Guidelines on Drinking Water Quality Management Plan for Non-Packaged Drinking Water

Introduction

1. The aim of this document is to provide a set of guidelines on preparation of water quality management plans (WQMP) by WQMP water providers, pertaining to provision of non-packaged drinking water regulated under the Food Safety and Security Act ["FSSA"] and Food Safety and Security (Non-Packaged Drinking Water) Regulations 2025 ["FSS (NPDW) Regs."].

2. WQMP water providers refer to those drinking water producers providing a drinking water service, whose drinking water production is capable of producing more than 4 cubic metres of drinking water per day, unless the drinking water capable at any time of being obtained from the drinking water production is permanently 4 cubic metres or lesser per day.

3. The guidelines incorporate certain best practices and measures relevant to monitoring, assessment and risk management practices that may be adopted by the WQMP water providers. They take reference from international guidelines such as those published by the World Health Organization (WHO).

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1.0 Definitions, acronyms and abbreviations

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

Drinking water	"Drinking water" in this Guidelines refers to non-packaged drinking water, and includes: (a) water that is intended for human consumption or for purposes connected with human consumption (such as the washing, preparation or cooking of food or the making of ice intended for human consumption, or for the preservation of unpackaged food), whether or not the water includes use for other purposes; or (b) water held out as water in paragraph (a).
Drinking water service (DWS)	A service that involves — (a) drinking water production; and (b) supplying to another the drinking water obtained from drinking water production in paragraph (a) - (i) by a reticulation system; or (ii) in bulk through the use of a vehicle (e.g. trucks, tankers or wagons) in an amount exceeding 4 cubic metres.
E. coli	*Escherichia coli*
FSSA	Food Safety and Security Act
FSS (NPDW) Regs.	Food Safety and Security (Non-Packaged Drinking Water) Regulations
Guidelines	Guidelines on Drinking Water Quality Management Plan (WQMP)
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)
Incident identification and notification protocol	An incident identification and notification protocol, as described under Regulation 12 of the FSS (NPDW) Regs. and is a part of the WQMP.
Monitoring programme	A water monitoring programme, as described under Regulation 11 of the FSS (NPDW) Regs. and is part of the WQMP.

Parameter	A property, characteristic, element, contaminant, substance or organism. Parameter includes chemical and non-chemical parameter defined in FSS (NPDW) Regs.
Ref.	Reference(s) listed under section 4.0 of this Guidelines
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
Risk management plan	A risk management plan, as described under Regulation 10 of the FSS (NPDW) Regs. and is part of the WQMP.
SFA	Singapore Food Agency
Water provider, or provider	A WQMP water provider, as defined under Regulation 6 of the FSS (NPDW) Regs.
Water treatment plant	A plant that produces piped drinking water (including waterworks)
WHO	World Health Organization
WHO Guidelines	WHO's Guidelines for Drinking-water Quality and Ref. 4.0(a) of this Guidelines
WQMP	Drinking Water Quality Management Plan as described under FSS (NPDW) Regs.

2.0 Monitoring programme under the Risk Management Plan of WQMP

2.1 General

(a) A monitoring programme may consist of three components – Basic, Comprehensive and Operational monitoring.

(b) The number and type of water quality parameters, their frequency of monitoring and the selection of sampling locations 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 the monitoring programme can form part of water provider's overall strategies for supply of wholesome drinking water. In addition, the water providers can also consider adopting other measures as part of such strategies where applicable, such as further analysing test results using data analytics techniques and carrying reviews of any adverse feedback received from consumers on drinking water quality.

(d) Each WQMP water provider can use the template available from SFA to document the monitoring programme, as a part of WQMP. Apart from the information as required under the FSS (NPDW) Regs., the monitoring programme can include details about Basic, Comprehensive and Operational monitoring and other applicable details mentioned in sections 2.2 to 2.8 and Appendix A, as necessary.

2.2 Basic monitoring

(a) Under Basic monitoring, a water provider can include monitoring of *E. coli*[2] bacteria in water from designated locations, which may include -

[1] Besides the monitoring programme mentioned under this Guidelines, a WQMP water 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., that may help to ensure the wholesomeness of drinking water supplied.

[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 water 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 meters[3], and other locations within the distribution network; and

(iv) water 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) As a guideline, the minimum frequencies for monitoring drinking water from the designated locations can be based on those stated under the Table 4.4 (namely, "Recommended minimum sample numbers for faecal indicator testing in distribution systems") of the WHO Guidelines[4]. The frequency of monitoring from other designated locations may vary depending upon the findings of risk assessment carried out under the WQMP.

(c) The number of samples collected can be spread throughout the year, as much as possible in the monitoring programme. Thus if 12 samples are planned per year from a designated location, a suggested frequency could be 1 sample per month.

2.3 Comprehensive monitoring

(a) Comprehensive monitoring can include the following.

(i) Taking into consideration paragraph 2.3(c) and (d), relevant water quality parameters specified under the First Schedule of the FSS (NPDW) Regs., except those parameters mentioned in paragraph 2.2(a);

[3] If the monitoring 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 WQMP water 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 WQMP water 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 propose the frequency of sampling.

(ii) Other parameters[5], which are included in the WQMP, or those that have been monitored historically by the WQMP water provider as part of surveillance to maintain consumer confidence or address unknown contaminants (including those mentioned in section 2.4), or those parameters identified as emerging concerns due to availability of any new information or change in the pollutant sources in source water or site specific conditions.

(b) Sample(s) may 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, if there is any need for additional monitoring of the entire water supply system, e.g. based on the factors mentioned under paragraph 2.3(a)(ii), other locations mentioned under paragraph 2.2(a) can also be included in the comprehensive monitoring.

(c) The frequency of sampling can be at least once a year, except for certain parameters that may 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 treated via 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 present only at concentrations much lower than the standards prescribed for quality of drinking water under the First Schedule of the FSS (NPDW) Regs . Hence, the WQMP water provider may propose monitoring frequencies for such parameters that are lower than the frequency stated under paragraph 2.3(b), or propose not to monitor the quality of drinking water for specific parameters that are not of concern based on risk assessment.

(e) In doing so, it is suggested for the WQMP water provider to take into consideration the following**,** but not limiting to:

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

(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 First Schedule of the FSS (NPDW) 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 WQMP water provider may want to consider, as soon as practicable, implementing monitoring for that parameter at a higher frequency and propose further amendment to the monitoring programme.

2.4 Operational monitoring

The WQMP water providers can consider monitoring the quality 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 can be tested at least once in a month in the drinking water to check on optimization of the coagulation process during water treatment.

(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) can 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 can be tested from the designated sampling locations more frequently than *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 can be done 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 their consistency and accuracy.

(e) Additional parameters: These may include parameters which are useful to be monitored as a part of the operational monitoring, preventive measures, risk management plan under WQMP, 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 can propose the frequency of sampling, may include some of the parameters mentioned in Appendix A of this Guidelines.

2.5 Monitoring frequency and parameters

(a) The WQMP 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 First Schedule of the FSS (NPDW) Regs.

(b) Examples of situations where a water provider may consider selecting additional parameters and/or higher frequencies of monitoring, in the monitoring programme 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 risk management plan under WQMP, operational failure, non-compliance of the test result with the regulatory standard, adverse feedback on the quality of water from consumers, or any other unsatisfactory situation.

2.6 Monitoring locations and points

(a) All locations included in the monitoring programme should be such that they can be identified using a location, name or address.

(b) The sampling points should 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 WQMP water provider may consider having multiple monitoring points with backflow prevention devices as necessary.

2.7 Test methods

(a) The test methods[6] proposed in the monitoring programme by the WQMP water provider should 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 SFA may allow.

(b) The accuracy, precision and limit of detection offered by the test method should be adequate for which the measurement is to be made.

(c) WQMP water providers may propose more than one test method for the parameters included in the monitoring programme so long as the test methods meet the criteria stated in paragraphs 2.7(a) and 2.7(b).

2.8 Sampling protocol

The WQMP water provider should 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 Quality Management Plan (WQMP)

3.1 General

(a) A WQMP is an effective way to minimize the likelihood of any drinking water failing to meet the water quality standards. The monitoring programme, as a part of WQMP, has been discussed in the preceding section 2.0. Details of other parts of WQMP (including risk management plan) are provided in this section 3.0.

(b) According to WHO Guidelines, a water safety plan, which is equivalent to WQMP in the context of this Guideline document, comprises key components that include system assessment, operational monitoring, and management plans, documentation and communication.

(c) The WQMP plan may vary in complexity, as appropriate for the situation, and its elements can 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 WQMP can form part of the WQMP water provider's overall strategies for supply of wholesome drinking water. The hazards identified during the preparation of WQMP can be used in determining the parameters to monitor under water quality monitoring programme, as mentioned in paragraph 2.1(b). To strengthen the WQMP framework, the WQMP water providers should also consider implementing measures to identify, investigate and take remedial actions if any unsatisfactory situation is identified.

(e) Where applicable, a WQMP water provider can also consider integrating certain parts of the WQMP 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 WQMP more robust.

(f) Each WQMP provider can adopt the template available from SFA to document the WQMP. The WQMP can 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 WQMP can take reference from the water safety plan described under Figure 4.1 and Chapter 4 ("Water Safety Plans")

of the WHO Guidelines. (For further guidance, the water providers can refer to the Section 4.0, "References" of this Guideline document.)

(b) The key steps that water providers can consider adopting are outlined in paragraphs 3.3 to 3.10 below.

3.3 Assemble a WQMP team

(a) The WQMP water provider should form a team to prepare the WQMP.

(b) This team can 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, there should be continuity and proper handing over of the roles and responsibilities with regard to the development and implementation of the WQMP.

3.4 Document and describe the system

(a) This can 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 WQMP 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 understanding of the water treatment 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 can help to identify 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 can 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 can be taken into consideration include**,** but not limiting to those mentioned in Appendix B.

(d) The water provider can 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 necessary, 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. In general, they can 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 WQMP 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 WQMP, where applicable.

3.7 Verification of the WQMP

(a) Verification provides a check on the overall performance of drinking water supply and the safety of drinking water being supplied by the WQMP water provider.

(b) The WQMP water provider should undertake verification of the WQMP, which may include checking or auditing of procedures and practices implemented against those documented in the WQMP, testing for quality of drinking water as per the monitoring programme, and monitoring of the water treatment processes and water quality parameters as per section 3.6 of this Guideline document.

(c) Appropriate quality assurance and analytical quality control measures should also be implemented for activities linked to verification of WQMP.

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 WQMP water provider should consider documenting them in the WQMP.

(b) The WQMP water provider should 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 can be implemented to support activities to ensure drinking water safety.

(c) With regard to training of staff, apart from the technical training, the provider should also implement programmes to train the staff in handling incident situations mentioned in Section 3.9.

(d) The WQMP water provider should also implement appropriate practices and measures to address potential cybersecurity and data security threats to Information and Communications Technology systems (ICT) systems involved in water treatment processes, water testing and water quality monitoring. Some of the best practices include:

(i) Access control mechanisms: Critical systems and data are accessed only by authorized personnel. This may include implementing user authentications, role-based access controls and regular reviews of user permissions.

(ii) Network security measures: Firewalls, intrusion detection/prevention systems, and secured network architecture to protect against external threats.

(iii) Security audits and penetration testing: Periodic security audits and penetration testing to evaluate the effectiveness of current security measures and identify areas for improvement.

(iv) Secure backup and recovery strategies: Reliable backup procedures and regulatory test the ability to restore data and systems in the event of a cyber-attack, data breach and data loss.

(v) Incident response plan: Incident response plan that outlines the steps to be taken in the event of a cyber incident or data breach.

3.9 Prepare management procedures

(a) WQMP water provider should prepare management plans and procedures (including corrective actions) for normal and "incident" conditions.

(b) The plans and procedures may include documenting 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 include communication and updating SFA[7], media and consumers/public, and also plans to stop water supply and provide alternative drinking water, where applicable.

[7] WQMP water providers could provide the relevant information to SFA by means such as via email.

(d) Where any water quality incident occurs that is likely to pose a potential danger to human health[8], as a part of best practices, the WQMP water provider should, 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 WQMP water 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), 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) The WQMP can include 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 WQMP.

(b) Communication strategy can also include appropriate procedures mentioned in sections 3.8 and 3.9 of this Guideline document.

(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 Guideline document.

3.11 Remedial and improvement measures

The water provider should take the necessary remedial and improvement measures identified during the preparation and review of the WQMP in order to minimize the likelihood of any drinking water failing to comply with the water quality requirements specified in the First and Second Schedule of the FSS (NPDW) Regs.

[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.

4.0 References

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

(a) Guidelines for Drinking-water Quality, Fourth Edition, incorporating the First and Second Addenda, published by WHO, 2022.

(b) Water Safety Plan Manual: Step-by-step risk management for drinking-water suppliers", second edition, published by WHO, 2023.

(c) "Water Safety Plans - Managing drinking-water quality from catchment to consumer", published by WHO, 2005.

(d) "National Primary Drinking Water Regulations", published by United States Environmental Protection Agency, Dec 2024.

(e) Secondary Drinking Water Standards: Guidance for Nuisance Chemicals, published by United States Environmental Protection Agency, Jun 2025.

(f) 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.

(g) Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption (recast).

(h) Cybersecurity Code of Practice for Critical Information Infrastructure, published by Cyber Security Agency of Singapore, 2022.

(i) Guide to Data Protection Practices for ICT Systems, published by Personal Data Protection Commission (PDPC) Singapore, 2024.

(j) PUB's Stipulation of Standards & Requirements for Water Fittings for Use in Potable Water Service Installations, 15 June 2023.

(k) Singapore Standard SS 636, Code of practice for water services, Singapore Standards Council, 2018.

(l) Singapore Standard SS 375-1, Suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of the water – Part 1: Specification, Singapore Standards Council, 2015.

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Appendix A: Drinking water parameters for operational and comprehensive monitoring

Note

(a) As a best practice, the WQMP water provider should review this Appendix during the preparation of the WQMP 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 WQMP 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 FSS (NPDW) 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 WQMP water 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 monitoring programme, or carry out internal studies, investigations or surveillance to address any emerging concerns[9]. 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 disrupters, Chromium (VI), synthetic nanoparticles, pesticides, Per- and Polyfluoroalkyl Substances (PFAS), 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 possible corrosion of materials can be taken into consideration 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: ▪ Max. 0.1 mg/litre or less in large water treatment facilities that serve 10,000 or more people[12] ▪ 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 should 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) may 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. To prevent such extreme values of pH of water,WQMP water provider can established appropriate control measures.

[11] For drinking water treatment involving the use of 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, to establish the internal control limits.

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	• 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	• Max. 0.3 NTU for water after filters[15] • 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 *cryptosporidium* 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 µS/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], *Cryptosporidium*[17], *Giardia*[18], *Legionella*[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].	• 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* can 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 can be used. Where instances of Legionella being detected, it may be useful to identify/quantify the species and serogroup(s) of Legionella detected in the sample.

[20] Although iodine and tritium are 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 considered during the preparation of WQMP

Note

(a) A list of common factors and hazards is shown below. These factors and hazards may be addressed in the WQMP, 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 WQMP 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

(ix) Contaminants or pathogens that may not be entirely removed from inadequately treated recycled water

(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 WQMP 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 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" or 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 can 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 can request the supplier/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 First Schedule of FSS (NPDW) 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 Singapore Standard SS 636.

(j) Inadequate backflow prevention of water towards source of supply from any tank or appliance.

(4) Transport and supply of non-packaged drinking water using vehicles such as water tankers, trucks and wagons

(a) Materials and surfaces of tanks, containers and water fittings in contact with drinking water that do not meet relevant guidelines/standards specified under PUB's Stipulation of Standards & Requirements for Water Fittings for Use in Potable Water Service Installations" and Singapore Standards, SS 636 and SS 375-1. For example, exposing drinking water to surfaces that are made of lead or lead-containing alloys.

(b) Improper connections between the water hose of transport vehicles and the plumbing lines that receive the water, can result in backflow, introducing contaminants into the drinking water.

(c) Integrity of tanks, containers and water fittings used in storage and supply of drinking water, that may be compromised due to lack of maintenance.

(d) Water stored in vehicles for extended period may become a breeding ground for bacteria and other microorganisms, especially in warm conditions.

(e) Cross-contamination may occur if the water is transported in vehicles that had previously carried hazardous materials, leading to the introduction of contaminants into the drinking water.

(f) Inadequate cleaning of equipment used for loading and unloading of drinking water may introduce contaminants.

(g) Poorly maintained vehicles, including air vents and overflow pipes may cause leaking of oil, fuel, or other contaminants into the water tank, compromising the quality of the drinking water.

(h) Insufficient documentation and tracking of water sources and transport conditions may hinder accountability and response in case of contamination event.
