



Code of Practice on Drinking Water Sampling and Safety Plans

Issue date: 1 April 2019

Issued under the provisions of the
Environmental Public Health
(Water Suitable for Drinking) (No. 2) Regulations 2019

Singapore Food Agency
52 Jurong Gateway Road
JEM Office Tower
Singapore 608550
www.sfa.gov.sg

All rights reserved. No part of this publication shall be altered in any way without prior written permission of the Singapore Food Agency.

Table of Contents

	Page number
Foreword	4
Acknowledgment	5
1.0 Definitions, acronyms and abbreviations	6
2.0 Water sampling plans	7
2.1 General	7
2.2 Basic water sampling plan	7
2.3 Comprehensive water sampling plan	8
2.4 Sampling plan for operational monitoring	9
2.5 Sampling frequency and parameters	10
2.6 Sampling locations and points	11
2.7 Test methods	11
2.8 Sampling protocol	11
3.0 Water safety plans	12
3.1 General	12
3.2 Methodology and key steps	12
3.3 Assemble a water safety team	12
3.4 Document and describe the system	13
3.5 Undertake a system assessment	13
3.6 Identify control measures and define monitoring of control measures	14
3.7 Verification of water safety plan	14
3.8 Develop supporting programmes	15
3.9 Prepare management procedures	15

3.10 Establish documentation and communication procedures	16
3.11 Review of the water safety plan	16
3.12 Submission of the report of the review of water safety plan	16
3.13 Remedial and improvement measures	16
4.0 References	17
Appendix A Parameters for operational monitoring of the quality of water suitable for drinking	18
Appendix B Factors and hazards that should be considered during the preparation of water safety plan	22

Foreword

The quality of drinking water for human consumption is of utmost importance in the protection of the public health.

In order to ensure that a high standard of the quality of drinking water is maintained, preventive measures such as the preparation and implementation of water sampling and safety plans for water suitable for drinking play an important role in the provision of drinking water.

These plans must conform to certain standards and should meet certain requirements so that there is a consistency in the monitoring, assessment and risk management practices adopted by the drinking water providers.

This Code of Practice is issued pursuant to regulatory requirements prescribed in the Environmental Public Health (Water Suitable for Drinking) (No. 2) Regulations. It is prepared based on international guidelines such as those published by the World Health Organization, and it aims to provide guidance to the water providers designated as “WSSP water providers” under the Regulations, on the preparation of drinking water sampling and safety plans.

The Code of Practice will help the WSSP water providers in their continuing efforts to maintain a high standard of the quality of the drinking water that they provide to the public in the course of business, and thereby protect public health in Singapore.

Director-General, Food Administration
Singapore Food Agency
Singapore

Acknowledgement

The Singapore Food Agency wishes to thank the following members of the Technical Committee on National Drinking Water Quality Standards for providing valuable advice on this Code of Practice.

Local members

Prof. Ong Say Leong (Chairman)	National University of Singapore
Dr. Pranav S. Joshi (Secretary)	Singapore Food Agency
Dr. Steven Ooi Peng Lim	Ministry of Health
A/Prof. Richard Webster	Nanyang Technological University
A/Prof. Hu Jiangyong	National University of Singapore
A/Prof. Lye Lin Heng	National University of Singapore
A/Prof. Sim Tiow Suan	National University of Singapore
Dr. Lim Mong Hoo	Public Utilities Board
Dr. Wong Kwok Onn	Singapore Food Agency
A/Prof. Joanne Chan Sheot Harn	Singapore Food Agency

Overseas members

Prof. Michael Rouse	Independent consultant, UK
Dr. Joseph Cotruvo	Joseph Cotruvo Associates, USA

1.0 Definitions, acronyms and abbreviations

For the purpose of this Code of Practice, the following definitions, acronyms and abbreviations will apply.

COP	Code of Practice on Drinking Water Sampling and Safety Plans
Drinking water	Refers to water suitable for drinking, provided by water providers who are regulated under the Environmental Public Health Act and EPH (WSD) (No. 2) Regulations
<i>E. coli</i>	<i>Escherichia coli</i>
EPH (WSD) (No. 2) Regulations	Environmental Public Health (Water Suitable for Drinking) (No. 2) Regulations
Hazard	A chemical, physical, radiological or biological/microbiological agent that has the potential to cause harm
Hazardous event	An incident or situation that can lead to the presence of a hazard (what can happen and how)
Parameter	A property, characteristic, element, contaminant, substance or organism
Ref.	Reference(s) listed under section 4.0 of this COP
Risk	It is the likelihood of identified hazards causing harm in exposed populations in a specified time frame, including the magnitude of that harm and/or the consequences
SFA	Singapore Food Agency
Water provider, or provider	A WSSP water provider, as defined under the EPH (WSD) (No. 2) Regulations
Water safety plan	A water safety plan, as defined under the EPH (WSD) (No. 2) Regulations
Water sampling plan	A water sampling plan, as defined under the EPH (WSD) (No. 2) Regulations
Water treatment plant	A plant that produces piped drinking water (including waterworks)
WHO	World Health Organization

WHO Guidelines Ref. 4.0(a) of this COP

2.0 Water sampling plans

2.1 General

- (a) A water sampling plan shall consist of a Basic water sampling plan, a Comprehensive water sampling plan and a sampling plan for Operational monitoring.
- (b) The number and type of water quality parameters, their frequency of monitoring and the selection of sampling locations will depend upon the factors such as source and raw water characteristics, type of water treatment used, site specific operational and management practices, hazards identified during the preparation and review of water safety plan, etc.¹ These factors may differ from one water provider to another.
- (c) Preparation and implementation of water sampling plan are important steps in the development of overall strategies for monitoring and surveillance of quality of drinking water. In addition, the water providers shall also implement measures to review and analyse the test data, and carry out investigations into any adverse feedback received from consumers, and conduct remedial actions if any unsatisfactory situation is identified.
- (d) Each provider shall use a template available from SFA to document the water sampling plan. The plan will include information such as the name of provider's organization and contact details; identification of the site(s) and system(s) included in the plan; date of preparation of the plan and revision number; amendment sheet; details about Basic, Comprehensive and Operational monitoring plans; and other applicable details mentioned in sections 2.2 to 2.8 and Appendix A, as necessary.

2.2 Basic water sampling plan

(Minimum sample numbers for verification of the microbial quality)

- (a) A water provider shall prepare a Basic sampling plan to monitor *E. coli*² bacteria from the designated sampling locations. These locations may include-

¹ Besides the water sampling plan as required under this COP, a provider may also implement additional on-line and off-line water quality monitoring - for internal process control, source water characterization, surveillance of parameters of emerging concerns, etc., as mentioned in Appendix A, to ensure quality of drinking water provided.

² Surveillance and verification of the microbial quality of drinking water typically includes testing for *E. coli*, as *E. coli* is considered the most suitable indicator organism for presence of faecal contamination, due to the large numbers in which *E. coli* is usually present in faecally polluted waters. Monitoring of specific pathogens or other micro-organisms/indicator organisms may be undertaken by the provider in certain situations, as mentioned in footnote 1 and Appendix A.

- (i) source or raw water facilities, or both;
 - (ii) water treatment systems;
 - (iii) service reservoirs or storage tanks supplying drinking water to various zones or areas, pumping stations, blending points, master or bulk water meters³, and other locations within the distribution network; and
 - (iv) sampling points within buildings or facilities (e.g. at the high level tank, or at common areas, or premises having taps - water from which is normally used for drinking, cooking or food preparation).
- (b) The minimum frequencies of sampling drinking water from the designated locations shall be in accordance with those stated under the Table 4.4 (namely, “Recommended minimum sample numbers for faecal indicator testing in distribution systems”) of the WHO Guidelines⁴. The frequency of sampling water from other designated locations may vary depending upon the findings of risk assessment carried out under the water safety plan.
- (c) The number of samples to be collected shall be spread throughout the year, as much as possible in the sampling plan. Thus if 12 samples are planned per year from a designated location, the frequency should ideally be set at 1 sample per month.

2.3 Comprehensive water sampling plan

- (a) The Comprehensive water sampling plan shall include the following.
- (i) Subject to paragraph 2.3(c) and (d), all the water quality parameters specified under the Schedule of the EPH (WSD) (No. 2) Regulations, except those parameters mentioned in paragraph 2.2(a);
 - (ii) Other parameters⁵, which are identified in the water safety plan, or those that have been monitored historically by the provider as part of surveillance to maintain consumer confidence or address unknown contaminants (including those mentioned in section 2.4), or those parameters that are identified as emerging concerns due to availability of any new information or change in the

³ Where sampling points at the master water meter are not available, water can be sampled from a downstream location for assessment of water quality, notwithstanding the fact that a provider may not be responsible for deterioration of drinking water quality if it arises due to water service installations owned or maintained by the management of the building or facility to which the water is provided.

⁴ Where data on estimated population served are not available, the provider may use the data on Singapore's per capita domestic water consumption or such other information, and may exclude the quantity of water used for non-potable applications, in order to determine the frequency of sampling.

⁵ Some of these parameters may also include those that are mentioned in Appendix A.

pollutant sources in source water or site specific conditions (e.g. before the next review of the water safety plan).

- (b) Sample(s) shall be collected at each entry point to the distribution system or from such locations where the drinking water is representative of its quality after the treatment. However, where the need for additional monitoring of the entire water supply system is identified, e.g. based on the factors mentioned under paragraph 2.3(a)(ii), other sampling locations mentioned under paragraph 2.2(a) will also be included in the comprehensive monitoring plan.
- (c) The default frequency of sampling shall be at least once a year, except for certain parameters that should be monitored more frequently based on relevant factors; e.g. those mentioned in paragraph 2.3(a)(ii). Examples of parameters that may be monitored more frequently include - boron for desalination membrane treatment plants, disinfection by-products for water supply systems with extensive distribution network, heavy metals and pesticides if the raw water for a traditional water treatment system is obtained from a source that is likely to be polluted by industrial or agricultural discharge, etc.
- (d) Depending upon the raw water quality, water treatment programme, and the type of distribution network used by the providers, it is expected that certain parameters or contaminants are unlikely to be present in the drinking water, or will be present only at concentrations much lower than the standards prescribed for quality of drinking water. Hence, the water provider may propose sampling frequencies for certain parameters that are lower than the default frequency, or may propose not to sample the drinking water for specific parameters/contaminants that are not of concern.
- (e) In doing so, the water provider shall take into consideration the following, but not limiting to:
 - (i) The nature and quality of the source water, and the type of the water treatment used.
 - (ii) Test results of three successive years showing that the concentration of the parameter is significantly lower than the water quality standards prescribed within the Schedule of the EPH (WSD) (No. 2) Regulations, and that the quality of drinking water is unlikely to deteriorate.
 - (iii) The type of pesticides that are not used for the control of pests in the raw water catchment areas.
 - (iv) If the situation changes or if provider becomes aware of any new information about the risk posed by any particular parameter, the provider shall, as soon as practicable, implement monitoring for that parameter at a higher frequency and also propose further amendment to the water sampling plan.

2.4 Sampling plan for operational monitoring

(Where necessary, operational monitoring will also form part of the water safety plan.)

The water providers shall carry out sampling of drinking water for the following parameters as a part of the operational monitoring.

- (a) Aluminium: Where aluminium-based coagulants are used in the water treatment process, the concentration of aluminium shall be tested at least once in a month in the drinking water.
- (b) Conductivity: For water treatment systems that use desalination membrane technologies, the electrical conductivity of the desalinated water (which may also be expressed as total dissolved solids as per Appendix A) should be monitored through on-line analysers, and through manual analysis of grab samples (for cross-checking of the result of on-line analysers).
- (c) Lead and copper: In samples collected from the point of use of drinking water, or from the water distribution network depending upon the boundary of the responsibility of the water provider.
- (d) pH and turbidity:
 - (i) These parameters should be tested from the designated sampling locations more frequently than the parameter, *E.coli*, mentioned in paragraph 2.2(a), where required due to risk assessment.
 - (ii) Monitoring for these two parameters at the water treatment system should ideally be through on-line analysers unless it is not practical or essential due to the type of the water supply system and surveillance used by the provider. The on-line analysers should be calibrated to maintain its consistency and accuracy.
- (e) Additional parameters, which are deemed necessary to monitor as a part of the operational monitoring, preventive measures, water safety plans or as a result of any contamination of raw water or an event which is likely to affect the quality of drinking water. These parameters, for which the water provider will propose the frequency of sampling, may include some of the parameters mentioned in Appendix A of this COP.

2.5 Sampling frequency and parameters

- (a) The water provider may select a frequency of sampling higher than that mentioned in paragraphs 2.2, 2.3 and 2.4, and may even include parameters other than those specified in the Schedule of the EPH (WSD) (No. 2) Regulations.
- (b) Examples of situations where a water provider should select additional parameters and/or higher frequencies of sampling, in the plan include: Initial monitoring of a new supply system, epidemiological findings of a waterborne disease, good practices or remedial actions identified during audits and preparation of water safety plans,

operational failure, non-compliance of the test result with the standard, adverse feedback on the quality of water from consumers, or any other unsatisfactory situation.

2.6 Sampling locations and points

- (a) All sampling locations shall be such that they can be identified using a location code, name or address.
- (b) Unless otherwise specified, the sampling points shall be, so far as practicable, such that they can be accessed safely, and the water sample is representative of the part of the water system or supply being monitored. To achieve this, the water provider may designate multiple sampling points with backflow prevention devices as necessary.

2.7 Test methods

- (a) The test methods⁶ proposed in the sampling plan by the water provider shall be those approved by a national accreditation body (e.g. Singapore Accreditation Council), or those that are based on the procedure(s) issued or endorsed by any international organization or a regulatory body in another country or others as the Director-General may allow.
- (b) The accuracy, precision and limit of detection offered by the test method shall be adequate for which the measurement is to be made.
- (c) Water providers may propose more than one test method for the parameters included in the water sampling plan so long as the test methods meet the criteria stated in paragraphs 2.7(a) and 2.7(b).

2.8 Sampling protocol

The water provider shall adopt an appropriate sampling protocol depending upon the parameter to be tested.

⁶ These may include test methods that are developed in-house, or developed by equipment suppliers, e.g. for on-line monitoring of parameters.

3.0 Water safety plans

3.1 General

- (a) A water safety plan is an effective way to minimize the likelihood of any drinking water failing to meet the water quality standards.
- (b) According to WHO Guidelines, a water safety plan comprises, as a minimum, the three key components that are the responsibility of the drinking water providers to ensure that drinking water provided is safe. These are: system assessment; operational monitoring; and management plans, documentation and communication.
- (c) The water safety plans will vary in complexity, as appropriate for the situation, but their elements shall be based on the multiple-barrier principle, the principles of hazard analysis and critical control points, and other systematic management approaches.
- (d) Preparation and implementation of water safety plan are important steps in the development of overall strategies for ensuring quality of drinking water. To strengthen the water safety plan framework, the providers shall also implement measures to identify, investigate and take remedial actions if any unsatisfactory situation is identified.
- (e) Where applicable, a water provider may also integrate certain parts of the water safety plan with the other systems implemented within the organization, such as Hazard Analysis and Critical Control Points (or HACCP), ISO 22000, ISO 9001, etc., to make the water safety plan more robust.
- (f) Each provider shall use a template available from SFA to document the water safety plan. The plan will include relevant information mentioned in paragraph 2.1, and details about raw water, water treatment programmes and facilities, water supply zones/areas, distribution network including service reservoirs and storage tanks, hazard assessment and risk characterization, sanitary inspection, and other details as necessary.

3.2 Methodology and key steps

- (a) The methodology and the key steps in developing a water safety plan shall be in accordance with Figure 4.1 and Chapter 4 (“Water Safety Plans”) of the WHO Guidelines. (For further guidance, the water providers should refer to the Section 4.0, “References” of this COP.)
- (b) The key steps that water providers should follow are outlined in paragraphs 3.3 to 3.10 below.

3.3 Assemble a water safety team

- (a) The water provider should form a team to prepare the water safety plan.

- (b) This team should ideally be multi-disciplinary, consisting of a group of stakeholders that may include managers, engineers, water quality controllers, technical staff involved in day-to-day operations, etc. Experts from external organizations (including consultants and contractors) may also participate in the team.
- (c) The team should have the knowledge of the water supply system and the types of safety hazards to be anticipated, and should have the authority to implement the necessary changes to ensure that safe water is produced and provided.
- (d) When a team member leaves the team, it should be ensured that there is a continuity and proper handing over of the roles and responsibilities with regard to the development and implementation of the water safety plan.

3.4 Document and describe the system

- (a) This should cover the whole system from the source to the point of drinking water supply, or from the source to the point of consumption if the relevant systems are owned/operated by the water provider, and should include the various types of source water, treatment processes, storage and distribution infrastructure, and measures for source and resource protection.
- (b) These descriptions, which can also take the form of flow diagrams, provide an overview of the supply and an initial understanding of the processes.

3.5 Undertake a system assessment

- (a) Conduct a hazard assessment and risk characterization to identify and understand how hazards can enter into the water supply. (Also assess the existing or proposed system.)
- (b) The hazard assessment requires that all potential hazards and hazardous events that could be associated with the water supply, including the proposed or new water supply systems, are identified. Such hazard assessment shall also include review of customer complaints and past events that had affected, or could possibly have affected drinking water quality, or sufficiency of supplies and, where as a result, there was a risk to the health of the consumer.
- (c) Typical areas that should be taken into consideration include, but not limiting to those mentioned in Appendix B.
- (d) The water provider shall conduct a sanitary inspection of the water supply either as a part of the hazard assessment or as a part of the verification practice when required, using a checklist available from SFA (prepared based on Ref. 4(d) or other suitable guidelines).
- (e) Once the potential hazards, their sources and hazardous events are identified, the risk associated with each hazard or hazardous event should be described by identifying the

likelihood of occurrence (e.g. almost certain, likely, moderately likely, unlikely and rare) and severity of consequences if the hazard occurred (e.g. catastrophic, major, moderate, minor and insignificant). Definitions of likelihood and severity categories are provided in Tables 4.1 and 4.2 of the WHO Guidelines.

- (f) By using a scoring matrix outlined in Table 4.1 of the WHO Guidelines or any other suitable classification framework, the risk identified as above can be reviewed in order to establish the significant hazards and hazardous events.

3.6 Identify control measures and define monitoring of control measures

- (a) According to WHO Guidelines, the identity and number of control measures (the means by which risk may be controlled) are system specific and will be determined by the number and nature of hazards and hazardous events as well as the magnitude of associated risks.
- (b) For the control measures relating to the hazards identified under section 3.5, the water providers should define monitoring of the control measures (i.e. what limits define acceptable performance and how these are monitored).
 - (i) Such monitoring may include process control parameters and water quality parameters that can be measured, for which limits can be set, and which can be monitored with sufficient frequency to reveal failures in a timely fashion, and for which procedures for corrective action can be implemented in response to deviation from limits.
 - (ii) Some other examples of operational monitoring parameters that can be used to monitor control measures can be found in Table 4.3 of the WHO Guidelines.
- (c) Where separate procedures for control measures exist, e.g. in the form of equipment manufacturer's instructions, SOPs for calibration and maintenance of analysers, etc., these can be cross-referenced in the water safety plan, where applicable.

3.7 Verification of water safety plan

- (a) Verification provides a check on the overall performance of drinking water supply and the safety of drinking water being provided by the provider.
- (b) The provider shall undertake verification of the water safety plan, which may include checking or auditing of practices implemented against those documented in the plan, testing for quality of drinking water as per the water sampling plan, and monitoring of the water treatment processes and water quality parameters as per section 3.6 of this COP.
- (c) Appropriate quality assurance and analytical quality control measures should also be implemented for activities linked to verification of water safety plan.

3.8 Develop supporting programmes

- (a) Many actions are important in ensuring drinking water safety, but they do not directly affect quality of drinking water, and are therefore not “control measures”. These are referred to as “supporting programmes”, and should be documented in the water safety plan.
- (b) The water provider shall prepare appropriate supporting programmes (e.g. those relating to security of plant premises, staff training, hygienic work practices, use of chemicals and materials, etc.) that are necessary to ensure drinking water safety.
- (c) With regard to training of staff, apart from the technical training, the provider shall also implement programmes to train the staff in handling incident situations mentioned in Section 3.9.

3.9 Prepare management procedures

- (a) Water provider shall prepare management procedures (including corrective actions) for normal and “incident” conditions.
- (b) Such procedures shall document actions to be taken in response to variations that occur during the normal operational conditions, and during specific “incident” situations where a loss of control of the system may occur, including unforeseen and emergency situations (e.g. when it is necessary to issue an advisory such as Boil Water, Do Not Drink or Do Not Use Water, or when a non-compliance with water quality standards occur).
- (c) The actions should spell out communication and notification to the SFA⁷, media and consumers/public, and also plans to stop water supply and provide alternative drinking water, where applicable.
- (d) Where any water quality incident occurs that is likely to pose a potential danger to human health⁸, the provider shall, as soon as practicable, make reasonable efforts to inform the members of public or persons to whom the water was sold or supplied, about the health risk and the measures that should be taken to address the risk, as a part of remedial measures.
- (e) Where necessary, the provider may issue a statement or a notice to the persons and deliver it through an appropriate mode (e.g. by hand, electronic mail or briefings),

⁷ Notification to the SFA shall include the 24-hour notification as required under Regulation 9 of the EPH (WSD) (No. 2) Regulations.

⁸ Examples of situations that may pose a potential danger to human health include receiving of information about water borne outbreaks or illnesses arising from consumption of drinking water, or detection of *E.coli* in drinking water or detection of pathogens, chemicals or radioactivity at a concentration or value that may cause illnesses. In assessing the concentration or value, data from testing of water or any other information or evidence that ascertain the quality of water should be used.

and/or publish it on the provider's website, or advertised on a bulletin board nearest to the place or building where water was provided, or advertised through appropriate media (radio, television, newspapers, social media).

3.10 Establish documentation and communication procedures

- (a) Under a water safety plan, these should include, as practicable, the documentation, records and communication strategies outlined within Section 4.6 of the WHO Guidelines, and others that are identified by the provider for effective implementation of water safety plan.
- (b) Communication strategy should include the appropriate procedures mentioned in sections 3.8 and 3.9 of this COP.
- (c) Some of the formats, terms and standard language that can be used for communication to consumers can be found in Ref. 4.0(g) of this COP.

3.11 Review of the Water safety plan

- (a) The review of the water safety plan shall be carried out by the water provider at least once a year, or when necessary as a result of any major water quality incident or major upgrading works. During the review, changes in the circumstances from the period when water safety plan was last prepared and was last reviewed if applicable, shall be examined.
- (b) The water safety plan shall be amended to reflect the relevant changes concerning Sections 3.3 to 3.10.

3.12 Submission of the report of the review of water safety plan

- (a) After the review of the water safety plan, the water provider shall submit to the Director-General or staff authorized by the Director-General, a report stating whether the water provider has identified any proposed amendments to the water safety plan. The report can be in the form of a notification or an e-mail stating the outcome of the review.
- (b) If the water provider has identified any proposed amendments to the water safety plan, the water provider shall submit a copy of these amendments for approval in the form and manner prescribed by the Director-General.

3.13 Remedial and improvement measures

The water provider shall take the necessary remedial and improvement measures identified during the preparation and review of the water safety plan in order to minimize the likelihood of any drinking water failing to comply with the water quality standards specified in the Schedule of the EPH (WSD) (No. 2) Regulations.

4.0 References

Following references are used to prepare this code of Practice. The references are available for download from the websites of respective organizations.

- (a) Guidelines for Drinking-water Quality, Fourth Edition, incorporating the First Addendum, published by WHO, 2017.
- (b) Water Safety Plan Manual: Step-by-step risk management for drinking-water suppliers”, published by WHO, 2009.
- (c) “Water Safety Planning for Small Community Water Supplies: step-by-step risk management guidance for drinking-water supplies in small communities”, published by WHO, 2012.
- (d) “Water Safety Plans - Managing drinking-water quality from catchment to consumer”, published by WHO, 2005.
- (e) “National Primary Drinking Water Regulations”, published by United States Environmental protection Agency, Doc. No. EPA 816-F-09-004, May 2009.
- (f) “National Secondary Drinking Water Regulation” published by United States Environmental protection Agency, Doc. No. EPA 816-F-09-004, May 2009.
- (g) Code of Federal Regulations, Title 40, “Protection of Environment”, PART 141— National Primary Drinking Water Regulations, Subpart Q, “Public Notification of Drinking Water Violations” including “Appendix B to Subpart Q of Part 141— Standard Health Effects Language for Public Notification”, published by Office of the Federal Register, United States.
- (h) COUNCIL DIRECTIVE 98/83/EC of 3 November 1998, on the quality of water intended for human consumption, issued by The Council of the European Union, and its latest amendments including Commission Directive (EU) 2015/1787 of 6 Oct 2015.

Appendix A: Drinking water parameters

Note

- (a) The water provider shall review this Appendix during the preparation of the drinking water sampling and safety plans and their subsequent reviews, to identify the water quality parameters that should be monitored as a part of the Operational or Comprehensive monitoring.
- (b) Where applicable, guideline values are provided to assist water providers in establishing internal control values.
- (c) For some parameters, such as copper and manganese, internal control values lower than the regulatory standards prescribed under the EPH (WSD) (No. 2) Regulations could be considered based on acceptability or aesthetic aspects (e.g. to prevent staining of surfaces).
- (d) Where the guidelines values are not provided, the provider may adopt a guideline value based on the historical values (e.g. using 2 Standard Deviations or one order of magnitude of the mean) for the purpose of identifying an unusual reading.
- (e) The list is not exhaustive as drinking water may be contaminated by a number of contaminants. Hence, as mentioned in sections 2.2 to 2.5, the water provider may include additional parameters in the water sampling plan, or carry out internal studies, investigations or surveillance to address any emerging concerns⁹. Some of these parameters are described within Chapters 7, 8, 9, 10, 11 and 12 of the WHO Guidelines.

⁹ Where applicable, such parameters may include pharmaceutical compounds, endocrine disruptors, Chromium (VI), synthetic nanoparticles, pesticides, etc., notwithstanding the fact that according to WHO Guidelines, routine monitoring for pharmaceuticals in drinking water and additional or specialized drinking water treatment to reduce the concentrations of pharmaceuticals in drinking water are not considered necessary.

Parameter	Guidance/guideline value	Remark
Physico-chemical and chemical		
pH	Where chlorine is used for disinfection, the pH should preferably be less than 8. However, lower-pH water (pH 7 or less) is more likely to be corrosive, and hence, corrosion of materials should be considered by water provider in setting the internal control value for pH.	Please refer to the footnote. ¹⁰
Aluminium ¹¹	For processes using aluminium-based coagulants: <ul style="list-style-type: none"> ▪ Max. 0.1 mg/litre or less in large water treatment facilities that serve 10,000 or more people¹² ▪ Max. 0.2 mg/litre or less in small facilities that serve less than 10,000 people 	Based on practicable levels considering optimization of the coagulation process.
Chloride	Max. 250 mg/litre	
Chlorine dioxide	Max. 0.8 mg/litre	
Conductivity	Max. 1,000 µS/cm (at 25° C)	Based on guideline value for total dissolved solids, where applicable

¹⁰ pH of water should be controlled during the water treatment process to ensure satisfactory coagulation, flocculation, clarification and disinfection of water where applicable. The pH of drinking water entering the distribution system must be controlled to minimize the corrosion of water mains and pipes in household water systems. Extreme values of pH (less than 3 or more than 12) can result from contamination or accidental spills, treatment breakdowns or lapse, and insufficiently cured cement mortar pipe linings or cement mortar linings applied when the alkalinity of the water is low. Control measures should be established to prevent such extreme values of pH of water.

¹¹ For all drinking water treatment involving aluminium, a health-based value of max 0.9 mg/l is recommended under WHO guidelines (Ref 4.0 (a)).

¹² Where data on estimated population served are not available, the provider may use the data on Singapore's per capita domestic water consumption or such other information, and may exclude the quantity of water used for non-potable applications, in order to set the guideline value.

Foaming agents	Max. 0.5 mg/litre	
Hydrogen sulfide	Taste and odour thresholds in water are estimated to be between 0.05 and 0.1 mg/litre	Please refer to parameter “Taste and odour” in this Table, below.
Iron	Max. 0.3 mg/litre	
Taste and odour	<ul style="list-style-type: none"> • Water should be free of tastes and odours that would be objectionable to the majority of consumers. • For odour: 3 threshold odour number 	Please refer to the footnote ¹³
Silver	Max. 0.1 mg/litre	
Sulfate	Max. 500 mg/litre	
Total Dissolved Solids ¹⁴	Max. 600 mg/litre	
Turbidity	<ul style="list-style-type: none"> • Max. 0.3 NTU for water after filters¹⁵ • Max. 1.0 NTU for water after end of entire treatment process • Max. 5.0 for water at the consumer’s tap 	To minimize the risk of <i>cryptosporidium</i> in drinking water, particular consideration should be given to any abnormal increase in the turbidity levels.
Zinc	Max. 5 mg/litre	
Microorganisms and parasites		
Heterotrophic plate count (also called as colony count by some laboratories)	Max. 500 cfu/millilitre	

¹³ Objectionable taste or odour may create concerns about the quality and acceptability of a drinking water supply. The concentration at which constituents are objectionable to consumers is variable. Tastes and odours may be detectible by consumers at lower or higher levels of the guideline values or regulatory standards, depending on individual and local circumstances.

¹⁴ Parameter, total dissolved solids, is sometimes estimated using the result of electrical conductivity of water by multiplying the conductivity reading in $\mu\text{S}/\text{cm}$ by a factor of 0.67.

¹⁵ To minimize the risk of *Cryptosporidium* and such other microbial contaminants in drinking water.

Total coliform ¹⁶ , <i>Cryptosporidium</i> ¹⁷ , <i>Giardia</i> ¹⁸ , <i>Legionella</i> ¹⁹ , and other relevant organisms	Public health goal for these micro-organisms and pathogens should be “zero” or <1 cfu per sample volume specified by the standard test method used.	
Radiological parameters		
If either of the gross Alpha or Beta level is exceeded above the level of 0.5 Bq/litre or 1 Bq/litre respectively, the specific radionuclides should be identified and individual activity concentrations measured ²⁰ .	<ul style="list-style-type: none"> • Guidance levels for individual radionuclides in Bq/litre - as per WHO Guidelines or other international guidelines • Individual dose criterion/IDC (or total indicative dose) equal to 0.1 mSv/year should not be exceeded, based on the criteria provided in Ref. 4.0(a)²¹. 	

¹⁶ Total coliform bacteria include a wide range of aerobic and facultatively anaerobic organisms that can survive and grow in water. They are not useful as an indicator of faecal pathogens, but they can be used as a disinfection indicator, and to assess the cleanliness and integrity of distribution systems and the potential presence of biofilms. [Ref. 4.0(a)]

¹⁷ *Cryptosporidium* is a parasite; whose oocysts are extremely resistant to chlorine. Ideally, control measures to reduce potential risk from *Cryptosporidium* should focus on prevention of source water contamination by human and livestock waste (with particular attention to cattle/farm animals), adequate treatment of water, and protection of water during distribution.

¹⁸ *Giardia* is a parasite, whose cysts are more resistant than *E. coli* bacteria to chlorine, but they are not as resistant as *Cryptosporidium*. Usually, same control measures, as those mentioned for *Cryptosporidium* should apply for *Giardia*.

¹⁹ *Legionella* are waterborne bacteria that may survive and grow in biofilms and sediments. If testing for *Legionella* is carried out, the ISO 11731 or equivalent method should be used. Where instances of *Legionella* being detected, it is recommended to identify/quantify the species and serogroup(s) of *Legionella* detected in the sample.

²⁰ Although iodine and tritium will not be detected by standard gross activity measurements and routine analysis for these radionuclides is not necessary, if there are any reasons for believing that they may be present, radionuclide specific sampling and measurement techniques should be used.

²¹ IDC = Guidance level of radionuclide (Bq/litre) X dose coefficient for ingestion by adults (mSv/Bq) X annual ingested volume of drinking water, assumed to be 730 litres/year. For Guidance levels and dose coefficients of radionuclides, please refer to Table 9.2 and Annex 6 of the Ref. 4.0(a), or other international guidelines.

Appendix B: Factors and hazards that should be considered during the preparation of water safety plan

Note

- (a) A list of common factors and hazards is shown below. These factors and hazards should be addressed in the water safety plan, where applicable. The list is non-exhaustive as it is not possible to include all the factors and hazards in this Appendix, due to the diverse and wide-ranging nature of the water treatment and distribution systems used by various water providers.
- (b) A multi-barrier approach in the water treatment process and distribution should be adopted, so as to ensure consistent quality and safety of drinking water.

(1) Source and raw water (including catchment areas, reservoirs, etc.)

- (a) Likelihood of water contamination due to:
 - (i) Industrial discharges
 - (ii) Accidental oil/chemical spills
 - (iii) Illegal discharge of silt-laden water from construction sites
 - (iv) Leakage from sewage pipes or septic tanks
 - (v) Activities within the catchment area and reservoir from animals and humans (recreational activities, farm activities, fogging, fireworks, horticulture, irrigation, littering, etc.)
 - (vi) Air pollution from nearby sources or transboundary haze
 - (vii) Natural events (earthquake, rainstorm, etc.) and seasonal variations
 - (viii) Climate change
- (b) Associated risk of algal and cyanobacteria blooms. Control of algal and cyanobacteria blooms in the reservoirs and waterways through physical, chemical and biological measures.
- (c) Sources mentioned in paragraph 1(a) that may contaminate the water by chlorine resistant microorganisms such as *Cryptosporidium*.

Note

Risk assessment for *Cryptosporidium* based on raw water quality and treatment programme should be incorporated in the water safety plan either separately or as a part

of “Hazard assessment and risk characterization”.

(2) Water treatment system

- (a) Inadequate physical security measures implemented at the site.
- (b) Inadequate disinfection of water.

Note

For effective disinfection with chlorine, there should be a residual concentration of free chlorine of ≥ 0.5 mg/litre after at least 30 minutes of contact time (or equivalent based on concentration X time value) at $\text{pH} < 8.0$.

- (c) Failure or malfunction of plant and laboratory equipment (including on-line analysers, piping connections and equipment parts).

Note

A treatment work should ideally shut down automatically almost immediately after a disinfection failure is detected through appropriate alarms; or procedures should be in place for a treatment work to be manually shut down almost immediately after an appropriate alarm warning of a failure of adequate treatment and disinfection. A provider should install such alarm systems or implement alert procedures.

- (d) Use of plumbing materials including liners which are not suitable for potable water (e.g. those that do not comply with Singapore Standard 636, “Code of Practice for Water Services” and those that do not comply with the guidelines or standards issued by the Public Utilities Board, Singapore).
- (e) Media/sand filter breakthrough leading to problems such as poor quality of filtered water, including presence of micro-animals in filtered water. Also, build-up of biofilms /algae/flotsam on sand filter/other surfaces.
- (f) Deterioration of the membrane in plants that use membrane treatment plant.
- (g) Over/ under dosing of chemicals such as fluoride, chlorine, lime, alum, ozone, polymer and ammonia.
- (h) Improper use of chemicals or use of chemicals that are of unacceptable purity.

Note

- (i) One of the control measures shall involve the use of only those water treatment chemicals for the production of drinking water, which are certified by the manufacturer, supplier, independent laboratory or a national or international authority to have conformed to the required purity.

- (ii) Water provider should require the vendor of chemicals to provide Certificate of Analysis or Certificate of Quality with each delivery of the chemicals, and compare the test results with the relevant specifications.
- (iii) Water treatment systems that use polymers should ensure that concentrations of residual monomers, Acrylamide and Epichlorohydrin, in the drinking water are calculated according to the product specifications of the maximum release from the corresponding polymers, Polyacrylamide and Polyamines, in contact with the water, for comparison with the standards prescribed under the Schedule of the EPH (WSD) (No. 2) Regulations.
- (i) Improper storage of water treatment chemicals leading to contamination of chemicals and compromising workplace safety.
- (j) Unauthorized access to any bypass line in the treatment process that may allow water to bypass a treatment stage.
- (k) Contamination of water storage tanks through air vents, overflow pipe, etc. (e.g. during fogging and such other activities carried out near the vents).
- (l) Build-up of trihalomethanes (THMs) in water storage tanks or clear water tanks during operation.
- (m) Power/electricity failure and risk of fire, explosion and lightning at the plant resulting in interrupted treatment and loss of disinfection of water.

(3) Distribution network and water service installations within buildings/facilities (where applicable)

- (a) Intrusion of contaminants in service reservoir and storage tanks (due to cracks/defects in walls, fogging, sabotage, intrusion by small animals, etc.).
- (b) Leaching of contaminants in water from new mains/pipes that may affect pH of water.
- (c) Inadequate maintenance (cleaning and disinfection of service reservoir and water storage tanks).
- (d) Intrusion of contaminants in water due to pipe burst, pipe failures, corrosion of plumbing materials, leaking joints and adapters, cracks in pipelines and deficient seals.
- (e) Opening/closing of valves, firefighting or testing of fire hydrants that may result in pressure fluctuations and suspension of sediments, causing discoloured water.
- (f) Stagnant water in mains that may result in high pH, high turbidity, discoloured water or biofilms.

- (g) Inadequate residual disinfectant in the distribution system.
- (h) Accidental or illegal connections of piping network.
- (i) Security measures for water storage tanks in buildings not meeting the minimum stipulated security requirements in the Public Utilities Act, Public Utilities (Water Supply) Regulations and SS 636:2018.
- (j) Inadequate backflow prevention of water towards source of supply from any tank or appliance.
