World Health Organization

# DEVELOPING DRINKING-WATER QUALITY REGULATIONS AND STANDARDS

## General guidance with a special focus on countries with limited resources

World Health Organization

# DEVELOPING DRINKING-WATER QUALITY REGULATIONS AND STANDARDS

General guidance with a special focus on countries with limited resources

Developing drinking-water quality regulations and standards: general guidance with a special focus on countries with limited resources

ISBN 978-92-4-151394-4



**Suggested citation.** Developing drinking-water quality regulations and standards: general guidance with a special focus on countries with limited resources. Geneva: World Health Organization; 2018. Licence: CC BY-NC-SA 3.0 IGO.

**Cataloguing-in-Publication (CIP) data.** CIP data are available at http://apps.who.int/iris.



Editorial Consultant: Vivien Stone.

Design and layout by L'IV ComSàrl, Switzerland.

Printed in Switzerland.

# Contents

# Acknowledgements

The World Health Organization (WHO) wishes to express its appreciation to all whose efforts made this publication possible by contributing their time and expertise.

Pre-publication versions of this document provided the basis for a series of national and international workshops to support the development or revision of drinking-water quality regulations and standards, and these workshops served to strengthen this guidance. The inputs of all who participated in these workshops are gratefully acknowledged, as are the valuable contributions made by the International Network of Drinking-water Regulators (RegNet) and the *Guidelines for drinking-water quality* (GDWQ) expert working group during the document's development.

Coordination and technical and strategic input to this document were provided by Jennifer De France and Bruce Gordon (both WHO, Switzerland), as well as Jamie Bartram (formerly WHO, Switzerland). Technical editing was provided by Angella Rinehold (WHO, Switzerland) and Jennifer Mercer (formerly WHO, Switzerland).

### Lead authors

**David Cunliffe**, Department of Health South Australia, Australia
**John Fawell**, Visiting Professor, Cranfield University, United Kingdom
**Darryl Jackson**, Consultant, Australia

### Key contributors

**Philip Callan**, Consultant, Australia
**David Drury**, Consultant (formerly Drinking Water Inspectorate), United Kingdom
**David Sheehan**, Coliban Water, Australia

### Other contributors and reviewers

**Joanne Brown**, Consultant, United Kingdom
**Ingrid Chorus**, German Environment Agency, Germany
**Lesley D'Anglada**, United States Environmental Protection Agency, United States of America
**Michèle Giddings**, Health Canada, Canada
**Idriss Kouotou Njoya**, Ministry of Water and Energy, Cameroon
**Luca Lucentini**, National Institute of Health, Italy
**Bonifacio Magtibay**, WHO, Philippines
**Rory Moses McKeown**, WHO, Switzerland

**Sophary Phan**, WHO, Cambodia
**Donald Reid**, Alberta Environment and Sustainable Resource Development, Canada
**Bettina Rickert**, German Environment Agency, Germany
**Joselito Riego de Dios**, Department of Health, Philippines
**Oliver Schmoll**, WHO Regional Office for Europe, Germany
**Enkhtsetseg Shinee**, WHO Regional Office for Europe, Germany
**Luís Simas**, Water and Waste Services Regulation Authority, Portugal
**Le Thai Ha**, National Institute of Occupational and Environmental Health, Viet Nam
**Nghia Ton Tuan**, WHO, Viet Nam
**Rachid Wahabi**, Ministry of Health, Morocco

WHO also gratefully acknowledges the financial support provided by the Department for International Development, United Kingdom; the Department of Foreign Affairs and Trade, Australia; the Ministry of Health, Labour and Welfare, Japan; the Public Utilities Board, the National Water Agency, a statutory board under the Ministry of Environment and Water Resources, Singapore; and the Environmental Protection Agency, United States of America.

# Acronyms and abbreviations

| | |
|---|---|
| ADI | allowable daily intake |
| DBP | disinfection by-product |
| DWD | Drinking Water Directive (European Union) |
| GDWQ | *Guidelines for drinking-water quality* |
| HAA | haloacetic acid |
| HPC | heterotrophic plate count |
| IAEA | International Atomic Energy Agency |
| IDC | individual dose criterion |
| MCL | maximum contaminant level |
| MCLG | maximum contaminant level goal |
| NDMA | *N*-nitrosodimethylamine |
| NTU | nephelometric turbidity unit |
| SDG | Sustainable Development Goal |
| TDI | tolerable daily intake |
| TDS | total dissolved solids |
| THM | trihalomethane |
| TOC | total organic carbon |
| TWG | technical working group |
| WASH | water, sanitation and hygiene |
| WHO | World Health Organization |
| WSP | water safety plan |

# 1 Target audience, purpose and scope

This guidance document is intended for those agencies in countries with limited resources that are responsible for developing, implementing and enforcing national or subnational drinking-water quality regulations and standards.[1] These agencies can vary from country to country but would generally be the ministry of health, ministry of environment, ministry of water supply and/or a separate drinking-water regulatory agency. In some countries, the agency (or agencies) setting the standards is different from the agency (or agencies) that implements and enforces the standards (see Box 1.1). However, the principles noted in this document are broadly applicable to all countries and all regulatory arrangements.

This document provides simple, practical guidance to assist the development or revision of drinking-water quality regulations and standards using the WHO *Guidelines for drinking-water quality* (GDWQ) (WHO, 2017a). This guidance should always be read and used in conjunction with the GDWQ.

The GDWQ present a framework for ensuring the safety of drinking-water, which comprises:

- **Health-based targets**, including water quality targets typically expressed as numeric guideline values (concentrations) for substances of concern.
- **Water safety plans (WSPs)** to be developed and implemented by water suppliers to support effective management of their systems.
- **Independent surveillance** to ensure that WSPs are effective and that health-based targets are met.

Developing drinking-water quality regulations and standards based on this guidance will ensure that these three elements of the GDWQ's Framework for Safe Drinking-water are addressed.

---

[1] The term "standard" is commonly used to describe a mandatory numerical value in a table of parameters and limits (such as 10 µg/l of arsenic). However, it is also used to describe technical standards and policy documents designed to help achieve improved water quality. Regulations are requirements that can include or refer to a table of parameters and limits. Regardless of how a country defines "standards" or "regulations", both are interdependent.

## BOX 1.1 Key drinking-water agencies in Cameroon

Key agencies with a role related to drinking-water in Cameroon include:

- The **National Standards and Quality Agency**,[a] whose responsibilities include the development and certification of standards; the development of proposals for standards to improve the quality of products and services and compliance with standards; and dissemination of information and documentation on standards.
- The **Ministry of Water and Energy**,[b] whose responsibilities include control of the quality of raw water; monitoring the quality of water resources; and monitoring the quality of drinking-water delivered for consumption.
- The **Ministry of Public Health**,[c] whose responsibilities include the certification of water quality standards and the control of their compliance (in liaison with other concerned parties); control and monitoring of water quality; and approval of the technologies used in the treatment of drinking-water (in liaison with other concerned parties).
- The **Cameroon Water Utilities Corporation**,[d] whose responsibilities include the planning, research, project management and financial management of drinking-water infrastructure; the construction, maintenance, renewal and management of drinking-water infrastructure; and awareness raising among drinking-water users.

[a] Decree N° 2009/296 of 17 September 2009 on the creation, organization and functioning of the National Standards and Quality Agency;
[b] Decree N° 2012/501 of 7 October 2012, organizing the Ministry of Water and Energy;
[c] Decree N° 2013/093 of 3 April 2013, organizing the Ministry of Public Health;
[d] Decree N° 2018/144 of 20 February 2018, reorganizing the Cameroon Water Utilities Corporation.

# 2 Why countries need customized regulations and standards

The GDWQ are not a substitute for customized national or subnational drinking-water quality regulations and standards that take into account local needs, priorities and capacities, as well as the economic and health benefits resulting from improved drinking-water supplies.

Rather, the GDWQ support customized regulations and standards by presenting good practice related to water supply risk management and surveillance, and by providing health-based targets. These health-based targets include numeric guideline values which define drinking-water that does not represent any significant risk to health, and they are generally based on lifetime consumption. The health-based targets in the GDWQ are based on the best available scientific evidence, as well as expert advice and opinion, for approximately 200 individual parameters.

The GDWQ are not intended to be mandatory and the guideline values included are not designed to be adopted as a complete set in national or subnational regulations and standards. As it is not possible for the GDWQ to account for the wide range of issues or conditions that may influence the significance of individual parameters in a particular country, not all parameters included in the GDWQ will be important for every country. The GDWQ should therefore be adapted to account for local circumstances, such as current hazards, environmental conditions, industrial and agricultural activities, and available resources.

Customized regulations and standards based on the GDWQ will help to:

- Protect public health associated with the consumption of drinking-water.
- Complement other national or regional drinking-water management policies (e.g. water resource management).
- Achieve balance in overall health objectives between health-related drinking-water issues and other health-related priorities.
- Ensure drinking-water management strategies are based on current scientific knowledge and proven good practice.
- Allow resources (of regulators, suppliers and communities) to be targeted appropriately.

# 3 When to revise existing regulations and standards

Drinking-water quality regulations and standards may be prepared as a new process or as a revision to existing regulations and standards. Both situations provide an opportunity to contribute to progressive improvements in drinking-water quality. It is therefore important to make allowance for gradual improvement in drinking-water quality and in strengthening the regulations and standards.

Regulatory agencies should consider revising regulations and standards in any of the following situations:

- There is information about hazards which indicates that the current regulations and standards are clearly inadequate to protect health or ensure acceptability.
- An evaluation of the existing regulations and standards shows they are insufficient or inappropriate.
- Current regulations and standards are deemed out of date due to improvements in scientific understanding (e.g. new information on the health impact of a chemical currently regulated results in a change in the GDWQ).
- There is a significant change in available drinking-water treatment technology that allows for better control of certain contaminants.
- There is a significant change in the analytical methods available for measuring contaminants (e.g. allowing the use of remote monitoring technologies in lieu of on-site monitoring).
- There is a significant change in the country context impacting the risk to public health (e.g. change in agriculture or industry that increases the potential for microbial or chemical contamination of drinking-water sources and the need for regulations to control contamination).
- There is a need to establish or upgrade regulations and standards due to requirements of legislation.
- Resources permit incremental expansion and/or strengthening of the regulations and standards (e.g. in terms of parameters included, limits set and/or types of water supply systems covered).

Occasionally, there are major policy changes to the GDWQ, such as the incorporation of WSPs into the GDWQ in 2004. These changes are infrequent but important. In these cases, changes to regulations and standards should be considered (see Box 3.1).

The decision on how often regulations and standards should be revised is a matter for individual jurisdictions. As new regulations and standards are developed, the inclusion of a "review" clause will provide a formal mechanism to ensure reviews occur regularly. Adopting a review date establishes a defined lifespan for the regulations and standards that triggers a review after a specified period (e.g. after 5 to 10 years), unless an earlier review is undertaken by a relevant national body.

### BOX 3.1 The Philippines' rationale for updating its 2007 national standards in 2017

- Recent national directive to implement water safety planning.
- New scope and definitions of the water supply indicators related to the transition from the Millennium Development Goal period to the Sustainable Development Goal (SDG) period.
- History of non-compliance by many water utilities, indicating issues with the feasibility of the existing standards.
- 2011 update of the GDWQ, which presented some new or updated guideline values.
- The national need for water quality standards during emergency/disaster response.

Source: Lomboy M, Riego de Dios J, Magtibay B et al (2017). Updating national standards for drinking-water: A Philippine experience. *Journal of Water and Health*. 15(2):288–295. doi:10.2166/wh.2016.177.

# 4 Key principles

Box 4.1 presents the key principles to consider during the development or revision of drinking-water quality regulations and standards to ensure they are contextually appropriate and successfully contribute to the achievement of safe and acceptable drinking-water supplies.

BOX 4.1 **Key principles**

**Take a risk-based approach**

This document presents three ways in which regulations and standards can follow a risk-based approach:

**1. Promote risk management**

A water supplier's primary responsibility is to provide safe drinking-water. This is best achieved by adopting a preventive risk management approach, such as a WSP. Regulations and standards should make clear that this responsibility is paramount by recommending or requiring WSPs rather than focusing only on numerical compliance with parameter limits. Numerous publications are available on WSPs, as outlined in *Water safety planning: A roadmap to supporting resources* (WHO, 2017b).

**2. Prioritize parameters according to the risk posed**

The guidance in this document on selecting parameters for inclusion in regulations and standards is grounded in the principle that parameters should be prioritized according to the actual risks posed in the local context (see Section 7).

**3. Allow risk-based monitoring programmes**

Regulations and standards may allow individual suppliers to request deviations from established water quality monitoring requirements on the basis of system-specific risk assessments (see Section 9).

**Be realistic**

Local considerations need to be allowed for in the development or revision of regulations and standards, including resource availability. Issues to consider include:

- local staff (e.g. personnel required to undertake surveillance activities);
- laboratories (e.g. location, number, equipment, testing capacity);
- logistics and seasonal constraints in collecting, storing, transporting and testing samples; and
- realistic budgets for monitoring and surveillance.

If regulations and standards are too complex, detailed or demanding, it will inevitably lead to non-compliance. Little is achieved by establishing regulations and standards that look good on paper, unless they can be implemented and enforced. Being realistic increases the likelihood that the regulations and standards can achieve the desired public health outcomes.

The regulations and standards must be realistic in terms of the parameters chosen, the limits set and the monitoring frequencies established. In practice, this means establishing a balance between the resources available and those that are obtainable, without being excessively optimistic.

**Be selective**

Inevitably, regulations and standards must be limited in what they include. The most important issues should be identified, particularly those with potential public health impacts. The selection of parameters should rely as much as possible on data from the country or region and reflect the best scientific data available, including those presented in the GDWQ.

## BOX 4.1 Key principles (continued)

**Enable incremental improvements**

Improving drinking-water quality takes time. For example, it may require investment and technical resources that may not be immediately available, or infrastructure that will require time to install and make operational. It is therefore necessary to accommodate gradual improvement. Regulations and standards should follow a stepwise approach to addressing the immediate and greatest threats to public health (e.g. microbial pathogens) and ultimately achieving long-term water quality targets, while maximizing the use of available resources and balancing other national priorities. Activities at each stage should demonstrate the benefits of the regulations and standards. As each step is successfully implemented, and as additional resources and capacity are gained, the regulations and standards can be increased in complexity and/or scope over time.

**Keep the regulations and standards active**

The regulations and standards should build in mechanisms for revisions. Changes to the regulations and standards should be made based on risk assessments and consideration of available resources.

**Ensure regulations and standards are well supported**

To ensure regulations and standards are well supported, it is important to seek wide participation and maintain ongoing communication with key stakeholders. This is especially important when establishing a regulations and standards committee (see Section 5.1) responsible for developing and/or revising the regulations and standards. It is also important to have political and legislative support for regulations and standards (e.g. from politicians/lawmakers, government officers, local health agencies, technical staff and the public) to ensure success. Ideally, supporting legislation needs to define roles and responsibilities, and should allow for the development, enforcement and, when necessary, revision of regulations and standards. Requirements can be specified in acts, regulations, decrees or other instruments.

**Be aware of implications**

Consider the practical and financial implications of the proposed regulations and standards, including:

- Will laboratories need more support or validation?
- Will new treatment plants be needed?
- Will the surveillance agency need more staff?
- Is enforcement practical?

For example:

- If there is insufficient laboratory capacity to conduct testing, or insufficient or only unskilled staff to carry out monitoring activities, consider developing less ambitious regulations and standards focusing on the highest priorities.
- If new infrastructure (e.g. treatment processes or plumbing materials) is likely to be required to comply with the regulations and standards, time may need to be allowed for these upgrades (see Box 4.5).

**Get drinking-water quality in context**

Care should be exercised that the regulations and standards do not unnecessarily divert often limited funding away from other important health priority areas. It is appropriate to consider the health benefits from drinking-water relative to other interventions (e.g. sanitation, hygiene, health care). In addition, it is important to consider the various sources of exposure (e.g. food, air) for various contaminants and the benefits and costs of controlling levels in drinking-water versus other sources of exposure.

In keeping with the principles presented in Box 4.1, it is possible for drinking-water quality regulations and standards to accommodate local needs as follows:

- **In time:** A period of grace can be allowed before either the whole or part of the regulations and standards come into effect (see Box 4.2).
- **By exceptions/exemptions:** This means that a particular component of the regulations and standards may not apply to a certain area or type of supply. Exceptions/exemptions may be temporary, permanent or phased and may be granted on the basis of a lack of significance or insufficient resources to address a problem (e.g. funding to treat the water) (see Box 4.3).
- **By derogations:** This means that a water supplier can be temporarily authorized to supply drinking-water with an exceedance for a parameter. Derogations may be useful when the public health risk of the exceedance is minor and where it may take time or resources to remedy the exceedance. Derogations are particularly important to consider where there are no alternative water sources. As drinking-water is a fundamental requirement of life, the risks of not having a drinking-water supply need to be balanced against the risk posed by the exceedance (see Box 4.4).
- **By the parameters chosen:** This means focusing attention on those issues relevant to local circumstances and not attempting to develop regulations and standards for every possible contaminant, particularly those that do not occur within the jurisdiction.
- **By the limits of parameters:** This is a common way to address the need to be realistic. It could be achieved by setting more than one limit for a parameter (e.g. ideal and mandatory) or by setting an interim limit. For example, if controlling a substance in a water supply will take time to achieve, it is possible to initially set an interim limit that is a higher value than the GDWQ guideline value (e.g. justified by using a smaller margin of safety than the value in the GDWQ; see Annex 2 for more information), while still being protective of public health. This approach should involve setting a suitable timeframe for improvements that will allow achievement of the guideline value in due course (e.g. within one to two years) (see Box 4.5).
- **By the frequency of monitoring:** It is important to get started. Initially a modest but realistic monitoring schedule should be implemented. This can be expanded as resources become available.
- **By consideration of resources:** For example, it may be appropriate to require more from providers that have better resources and less from those with fewer resources (see Box 4.6).
- **By a combination of the above.**

## BOX 4.2 Example of grace periods

In the **Lao People's Democratic Republic**, the 2014 national drinking-water quality standards allow a period of grace before WSP requirements are enforceable. In the case of urban water supply systems, for instance, the national standards require water suppliers to arrange to receive WSP training within five years of the standards taking effect and to develop their WSPs within one year of the said training.

Source: Department of Hygiene, and Health Promotion, Ministry of Health, Lao People's Democratic Republic (2014). Minister's Decision on Water Quality Standard Management for Drinking and Domestic Use.

## BOX 4.3 Example of exemptions

In **Cambodia**, urban water suppliers may apply for exemptions, in part or in full, for the starting date to comply with the provisions of the 2015 national drinking-water quality standards, or for some treatment system types or network areas to which the national standards apply. All exemptions must be parameter and location specific. The water suppliers must justify the basis of the exemption and provide a timed improvement programme to rectify the problems that make it unfeasible to comply with the national standards. Such applications, if granted by the regulator, must stipulate a time period by which the exemption will cease. Exemptions may state the conditions under which the exemption is granted.

Source: Ministry of Industry and Handicraft, Cambodia (2015). National Drinking-Water Quality Standards.

## BOX 4.4 Examples of derogations

In **Morocco**, water suppliers can, in certain circumstances, ask the Ministry of Health to approve a derogation to continue water distribution while exceeding the limit for certain parameters. This type of request should not concern the "health parameters" identified as such in the national standard. Water suppliers must support their application by:

- specifying the particular location to which the derogation will apply;
- justifying derogation of that parameter;
- providing water quality data for a minimum of two previous years;
- describing the measures and actions that will be implemented to return to the normal situation; and
- giving a time period within which the situation will be improved so that the derogation will no longer be required.

Source: Government of Morocco (2015). Moroccan Standard NM 03.7.001 on the Quality of Drinking Water adopted on 25 February 2015 by Joint Order No. 570-15.

**Estonia** faced challenges with naturally occurring fluoride above the limit specified in the 1998 European Union Drinking Water Directive (DWD). Following a health risk assessment, the country was allowed two three-year periods to comply with the DWD, having provided a programme of work and a timetable with a review after the first three years.

Source: Information provided by the Estonian Health Board, 2018.

## BOX 4.5 Examples of limits of parameters

### Interim limits

Due to the significant health risk associated with lead, a series of actions undertaken in **Europe** focused on a general reduction of population exposure to lead. Accordingly, the DWD set strict maximum lead occurrence levels to control lead in the drinking-water system. As the main cause of lead in drinking-water is from leaching from household plumbing, decreasing the lead limit in drinking-water from 50 to 10 µg/l was approached by setting an interim limit of 25 µg/l for the period between five and 15 years after the DWD took effect to allow sufficient time to implement the necessary actions (i.e. replace lead service connections) to comply with new standards.

Source: European Commission (1998). Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption. Official Journal of the European Communities (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1998:330:0032:0054:EN:PDF, accessed 18 March 2018).

### Ideal versus mandatory limits

The **United States** Environmental Protection Agency sets a maximum contaminant level goal (MCLG) for each contaminant. The MCLG is the maximum level of a contaminant in drinking-water at which no known or anticipated adverse effect on the health of persons would occur, and which allows an adequate margin of safety. The MCLGs are not legal limits set for public water systems and are not enforceable. Rather, they are based solely on human health considerations. The Chemical Contaminants Rules also set a maximum contaminant level (MCL) for each contaminant within three contaminant groups: inorganic contaminants, including nitrate and arsenic; volatile organic contaminants; and synthetic organic contaminants. These MCLs are enforceable. The MCL weighs the technical and financial barriers with public health protection with the aim to set MCLs as close to the health goal as possible. As an example, the MCL for arsenic is 10 µg/l, while the MCLG is zero.

Source: US EPA. National Primary Drinking Water Regulations (https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations, accessed 18 March 2018).

## BOX 4.6 Examples of resource consideration

Both **Nepal** and **Fiji's** drinking-water quality standards present a list of parameters and parameter limits for urban and rural areas. The list for rural areas is shorter than that for urban areas.

Sources: Government of Nepal (2005). National Drinking Water Quality Standards, 2005 Implementation Directives for National Drinking Water Quality Standards 2005. Singhadarbar, Kathmandu: Ministry of Physical Planning and Works.
Fiji Government of Fiji (2013). Fiji National Drinking Water Standards. Ministry of Health.

# 5 Getting started

## 5.1 Who should be involved and consulted

Typically, development or revision of drinking-water quality regulations and standards includes consultation with or the involvement of numerous stakeholders, helping to ensure that the regulations and standards are well supported and allowing the process to benefit from a range of expertise (see Box 5.1). In some countries, a national standards agency is responsible for establishing drinking-water quality regulations and standards, although the agency may have little technical knowledge or working experience of drinking-water issues. In other countries, the regulator (often under the health ministry) is responsible for establishing the regulations and standards, although the agency may be under-resourced and/or lacking technical knowledge. In these circumstances, stakeholder coordination, cooperation and communication is particularly vital to success. For example, water sector professionals should have a key role to play, as they are likely to be aware of pathogens and chemicals that may be present in significant concentrations in some drinking-water supplies. This is a body of local knowledge that has been built up by practical experience over a period of time and through the systematic identification of potential sources of hazards, and it is invaluable as an input into the regulations and standards development or revision process.

### BOX 5.1 Establishing a national standards committee in Viet Nam

A multistakeholder working group was established in Viet Nam to support the revision of the Viet Nam National Technical Regulations on Water Quality. The composition of the working group included:

- Health Environmental Management Agency of the Ministry of Health
- Administration of Technical Infrastructure of the Ministry of Construction
- Department of Water Resources of the Ministry of Agriculture and Rural Development
- Department of Water Resources of the Ministry of Natural Resources and Environment
- Directorate of Standards, Metrology and Quality of the Ministry of Science and Technology
- Viet Nam Water Supply and Sewerage Association
- National Institute for Occupational and Environmental Health
- National Centre for Rural Water Supply and Sanitation
- Hanoi Civil Engineering University

Source: Information provided by WHO, Viet Nam, 2018.

A useful first step is to convene a meeting of representatives from each of the agencies with a role in the provision of drinking-water to identify the key issues that need to be addressed in regulations and standards; to identify the agency that will lead the development or revision of the regulations and standards, as well as the agency responsible for their implementation and enforcement; and to confirm the scope of responsibility of each institution in the process.

Stakeholders that could be engaged include:

- national public health authorities
- environment, agriculture and/or resource management authorities
- drinking-water supply agencies
- local/regional environmental health agencies
- local governments
- industry groups, including plumbers/operators
- professional groups (e.g. engineers, toxicologists, microbiologists)
- national accreditation bodies
- academics and universities
- analytical laboratories
- consumer representatives (see Box 5.2)
- water, sanitation and health (WASH) nongovernmental organizations (depends on the country context).

### BOX 5.2 **Public participation**

When developing drinking-water quality regulations and standards, it is important to ensure that the process is open and transparent. Therefore, it is important to engage with the public through the development process. Consumers should be encouraged to provide input on the scope and features of the regulations and standards. This can be achieved by encouraging written submissions and participation in open communication sessions where the public can ask questions of regulatory agencies and provide opinions and comments on proposed regulations and standards. These sessions should be held at various locations/centres to encourage attendance. Consultation should be continued through each stage of development.

An open and transparent development process helps build public trust in the regulations and standards.

## 5.2 Suggested process

Table 5.1 presents seven steps involved in developing or revising national or subnational drinking-water quality regulations and standards. See Box 5.3 for a country example of the process of revising a national standard.

TABLE 5.1 **Suggested steps involved in developing or revising drinking-water quality regulations and standards**

| | |
|---|---|
| STEP ① **Identify the lead institution** | This institution would:<br>■ prepare a plan for developing or revising the regulations and standards;<br>■ drive the process;<br>■ convene meetings and distribute tasks;<br>■ support research; and<br>■ process and record the information discussed and decisions made. |
| STEP ② **Define roles to support the process** | To support this, the lead institution could:<br>■ create a regulations and standards committee (see Box 5.1);<br>■ select a group of advisors[a] (as necessary) to support the regulations and standards committee;<br>■ identify and maintain communication with stakeholders; and<br>■ assign responsibilities and share criteria, methods and timeframes. |
| STEP ③ **Define objectives and scope of the regulations and standards** | This would involve establishing why the regulations and standards are being developed or revised, as well as:<br>■ defining clearly the types of systems the regulations and standards are expected to cover, e.g. large supplies, small supplies, self-supply systems, non-piped supplies, vended water, and/or bottled water;[b]<br>■ determining the point(s) of compliance (see Section 9.2), which is usually the delivery point to consumers, e.g. hand pump or, for piped systems, the delivery point to buildings/dwellings or inside taps; and<br>■ agreeing on the major topics to be addressed in the regulations and standards, e.g. proactive risk management by suppliers, parameters and limits, monitoring and independent surveillance. |
| STEP ④ **Review existing regulations and standards** | When existing regulations and standards are being revised, the actual outcomes, strengths and challenges of the existing regulations and standards should be reviewed. Some useful questions may be:<br>■ Did they help to improve the quality of drinking-water and contribute to improved public health? If so, how and to what extent? If not, why not?<br>■ Were there any recurring problems with implementation? If so, what were these and how might they be overcome in the future?<br>It is important to focus on lessons to be learned for the new regulations and standards. Stakeholder focus group discussions may be useful tools. |

[a] WHO may be able to suggest potential advisors. If interested, contact WHO at gdwq@who.int.

[b] Water vending and bottled water tend to be managed differently. Water vendors are subject to the GDWQ and should be included in drinking-water quality regulations and standards where appropriate. However, while guidelines and standards for bottled water are generally derived from the GDWQ, bottled water is typically regulated through national food legislation.

TABLE 5.1 **Suggested steps involved in developing or revising drinking-water quality regulations and standards** (continued)

| | |
|---|---|
| STEP ⑤ **Gather baseline data for analysis** | It is important that regulations and standards are informed by careful analysis of local data, including:<br>■ source water quality data;<br>■ drinking-water quality data;<br>■ water quality surveillance data;<br>■ drinking-water consumption rates;<br>■ risks identified through WSPs, e.g. from local industry, agricultural activity and urban settlements;<br>■ cultural habits related to drinking-water;<br>■ human and financial resources available;<br>■ compliance issues; and<br>■ capacity issues.<br>See Section 5.3 for guidance on water quality data sources. |
| STEP ⑥ **Prepare the separate sections of the regulations and standards** | Most of the effort will be in this step, which is the focus of the guidance provided in Sections 6–10. The details will be driven by the table of contents of the regulations and standards, but activities will generally include:<br>■ specifying responsibilities;<br>■ specifying requirements for proactive risk management by water suppliers (e.g. sanitary inspections or WSPs);<br>■ selecting the parameters to be included;<br>■ deciding the parameter limits;<br>■ selecting monitoring requirements and methodologies (e.g. frequencies, locations, methods and reporting); and<br>■ specifying additional independent surveillance requirements. |
| STEP ⑦ **Ensure peer review** | It is advisable for draft(s) to be reviewed by independent experts who are aware of the national context so that any expert advice provided is relevant for the local situation. |

The time needed to develop or revise the regulations and standards depends on:

- A country's institutional working practices and procedures.
- The quality, amount and variability of surveillance and monitoring data.
- The need for additional water quality data and the ease with which it can be obtained. For example, it may take considerable time to get samples (particularly when there is seasonal variation in parameter concentrations) and send elsewhere for testing where laboratory capabilities are limited.
- Inputs from stakeholder consultations.
- The time since the last review.

As a guide, nine to 18 months should be allowed, but this timeframe may vary according to local circumstances. It is important to take sufficient time to develop sound regulations and standards without allowing processes to be subject to unnecessary delays.

BOX 5.3 **The process of revising the Philippine National Standards for Drinking-Water (2017)**

| Associated step in Table 5.1 | Key activity in the Philippines | Notes on process |
|---|---|---|
| Steps ①, ② and ③ | ■ Stakeholder identification and consultation and establishing objectives | ■ Consultations with the national technical working group (TWG), TWG subcommittee groups, and local/international experts |
| Step ④ | ■ Reviewing issues faced by service providers related to existing national standards (2007) | ■ Development of data collection tools (e.g. questionnaires)<br>■ Focus group discussions<br>■ Key informant interviews<br>■ National TWG review of the findings |
| Steps ⑤ and ⑥ | ■ Establishing parameters, limits and monitoring requirements<br>■ Establishing testing methodologies for normal and emergency situations<br>■ Establishing linkage with SDG indicators | ■ Review of parameters (e.g. for microbial, organic and inorganic chemicals)<br>■ Literature review, review of data and consultation with experts<br>■ Review of parameter limits, methods of detection, minimum frequency of sampling and sampling protocols<br>■ Classification into mandatory/primary/secondary parameters<br>■ Survey of 50 accredited laboratories<br>■ Skill gap analysis of testing in normal and emergency situations<br>■ Review of the SDG indicators on water quality (this was related to one of the objectives of the new national standards) |
| Step ⑦ | ■ Peer review, expert input and public hearings | ■ Expertise of local and international experts sought throughout process<br>■ Consultations with stakeholders/public hearings<br>■ TWG meetings for finalization<br>■ Department of Health internal review (legal/health policy departments) for approval |

Source: University of the Philippines Manila (2015). Updating of the 2007 Philippine National Standards for Drinking-Water (PNSDW). Final report. College of Public Health: Department of Environmental and Occupational Health.

## 5.3 Water quality data sources

As described in Table 5.1, reviewing available water quality data and sources of contamination is an important preparatory step for developing customized national or subnational regulations and standards. Ideally, data for both the raw water (surface water and groundwater) and the drinking-water supplied to the population should be reviewed. Potential sources of data will include water suppliers, the surveillance agency, other government agencies (e.g. ministry of health, ministry of environment), major industries that may discharge into the water source (e.g. mining and rubber companies), and research and development agencies. Risk assessments undertaken as part of WSPs can also be a useful data source.

The microbiological quality of drinking-water is always of paramount importance. Microbiological data normally take the form of *Escherichia coli* (*E. coli*) results, as an indicator of faecal contamination and the potential presence of pathogenic bacteria, protozoa or viruses. Where microbiological data are not available, it should be assumed that pathogens are likely to be present, particularly for surface water supplies.

Aesthetic or nuisance water quality issues (e.g. bitter or salty tastes, hard water, indications of blue-green staining from copper content, laundry staining, rusty or corrosive water) reported by customers may also be useful. Customer complaint records from water suppliers may therefore be another source of data.

Some typical data sources for chemicals that are categorized based on the source of the substance are:

- **Naturally occurring chemicals:** Geological survey departments and mining companies.
- **Chemicals from agricultural activities:** Information on fertilizer and pesticide use and importation from government authorities/regulators that issue approvals for use.
- **Chemicals from human settlements:** Water supply and wastewater agencies, local government and municipal authorities, and environmental agencies.
- **Chemicals from industrial activities:** Environmental agencies and major industries.
- **Chemicals used in water treatment and distribution:** Water suppliers and surveillance agencies (including monitoring records).

Refer to *Chemical safety of drinking-water: Assessing priorities for risk management* (WHO, 2007) for further details on potential data sources for chemical contaminants.

Chemical data are frequently not available and assumptions are often required. Where this is the case, the risk-based approach outlined in *Chemical safety of drinking-water: Assessing priorities for risk management* (WHO, 2007) can be followed to identify priority chemicals (see Section 7.3). This can be used as the basis of a targeted sampling and testing programme to complement existing data.

Legislation and monitoring data from neighbouring countries with similar drinking-water sources and quality may be also considered among the information sources.

Where there are gaps in existing data, new studies can be commissioned where practical to obtain the relevant data. However, where such studies may take considerable time, this should not unnecessarily delay the development or finalization of regulations and standards.

# 6 Overview of typical content

This section presents an overview of the topics typically covered in national or subnational drinking-water quality regulations and standards. While the structure and content of regulations and standards will vary by country, and may be influenced by legislative norms in individual countries, Table 6.1 provides general guidance on typical content. The topics shaded in blue are covered in more detail in Sections 7–10.

TABLE 6.1 **Typical drinking-water quality regulations and standards content**

| Topics to consider | Remarks |
|---|---|
| **Introduction** | This would typically cover the importance of regulations and standards, specific goals and objectives (see Box 6.1), a brief history and guiding principles. |
| **Timelines** | This would specify when the regulations and standards take effect, including discussion of any phased or staged implementation. |
| **General clauses** | This would usually include:<br>▪ Scope, e.g. whether the regulations and standards cover drinking-water for the general population and/or other uses, as well as types and sizes of water supplies for which the regulations and standards apply.<br>▪ At which points in the water supply systems the regulations and standards apply.<br>▪ Proposed revision process and the frequency of revision for the regulations and standards.<br>▪ General principles for drinking-water emergencies/waterborne disease outbreaks.<br>▪ Definitions. |
| **Exceptions/ exemptions and derogations** | This would present the terms surrounding any exceptions/exemptions allowed (including whether they are to be permanent, temporary or phased), as well as derogations. |
| **Roles, rights and responsibilities** | This section would typically include the roles and responsibilities related to standard setting, provision of water supply, and the implementation and enforcement of the regulations and standards. The roles and responsibilities of specific institutions should also be included in relevant enabling legislation, with each relevant institution listed and their roles, rights and responsibilities described. |
| **Water safety plans (WSPs)** | Recommendations or requirements for a risk management approach, such as a WSP, should be a fundamental component of regulations and standards. Proactive risk management by the water supplier is essential, and promotion of this good practice is of primary importance for regulations and standards. The regulations and standards should generally focus on the key principles of WSPs and refer to separate guidance for details, such as national or international WSP manuals.[a] It is important that implementation of WSPs is supported by a mechanism of WSP audit undertaken as part of surveillance to make sure WSPs are adequate and effective (see surveillance section of this table). |

TABLE 6.1 **Typical drinking-water quality regulations and standards content** (continued)

| Topics to consider | Remarks |
|---|---|
| **Table of parameters and limits**<br>*Sections 7 and 8* | These tables should present the most relevant parameters in the local context, with appropriate limits. Historically, these tables were usually the most visible and consulted part of the regulations and standards. Considering the GDWQ's strong promotion of preventive management, however, the attention given to these tables is now expected to be balanced with recommendations or requirements for WSPs or similar. To reinforce a focus on proactive risk management, it may be appropriate to locate these tables in an appendix. See Sections 7 and 8 for guidance on selecting appropriate parameters and limits. |
| **Monitoring requirements**<br>*Section 9* | This would specify water quality monitoring requirements, including frequencies, locations and reporting requirements, which would need to take into account available resources. See Section 9 for guidance on specifying monitoring requirements. |
| **Analytical requirements**<br>*Section 9.4* | This would typically specify any analytical requirements to strengthen the accuracy of water quality testing, such as methods to be used, requirements for laboratory certification or accreditation, quality assurance and quality control, sampling guidelines and the required training and skills for analysts or sample collectors. These requirements should take into account local resources and capacities and should allow for variations (e.g. methods used and use of field testing where appropriate). There is little value in specifying requirements that cannot be achieved. See Section 9.4 for additional guidance on specifying analytical requirements. |
| **Incident protocols**<br>*Section 10/Annex 1* | This would specify what to do in the case of incidents and exceedances. See Section 10 and Annex 1 for further guidance. |
| **Surveillance** | This would identify the:<br>■ Responsible agencies for surveillance, as well as other stakeholders and their obligations (if not described sufficiently in the roles, rights and responsibilities section).<br>■ Elements of surveillance, ideally including WSP auditing[b] and/or sanitary inspection to assess risk management, direct measurement of water quality through testing, and review of water quality monitoring reports prepared by suppliers.<br>■ Any special considerations for the surveillance of small water supplies.<br>■ Frequency of surveillance activities.<br>■ Requirements for reporting surveillance results. |
| **Good practice recommendations or requirements** | This optional content could cover nationally relevant topics, such as guidance for monitoring practices or special water quality issues (e.g. pesticide and algal management). This content may be best placed in appendices. |
| **Violations, penalties and incentives** | This would establish incentives for complying with the regulations and standards and/or penalties for violations. Normally, the use of penalties is a last resort and more proactive support to water suppliers facing difficulty with compliance is encouraged. |

[a] Where national WSP materials are developed, these should be referenced in the drinking-water quality regulations and standards. Where these are not available, reference can be made to the *Water safety plan manual* (WHO & IWA, 2009) and/or *Water safety planning for small community water supplies* (WHO, 2012).

[b] See *A practical guide to auditing water safety plans* (WHO & IWA, 2016) for more details.

## BOX 6.1 Examples of objectives

### Bhutan Drinking Water Quality Standard (2016)

**Overall goal:** To ensure safe drinking-water to protect consumer health.

**Objectives:**

- To set safe concentrations of nationally relevant drinking-water parameters.
- To contribute towards a progressive improvement of drinking-water quality management (e.g. sampling, testing, reporting and documentation) by service providers.
- To strengthen the application of WSPs in all drinking-water systems.
- To contribute towards increased public awareness of drinking-water safety.
- To build a national drinking-water quality database.
- To improve accountability of all stakeholders for drinking-water supply.

Source: Royal Government of Bhutan (2016). Bhutan Drinking Water Quality Standard 2016. Thimphu, Bhutan: National Environment Commission.

### Philippine National Standards for Drinking-Water (2017)

**Overall goal:** To protect public health by prescribing standards and procedures for drinking-water.

**Objectives:**

- Set safe concentrations for parameters that may affect consumers' health.
- Standardize methodologies used in collecting, handling, storing and testing water samples for different parameters.
- Guide water service providers and regulators in the application of the standards, interpretations of results and corrective actions in case of exceedances.
- Ensure safe drinking-water is provided during emergency situations.
- Emphasize the linkage between WSPs and drinking-water quality.
- Establish linkage between national drinking-water standards and SDG indicators.

Source: University of the Philippines Manila (2015). Updating of the 2007 Philippine National Standards for Drinking-Water (PNSDW). Final report. College of Public Health: Department of Environmental and Occupational Health.

# 7 Parameters

A critical and challenging step in the development of realistic drinking-water quality regulations and standards is the selection of the particular parameters to be included. This section discusses the importance of keeping the list of parameters short and relevant and presents guidance to support prioritization of microbiological, chemical, acceptability and (where appropriate) radiological parameters for inclusion in regulations and standards.

## 7.1 Keeping the list of parameters relevant and short

It is not necessary or desirable to include all the GDWQ parameters in national or subnational regulations and standards. The GDWQ cover a broad range of constituents that can affect drinking-water quality, and not all of these constituents will be relevant within a country.

By including parameters in regulations and standards, there is an implication that there will be some monitoring of those parameters. In most cases, this will be an explicit requirement, i.e. monitoring frequencies will be included. Excessively strict regulation that requires monitoring of all chemicals in the GDWQ is unlikely to provide health benefits, would be prohibitively expensive and time consuming, and would undermine the credibility and usefulness of the regulations and standards.

It is important that the parameters included in the regulations and standards are only those that have been, or may reasonably be, detected in water supplies in the country. There is little or no benefit to regulations and standards including contaminants that do not, or are unlikely to, occur in a water supply. Nationally relevant parameters should be reviewed and prioritized so that scarce resources are not unnecessarily directed towards the management of parameters that do not pose a threat to health and/or do not affect the acceptability of drinking-water. As resources permit, additional parameters could be incrementally included in the regulations and standards where new information becomes available from local investigations indicating a parameter represents a significant concern. For example, this approach was used by the United States Environmental Protection Agency when it used the Information Collection Rule Federal Database to collect occurrence information on microbial contaminants and disinfection by-products (DBPs) in drinking-water to refine its assessment of public health risks and associated response. Once information becomes available and important parameters are identified, regulations and/or standards are revisited (US EPA, 1997).

As a general rule, where there is a recorded history of a contaminant in drinking-water that affects public health or acceptability, inclusion in the regulations and standards would be considered appropriate. Parameters not specifically included in the regulations and standards could be covered by a general "catch-all" clause (see Box 7.1).

BOX 7.1 **Catch-all clause**

To account for potential parameters of concern that are not specifically included in the regulations and standards, it is valuable to include a general statement such as: "Water suppliers have an obligation to provide safe water for consumers. If any parameters or substances are identified in the water which are not specifically included in these regulations and standards, the current edition of the WHO *Guidelines for drinking-water quality* shall be the primary reference to assess the safe level of those substances and parameters."

**Public health principles** to consider when choosing which parameters to specify in regulations and standards include:

- Priorities should be directed at the most important public health concerns. Control of microbiological contaminants in drinking-water is the highest priority.
- Consideration needs to be given to other exposure routes of the parameter. Exposure to chemicals from drinking-water is typically minor in comparison with other sources with a few important exceptions (e.g. arsenic and fluoride). Where the overall burden of disease from multiple exposures is high, there is limited value in setting strict targets if drinking-water only provides a small proportion of the total exposure to that chemical (see Box 8.2).
- For most chemical parameters, there is no direct evidence that they have a significant impact on public health as a consequence of exposure through drinking-water. These should have a lower priority for action, even if present, compared with microbiological parameters and chemicals for which there is direct evidence of health impact through drinking-water (e.g. arsenic and fluoride). These chemicals should be considered within overall public health priorities.
- Radiological parameters are unlikely to have a significant impact on public health as a consequence of exposure through drinking-water in non-emergency situations. However, consideration needs to be given to areas where there are high levels of natural radionuclides in the underlying rocks and soil and, therefore, in groundwater sources of drinking-water.

**Cost considerations** to bear in mind when choosing which parameters to specify in regulations and standards include:

- Control and monitoring of parameters require financial resources. Particularly where there are limited resources, e.g. in the case of small supplies, it is important to ensure these are targeted to the highest priority issues.
- If risk assessment shows that a contaminant is rarely present and/or well below the GDWQ guideline value, it may not be appropriate to include it in the regulations and standards because the cost of monitoring would not be justified in terms of the benefits.
- Even if a substance is present at a concentration close to or above the GDWQ guideline value, it is appropriate to consider the costs of control in setting the parameter limit, as long as no immediate health impacts are expected (see Box 8.2).

## 7.2 Microbiological parameters

In order to decrease the risk of waterborne diseases in any country, ensuring that drinking-water is free of microbiological hazards is the most important priority for regulations and standards. Waterborne microbial disease is essentially acute, potentially occurring after even a single exposure.

The recommended approach to assessing faecal contamination and verifying the microbial safety of drinking-water is based on testing of indicator organisms. The organism of choice is *E. coli*, although thermotolerant coliforms provide a less precise but acceptable alternative. (Annex 3 provides additional information on other microbial indicators.) *E. coli* is excreted in large numbers in the faeces of humans and other warm-blooded animals; while most are non-pathogenic, certain strains can cause acute diarrhoea. Despite having some shortcomings, particularly as an indicator of viruses and protozoa due to higher sensitivity to inactivation and environmental pressures, *E. coli* remains an important indicator of the presence of faecal contamination and associated pathogens.

As a complement to *E. coli* testing, certain operational parameters can serve as indicators of pathogen removal or inactivation and are often included in regulations and standards, namely:

- **Turbidity:** Where treatment is applied, turbidity provides an indication of the effectiveness of particle removal processes and/or of disinfection effectiveness (as high turbidity can interfere with disinfection). It also provides an indication of rapid changes in source water quality and distribution system integrity.

- **Disinfectant residual:** This serves as an important indicator of pathogen inactivation at the treatment plant and of protection against recontamination in the distribution system.
- **pH:** This is an important operational parameter in determining disinfection efficacy.

Turbidity, disinfectant residual and pH should be measured where samples are collected for *E. coli*. Where resources for monitoring are particularly constrained and only occasional *E. coli* testing is feasible, e.g. in the case of some small supplies, these other parameters can serve as surrogates for gauging microbial water quality between *E. coli* monitoring events.

All key parameters related to confirming microbiological water quality can be measured using field testing kits (see Section 9.4).

## 7.3 Chemical parameters

In contrast to the acute and immediate nature of waterborne microbial disease, the great majority of chemical contaminants only exert an effect after a long period of exposure (i.e. years).

When developing or revising regulations and standards, the challenge is to select the most important chemicals in a given setting. As noted in Section 7.1, for most chemical parameters, there is no direct evidence that they have a significant impact on public health as a consequence of exposure through drinking-water. These chemicals should therefore be a lower priority for action, even if present, compared with microbiological parameters and chemicals known to impact human health through drinking-water. A chemical should be prioritized if:

- There is evidence that health effects can arise specifically from exposure to a chemical through drinking-water (e.g. arsenic, fluoride, nitrate, lead and possibly manganese).
- The chemical is widely present in water sources in the country.
- There is a reasonable chance of consumers being exposed to the chemical at concentrations of concern, i.e. above or close to the GDWQ guideline value. Where concentrations vary between supplies, it may be appropriate for the regulations and standards to allow for flexibility according to site-specific risk assessments (see Section 9).

It is important to pay particular attention to the limited number of chemicals that have been found to present serious human health hazards due to exposure through drinking-water. These include fluoride, arsenic, nitrate, lead and possibly manganese.

A list of potential chemical hazards is required to establish chemicals of concern in the local context. To support the development of such a list, Box 7.2 provides examples of potential chemical contaminants according to five source categories: naturally occurring, agricultural sources, human settlements, industrial activities, and water treatment and distribution. For further guidance on preparing a list of potential chemical hazards, see *Chemical safety of drinking-water* (WHO, 2007); *Protecting groundwater for health* (WHO, 2006); and *Protecting surface water for health* (WHO, 2016).

To identify priority chemicals, available water quality data should be reviewed, (see Section 5.3), along with the likely sources of the contaminants. To assess the potential sources of contaminants and their significance, the approach outlined in *Chemical safety of drinking-water* (WHO, 2007) can be followed. This approach involves categorizing chemical parameters into five source categories (see Box 7.2) and identifying risk factors related to the probability of exposure close to or above the GDWQ guideline value. Those chemicals with higher probability of elevated exposure, particularly those with known public health impacts, should be prioritized.

An additional consideration when prioritizing chemicals for inclusion in regulations and standards is that there may be other sources of exposure (e.g. pesticides in food, heavy metals in fish, lead in paint) that should be considered when weighing the costs and benefits of controlling and regulating levels in drinking-water, particularly for chemical parameters that have a direct impact on human health. In some cases, drinking-water will be a minor source of exposure, and controlling levels in water may have little if any impact on overall exposure. In other cases, controlling a chemical in water may be the most cost-effective way of reducing exposure to the public. The chemical fact sheets in Chapter 12 of the GDWQ, including supporting background documents referenced in the fact sheets, give some background data on the exposure of each chemical from drinking-water compared with other sources, although local circumstances may vary.

## BOX 7.2 Examples of chemical contaminants by source category

**Naturally occurring chemicals**

- Many of these chemicals generally have a far greater impact on groundwater than surface water (e.g. arsenic, fluoride, uranium), with the notable exception being cyanobacterial toxins.
- The concentrations of naturally occurring chemicals are generally, but not always, stable in groundwater.
- Cyanotoxins can be produced by some cyanobacteria. Cyanobacteria are common in surface water, with occurrence often linked to seasonal conditions and nutrient availability (primarily phosphorus).

**Chemicals from industrial activities**

- These will depend on the nature of the industry and need to be identified through the development of a list of industrial processes undertaken locally. See *Chemical safety of drinking-water* (WHO, 2007) for guidance.
- Some commonly used degreasing agents, e.g. trichloroethene, can persist in groundwater.
- Specific chemicals associated with certain production industries include:
  - battery manufacturing can be a source of cadmium, lead, nickel, manganese, mercury, copper and lithium;
  - electroplating and tanneries can be a source of chromium; and
  - chemical and pharmaceutical industries can discharge chemicals associated with their products.
- Mine sites can be sources of contaminated waste materials, particularly where management practices are poor or where mines have been abandoned. Chemicals associated with extractive industries include:
  - those being extracted, e.g. uranium, copper and other base metals, hydrocarbons;
  - those used to extract deposits, e.g. cyanide, mercury; and
  - chemicals released due to the method of extraction (such as acid leaching) and from acid mine drainage, e.g. arsenic, antimony, cadmium, chromium, fluoride, lead, mercury, nickel, selenium.

**Chemicals from agricultural activities**

- Chemicals of significance will vary depending on use, precipitation, run-off and leaching, and include:
  - pesticides (types depend on local use);
  - nitrates (e.g. from inorganic fertilizers and manure), which can impact surface water and groundwater; and
  - phosphorus (e.g. from inorganic fertilizers), which generally will not have a direct health impact, but can support the growth of cyanobacteria in surface water.

**Chemicals from human settlements**

- Chemical contamination may result from:
  - use of chlorinated solvents (e.g. trichloroethane);
  - fuel storage (petroleum hydrocarbons, benzene, ethyl benzene, toluene, xylene);
  - sewage and waste disposal (nitrate and ammonia);
  - industrial waste discharges;
  - urban run-off (e.g. nitrate, ammonia, heavy metals); and
  - landfill sites where industrial solids and liquid materials are stored.

## BOX 7.2 Examples of chemical contaminants by source category (continued)

**Chemicals from water treatment and distribution**

- Chemicals associated with water treatment and distribution fall into two broad categories, namely:
  - Substances resulting from the addition of chemicals used for water treatment, including coagulants and disinfectants. These chemicals are intentionally added but can give rise to residues or by-products (e.g. acrylamide from polyacrylamide coagulant or DBPs from chlorination). Treatment chemicals can also contain contaminants.
  - Substances that arise from the corrosion of pipes or leach from materials used in distribution or plumbing (e.g. lead, nickel, copper, or vinyl chloride from pipes, solder and fittings).
- Disinfection should never be compromised in an attempt to control DBPs.
- The preferred approach to controlling chemicals associated with water treatment and distribution is through a certification system (see Box 7.3).

## BOX 7.3 Certification schemes

Drinking-water in a piped distribution network is exposed to numerous surfaces, and it is important that no materials used in the network leach high concentrations of hazardous chemicals, promote microbial growth, impart unacceptable tastes and odours or react with drinking-water (e.g. leaching of *N*-nitrosodimethylamine [NDMA] from rubber seals). It is also important to ensure that chemicals used in treatment or associated by-products do not pose a risk to health. This includes consideration of impurities contained in treatment products (e.g. aluminium sulfate can contain trace amounts of lead). The preferred approach to controlling chemicals associated with water treatment and distribution (e.g. vinyl chloride from plastic piping or chemicals leaching from ion-exchange resins or membranes) is through a certification system, whereby materials and chemicals are tested to confirm compliance with defined standards and certified to be of suitable quality and type for drinking-water applications. Various tests can be carried out to determine whether the material, additive or contaminant arising from the material or additive can adversely affect general water quality (e.g. taste and appearance) and/or exceed permissible levels and pose a health risk to consumers. Certification systems can be overseen by government agencies or private organizations. Where a country has yet to establish a certification scheme, it may be appropriate to consider using materials already approved through another country's certification scheme. (Note that these schemes may or may not address the ability of the materials to support or promote microbial growth.)

A further consideration when prioritizing chemicals for inclusion in regulations and standards is whether or not there is a guideline value in the GDWQ. For some chemicals, no formal guideline value is included because occurrence is only at concentrations well below those that would be of concern for health. The GDWQ do not propose guideline values for such substances so as not to encourage countries to incorporate these chemicals into regulations and standards when inclusion is neither necessary nor appropriate. However, the GDWQ may present health-based values (rather than formal guideline values) for these substances to help assess the significance of occurrence if they are found in drinking-water or in source water. Note that acceptability concerns (see Section 7.4) may be relevant for some of these chemicals without a guideline value.

## 7.4 Acceptability parameters

In addition to pathogens and chemicals that affect health, a secondary but important consideration is for parameters that influence the acceptability of the water to consumers. These parameters are typically related to the taste, odour or appearance of drinking-water, and they may lead to consumers rejecting the drinking-water and turning to other water that is aesthetically more acceptable but potentially less safe. In addition, some of these parameters may cause operational problems such as corrosion, fouling of filtration media, or encrustation of distribution systems, which may have an indirect impact on public health by compromising the ability to maintain a safe drinking-water supply.

Typical parameters that can reduce acceptability are physical parameters (e.g. taste, turbidity, odour, colour) and some inorganic constituents and contaminants (e.g. iron, manganese, aluminium, sodium, sulfate, total dissolved solids, pH, ammonia, chloramines, chlorides, chlorine, chlorobenzenes, copper, dissolved oxygen, hydrogen sulphide, zinc).

Generally, the concentrations that affect acceptability are significantly lower than those of concern for health. Some parameters have no direct health effects at any concentration. Where a parameter is normally detected aesthetically at concentrations lower than those of health concern (e.g. chlorobenzenes and some petroleum derived hydrocarbons such as toluene, ethyl benzene, xylene):

- It is not normally necessary to directly regulate or monitor such substances. Rather, these parameters may be addressed through a general requirement in the regulations and standards that the drinking-water supplied must be acceptable to most consumers.

- For these parameters, the GDWQ may include a health-based value[1] in order to assist in determining a response when problems are encountered and to provide reassurance with regard to possible health risks. (Note that health-based values, rather than formal guideline values, are also established in the GDWQ for parameters that are less frequently encountered on a global basis, as discussed in Section 7.3.)

An exception to the general rule above is manganese, which is widely found in drinking-water sources. The current edition of the GDWQ includes a health-based value for manganese of 0.4 mg/l. This concentration is above concentrations normally causing acceptability problems in drinking-water.[2] However, there are circumstances in which manganese can remain in solution at concentrations of health concern in some acidic or anaerobic waters, particularly groundwaters. It may therefore be appropriate to regulate and monitor manganese and consider both aesthetic as well as health aspects when considering the acceptability of drinking-water (see Annex 4 for more information).

## 7.5 Radiological parameters

The health risks associated with radionuclides are generally low compared with those from microorganisms or chemicals. Health risks for radionuclides in drinking-water will not be acute or immediate. However, there are circumstances where natural radionuclides are significant and may dominate the chemical hazards, for example some deeper groundwater sources in the Middle East. Concentrations of radionuclides in drinking-water are most likely to be from naturally occurring radionuclides, although mining, medical facilities and nuclear energy facilities are also potential sources.

Where it is considered appropriate to include radiological parameters in regulations and standards, a screening approach for radionuclides, consistent with the approach included in the GDWQ, should usually be applied. This involves inclusion of gross α and gross β screening to assess whether there is a radiological hazard present. The screening approach enables a cost-effective and efficient means to assess radiological hazards, minimizing the need to carry out detailed radionuclide analysis when the screening values are not exceeded.

---

1 The GDWQ address acceptability related parameters in two ways: (i) a guideline value designated as a "GV (C)" is included, or (ii) a health-based value, rather than a formal guideline value, is included. Both approaches indicate that these substances can impact on the acceptability of the drinking-water supply, usually at levels that are far below those of health concern. For example, Table A3.3 in Annex 3 of the GDWQ presents guideline values for approximately 90 substances. Some of these (e.g. chlorine, ethylbenzene, styrene) are designated with (C), indicating that concentrations at or below the (health-based) guideline value may affect acceptability.

2 For example, at concentrations above 0.1 mg/l, manganese in water supplies may cause an undesirable taste in beverages, and stain sanitary ware and laundry (WHO, 2017a).

When the screening value is exceeded, detailed analysis for individual radionuclides should be required. Specialist input may be needed to support the identification of the radionuclides that are causing the problem.

It should be noted that this screening approach is not applicable for radon. However, standards for radon do not generally need to be established even in areas where radon is in water sources, as exposure is predominantly from inhalation inside buildings rather than drinking-water.

For further information, see *Management of radioactivity in drinking-water* (WHO, 2018b).

## Additional reading

*A global overview of national regulations and standards for drinking-water quality* (WHO, 2018a) summarizes information from 104 countries and territories on the microbiological, chemical, acceptability and radiological parameters specified in national drinking-water quality standards. The report shows considerable variability in parameters from country to country. Any comparisons should be approached with caution, as local circumstances will vary widely and regulations and standards should always reflect due consideration of local priorities and available resources.

# 8 Parameter limits

Determining appropriate numeric limits for the various parameters that are prioritized for inclusion in the drinking-water quality regulations and standards requires careful consideration in order to ensure public health protection while also making limits realistic and appropriate. The health benefits and costs associated with achieving the parameter limits set should be considered, as should the health benefits and costs of controlling levels in drinking-water as compared with controlling other sources of exposure, such as food or air.

In many circumstances, it will be appropriate to adopt the GDWQ guideline values as the numeric limits for those parameters included in the regulations and standards. Where a GDWQ guideline value is not considered achievable or cost-effective due to practical constraints in the local context, e.g. where existing treatment systems (or lack thereof) are incapable of sufficiently reducing concentrations, it is important to ensure that the parameter limit established in the regulations and standards is both protective of human health and realistic. Interim and/or ideal versus mandatory limits can be established, as discussed in Section 4. Additional options for establishing parameter limits that differ from the GDWQ guideline values are presented in the next sections according to parameter type.

## 8.1 Microbiological limits

Ideally, *E. coli* should not be present in any samples of drinking-water. However, this may not always be achievable. For example, small community supplies may have difficulty in meeting this target. Table 5.2 of the GDWQ presents a grading approach based on the proportion of samples that are negative for *E. coli* and the population size. Grading schemes can be used in combination with sanitary inspections to categorize systems and identify priorities for improvement (see Box 8.1 for further discussion of the role of sanitary inspection in achieving microbiologically safe water).

### BOX 8.1 The role of sanitary inspection

Recognizing that it is not feasible to monitor for all potential waterborne pathogens and that all monitoring is necessarily limited in space and time, the focus of ensuring the microbiological safety of drinking-water should be on proactive risk assessment and risk management. This can be addressed in regulations and standards by promoting or requiring WSPs or sanitary inspections, and by including sanitary inspection and/or WSP auditing in water quality surveillance programmes.

## 8.2 Chemical limits

For those substances that are particularly difficult to control, such as some of the natural contaminants found in groundwater, it is possible to set a parameter limit higher than the GDWQ guideline value while still being protective of health. The process for determining such values is beyond the scope of this guidance document, although key considerations are presented in Annex 2. In brief, this involves comparing the assumptions made in deriving the GDWQ guideline values (which are generally conservative) with local conditions and/or undertaking a local risk assessment to determine safe limits. Examples of substances for which adaptation of the GDWQ guideline values may be appropriate include arsenic and fluoride (see Box 8.2).

### BOX 8.2 Setting limits higher than GDWQ guideline values

It is important to consider overall exposure from a chemical when determining appropriate drinking-water limits, including exposure from food, consumer products and air. For example, food and/or dental preparations may be significant sources of fluoride exposure. In some cases, it may be more practical to exert control through reducing exposure from food and allowing higher concentrations in drinking-water, particularly when considering small supplies that may not have appropriate treatment in place. For example, high fluoride in water in one state in India has been managed by using low fluoride surface water sources for irrigation in order to reduce fluoride concentrations in crops. By reducing fluoride exposure through food, the fluoride intake from drinking-water can be increased while staying within the limits of the maximum daily fluoride intake deemed safe. This approach, combined with increasing the intake of calcium (which helps to reduce the impact of fluoride), allowed authorities to set the limit for fluoride in drinking-water at 3 mg/l (as compared with the GDWQ guideline value of 1.5 mg/l) without a higher risk of skeletal effects.

Setting a parameter limit higher than the GDWQ guideline value may also be justified on the basis of a local health risk assessment. A number of countries, including Bangladesh, have set their limit for arsenic at 50 µg/l, which is five times the current GDWQ guideline value of 10 µg/l. (50 µg/l is the previous GDWQ guideline value for arsenic.) After consultation with health authorities, it was determined that achieving 50 µg/l will have a clear and measurable impact on the burden of disease from arsenic, while it is more difficult to demonstrate additional gains at lower concentrations (WHO, 2011). The assessment by the Joint FAO/WHO Expert Committee on Food Additives concluded that, "For certain regions of the world where concentrations of inorganic arsenic in drinking-water exceed 50–100 µg/l, some epidemiological studies provide evidence of adverse effects. There are other areas where arsenic concentrations in water are elevated (e.g. above the GDWQ guideline value of 10 µg/l) but are less than 50 µg/l. In these circumstances, there is a possibility that adverse effects could occur as a result of exposure to inorganic arsenic from water and food, but these would be at a low incidence that would be difficult to detect in epidemiological studies."

Source: Government of Bangladesh (1997). The Environment Conservation Rules.

*Further information on how the GDWQ guideline values are calculated and can be adapted is available in Annex 2 and in Chapter 8.2 of the GDWQ.*

When there is no guideline value or health-based value presented in the GDWQ but a suitable international toxicological review is available in which a tolerable daily intake (TDI), allowable daily intake (ADI) or tolerable weekly or monthly intake has been determined by the International Programme on Chemical Safety, the Joint FAO/WHO Expert Committee on Food Additives and Contaminants, or the Joint Meeting on Pesticide Residues, this can be used to determine a suitably safe level for drinking-water following the WHO methodology as described in Chapter 8.2 of the GDWQ.

## 8.3 Radiological limits

The screening values and radionuclide guidance levels in the GDWQ are based on an individual dose criterion (IDC) of 0.1 mSv/year. In countries where natural radioactivity in drinking-water is not an issue, adopting the IDC (and corresponding screening values and guidance levels) should be appropriate. However, in situations where it is difficult to achieve the IDC (e.g. where natural radionuclides are an issue), countries may wish to use a different dose criterion and adjust the screening values and guidance levels accordingly. In these situations, regulatory authorities may establish a dose criterion greater than the IDC of 0.1 mSv/year, but generally less than the International Basic Safety Standard reference level of 1 mSv/year, depending on the circumstances.[1] Factors to consider in establishing the dose criterion include the costs of remediation and the availability of other drinking-water supplies. In any case, it is recommended to set a national reference level as low as reasonably achievable. For further information, see *Management of radioactivity in drinking-water* (WHO, 2018b).

1 The International Basic Safety Standard for Radiation Protection and Safety of Radiation Sources, co-sponsored by eight UN agencies, including WHO, recommends a dose criterion (reference level) for drinking-water of approximately 1 mSv/year. A reference level represents the level of dose or risk above which it is judged to be inappropriate to plan to allow exposures to occur and below which optimization of protective actions should be planned in order to keep doses as low as reasonable achievable. It should not be regarded as an acceptable dose or as a dose limit. Source: International Atomic Energy Agency (IAEA) (2014). Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3 (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1578_web-57265295.pdf, accessed 23 February 2018).

# 9 Compliance monitoring

One of the key functions of drinking-water quality regulations and standards is to establish requirements for compliance monitoring (see Box 9.1), which is the focus of this section. Minimally, regulations and standards should address:

- which entities are responsible for monitoring;[1]
- which parameters to monitor (Section 7);
- frequency of monitoring (Section 9.1);
- where (in general terms) monitoring should take place (Section 9.2);
- routine reporting requirements (Section 9.3);
- acceptable sampling and testing procedures (Section 9.4); and
- what action to take in the event of non-compliance (Section 10 and Annex 1).

### BOX 9.1 Operational versus compliance monitoring

When establishing monitoring requirements in drinking-water quality regulations and standards, it is important to consider the distinction between compliance monitoring and operational monitoring.

The regulations and standards should stipulate that certain monitoring must be undertaken to demonstrate compliance with the regulations and standards. This monitoring may be undertaken to assess the performance of a treatment process (e.g. by measuring operational parameters such as turbidity, chlorine residuals and pH) or to verify that the drinking-water being supplied to consumers is safe. Regardless of where the monitoring occurs or which parameters are monitored, if the requirement to undertake this monitoring activity is specified in the regulations and standards, it is **compliance monitoring**. Compliance monitoring may be undertaken by the water suppliers and/or by the surveillance agency.

An important complement to the compliance monitoring required by the regulations and standards is **operational monitoring**, which is undertaken by water suppliers as and where needed to confirm that the system is functioning as expected, to inform operational decisions (e.g. chemical dosing rates) and to provide evidence that the system will deliver water that meets the regulations and standards. Operational monitoring is generally undertaken at a higher frequency than compliance monitoring, with the particular monitoring locations (e.g. raw water, filtered water) and water quality targets at each location determined by the water supplier. Operational monitoring data are generally for the water suppliers' own use, whereas compliance monitoring data are shared with the regulator. (Note that water suppliers may also undertake investigative monitoring as part of risk assessments of drinking-water supplies, including catchments. This monitoring is also generally for the water suppliers' own use.)

Within this document, "monitoring" refers to compliance monitoring unless operational monitoring is specifically indicated.

[1] When the water supplier and the surveillance agency both undertake monitoring activities, it is important for the programmes to be coordinated and for data to be shared.

As with all elements of the regulations and standards, it is important to consider practical constraints when setting out monitoring requirements, including available human resources to carry out sampling, availability of analytical facilities and budgets. The principle of incremental improvement should be applied as appropriate, whereby a modest monitoring schedule could be established initially and expanded as resources become available over time. In all cases, and particularly where there are limited capacity and resources to perform laboratory testing, sanitary inspections and/or WSP audits to confirm risk management along the water supply chain are important complements to water quality monitoring to verify the safety of drinking-water supplies.

Also, when establishing monitoring requirements in the regulations and standards, there should be some flexibility built in so that water suppliers can propose alternative monitoring programmes based on the actual risk that a particular parameter will be present at concentrations of concern. This concept is discussed in in Box 9.2 and in Section 9.1.

BOX 9.2 **Risk-based monitoring programmes**

Water suppliers should be given an option to develop risk-based monitoring programmes that deviate from the monitoring requirements set out in the regulations and standards on the basis of a system-specific risk assessment. Issues to consider include:

- historical water quality monitoring results;
- the different sources of water (e.g. groundwater, surface water, springs);
- potential contamination sources (e.g. industrial, agricultural);
- treatment processes (e.g. chlorination); and
- size and complexity of the water supply system.

All decisions regarding risk-based monitoring need to be justified, documented and approved by the drinking-water regulator before being implemented.

## 9.1 Sampling frequency

The frequency of compliance monitoring should depend on the:

- quality and variability of the source water;
- type of treatment the water receives;
- risks of contamination in various parts of the system;
- complexity of the system (e.g. number of pressure zones, intermittency of operation, pipe material, pipe condition, reservoir condition);
- water quality history;
- size of the population supplied with drinking-water; and
- availability of data produced by monitoring for other purposes (e.g. environmental monitoring).

These conditions should also be balanced with consideration of the availability of personnel, transport, laboratory facilities and funds to undertake monitoring. That is, it is the resources available to both the water suppliers and the surveillance agency that will dictate what may feasibly be assigned to these entities. Higher frequencies of analysis will have higher costs and require greater resources. It is generally appropriate to require more frequent monitoring for better resourced systems, e.g. professionally managed versus community-managed systems.

Similarly, it is important to consider which entity is likely to undertake monitoring when establishing frequency requirements. Where compliance monitoring is undertaken by water suppliers, more frequent monitoring will generally be feasible. Where the surveillance agency is expected to carry out the required monitoring, as may be the case for small water supplies, monitoring will generally need to be less frequent due to resource limitations.

Some key considerations for establishing the appropriate monitoring frequency for the various parameters included in the regulations and standards are described below.

**Parameter stability:** For those parameters that have the potential to change rapidly, such as microbiological indicators or chemicals used in water treatment, the required sampling frequency should be greater than that required for more stable parameters, such as some of the inorganic chemicals found in groundwater. Groundwater sources are likely to be less variable and typically require less frequent monitoring relative to surface water, depending on the contaminant and its importance. For stable parameters, sampling once per year (or even less) may be adequate. Where parameter concentrations are both stable and well below the GDWQ guideline value or established parameter limit, monitoring as infrequently as once every five years or less could be justified.

In the case of radiological parameters, it is generally recommended to monitor new sources with a significant radiological risk at least four times per year for one year (i.e. once per season). Then, in the absence of exceedances, the frequency can be decreased to once per two to five years (or longer), depending on the level of activity concentrations in the water, the source of the supply (surface or groundwater) and how likely it is that activity concentrations may vary across the year (e.g. groundwater sources may display less variability than surface water sources), the size of the population supplied and the quantity of historical monitoring records. For further information, see *Management of radioactivity in drinking-water* (WHO, 2018b).

**Likelihood of occurrence at concentrations of concern:** The frequency of monitoring for chemical parameters should reflect the risk that a parameter will be present at a concentration of concern. For instance, monitoring for cyanobacterial toxins should not be performed on a regular basis, but rather should only be undertaken when there is evidence of significant cyanobacteria growth.[1] As risk will often vary between individual water supply systems, the frequency set out in the regulations and standards should be sufficient to account for higher risk scenarios while also making allowance for lower frequencies where justified through a system-specific risk assessment. See Box 9.3 for an example of such allowances within regulations and standards, and see Box 9.4 for tips on when a reduced monitoring frequency may be justified.

**Seasonal influences:** The presence of certain substances may be subject to seasonal influences, for example, pesticides resulting from agricultural activities. The timing and frequency of required monitoring should account for any seasonal variations.

### BOX 9.3 Example of risk-based monitoring frequency

The **European Union** has adopted a risk-based sampling approach in Annex II of the DWD. This enables the development of customized monitoring programmes based on system-specific risk assessment. Under this approach, when the risk assessment shows that there is a low risk of a parameter exceeding the established limit, a lower frequency of monitoring for that particular parameter can be justified. Where a system-specific risk assessment has not been conducted (and approved by the competent authority), the water supplier would monitor according to the parameter and frequency schedule set out in the DWD.

Source: Commission Directive (EU) 2015-1787 of 6 October 2015, amending Annexes II and III (https://publications.europa.eu/en/publication-detail/-/publication/0e53d4eb-6cba-11e5-9317-01aa75ed71a1/language-en, accessed 30 May 2018).

[1] Every effort should be made to prevent blooms forming, and this should be the primary management approach. Where there are heavy algal blooms, it is best to consider an alternative source of water unless appropriate treatment is available.

BOX 9.4 **Justifying reduced monitoring frequency**

Where a system-specific risk assessment shows that a substance is not expected to be present in a particular water supply, there may be no need for more than very occasional monitoring to check for its presence, or no monitoring at all may be required. For example, if a water supplier can demonstrate that a parameter or the process giving rise to the parameter is not present or in use within a particular water supply system, the supplier could be exempted from associated monitoring. For instance, where chlorination is not applied, there would be no need to monitor for chlorine residuals, trihalomethanes (THMs) or haloacetic acids (HAAs).

As another example, if a substance is present, but at less than approximately 50% of the GDWQ guideline value, the following questions should be considered:

- Does the concentration change or is it stable over time? If it is stable over time, reduced monitoring may be justified, even with a concentration of up to 75% of the GDWQ guideline value.
- Is operational monitoring carried out for this substance at the treatment works, e.g. for aluminium? If undertaken correctly, such monitoring can justify reduced compliance monitoring requirements.

Risk assessments that are used to justify customized monitoring programmes will ideally be undertaken as part of a WSP. It may be appropriate to start with more frequent monitoring to gain initial information for WSPs, and then adjust accordingly, based on the outcomes of the risk assessment.

## 9.2 Sampling locations

Compliance monitoring data should reflect the quality of the drinking-water that consumers receive. The regulations and standards should therefore provide guidance on sampling locations for those parameters that will be used to assess compliance with the regulations and standards.

The number of sites at which monitoring is undertaken will impact on resources (financial, as well as sampling and testing) and needs to be balanced against other requirements associated with ensuring drinking-water quality (e.g. implementation of WSPs).

Some broad principles to follow when selecting monitoring locations are:

- Optimal sampling locations depend on where in the system the contaminant is expected to be introduced and the likelihood that the parameter's concentration or character will change through the water supply system (see Table 9.1).
- Sample sites in a distribution system should give good geographic representation of the water supply system and enable the comparison of water quality over time for particular sections of the system. While the regulations and standards may not be specific in this regard, they could state this as a principle that needs to be followed when designing compliance monitoring programmes.
- It is best if sites are rotated amongst the designated sample sites throughout the distribution system. However, a limited number of sites could be maintained in order to collate a series of historical data.

- The sampling of microbial parameters or indicators should be representative in terms of exposure (e.g. more samples need to be collected in areas of higher population densities) and be designed to detect contamination if it occurs. This means that sampling locations should account for:
  – locations within the system with long travel times;
  – times of increased likelihood of contamination (e.g. seasonal variations or in intermittent water supplies); and
  – deterioration in water quality as a result of the condition of the distribution system or household storage.
- If water is supplied through point source supplies, e.g. village wells, ideally samples should be collected for microbiological testing from the point of collection and from the home in order to identify any degradation of water quality through household practices (e.g. storage, treatment and handling).

TABLE 9.1 **Guidance on monitoring locations**

| Parameter concentration | Examples[a] | Primary monitoring locations[b] |
|---|---|---|
| **Is unlikely to change after treatment** | ■ Arsenic<br>■ Nitrate (except where chloramines are being used as a residual disinfectant)<br>■ Fluoride<br>■ Aluminium<br>■ Ammonia (except where chloramines are being used as a residual disinfectant)<br>■ Barium<br>■ Selenium<br>■ Radionuclides | Exit of treatment plant |
| **Can change after treatment and through the distribution system** | ■ Microbial indicators (e.g. *E.coli*)<br>■ THMs<br>■ Other DBPs<br>■ Chlorine residual<br>■ Ammonia (where chloramines are being used as a residual disinfectant)<br>■ Taste and odours<br>■ Turbidity<br>■ Manganese<br>■ Nitrite and nitrate (where chloramines are being used as a residual disinfectant) | One of the following locations:<br>■ Within the distribution system<br>■ Consumers' taps |
| **Is largely influenced by service connections or plumbing within buildings** | ■ Lead<br>■ Copper | Consumers' taps |

[a] Inclusion of a parameter in this table does not imply that the parameter is a high priority in all water supply systems.
[b] Not all jurisdictions can monitor at the consumer's tap. If the samples cannot be collected from the consumer's tap, the point of supply to the consumer's property is a satisfactory alternative. For more detailed guidance on monitoring in distribution systems, refer to *Water safety in distribution systems* (WHO, 2014).

## 9.3 Review and reporting of results

To realize the full benefit of water quality monitoring, monitoring results must be periodically reviewed. All monitoring data need to be examined, even if the concentrations are below the established parameter limits, in order to assess trends (e.g. the stability of concentrations over time). It is therefore important that regulations and standards specify requirements for routinely reporting monitoring results. (Reporting in the event of a parameter limit exceedance or other incident is addressed as a separate topic in Section 10.) As a minimum, the regulations and standards should address:

- **Who is responsible for compiling and submitting reports?** This may be the drinking-water supplier and/or field divisions of the surveillance agency.
- **To whom should reports be submitted?** Generally, reports should be submitted to the appropriate level within the regulatory (or surveillance) agency. In cases where monitoring is led by an entity other than the water supplier, e.g. the surveillance agency, it is critical that results are also shared with the water supplier as soon as possible after the results become available.
- **How often should reports be compiled and submitted?** This will generally be more frequent (e.g. monthly) for larger, better resourced water suppliers and less frequent (e.g. annually) for smaller water suppliers.
- **How will the results be shared with consumers?** Regulations and standards should require results to be shared with consumers. It is important to consider how, how often and possibly in what format the monitoring results will be made available to consumers. For example, results may be disseminated through a website, posted or available for review at the office of the water supplier, provided upon request and/or summarized in a publicly available annual report.

## 9.4 Analytical requirements

To strengthen the accuracy of water quality monitoring results, regulations and standards should specify analytical requirements, which may include methods to be used, requirements for laboratory certification or accreditation, quality assurance and quality control, sampling guidelines and training and skills of analysts or sample collectors.

Various collections of "standard" or "recommended" methods for water analysis have been published by a number of national and international agencies. It is often thought that adequate analytical accuracy can be achieved provided that all laboratories use the same standard method. However, experience shows that this is not always the case, as a variety of factors may affect the accuracy of the results. Examples of issues that can lead to inaccurate results include: reagent impurity; the type of apparatus used; the performance, calibration and general maintenance of the apparatus used;

the degree of modification of the method applied by the laboratory; and the skill and care of the analyst. These factors are likely to vary both between laboratories and over time within an individual laboratory. Moreover, the precision and accuracy that can be achieved with a particular method frequently depends upon the adequacy of sampling and nature of the sample.

A number of considerations are important in specifying analytical requirements:

- While the use of standard methods is ideal, alternatives could be considered provided that they have been validated to confirm that they are fit for their intended uses.
- The overriding consideration in selecting methods is that the method chosen is demonstrated to have the required sensitivity and accuracy. Other factors, such as speed and convenience, should be considered only in selecting among methods that meet this primary criterion.
- A list of approved analytical methods could be included in an appendix to the main document. Alternatively, a set of minimum performance characteristics of the methods could be established, including limits of quantification, which need to be below regulatory limits.
- External laboratory certification is highly desirable. However, if not available, the regulations and standards could instead specify an approval process for laboratories. Requirements such as application of standard methods, quality assurance and control, and skills and training of analysts could be described in an appendix to the main document or in supporting guidance.

It is also important to consider field testing when specifying analytical requirements. Many types of low-cost, portable field test kits are available to measure the concentrations of various contaminants in water, e.g. *E. coli*, chlorine residuals, turbidity, pH and some chemicals. Some parameters, such as chlorine residuals and temperature, have to be measured in the field given their instability. Field test kits have the advantage of being simple to use in non-laboratory environments and are often available at relatively low prices, and they allow those carrying out the testing (e.g. surveillance officers) to share and discuss results with operators or community members during site visits. However, their analytical accuracy is generally lower than laboratory methods. Many of the test kits are semi-quantitative, while others simply measure the presence or absence of a contaminant. However, when properly used, they provide valuable tools for rapidly assessing numerous contaminants in a non-formal laboratory setting at low cost compared with commercial laboratory tests, and may be particularly useful for monitoring in remote settings. It is recommended that field test kits be validated for performance against reference or standard methods and approved for use. Regular calibration of test kits is also required. Quality assurance of all analytical methods and testing is essential regardless of who is carrying out the activities.

# 10 Incident protocols

Incident response and reporting protocols should be addressed in drinking-water quality regulations and standards to protect public health in the event of a parameter exceedance or other incident, such as a major fault or loss of treatment.

If a parameter limit established in the regulations and standards is exceeded, or if another type of incident or contamination event occurs that may impair safety, the water supplier should take appropriate action as quickly as possible to prevent unacceptable risks to consumers. It is also important to report the issue to the appropriate agency or agencies, which should be identified in the regulations and standards. The regulations and standards may also specify the timeframe in which such reports need to be submitted to the appropriate agency or agencies.

Broad indications of what must be done could be included in the regulations and standards. Refer to Annex 1 for more guidance on this issue.

# Annex 1
## Responding to exceedances

Occasionally, a test result will exceed an established parameter limit even in systems that are usually in compliance with all of the parameter limits. Such results can arise from a number of causes that are related to analytical error, or they can happen by chance through variations within the analytical procedure, particularly if the concentrations are normally close to the parametric limit for the analytical procedure. Such causes should never be assumed, and all exceedances require investigation to determine if the result is credible and to check that there is no threat to public health.

While an investigation for an exceedance of the parameter limit for *E. coli* is essential due to the immediate public health threats from a single exposure, investigation for an exceedance of a chemical parameter limit is also important because the result may be an indication of a more severe problem. Decisions should be made on the basis of facts rather than assumptions.

### Guidance following detection of *E. coli* (or thermotolerant coliforms)

All reasonable actions should be taken to ensure that *E. coli* is not present in samples of drinking-water. However, in practice, low concentrations of *E. coli* may occasionally be detected. If this occurs, an immediate investigation should be undertaken including the following actions:

- Immediately collect further samples to confirm the presence of *E. coli*, identify possible sources and extent of the contamination. As a minimum, if *E. coli* is detected:
  - **In piped systems:** A repeat sample should be collected from the original sample location, an upstream sample location (e.g. a service reservoir) and a downstream sample location.
  - **At the consumer's tap:** One repeat sample should be collected at the tap, another one outside the house, and another one in a house nearby to determine if the problem is in the distribution network or in the household system.
  - **In non-piped systems:** A repeat sample should be collected from the point of supply (e.g. hand pump).
- If the contamination is widespread through the system, immediately inspect the catchment area to identify the possible source of contamination.
- Immediately inspect the drinking-water system to identify and rectify any failures, including breaks in pipework, or failure or poor performance of treatment processes (e.g. check disinfectant residuals in disinfected systems).
- In disinfected systems, concentrations of the disinfectant could be increased, service tanks could be chlorinated, or mains flushing could be considered.

- In non-disinfected systems, consider chlorination as a temporary emergency measure.
- Where corrective actions are taken, further samples should be collected to verify they have been effective.
- If *E. coli* is detected in repeat samples, or if faults are identified that could lead to repeat events, the health regulator should be notified to enable further action to be determined.

## Guidance following exceedance of chemical and radiological parameters

Exceedance of chemical or radiological parameters should be a signal, as a minimum, to:

- Collect further samples to confirm exceedances and assess the persistence of the chemical or radionuclide.
- Investigate the cause with a view to taking remedial action as necessary.
- Consult the authority responsible for public health for advice on suitable action, taking into account the extent of exceedance, duration of exceedance, intake of the substance from sources other than drinking-water, the toxicity of the substance, the likelihood and nature of any adverse effects, the practicality of remedial measures and the availability of alternative water supplies.

Chemicals almost invariably require long-term exposure to high levels to cause health effects and, generally, there is a substantial margin of safety built into the GDWQ guideline values. Therefore, exceedance does not necessarily imply health effects and the extent of any health impact depends on the value and duration of the exceedance. Refer to Annex 2 for guidance in assessing risks to health from chemical contaminants.

These general principles are also applicable to radiological parameters. However, confirmed exceedance of the screening value should trigger a more detailed investigation to determine which radionuclides are present.

# Annex 2
## Implications of exceeding chemical guideline values

This annex provides guidance on how to assess the health risks if monitoring indicates that the GDWQ guideline value or national/subnational parameter limit is exceeded. This guidance may also be useful in tailoring the GDWQ guideline values to national contexts.

This annex does not attempt to give guidance on acute values in emergencies or in rapid responses.

In assessing health risks, it should be remembered that chemical guideline values in the GDWQ are generally conservative with respect to the health endpoints considered. For example, values for threshold chemicals[1] are based on the most sensitive endpoint, incorporate large safety factors, and generally assume lifetime continuous exposure at the guideline value concentration. Values for non-threshold chemicals (usually genotoxic carcinogens) are based on potentially causing less than one excess cancer per 100 000 people after 70 continuous years of exposure at the guideline value concentration using conservative models.

### Assessing risks to health from chemical contaminants

**Stage 1** is to determine the magnitude of exceedance against the GDWQ guideline value or the parameter limit established in the drinking-water quality regulations and standards.

**Stage 2** is to determine the expected period of exposure to the elevated level and whether it is short term (e.g. hours or days) or longer term (e.g. weeks, months or years).

GDWQ guideline values are generally protective for lifetime exposure. For these chemicals, when the guideline value is exceeded for a shorter period, a small exceedance is unlikely to result in any discernible increase in risk.

When a longer term exceedance is anticipated, there will be a need to consider either issuing public notification or a derogation allowing the exceedance for a period, during

[1] Threshold chemicals are those chemicals for which a level of exposure exists below which adverse effects will not occur even after a long-term exposure.

which action can be taken to remedy the situation. A derogation should only be granted following an assessment of the risk to public health, and usually there will be a specified period allowed to remedy the problem. In some exceptional cases, often with small supplies, a derogation may be allowed for an extended period, but should be reviewed at intervals.

**Stage 3** is to review the assumptions and uncertainties involved in the derivation of the GDWQ guideline value or parameter limit, including:

- **Assumed exposure from drinking-water compared with other sources of exposure:** Where the guideline value or parameter limit was derived assuming a proportion of a TDI or ADI allocated to drinking-water,[1] it may be appropriate to adjust the proportion allocated to drinking-water, which will impact the concentration considered safe in drinking-water. The allocation assumed in the GDWQ is typically 20%, although there can be variation depending on the substance. Where exposure from other sources is less than assumed, it is possible to increase the allocation to drinking-water to derive a new value against which to compare the concentration of the parameter detected. For example, the GDWQ guideline value for barium of 1.3 mg/l is based on the allocation of 20% of a TDI of 0.21 mg/kg body weight for a 60 kg adult drinking 2 litres of water, and is based on a lifetime study in laboratory animals. If less barium is believed to be coming from other exposure routes than assumed in the GDWQ, allowing an allocation of 30% of the TDI to come from water would allow a parameter limit of 1.9 mg/l, or potentially 2 mg/l after rounding. Another example could be carbon tetrachloride, which was widely used as an industrial solvent and degreasing agent and is found as a contaminant in some groundwaters impacted by poor disposal practices. The GDWQ guideline value is based on an allocation of 10% of the TDI to drinking-water. However, exposure from food has fallen significantly in most countries, therefore it may be appropriate to increase the allocation of the TDI to drinking-water, taking into account actual exposure.
- **Considerations for non-threshold chemicals:** As noted earlier, the models used to derive these guideline values are often conservative. The models compute an estimate of risk at a particular level of exposure, along with upper and lower bounds of confidence on the calculation. The lower bound may be zero or below zero, and the GDWQ guideline values are set according to the upper-bound value. This value does not equate to the number of cases of cancer that will be caused by exposure to the substance at this level; rather, it is the maximum potential risk, and it is highly probable that the actual level of risk is less than this.

[1] ADI or TDI cover exposure from all sources, e.g. food, water, air, soil and consumer products.

In establishing drinking-water quality regulations and standards, countries may consider that a different level of hypothetical risk is more appropriate than less than one excess cancer per 100 000 people (risk level of $10^{-5}$) after 70 continuous years of exposure, which is the risk level associated with these GDWQ guideline values. The guideline values could be multiplied or divided by 10, relating to a risk level of $10^{-4}$ or $10^{-6}$, respectively. At the lower risk level, this may also require consideration of non-cancer endpoints. However, as indicated, a small exceedance may not have any (or only marginal) public health implications.

# Annex 3
## Additional microbial indicators

This annex presents information on coliform bacteria and heterotrophic plate counts (HPCs), particularly their value and limitations as indicators of drinking-water quality. For more information on these and other microbial indicators, see Chapter 7.4 of the GDWQ, the microbial fact sheets in Chapter 11 of the GDWQ and *Assessing microbial safety of drinking water: Improving approaches and methods* (OECD, WHO, 2003).

### Coliform bacteria

Coliform bacteria include a wide range of bacteria traditionally defined by their ability to produce acid from lactose or demonstrate the presence of ß-galactosidase enzyme on laboratory media at 35°–37°C. Coliform bacteria occur in both sewage and natural waters and some, such as *E. coli*, are excreted in the faeces of humans and other animals. However, because the coliform bacteria group includes organisms that can survive and grow in water and plumbing systems, total coliforms are not a useful indicator of faecal pathogens and are of limited value in standards.

Coliform bacteria can be a useful operational indicator, however. Coliform bacteria can be used to assess the cleanliness and integrity of distribution systems, as their presence can reveal regrowth and possible biofilm formation or contamination through the ingress of foreign material, including soil or plant material. Also, their presence immediately after disinfection indicates inadequate treatment. In the absence of *E. coli*, their presence in treated water samples may indicate a need to further investigate the cause of contamination rather than holding any significance as a contravention of a specified numerical value for compliance. If the drinking-water supply is not disinfected, coliform bacteria may be detected regularly.

### Heterotrophic plate counts (colony counts)

HPCs will detect a wide range of heterotrophic microorganisms, including bacteria and fungi, based on the ability of the microorganisms to grow on the particular medium and at a defined temperature in the time period used for measurement. HPCs have no value as an indicator of the presence of faecal contamination or pathogens but can be useful, and are better than total coliforms, for operational monitoring of the efficacy of treatment processes (including disinfection) and the integrity of distribution systems. However, they are not a high priority where resources for monitoring are limited. HPC results can be highly variable and actual numerical counts are of limited value, but the range of counts from regular sampling at particular locations within the distribution system using the same analytical method can be useful. Changes of an order of magnitude from an expected normal range may be an indication of a problem with treatment or the distribution system, which requires investigation.

# Annex 4
## Practical guidance on selected chemical and acceptability parameters

This annex provides practical general guidance on some parameters for which questions are often raised by those developing drinking-water quality regulations and standards. This list is not exhaustive. Inclusion of a parameter in this annex does not imply that the parameter would typically be a candidate for inclusion in regulations and standards.

For the parameters in this annex, and all other parameters of interest, more information can be obtained from:

- **GDWQ: Acceptability aspects (Chapter 10):** In addition to biologically derived contaminants, this chapter provides additional information on 26 chemically derived contaminants than can result in acceptability issues.
- **GDWQ: Chemical fact sheets (Chapter 12):** This chapter includes a summary of occurrence and health information for over 140 chemicals. Where a guideline value has been derived, information on analytical methods and treatment are also included. Further details on these chemicals are included in the chemical background documents that informed the development of these fact sheets (see: http://www.who.int/water_sanitation_health/water-quality/guidelines/chemicals/en/#B).
- **Chemical safety of drinking-water: Assessing priorities for risk management (WHO, 2007):** Appendix 4 (Practical comments on selected parameters) provides some guidance on 51 contaminants, including monitoring advice, based on broad experience worldwide.

**Algal toxins:** Blue-green algae (cyanobacteria) can occur in large numbers (called blooms) in surface water bodies used for water supply. Some species of cyanobacteria contain toxins of concern for human health (e.g. microcystins) and these toxins can be released into the drinking-water when the algal cells are damaged. There is a range of toxins and it is probable that not all of the toxins have been identified. These toxins can be difficult to analyse at low concentrations in water. There are treatments to remove the toxins but these require careful assessment and operation so prevention is the primary management approach. Where heavy blooms occur, it is best to consider alternative sources of water unless appropriate and validated treatment is available. It is not usually considered necessary to monitor for toxins as the presence of blooms can be observed visually in water bodies.

**Arsenic:** Arsenic is commonly found in groundwater in many parts of the world at high concentrations. It is the only substance that has been proven to be a cause of cancer in humans as a consequence of exposure through drinking-water. There is a great deal of uncertainty as to the concentration that is a practical no effect level and the basis of the GDWQ guideline value is practical achievability. Every effort should therefore be made to keep concentrations as low as reasonably possible and below the guideline value when resources are available. However, achievability may carry a very heavy cost in relation to small supplies in particular, but also for larger municipal supplies. See Box 8.2 for an example from Bangladesh of setting the national parameter limit for arsenic at a higher level than the GDWQ guideline value on the basis of a local health risk assessment. Ideally, it is important that the guideline value be retained as a long-term goal and that the standard is included in a process of improvement that will provide an equitable outcome for all consumers.

Where arsenic-rich water is used to irrigate crops such as rice, exposure may be increased through accumulation in the crop. Under these circumstances, achievability and practicality are important and there is an argument for differentiation between large municipal supplies and small supplies and for stepped changes in drinking-water quality regulations and standards to allow time for the introduction of appropriate interventions.

Where concentrations are likely to be stable (i.e. deep groundwater), monitoring would normally only need to take place infrequently. Where water supplies for populations are subject to treatment to remove arsenic, samples are normally best taken at the treatment works, where the frequency of monitoring should be sufficient to ensure that the process is effective.

**Asbestos:** Asbestos fibres can be found in water naturally and from asbestos cement pipes. There is little credible evidence of health effects arising from waterborne asbestos. However, asbestos cement pipe deteriorates as the cement is leached away and this results in threats to the integrity of the pipe. While it is not recommended that existing asbestos cement pipes are removed, it is not considered appropriate to lay new asbestos cement pipe. It is not recommended to monitor for asbestos fibres.

**Disinfectants and disinfection by-products:** Chlorine is often used to provide a residual disinfectant in water supply systems to help maintain the hygienic status of the distribution system. A free chlorine residual of at least 0.2 mg/l throughout the distribution system is generally considered optimal under normal conditions, increasing to greater than 0.5 mg/l during faecal contamination events or potential waterborne disease outbreaks.

Chlorine can react with natural organic matter to produce unwanted by-products such as THMs. WHO emphasises that disinfection efficacy should never be compromised by attempts to meet standards for DBPs. It is important to try and minimize by-product formation by removing as much organic matter as possible by optimizing coagulation and sedimentation where organic concentrations are elevated, such as in many surface sources. However, standards for DBPs are not as high a priority as other contaminants such as arsenic and fluoride. It should be noted that many countries have established standards for total THMs and total HAAs at about 100 and 80 µg/l, respectively. Both THMs and HAAs change in distribution. Where hypochlorite is used as a source of free chlorine, it may deteriorate to produce high concentrations of chlorate. While standards may not be a high priority, it may be appropriate to specify that appropriate management procedures should be implemented, such as not storing for longer than necessary and not mixing old and new hypochlorite. See the GDWQ chemical fact sheet in Chapter 12 (WHO, 2017a) for additional information.

**Fluoride:** Fluoride is found in many parts of the world, particularly in groundwater. Fluoride can cause adverse effects on teeth and bones and, at very high concentrations, can cause crippling skeletal malformation called skeletal fluorosis. WHO suggests a guideline value of 1.5 mg/l to avoid discolouration of tooth enamel, but the value depends on the intake of water and the potential for exposure from other sources such as food. WHO has assessed fluoride and has suggested that significant effects are unlikely if the intake is less than 6 mg fluoride per day, but that above an intake of 14 mg fluoride per day, there is clear evidence for an increasing risk of adverse skeletal effects.

Understanding the likely exposure from other sources is important. For example, if a large amount of brick tea is consumed as a beverage, this may be high in fluoride. Where crops are irrigated with water with high concentrations of fluoride, there may be some accumulation of fluoride in food, e.g. rice. See Box 8.2 for an example from India where fluoride intake is managed in part by reducing fluoride levels in irrigation water.

**Lead:** In the case of a contaminant such as lead, which primarily comes from plumbing, solder or fittings containing lead in buildings, the concentration will vary according to the period that the water has been in contact with the lead bearing material. Therefore, it is not possible to make an assessment of the potential risk to consumers from just one sample or one property. Assessment of the risk requires consideration of exposure of the most vulnerable groups (usually bottle-fed infants and small children) over a period of several days, as it is the average exposure of an individual that is important. This is particularly important because the lead guideline value is not based on health but on practical considerations, and lead concentrations should be maintained as low as reasonably practical. New sources of lead should not be introduced and low lead alloy fittings should be used both in repairs and new installations.

**Nitrate:** Nitrate can reach surface and groundwater from agricultural activities, such as spreading manure or excessive application of other nitrogen-rich fertilizers. It can also come from poorly sited and maintained latrines and septic tanks. High nitrate and nitrite concentrations well above the guideline value can give rise to blue-baby syndrome in bottle-fed infants, particularly where there is endemic diarrhoea in infants. It is therefore important to maintain good microbiological quality where nitrate and nitrite levels are elevated. Nitrite and nitrate need to be considered together, but monitoring for nitrite is difficult because formation will be in the distribution system. Nitrate levels in surface waters can change quite quickly, but levels in groundwater usually change very slowly unless the groundwater is heavily influenced by surface water.

## Parameters affecting acceptability

**Aluminium:** Aluminium can occur in raw water, but the most important source is from its use as a coagulant in drinking-water treatment. There is no guideline value for aluminium in the GDWQ, but high concentrations reaching the distribution system can result in deposits of aluminium flocs, which cause unacceptable turbidity or discolouration at the tap if they are disturbed. Concentrations can normally be maintained below 0.2 mg/l, and less than 0.1 mg/l should be easily achievable in well-run large treatment works. Control is best achieved by optimizing coagulation and filtration, which are important barriers against pathogenic microorganisms. Monitoring of aluminium is sometimes carried out in the final water from treatment works for operational reasons.

**Ammonia:** Ammonia can be present in some drinking-water sources. Although it is of no direct risk to health, it readily combines with free chlorine to form chloramines, which are not as effective as primary disinfectants, and which can give rise to unacceptable tastes if certain chloramines (e.g. dichloramine or trichloramine) are formed. Ammonia is occasionally found in distribution systems where chloramine is used as a residual disinfectant and if the process of producing chloramine is not sufficiently well controlled. Monitoring could be carried out in the final water from treatment works, but other parameters (e.g. free chlorine) are normally considered to be more important.

**Conductivity:** Conductivity is a measure of the inorganic ion content of water and is not of direct concern for health. High conductivity may be an indicator of acceptability in high total dissolved solids (TDS) waters, and sudden changes can be an indicator of pollution or ingress into distribution. It may therefore be a useful indicator or operational parameter.

**Dissolved oxygen:** Dissolved oxygen is an indicator parameter and measurement can be used in a relative, not absolute, sense. It would not normally be a candidate for standard setting.

**Hardness:** Hardness is a natural feature of water, reflecting calcium and magnesium, as carbonates, bicarbonates and sulphates. It is normally very stable. It can cause scale formation in distribution systems and plumbing in buildings, but it is not of consideration for health.

**Manganese and iron:** Both occur naturally, ferric salts are used as coagulants, and iron can arise in distribution due to the corrosion of cast-iron pipes. Both metals can give rise to deposition in distribution with discolouration of water that may be unacceptable to consumers. There is new evidence that high manganese in drinking-water, where it remains in solution, such as in some anaerobic groundwaters, may have an adverse impact on learning capacity in young children, although there remain many uncertainties. WHO has proposed a health-based value and the lack of a formal guideline value does not mean that manganese is of no concern when soluble manganese concentrations are elevated. Furthermore, it should be noted that the health-based value is above concentrations of manganese normally causing acceptability problems in drinking-water and, accordingly, aesthetic as well as health aspects should be considered when setting drinking-water quality regulations and standards, and confirming the acceptability of drinking-water. Monitoring of manganese is only likely to be required for operational reasons where a potential problem has been identified, in which case, final water from the treatment works would normally be the most appropriate sample site. In some acidic or anaerobic groundwaters, manganese may stay in solution, even at levels exceeding 0.1 mg/l – the level that can cause impacts on taste and staining of laundry. However, these are normally smaller supplies and they may still be acceptable to consumers. Under these circumstances there may be a requirement to set a health-based standard and to instigate some form of monitoring to ensure control measures are working.

Iron is controlled at the treatment works by optimizing treatment, and in distribution systems by a structured programme of maintenance. Iron is rarely a direct health concern in water. Monitoring is normally for operational reasons but may be undertaken in the final water from the treatment works, and in the distribution system.

**pH:** pH is an important operational parameter, particularly in terms of the effectiveness of chlorination or the optimization of coagulation. It can be an important factor in corrosion of metals in distribution systems and plumbing, but it is not of direct concern for health.

**Taste and odour:** Taste and odour are important for acceptability and drinking-water should be acceptable to consumers. There are many factors that can impact taste or odour that are not normally of direct concern for health, including chloride, sulfate, hydrogen sulphide and some cyanobacteria.

**Total organic carbon:** Total organic carbon (TOC) is a measure of the amount of dissolved organic carbon in water. It is non-specific and is not of direct concern for health, but sudden changes can be an operational indicator of pollution and high TOC is often reflected by high DBPs.

**Turbidity:** Turbidity is an important operational parameter as an indicator of the efficiency of the treatment processes coagulation, sedimentation and filtration. Removal of turbidity improves the effectiveness of chlorination, can help to minimize the formation of DBPs, and is an indicator of the removal of microorganisms in filtration. High turbidity at 4 NTU (nephelometric turbidity unit) and above can be seen by consumers and may be unacceptable at the tap. However, efforts should be made to reduce turbidity as much as possible through treatment and before distribution. Large, well-run municipal supplies should be able to achieve less than 0.5 NTU before disinfection at all times and an average of 0.2 NTU or less, irrespective of source water type and quality. For further information on uses and significance of turbidity in drinking-water, including turbidity targets for filtration and disinfection, as well as guidance on monitoring frequency, see *Water quality and health – Review of turbidity: Information for regulators and operators of water supplies* (WHO, 2017c).

# References

OECD, WHO (2003). Assessing microbial safety of drinking water: Improving approaches and methods. Published on behalf of the World Health Organization and the Organisation for Economic Co-operation and Development by IWA Publishing, London, UK (http://www.who.int/water_sanitation_health/publications/9241546301/en/, accessed 27 February 2018).

US EPA (1997). Information Collection Rule Federal Database. EPA 816 F-97-013. Office of Water, United States Environmental Protection Agency.

WHO (2006). Protecting groundwater for health: Managing the quality of drinking-water sources. Geneva: Word Health Organization (http://www.who.int/water_sanitation_health/publications/protecting_groundwater/en/, accessed 22 February 2018).

WHO (2007). Chemical safety of drinking-water: Assessing priorities for risk management. Geneva: World Health Organization (http://www.who.int/water_sanitation_health/publications/dwchem_safety/en/, accessed 22 February 2018).

WHO (2011). Arsenic in drinking-water. Background document for development of WHO Guidelines for drinking-water quality. Geneva: World Health Organization (http://www.who.int/water_sanitation_health/publications/arsenic/en/, accessed 18 March 2018).

WHO (2012). Water safety planning for small community water supplies: Step-by-step risk management guidance for drinking-water supplies in small communities. Geneva: World Health Organization (http://www.who.int/water_sanitation_health/publications/small-comm-water_supplies/en/, accessed 22 February 2018).

WHO (2014). Water safety in distribution systems. Geneva: World Health Organization (http://www.who.int/water_sanitation_health/publications/water-safety-in-distribution-system/en/, accessed 23 February 2018).

WHO (2016). Protecting surface water for health: Identifying, assessing and managing drinking-water quality risks in surface-water catchments (http://www.who.int/water_sanitation_health/publications/pswh/en/, accessed 22 February 2018).

WHO (2017a). Guidelines for drinking-water quality. Fourth edition incorporating the first addendum. Geneva: World Health Organization (http://www.who.int/water_sanitation_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/, accessed 22 February 2018).

WHO (2017b). Water safety planning: A roadmap to supporting resources. Geneva: World Health Organization (http://www.who.int/water_sanitation_health/publications/water-safety-planning-roadmap/en/, accessed 19 April 2018).

WHO (2017c). Water quality and health – Review of turbidity: Information for regulators and operators of water supplies. Geneva: World Health Organization (http://www.who.int/water_sanitation_health/publications/turbidity-technical-brief/en/, accessed 26 February 2018).

WHO (2018a). A global overview of national regulations and standards for drinking-water quality. Geneva: World Health Organization (http://who.int/entity/water_sanitation_health/publications/national-regulations-and-standards-for-drinking-water-quality/en/, accessed 9 May 2018).

WHO (2018b). Management of radioactivity in drinking-water. Geneva: World Health Organization (http://who.int/entity/water_sanitation_health/publications/management-of-radioactivity-in-drinking-water/en/).

WHO & IWA (2009). Water safety plan manual. Geneva: World Health Organization (http://www.who.int/water_sanitation_health/publications/publication_9789241562638/en/, accessed 22 February 2018).

WHO & IWA (2016). A practical guide to auditing water safety plans. Geneva: World Health Organization (http://www.who.int/water_sanitation_health/publications/auditing-water-safety-plans/en/, accessed 22 February 2018).

For more information, contact:

World Health Organization
Water, Sanitation, Hygiene and Health
20, Avenue Appia
1211 Geneva 27
Switzerland

E-mail: gdwq@who.int

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

ISBN 978 92 4 151394 4