	113
6.5.1	Safety of packaged drinking-water	113
6.5.2	Potential health benefits of bottled drinking-water	114
6.5.3	International standards for bottled drinking-water	114
6.6	Food production and processing	115
6.7	Aircraft and airports	116
6.7.1	Health risks	116
6.7.2	System risk assessment	116
6.7.3	Operational monitoring	116
6.7.4	Management	117
6.7.5	Surveillance	117
6.8	Ships	117
6.8.1	Health risks	117
6.8.2	System risk assessment	118
6.8.3	Operational monitoring	119
6.8.4	Management	119
6.8.5	Surveillance	120
7.	Microbial aspects	121
7.1	Microbial hazards associated with drinking-water	121
7.1.1	Waterborne infections	121
7.1.2	Persistence and growth in water	124
7.1.3	Public health aspects	125
7.2	Health-based target setting	126
7.2.1	Health-based targets applied to microbial hazards	126
7.2.2	Risk assessment approach	126
7.2.3	Risk-based performance target setting	131
7.2.4	Presenting the outcome of performance target development	133
7.2.5	Issues in adapting risk-based performance target setting to national/local circumstances	133
7.2.6	Health outcome targets	134
7.3	Occurrence and treatment of pathogens	135
7.3.1	Occurrence	136
7.3.2	Treatment	137
7.4	Verification of microbial safety and quality	142
7.5	Methods of detection of faecal indicator bacteria	143

GUIDELINES FOR DRINKING-WATER QUALITY

7.6	Identifying local actions in response to microbial water quality problems and emergencies	144
7.6.1	Boil water and water avoidance advisories	144
7.6.2	Actions following an incident	144c

CONTENTS

8. Chemical aspects	145
8.1 Chemical hazards in drinking-water	145
8.2 Derivation of chemical guideline values	147
8.2.1 Approaches taken	148
8.2.2 Threshold chemicals	149
8.2.3 Alternative approaches	152
8.2.4 Non-threshold chemicals	154
8.2.5 Data quality	154
8.2.6 Provisional guideline values	155
8.2.7 Chemicals with effects on acceptability	156
8.2.8 Non-guideline chemicals	156
8.2.9 Mixtures	156
8.3 Analytical aspects	157
8.3.1 Analytical achievability	157
8.3.2 Analytical methods	158
8.4 Treatment	166
8.4.1 Treatment achievability	166
8.4.2 Chlorination	171
8.4.3 Ozonation	172
8.4.4 Other disinfection processes	172
8.4.5 Filtration	173
8.4.6 Aeration	175
8.4.7 Chemical coagulation	175
8.4.8 Activated carbon adsorption	176
8.4.9 Ion exchange	177
8.4.10 Membrane processes	178
8.4.11 Other treatment processes	178
8.4.12 Disinfection by-products – process control measures	179
8.4.13 Treatment for corrosion control	180
8.5 Guideline values for individual chemicals, by source category	184
8.5.1 Naturally occurring chemicals	184
8.5.2 Chemicals from industrial sources and human dwellings	185
8.5.3 Chemicals from agricultural activities	187
8.5.4 Chemicals used in water treatment or from materials in contact with drinking-water	188
8.5.5 Pesticides used in water for public health purposes	190
8.5.6 Cyanobacterial toxins	192
8.6 Identifying local actions in response to chemical water quality problems and emergencies	196
8.6.1 Trigger for action	196a
8.6.2 Investigating the situation	196a
8.6.3 Talking to the right people	196b

CONTENTS

8.6.4	Informing the public	196b
8.6.5	Evaluating the significance to public health and individuals	196b
8.6.6	Determining appropriate action	196e
8.6.7	Consumer acceptability	196e
8.6.8	Ensuring remedial action, preventing recurrence and updating the water safety plan	196e
8.6.9	Mixtures	196f
8.6.10	Water avoidance advisories	196f
9.	Radiological aspects	197
9.1	Sources and health effects of radiation exposure	198
9.1.1	Radiation exposure through drinking-water	200
9.1.2	Radiation-induced health effects through drinking-water	200

GUIDELINES FOR DRINKING-WATER QUALITY

9.2	Units of radioactivity and radiation dose	201
9.3	Guidance levels for radionuclides in drinking-water	202
9.4	Monitoring and assessment for dissolved radionuclides	204
	9.4.1 Screening of drinking-water supplies	204
	9.4.2 Strategy for assessing drinking-water	205
	9.4.3 Remedial measures	205
9.5	Radon	206
	9.5.1 Radon in air and water	206
	9.5.2 Risk	207
	9.5.3 Guidance on radon in drinking-water supplies	207
9.6	Sampling, analysis and reporting	207
	9.6.1 Measuring gross alpha and gross beta activity concentrations	207
	[9.6.2 Deleted in first addendum to third edition]	
	9.6.3 Measuring radon	208
	9.6.4 Sampling	209
	9.6.5 Reporting of results	209
10. Acceptability aspects		210
10.1	Taste, odour and appearance	211
	10.1.1 Biologically derived contaminants	211
	10.1.2 Chemically derived contaminants	213
	10.1.3 Treatment of taste, odour and appearance problems	219
10.2	Temperature	220
11. Microbial fact sheets		221
11.1	Bacterial pathogens	222
	11.1.1 <i>Acinetobacter</i>	222
	11.1.2 <i>Aeromonas</i>	224
	11.1.3 <i>Bacillus</i>	225
	11.1.4 <i>Burkholderia pseudomallei</i>	226
	11.1.5 <i>Campylobacter</i>	228
	11.1.6 <i>Escherichia coli</i> pathogenic strains	229
	11.1.7 <i>Helicobacter pylori</i>	231
	11.1.8 <i>Klebsiella</i>	232
	11.1.9 <i>Legionella</i>	233
	11.1.10 <i>Mycobacterium</i>	235
	11.1.11 <i>Pseudomonas aeruginosa</i>	237
	11.1.12 <i>Salmonella</i>	239
	11.1.13 <i>Shigella</i>	240
	11.1.14 <i>Staphylococcus aureus</i>	242
	11.1.15 <i>Tsukamurella</i>	243

11.1.16	<i>Vibrio</i>	244
11.1.17	<i>Yersinia</i>	246
11.2	Viral pathogens	247
11.2.1	Adenoviruses	248
11.2.2	Astroviruses	250
11.2.3	Caliciviruses	251
11.2.4	Enteroviruses	253
11.2.5	Hepatitis A virus	254
11.2.6	Hepatitis E virus	256
11.2.7	Rotaviruses and orthoreoviruses	257
11.3	Protozoan pathogens	259
11.3.1	<i>Acanthamoeba</i>	259
11.3.2	<i>Balantidium coli</i>	261
11.3.3	<i>Cryptosporidium</i>	262
11.3.4	<i>Cyclospora cayetanensis</i>	264
11.3.5	<i>Entamoeba histolytica</i>	265
11.3.6	<i>Giardia intestinalis</i>	267
11.3.7	<i>Isospora belli</i>	268
11.3.8	Microsporidia	270
11.3.9	<i>Naegleria fowleri</i>	272
11.3.10	<i>Toxoplasma gondii</i>	274
11.4	Helminth pathogens	275
11.4.1	<i>Dracunculus medinensis</i>	276
11.4.2	<i>Fasciola</i> spp.	278
11.5	Toxic cyanobacteria	279
11.6	Indicator and index organisms	281
11.6.1	Total coliform bacteria	282
11.6.2	<i>Escherichia coli</i> and thermotolerant coliform bacteria	284
11.6.3	Heterotrophic plate counts	285
11.6.4	Intestinal enterococci	287
11.6.5	<i>Clostridium perfringens</i>	288
11.6.6	Coliphages	289
11.6.7	<i>Bacteroides fragilis</i> phages	292
11.6.8	Enteric viruses	294
12.	Chemical fact sheets	296
12.1	Acrylamide	296
12.2	Alachlor	297
12.3	Aldicarb	298
12.4	Aldrin and dieldrin	300
12.5	Aluminium	301
12.6	Ammonia	303

GUIDELINES FOR DRINKING-WATER QUALITY

12.7	Antimony	304
12.8	Arsenic	306
12.9	Asbestos	308
12.10	Atrazine	308
12.11	Barium	310
12.12	Bentazone	311
12.13	Benzene	312
12.14	Boron	313
12.15	Bromate	315
12.16	Brominated acetic acids	316
12.17	Cadmium	317
12.18	Carbofuran	319
12.19	Carbon tetrachloride	320
12.20	Chloral hydrate (trichloroacetaldehyde)	321
12.21	Chlordane	323
12.22	Chloride	324
12.23	Chlorine	325
12.24	Chlorite and chlorate	326
12.25	Chloroacetones	329
12.26	Chlorophenols (2-chlorophenol, 2,4-dichlorophenol, 2,4,6-trichlorophenol)	329
12.27	Chloropicrin	331
12.28	Chlorotoluron	332
12.29	Chlorpyrifos	333
12.30	Chromium	334
12.31	Copper	335
12.32	Cyanazine	337
12.33	Cyanide	339
12.34	Cyanogen chloride	340
12.35	2,4-D (2,4-dichlorophenoxyacetic acid)	340
12.36	2,4-DB	342
12.37	DDT and metabolites	343
12.38	Dialkyltins	345
12.39	1,2-Dibromo-3-chloropropane (DBCP)	346
12.40	1,2-Dibromoethane (ethylene dibromide)	347
12.41	Dichloroacetic acid	349
12.42	Dichlorobenzenes (1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene)	350
12.43	1,1-Dichloroethane	352
12.44	1,2-Dichloroethane	353
12.45	1,1-Dichloroethene	354
12.46	1,2-Dichloroethene	355

CONTENTS

12.47	Dichloromethane	357
12.48	1,2-Dichloropropane (1,2-DCP)	358
12.49	1,3-Dichloropropane	359
12.50	1,3-Dichloropropene	360
12.51	Dichlorprop (2,4-DP)	361
12.52	Di(2-ethylhexyl)adipate	362
12.53	Di(2-ethylhexyl)phthalate	363
12.54	Dimethoate	364
12.54(a)	1,4-Dioxane	366
12.55	Diquat	366a
12.56	Edetic acid (EDTA)	367
12.57	Endosulfan	368
12.58	Endrin	369
12.59	Epichlorohydrin	370
12.60	Ethylbenzene	372
12.61	Fenitrothion	373
12.62	Fenoprop (2,4,5-TP; 2,4,5-trichlorophenoxy propionic acid)	374
12.63	Fluoride	375
12.64	Formaldehyde	377
12.65	Glyphosate and AMPA	379
12.66	Halogenated acetonitriles (dichloroacetonitrile, dibromoacetonitrile, bromochloroacetonitrile, trichloroacetonitrile)	380
12.67	Hardness	382
12.68	Heptachlor and heptachlor epoxide	383
12.69	Hexachlorobenzene (HCB)	385
12.70	Hexachlorobutadiene (HCBd)	386
12.71	Hydrogen sulfide	387
12.72	Inorganic tin	388
12.73	Iodine	389
12.74	Iron	390
12.75	Isoproturon	391
12.76	Lead	392
12.77	Lindane	394
12.78	Malathion	396
12.79	Manganese	397
12.80	MCPA [4-(2-methyl-4-chlorophenoxy)acetic acid]	399
12.81	Mecoprop (MCPp; [2(2-methyl-chlorophenoxy) propionic acid])	401
12.82	Mercury	402
12.83	Methoxychlor	403
12.84	Methyl parathion	404

|

|

12.84(a) Methyl *tertiary*-butyl ether (MTBE)

405

12.85 Metolachlor

405a

GUIDELINES FOR DRINKING-WATER QUALITY

12.86	Microcystin-LR	407
12.87	Molinate	408
12.88	Molybdenum	410
12.89	Monochloramine	411
12.90	Monochloroacetic acid	412
12.91	Monochlorobenzene	413
12.92	MX	414
12.93	Nickel	415
12.94	Nitrate and nitrite	417
12.95	Nitrilotriacetic acid (NTA)	420
12.96	Parathion	421
12.97	Pendimethalin	422
12.98	Pentachlorophenol (PCP)	424
12.99	Permethrin	425
12.99(a)	Petroleum products	426a
12.100	pH	426b
12.101	2-Phenylphenol and its sodium salt	427
12.102	Polynuclear aromatic hydrocarbons (PAHs)	428
12.103	Propanil	430
12.104	Pyriproxyfen	431
12.105	Selenium	432
12.106	Silver	434
12.107	Simazine	435
12.108	Sodium	436
12.109	Styrene	437
12.110	Sulfate	438
12.111	2,4,5-T (2,4,5-trichlorophenoxyacetic acid)	439
12.112	Terbuthylazine (TBA)	440
12.113	Tetrachloroethene	442
12.114	Toluene	443
12.115	Total dissolved solids (TDS)	444
12.116	Trichloroacetic acid	445
12.117	Trichlorobenzenes (total)	446
12.118	1,1,1-Trichloroethane	447
12.119	Trichloroethene	448
12.120	Trifluralin	450
12.121	Trihalomethanes (bromoform, bromodichloromethane, dibromochloromethane, chloroform)	451
12.122	Uranium	454
12.123	Vinyl chloride	456
12.124	Xylenes	458
12.125	Zinc	459

CONTENTS

Annex 1 Bibliography	461
Annex 2 Contributors to the development of the third edition of the <i>Guidelines for Drinking-water Quality</i>	467
[Annex 3 Deleted in first addendum to third edition]	
Annex 4 Chemical summary tables	488
Index	494

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 a national, regional and local level. 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.

This revised Volume 1 of the Guidelines 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.

This volume 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. The volume 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 this 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).

Since the second edition of WHO's *Guidelines for Drinking-water Quality*, there have been a number of events that have highlighted the importance and furthered understanding of various aspects of drinking-water quality and health. These are reflected in this third edition of the Guidelines.

These Guidelines supersede those in previous editions (1983–1984, 1993–1997 and addenda in 1998, 1999 and 2002) 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 amongst the 24 UN agencies and programmes concerned with water issues. This edition of the Guidelines further develops concepts, approaches and information in previous editions:

- Experience has shown that microbial hazards continue to be the primary concern in both developing and developed countries. Experience has also shown the value

of a systematic approach towards securing microbial safety. This edition includes significantly expanded guidance on ensuring microbial safety of drinking-water, building on principles – such as the multiple-barrier approach and the importance of source protection – considered in previous editions. The Guidelines are accompanied by documentation describing approaches towards fulfilling requirements for microbial safety and providing guidance to good practice in ensuring that safety is achieved.

- Information on many chemicals has been revised. This includes information on chemicals not considered previously; revisions to take account of new scientific information; and, in some cases, lesser coverage where new information suggests a lesser priority.
- Experience has also shown the necessity of recognizing the important roles of many different stakeholders in ensuring drinking-water safety. This edition includes discussion of the roles and responsibilities of key stakeholders in ensuring drinking-water safety.
- The need for different tools and approaches in supporting safe management of large piped supplies versus small community supplies remains relevant, and this edition describes the principal characteristics of the different approaches.
- There has been increasing recognition that only a few key chemicals cause large-scale health effects through drinking-water exposure. These include fluoride, arsenic and nitrate. Other chemicals, such as lead, selenium and uranium, may also be significant under certain conditions. Interest in chemical hazards in drinking-water was highlighted by recognition of the scale of arsenic exposure through drinking-water in Bangladesh and elsewhere. The revised Guidelines and associated publications provide guidance on identifying local priorities and on management of the chemicals associated with large-scale effects.
- WHO is frequently approached for guidance on the application of the *Guidelines for Drinking-water Quality* to situations other than community supplies or managed utilities. This revised edition includes information on application of the Guidelines to several specific circumstances and is accompanied by texts dealing with some of these in greater detail.

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

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 current edition of the *Guidelines for Drinking-water Quality* and supporting documentation covered a period of eight 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 *Guidelines for Drinking-water Quality*, including those individuals listed in Annex 2, are gratefully acknowledged.

The work of the following Working Groups was crucial to the development of the third edition of the *Guidelines for Drinking-water Quality*:

Microbial aspects working group

Ms T. Boonyakarnkul, Department of Health, Thailand (*Surveillance and control*)

Dr D. Cunliffe, SA Department of Human Services, Australia (*Public health*)

Prof. W. Grabow, University of Pretoria, South Africa (*Pathogen-specific information*)

Dr A. Havelaar, RIVM, The Netherlands (Working Group coordinator; *Risk assessment*)

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

Chemical aspects working group

Mr J.K. Fawell, United Kingdom (*Organic and inorganic constituents*)

Ms M. Giddings, Health Canada (*Disinfectants and disinfection by-products*)

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

Dr E. Ohanian, EPA, USA (*Disinfectants and disinfection by-products*)

Dr P. Toft, Canada (*Pesticides*)

Protection and control working group

Dr I. Chorus, Umweltbundesamt, Germany (*Resource and source protection*)

Dr J. Cotruvo, USA (*Materials and additives*)

Dr G. Howard, DfID, Bangladesh, and formerly Loughborough University, United Kingdom (*Monitoring and assessment*)

Mr P. Jackson, WRc-NSF, United Kingdom (*Treatment achievability*)

ACKNOWLEDGEMENTS

The WHO coordinators were:

- Dr J. Bartram, Coordinator, Programme on Water Sanitation and Health, WHO Headquarters, and formerly WHO European Centre for Environmental Health
- Mr P. Callan, Programme on Water Sanitation and Health, WHO Headquarters, on secondment from National Health and Medical Research Council, Australia

Ms C. Vickers acted as a liaison between the Working Groups and the International Programme on Chemical Safety, WHO Headquarters.

Ms Marla Sheffer of Ottawa, Canada, was responsible for the editing of the Guidelines. Mr Hiroki Hashizume provided support to the work of the Chemical Aspects Working Group. Ms Mary-Ann Lundby, Ms Grazia Motturi and Ms Penny Ward provided secretarial and administrative support throughout the process and to individual meetings.

The preparation of these Guidelines would not have been possible without the generous support of the following, which is gratefully acknowledged: the Ministry of Health of Italy; the Ministry of Health, Labour and Welfare of Japan; the National Health and Medical Research Council, Australia; the Swedish International Development Cooperation Agency, Sweden; and the United States Environmental Protection Agency.

Acronyms and abbreviations used in text

AAS	atomic absorption spectrometry
AD	Alzheimer disease
ADI	acceptable daily intake
AES	atomic emission spectrometry
AIDS	acquired immunodeficiency syndrome
AMPA	aminomethylphosphonic acid
BaP	benzo[<i>a</i>]pyrene
BDCM	bromodichloromethane
BMD	benchmark dose
bw	body weight
CAC	Codex Alimentarius Commission
CAS	Chemical Abstracts Service
CICAD	Concise International Chemical Assessment Document
CSAF	chemical-specific adjustment factor
Ct	product of disinfectant concentration and contact time
DAEC	diffusely adherent <i>E. coli</i>
DALY	disability-adjusted life-year
DBCM	dibromochloromethane
DBCP	1,2-dibromo-3-chloropropane
DBP	disinfection by-product
DCA	dichloroacetic acid
DCB	dichlorobenzene
DCP	dichloropropane
DDT	dichlorodiphenyltrichloroethane
DEHA	di(2-ethylhexyl)adipate
DEHP	di(2-ethylhexyl)phthalate
DNA	deoxyribonucleic acid

ACRONYMS AND ABBREVIATIONS USED IN TEXT

EAAS	electrothermal atomic absorption spectrometry
EAEC	enteroaggregative <i>E. coli</i>
EBCT	empty bed contact time
EC	electron capture
ECD	electron capture detector
EDTA	edetic acid; ethylenediaminetetraacetic acid
EHC	Environmental Health Criteria monograph
EHEC	enterohaemorrhagic <i>E. coli</i>
EIEC	enteroinvasive <i>E. coli</i>
ELISA	enzyme-linked immunosorbent assay
EPEC	enteropathogenic <i>E. coli</i>
ETEC	enterotoxigenic <i>E. coli</i>
EURO	WHO Regional Office for Europe
FAAS	flame atomic absorption spectrometry
FAO	Food and Agriculture Organization of the United Nations
FD	fluorescence detector
FID	flame ionization detector
FPD	flame photodiode detector
GAC	granular activated carbon
GAE	granulomatous amoebic encephalitis
GC	gas chromatography
GL	guidance level (used for radionuclides in drinking-water)
GV	guideline value
HACCP	hazard analysis and critical control points
HAd	human adenovirus
HAsV	human astrovirus
HAV	hepatitis A virus
Hb	haemoglobin
HCB	hexachlorobenzene
HCBD	hexachlorobutadiene
HCH	hexachlorocyclohexane
HEV	hepatitis E virus
HIV	human immunodeficiency virus
HPC	heterotrophic plate count
HPLC	high-performance liquid chromatography
HRV	human rotavirus
HuCV	human calicivirus
HUS	haemolytic uraemic syndrome

GUIDELINES FOR DRINKING-WATER QUALITY

IAEA	International Atomic Energy Agency
IARC	International Agency for Research on Cancer
IC	ion chromatography
ICP	inductively coupled plasma
ICRP	International Commission on Radiological Protection
IDC	individual dose criterion
IPCS	International Programme on Chemical Safety
ISO	International Organization for Standardization
JECFA	Joint FAO/WHO Expert Committee on Food Additives
JMPR	Joint FAO/WHO Meeting on Pesticide Residues
K_{ow}	octanol/water partition coefficient
LI	Langelier Index
LOAEL	lowest-observed-adverse-effect level
MCB	monochlorobenzene
MCPA	4-(2-methyl-4-chlorophenoxy)acetic acid
MCPP	2(2-methyl-chlorophenoxy) propionic acid; mecoprop
metHb	methaemoglobin
MMT	methylcyclopentadienyl manganese tricarbonyl
MS	mass spectrometry
MTBE	methyl <i>tertiary</i> -butyl ether
MX	3-chloro-4-dichloromethyl-5-hydroxy-2(5H)-furanone
NAS	National Academy of Sciences (USA)
NOAEL	no-observed-adverse-effect level
NOEL	no-observed-effect level
NTA	nitrilotriacetic acid
NTP	National Toxicology Program (USA)
NTU	nephelometric turbidity unit
P/A	presence/absence
PAC	powdered activated carbon
PAH	polynuclear aromatic hydrocarbon
PAM	primary amoebic meningoencephalitis
PCP	pentachlorophenol
PCR	polymerase chain reaction
PD	photoionization detector
PMTDI	provisional maximum tolerable daily intake

GUIDELINES FOR DRINKING-WATER QUALITY

PT purge and trap
PTDI provisional tolerable daily intake

ACRONYMS AND ABBREVIATIONS USED IN TEXT

PTWI	provisional tolerable weekly intake
PVC	polyvinyl chloride
QMRA	quantitative microbial risk assessment
RDL	reference dose level
RIVM	Rijksinstituut voor Volksgezondheid en Milieu (Dutch National Institute of Public Health and Environmental Protection)
RNA	ribonucleic acid
SI	Système international d'unités (International System of Units)
SOP	standard operating procedure
SPADNS	sulfo phenyl azo dihydroxy naphthalene disulfonic acid
TBA	terbutylazine
TCB	trichlorobenzene
TCU	true colour unit
TD ₀₅	tumorigenic dose ₀₅ , the intake or exposure associated with a 5% excess incidence of tumours in experimental studies in animals
TDI	tolerable daily intake
TDS	total dissolved solids
THM	trihalomethane
TID	thermal ionization detector
I TPH	total petroleum hydrocarbons
UF	uncertainty factor
UNICEF	United Nations Children's Fund
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
USA	United States of America
US EPA	United States Environmental Protection Agency
UV	ultraviolet
UVPAD	ultraviolet photodiode array detector
WHO	World Health Organization
WHOPES	World Health Organization Pesticide Evaluation Scheme
WQT	water quality target
WSP	water safety plan
YLD	years of healthy life lost in states of less than full health, i.e., years lived with a disability
YLL	years of life lost by premature mortality

