Handbook for Preparing a Water Safety Plan

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Contents

[Introduction 1](#_Toc3794839)

[Handbook structure 1](#_Toc3794840)

[1 Commitment to drinking-water quality management 3](#_Toc3794841)

[1.1 Relationship of water safety plans to organisational policy and strategy 3](#_Toc3794842)

[1.2 Engaging stakeholders 6](#_Toc3794843)

[1.3 Engaging community 8](#_Toc3794844)

[2 Assessment of the drinking-water supply system 9](#_Toc3794845)

[2.1 Water supply system description and analysis 9](#_Toc3794846)

[2.2 Assessment of water quality data 14](#_Toc3794847)

[2.3 Hazard and hazardous event identification and risk assessment 15](#_Toc3794848)

[3 Preventive measures for drinking-water quality management 25](#_Toc3794849)

[3.1 Assessment of existing preventive measures and multiple barriers 25](#_Toc3794850)

[3.2 Identification of additional preventive measures 27](#_Toc3794851)

[4 Operational procedures 29](#_Toc3794852)

[4.1 Operational procedures 29](#_Toc3794853)

[4.2 Operational monitoring and inspection 31](#_Toc3794854)

[4.3 Critical control points 34](#_Toc3794855)

[4.4 Corrective actions 36](#_Toc3794856)

[5 Verification monitoring programme 39](#_Toc3794857)

[5.1 Drinking-water quality monitoring 39](#_Toc3794858)

[5.2 Consumer satisfaction 42](#_Toc3794859)

[5.3 Short-term evaluation results 44](#_Toc3794860)

[6 Improvement plan 47](#_Toc3794861)

[6.1 Drinking-water quality management improvement plan 47](#_Toc3794862)

[7 Management of incidents and emergencies 49](#_Toc3794863)

[7.1 Incident and emergency response plans 50](#_Toc3794864)

[8 Documenting and reporting 55](#_Toc3794865)

[8.1 Management of documentation and records 55](#_Toc3794866)

[8.2 Reporting 57](#_Toc3794867)

[9 Investigations 59](#_Toc3794868)

[9.1 Investigative studies 59](#_Toc3794869)

[9.2 Validation of equipment, processes and practice 60](#_Toc3794870)

[10 Oversight review and continual improvement 63](#_Toc3794871)

[10.1 Long-term evaluation of results 63](#_Toc3794872)

[10.2 Audit of drinking-water quality management 64](#_Toc3794873)

[10.3 Review by senior leadership 67](#_Toc3794874)

[References 69](#_Toc3794875)

[Appendix 1: Example template for recording source, treatment plant and distribution zone characteristics 71](#_Toc3794876)

[Appendix 2: World Health Organization table of log reduction values for bacteria, viruses and protozoa 74](#_Toc3794877)

[Appendix 3: Preparation of risk assessment tables 77](#_Toc3794878)

[Appendix 4: Catchment land use hazards table 86](#_Toc3794879)

[Appendix 5: Example of an operational procedure 98](#_Toc3794880)

[Appendix 6: Critical control points 102](#_Toc3794881)

[Appendix 7: Example of a plan for operational monitoring 108](#_Toc3794882)

List of Figures

[Figure 1: Recommended order for preparing water safety plan subcomponents 2](#_Toc3794883)

[Figure 2: Conventional water supply treatment process schematic 10](#_Toc3794884)

[Figure 3: Holistic water supply treatment process schematic (inclusion of critical points, critical control points and barriers to contamination) 11](#_Toc3794885)

[Figure 4: Partial water supply treatment process schematic 11](#_Toc3794886)

[Figure 5: Example of a plot of data for a determinand to help identify trends 42](#_Toc3794887)

[Figure A1: Decision tree for identifying critical control points 103](#_Toc3794888)

List of Tables

[Table 1: Example of qualitative descriptors of the likelihood that an event will happen 17](#_Toc3794889)

[Table 2: Example of qualitative descriptors of consequences (public health and system disruption) 18](#_Toc3794890)

[Table 3: Example of a qualitative risk analysis matrix: level of risk 18](#_Toc3794891)

[Table 4: Example of degrees of uncertainty 19](#_Toc3794892)

[Table 5: Example showing levels of acceptable microbiological risk and how management actions are influenced by the level of uncertainty in the assessment 20](#_Toc3794893)

[Table 6: Example of a monitoring plan showing the requirements of the DWSNZ for a specific supply 41](#_Toc3794894)

[Table 7: Example template for summarising verification monitoring data 41](#_Toc3794895)

[Table 8: Examples of emergency level descriptors 51](#_Toc3794896)

[Table 9: Example of actions required for responding to a Level 3 incident 53](#_Toc3794897)

[Table 10: Basic example of a record of each document used in the water quality management system and its associated information 56](#_Toc3794898)

[Table A1: Example fragment of a risk assessment table for a hazardous event affecting a groundwater supply element (well/bore) 84](#_Toc3794899)

[Table A2: Example fragment of a risk assessment table for a hazardous event affecting a treatment process (chlorination) 85](#_Toc3794900)

[Table A3: Chemical determinands within discreet land use categories 87](#_Toc3794901)

Introduction

Central to the preparation of water safety plans (WSPs) for New Zealand water supplies is the *New Zealand Drinking-water Safety Plan Framework* (the Framework) (Ministry of Health 2018). It draws on current international best practice in developing WSPs while remaining consistent with the World Health Organization (WHO)’s *Water Safety Plan Manual* (WHO 2009).

The Framework outlines the Ministry of Health’s expectations for the content of a water supplier’s WSP, but it provides no guidance on how these expectations can be met. That is the role of this document, the *Handbook for Preparing a Water Safety Plan* (the Handbook), which itself references other sources of information. See the Ministry of Health’s webpage, which provides other supporting information (https://www.health.govt.nz/publication/guidelines-drinking-water-quality-management-new-zealand). The Handbook’s primary target audience is local government and water utility suppliers. Guidance for non-utility or local government supplies can be found elsewhere (see Ministry of Health 2014a). Although smaller suppliers are not the Handbook’s intended primary audience, much of the Handbook’s content is relevant for these supplies.

Australia is at the forefront of developments in water safety planning best practice. This Guideline draws heavily on the *Australian Drinking Water Guidelines* (NHMRC, NRMMC 2011) and Queensland’s *Drinking Water Quality Management Plan Guideline* (Department of Energy and Water Supply 2010) to help in ensuring that New Zealand practice is in line with international best practice.

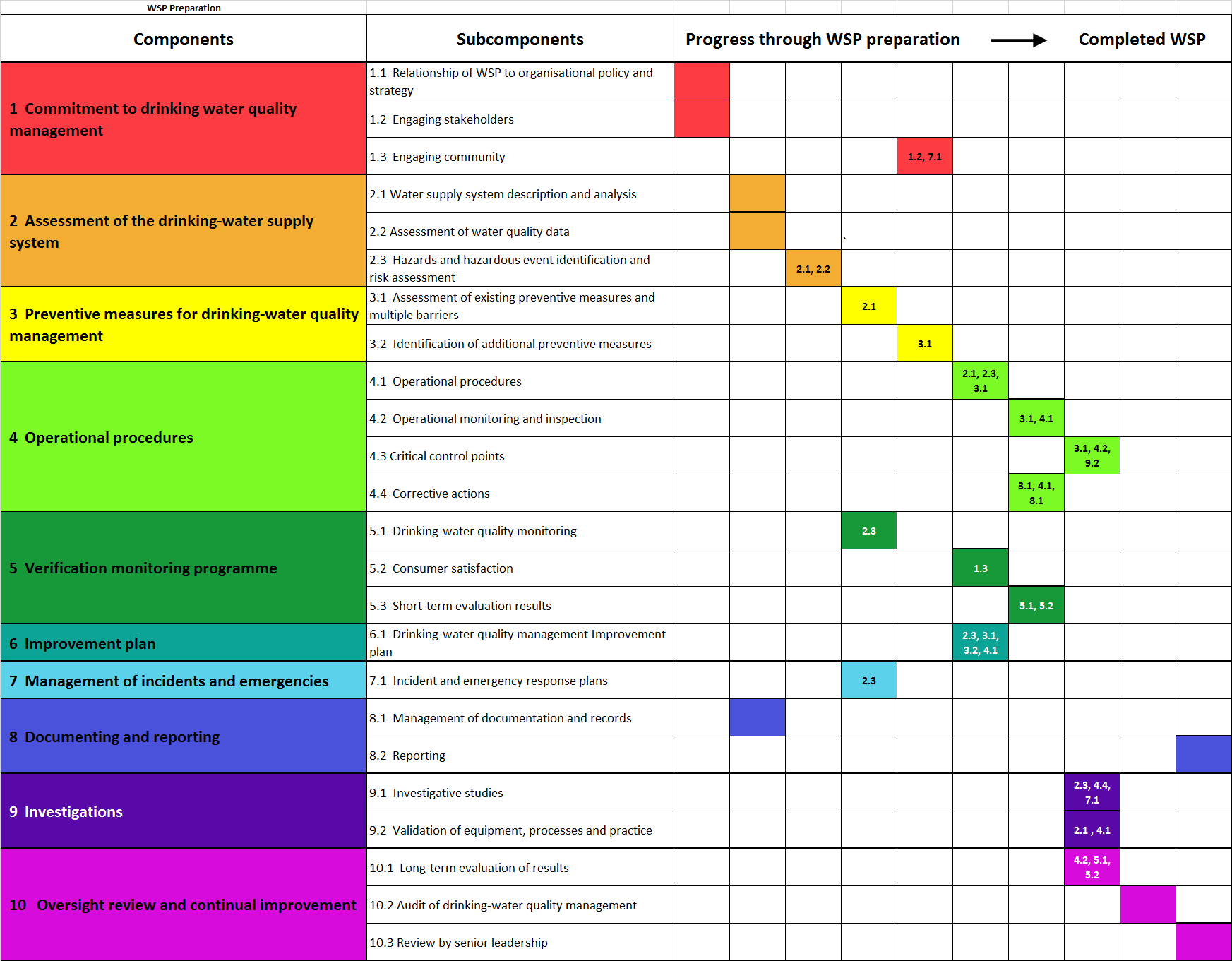
## Handbook structure

For each of the 10 components of the Framework, the Handbook sets out what the WSP should contain and what the water supplier needs to do to prepare the content of that Framework component. This information is summarised in text boxes labelled “INCLUDE IN THE WSP” and “ACTION”. The summaries are contain greater detail about the content needed for the WSP and the actions suppliers should take in preparing and maintaining the WSP. The Handbook’s appendices contain examples, and in some cases information, such as the sources of potential contaminants in catchments or groundwater capture zones, to help in the preparation of the WSP.

The order in which the components and subcomponents of the Framework need to be completed does not always follow the order in which they are discussed in this Handbook (which follows the Framework), because of the interdependencies of many of the subcomponents. Figure 1 provides guidance on the recommended order for preparing WSP components. Where necessary, the dependence of sub-components on other components is noted in coloured cells.

The Handbook is a working document. The Ministry of Health invites constructive comment for its improvement.

Figure 1: Recommended order for preparing water safety plan subcomponents



Numbers in the cells indicate which sub-component(s) must be completed to allow the sub-component to be prepared.

# Commitment to drinking-water quality management

Organisational support and long-term commitment by senior leadership is the foundation of an effective system for providing safe and secure drinking-water. In addition to understanding and committing to legislative requirements, successful implementation requires:

* an awareness and understanding of the importance of drinking-water quality management, and how decisions affect the protection of public health
* an organisational philosophy that fosters commitment to continual improvement, and cultivates employee responsibility and motivation
* the ongoing and active involvement of senior leadership to maintain and reinforce the importance of drinking-water quality management to all employees, as well as those outside the organisation.

## Relationship of water safety plans to organisational policy and strategy

Senior leadership should ensure that its policies and actions support the effective management of drinking-water quality (eg, through appropriate staffing; employee training; adequate financial resources; and active participation on and reporting to the board, chief executive or elected officials).

INCLUDE IN THE WSP

* A statement regarding the organisation’s commitment to the provision of safe and secure drinking-water.
* An explanation of how the organisation is putting this commitment into practice through policy, strategic plans, the adoption of water safety planning, budgets and relationships.

ACTION

Develop a policy or statement on drinking-water quality.

Review organisational policies, strategies and planning documents to ensure they support the effective management of the drinking-water supply.

Development of a drinking-water quality policy or statement is an important step in formalising the level of service to which drinking-water suppliers are committed, and in increasing focus on water quality management throughout the organisation. This policy or statement should define the organisation’s commitments and priorities relating to drinking-water quality. It should incorporate the six fundamental principles of drinking-water safety in New Zealand (Government Inquiry into Havelock North Drinking Water 2017):

* Principle 1: A high standard of care must be embraced
* Principle 2: Protection of source water is of paramount importance
* Principle 3: Maintain multiple barriers against contamination
* Principle 4: Change (including changes to processes and hazardous events) precedes contamination
* Principle 5: Suppliers must own the safety of drinking-water
* Principle 6: Apply a preventive risk management approach.

The policy or statement provides the basis on which all subsequent actions can be judged. As such, it should be clear and succinct, and should address broad issues and requirements of the organisation’s commitment and approach to safe and secure drinking-water. The policy may cover issues such as:

* commitment to best-practice drinking-water quality management and continual improvement
* intention to adopt the use of multiple barriers
* the level of service provided, connected to affordability
* the involvement of employees
* compliance with relevant regulations and other requirements
* liaison and cooperation with relevant agencies, including health and other regulators
* communication with employees and the public.

In developing the policy or statement, the organisation should consider the opinions and requirements of employees, consumers and other stakeholders.

Management should ensure that the policy or statement is highly visible, understood and implemented by all employees of the organisation involved in the supply of drinking-water and elected officials. It is the responsibility of all employees to support this commitment. Box 1 gives an example of a drinking-water quality policy/statement.

Box 1: Example of a drinking-water quality policy/statement

[Name of organisation] is committed to managing its water supply effectively to provide safe, high-quality drinking-water that consistently meets the expectations of the *New Zealand Drinking-water Safety Plan Framework* the requirements of the Health (Drinking Water) Amendment Act 2007 and *Drinking-water Standards for New Zealand*, and consumer and other regulatory requirements.

To achieve this, in partnerships with stakeholders and relevant agencies, [Name of organisation] will:

* embrace a high standard of care to manage water quality at all points along the delivery chain from source water to the consumer to provide a continuous supply of safe drinking-water
* maintain a personal sense of responsibility and dedication to providing consumers with safe drinking-water
* integrate the needs and expectations of our consumers, stakeholders, regulators and employees into our planning
* use a preventive risk-based approach in which potential threats to water quality and quantity are identified and managed
* acknowledge that protection of source water is of paramount importance in protecting consumers against drinking-water contamination and illness
* maintain robust multiple barriers against contamination appropriate to the level of potential contamination and harm
* acknowledge that contamination is almost always preceded by some kind of change (including changes to processes and hazardous events), and will monitor and always respond to change
* develop appropriate contingency planning and incident response capability
* establish regular monitoring of the quality of drinking-water and effective reporting mechanisms to provide relevant and timely information, and promote confidence in the water supply and its management
* participate in appropriate investigative activities to ensure continued understanding of drinking-water quality issues and performance
* continually improve our practices by assessing performance against corporate commitments, stakeholder expectations and regulatory requirements.

All managers and employees involved in the supply of drinking-water are responsible for understanding, implementing, maintaining and continually improving the drinking-water quality management system.

Dated Signed by responsible officer

## Engaging stakeholders

Several aspects of drinking-water quality management require water suppliers to work with other agencies. This includes the development of the WSP. An integrated management approach with collaboration from all relevant agencies (including, at least, the water supplier, the regional council and the district health board (public health unit)) is essential.

Stakeholders are internal as well as external. Internal stakeholders are those people who know about the operation and management of the drinking-water supply, have the ability and authority to make decisions and changes, and know about the relevant regulations. They will form the heart of the WSP team.

INCLUDE IN THE WSP

* A list of external stakeholders who could affect, or be affected by, decisions or activities involving the drinking-water supply.
* A list of water supplier staff who are actively involved in the operation and management of the drinking-water supply, and their roles.
* A list of the core team/roles/qualifications necessary to develop the WSP, led by the water supplier, and a description of how the external stakeholders have been (or will be) engaged in the process of preparing and implementing the WSP.
* Reference to external stakeholder engagement plans (eg, plans for meetings, workshops, newsletters, etc).
* Reference to an employee awareness and training plan.

ACTION

Identify and keep an updated list of all external stakeholders who have some responsibility for:

– managing activities in the catchment that may impact on source water quality

– significant or special demands on the distribution system

– relevant regulatory enforcement.

Identify water supplier staff/roles who have the knowledge and skills needed to develop and implement (or oversee implementation of) the WSP.

Form the core WSP team (water supplier and external stakeholders), and develop appropriate mechanisms and documentation for the team’s commitment to and involvement in the development and implementation of the WSP.

Develop (or review) a long-term stakeholder engagement plan on awareness and involvement in achieving and maintaining safe and secure drinking-water.

Develop (or review) a long-term employee engagement and training plan (management and operations) on awareness and involvement in achieving and maintaining safe and secure drinking-water.

Water suppliers should identify all major stakeholders that could affect (eg, regulators, resource managers) or be affected by (eg, consumers, industry) decisions or activities involving the drinking-water supplier, and regularly update this list. The range of stakeholders associated with individual water supply systems will vary by water supply. It will be essential for some of these stakeholders to participate in WSP development. Stakeholders may include:

* health and environment protection authorities
* resource managers from regional councils
* local government and planning authorities
* industries that discharge contaminants to the environment
* industrial users of the water supply
* community user representatives
* high-risk users (eg, hospitals, schools, aged-care facilities).

Suppliers should encourage the various stakeholders involved to define their accountabilities and responsibilities to support the drinking-water supplier and, where appropriate, to coordinate their planning and management activities. Depending on the size and complexity of the water supply, suppliers should establish fit-for-purpose mechanisms and documentation for ensuring stakeholder commitment and involvement. This may include establishing joint working groups, committees or task forces, with appropriate representatives, and developing partnership agreements, including signed memoranda of understanding. Suppliers should also develop appropriate mechanisms for stakeholder engagement (eg, meetings, workshops, newsletters, etc).

## Engaging community

Suppliers must view consumers as active partners in making decisions about levels of service to be adopted and the aesthetic properties of the water supplied. While consumer views about aspects of drinking-water quality that may affect public health should be heard, decisions about these aspects of water supply are the responsibility of elected officials and the water supplier.

INCLUDE IN THE WSP

* Details and location of the consumer engagement plan, including a description of how other organisations, customers and the community are involved in drinking-water quality issues.
* Specific reference to communication plans and a contact list linked to incident and emergency plans.

ACTION

Develop (or review) a long-term consumer engagement plan (including participation of elected officials) on awareness of and involvement in maintaining safe and secure drinking-water.

Ensure the consumer engagement plan is also linked to a consumer complaint and response process, and to incident and emergency plans.

Consumer expectations for service delivery, views on acceptable treatment and willingness to pay will likely be discussion points. Where possible, public discussions should be incorporated into existing consultation processes (which include the long-term plan consultation process for Councils). It is the responsibility of drinking-water suppliers, whether council or non-local authority, to keep the community fully informed about the importance of drinking-water quality management. This should include suppliers telling the community about how public health and regulatory requirements may influence drinking-water quality management decisions. Suppliers should set discussions in the context of the current water quality, existing problems and needs for improvement. Elected officials have an important role in facilitating community and water supplier discussions, and explaining council-endorsed policy and decisions. Medical Officers of Health can assist with public health aspects.

Suppliers need to inform consumers about their responsibilities in relation to aspects of safe and secure drinking-water that they can control, including water conservation and cross-connections (links between drinking-water and wastewater systems, or backflow) created by consumers.

# Assessment of the drinking-water supply system

A holistic assessment of the drinking-water supply system is an essential prerequisite for the development of effective strategies to prevent and control hazards. This includes understanding the characteristics of the drinking-water system, what hazards and hazardous events may arise, how these create risks, and the processes and practices that affect drinking-water quality.

## Water supply system description and analysis

Effective system management requires, first and foremost, an understanding of the water supply system from catchment to consumer. Suppliers should describe each element of the water supply system thoroughly, and analyse it with respect to factors that affect drinking-water quality.

INCLUDE IN THE WSP

* An accurate schematic or flow diagram from catchment to tap.
* A detailed description and analysis of each element of the drinking-water supply system, including any sources that do not undergo treatment and the reasons for this.
* Identification of the microbiological log reduction values achieved by treatment processes in the supply for microbiological classes (eg, protozoa) specified in the *Drinking-water Standards for New Zealand 2005* (DWSNZ) (Ministry of Health 2018).

ACTION

Develop an accurate schematic(s) or flow diagram of the water supply system (see Figures 2–4 below for examples).

Gather and analyse sufficient information to describe and assess the drinking-water supply system for factors that could affect drinking-water quality, to support the hazard identification and risk assessment process.

### Schematic or flow diagram of the water supply system

Develop an accurate schematic or flow diagram of the water supply system. The drinking-water supply system is defined as everything from the catchment from which the water is sourced to the point of supply to the consumer, covering the physical environment and infrastructure (source, treatment, storage and distribution). The system also needs to cover organisations/people and their processes and practices.

The level of detail in the schematic(s) needs to be sufficient to adequately support the hazard identification and risk assessment process. For example, identifying all water treatment steps, dosing points and monitoring points in the schematic will assist in ensuring that all infrastructure-related preventive measures identified are detailed in the risk assessment.

Figure 2: Conventional water supply treatment process schematic

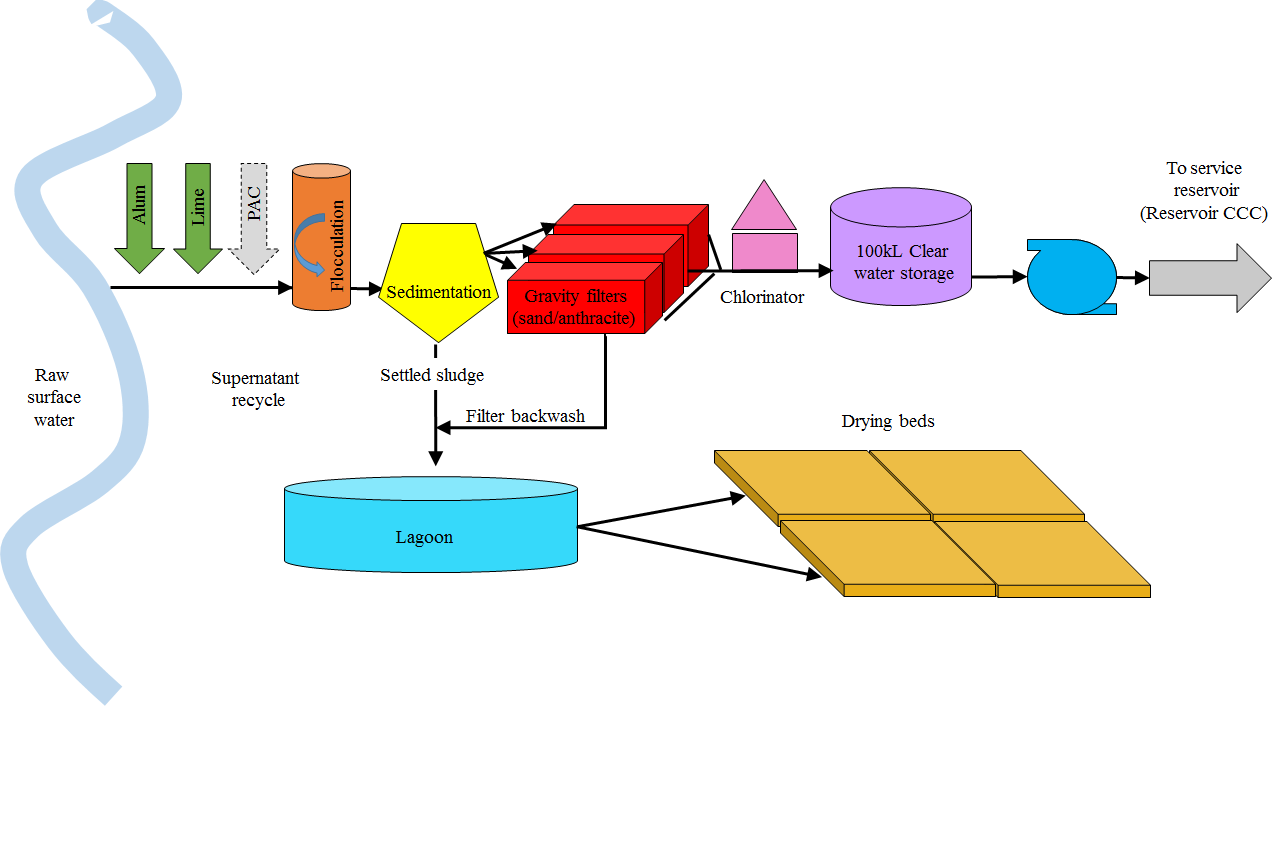


Figure 3: Holistic water supply treatment process schematic (inclusion of critical points, critical control points and barriers to contamination)

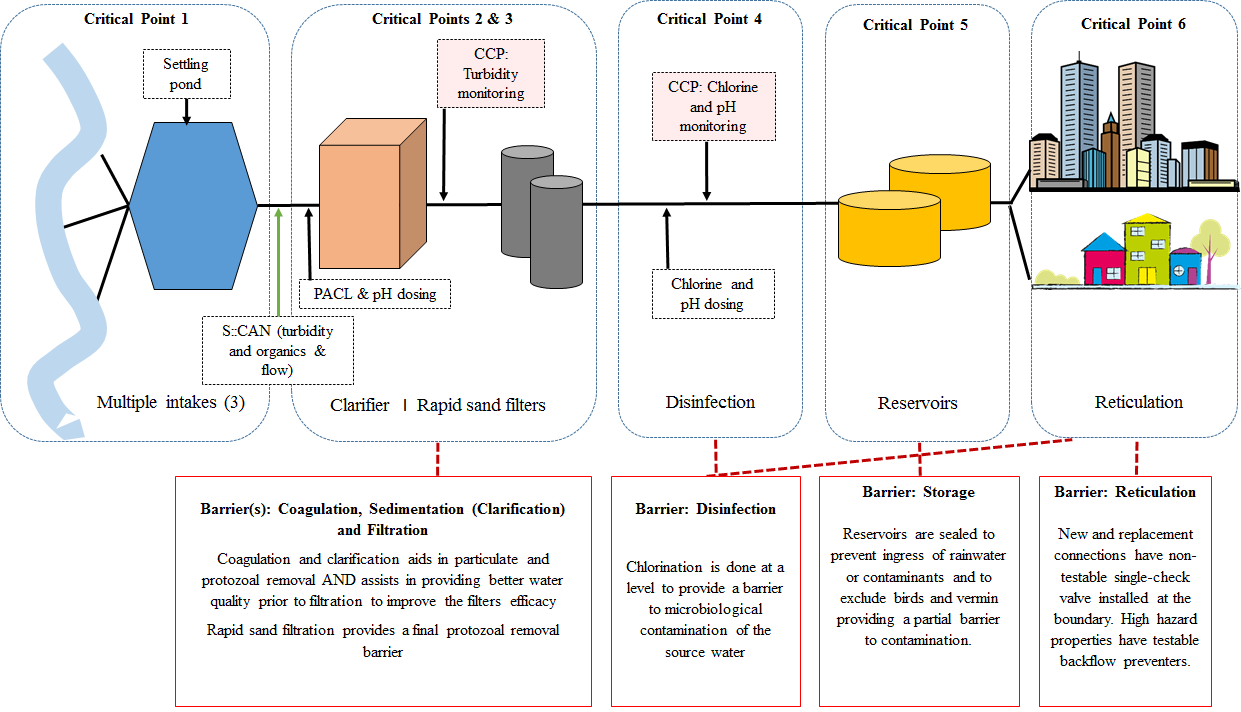
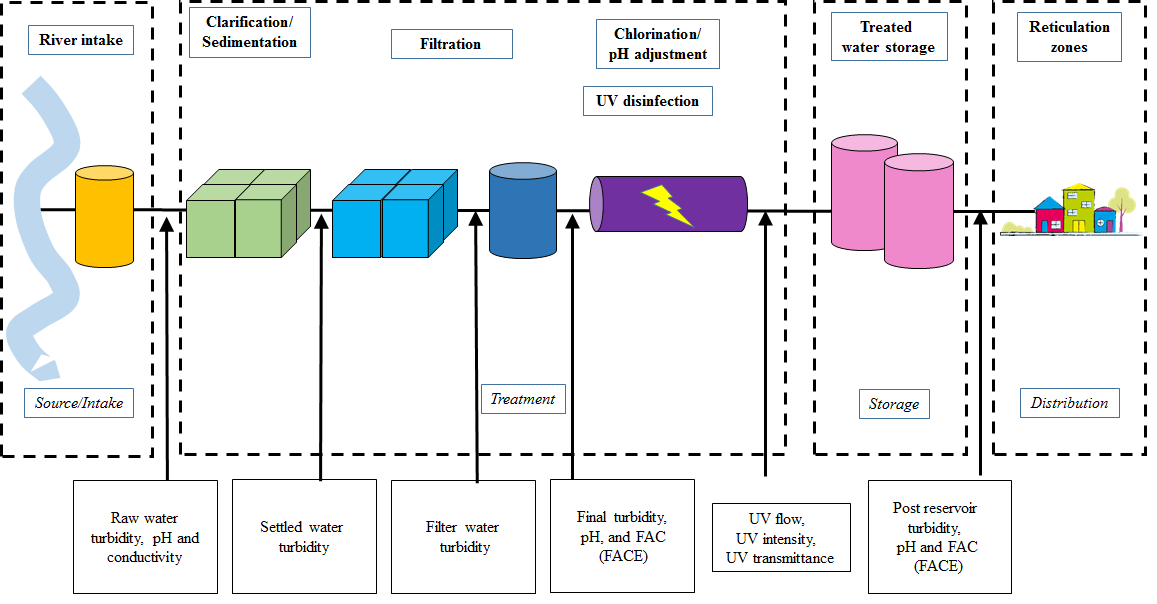


Figure 4: Partial water supply treatment process schematic



The schematic or flow diagram should:

* include all elements of the water supply from catchment to consumer, including sources, treatment plants, reservoirs, pump stations and booster chlorination facilities (where they exist), and the connections between the elements
* outline all steps and processes, whether or not they are under the control of the drinking-water supplier
* include the locations of changes in system ownership and/or operational responsibility.

### Description and analysis of each element of the drinking-water supply system

The drinking-water supply analysis assists with identification of hazards and assessment of risks to water quality. This needs to be more than a narrative about the features; it needs to reflect critical thinking about whether and how the features may affect drinking-water quality. For example, it could make statements such as: ‘The catchment is surrounded by pine planation. After logging, the steep slopes are prone to erosion, resulting in a significant increase in turbidity of the source water during heavy rain events’.

The level of detail required for each water supply system will vary according to the complexity of the system. As a general guide, details of each water source and associated infrastructure should include:

* the catchment characteristics, including:
* catchment area or groundwater recharge zone, including any designated catchment/recharge protection zones
* topography
* main geological features
* land use, current and past, and likely land use change
* climatic features, including significant climate variability and expected longer-term changes
* water source(s), including:
* unique “Drinking-water Online” database identification code
* name
* characteristics
* source infrastructure
* treatment process details for each drinking-water source, including:
* unique “Drinking-water Online” identification code
* the process steps, including process control, critical control points and their critical limits, and microbiological log reduction values and chemical reduction values
* target microbiological log reduction values (see section 2.1.3) and chemical reduction values for treatment components
* location, if the process is not at the treatment plant (eg, booster chlorination)
* overall treatment plant capacity, and capacity of each treatment component operation
* current loading (percentage of maximum treatment component and overall plant capacity)
* proportion of flow from each source
* proportion of scheme supply distribution area
* a list of treatment chemicals (if added)
* a description of any possible variations to process operation (for example, bypassing a process step)
* availability of stand-by equipment
* any sources that do not undergo disinfection, with an explanation of why no disinfection undertaken
* details of the reticulation network and storage, including the:
* unique DW-Online identification code
* extent and coverage of community
* physical characteristics (eg, size of pipes and reservoirs, age, composition)
* operation (eg, system pressure)
* supply and demand characteristics, including projections and quality requirements
* drinking-water supply management system
* any planned improvements to the drinking-water supply system.

Appendix 1 provides an example table for recording the source, treatment plant and distribution zone characteristics as described above.

Suppliers should review the water supply system analysis and update the WSP periodically or following significant changes to the system that need to be included in the system description. Such changes may include changes in land use, treatment processes or consumer distribution, and significant incidents or emergencies. The Health Act 1956 specifies the minimum frequency at which the WSP must be reviewed and reapproved.

### Microbiological log reduction values

The risk of infection from drinking-water contaminated with pathogenic microorganisms is affected by the concentrations of the specific organisms in the raw water and the extent to which the pathogens are removed or inactivated by treatment. The cumulative effect on removal or inactivation of successive treatment processes can be calculated by adding together the log reduction values (LRVs) for each process (the percentages cannot be added for the cumulative effects of more than one treatment process).

The WHO provides approximate values for removal for bacteria, viruses and protozoa by various generic treatment processes in its *Guidelines for Drinking-water Quality* (4th ed) (WHO 2011). Appendix 2 reproduces these tables.

The DWSNZ makes use of the cumulative LRV approach for protozoal compliance. It sets the target log reduction for source waters of given quality. This approach may be extended to other microbiological classes (eg, bacteria). Based on the quality of the water supply’s source water, the water supply system description should include the target microbiological LRVs the DWSNZ require. The description should also include the LRVs for the water supply’s individual treatment processes that the water supplier has determined, and the basis of the determination. The cumulated LRVs of the individual processes must achieve the target required by the DWSNZ. The supplier should refer to the LRVs achieved by the combined treatment processes during the risk assessment of existing preventative measures, and in determining residual risk.

## Assessment of water quality data

A review of historical water quality data can assist in understanding source water characteristics and variability, especially related to treatability and hazards, and system performance both over time and following specific events such as heavy rainfall.

INCLUDE IN THE WSP

* A summary of the available water quality information, and an analysis and interpretation that identifies actual and potential water quality characteristics, variability and problems.
* A review of previous water quality incidents for causes and effectiveness of responses.
* A list of the sources of information and how the data were validated (eg, inspection of records, calculations, etc).

ACTION

Gather and analyse recent and historical water quality information for source, treated and reticulated water. Analysis should consider trends over time and following specific extreme events (especially those that could or did lead to illness), exceedances, major variations, abnormal results and absences of results.

Where available, suppliers should assess water quality data from monitoring of source waters, the operation of treatment processes, and drinking-water as supplied to consumers. Analysing the sets of results for trends and using control charts can be valuable ways to recognise potential problems or hazards and the build-up of any gradual changes or cumulative effects.

Sources of information may include drinking-water quality monitoring records (see section 5.1), routine inspection records, health agency records, local knowledge and consumer complaints (see section 5.2) and reports on previous water quality problems or investigations of disease outbreaks (see sections 5.3 and 9.1).

The analysis should be based around questions such as:

* What is the typical range of source water quality determinands that affect the effectiveness of treatment steps?
* How frequent is the more typical range of source water quality exceeded?
* What are the extremes of source water quality determinands that affect the effectiveness of treatment steps?
* Is there any seasonal (or other period) pattern in source water or treated water quality?
* How stable/consistent is the treated water quality? What causes the instability?
* How stable/consistent is the reticulated water quality? What causes the instability?
* Is there any upward trending in contaminants of potential concern?
* What are the most common complaints from consumers? Are these associated with particular locations or times?

## Hazard and hazardous event identification and risk assessment

Effective risk management requires identification of all potential hazards and hazardous events, and an assessment of the level of risk presented by each hazard and hazardous event. A structured approach is important, to ensure that significant problems are not overlooked and that areas of greatest risk are identified. Measures to reduce hazardous concentrations of contaminants in the source water or prevent hazardous events in the catchment are arguably the most important steps in protecting water safety. Control of the hazards at this point reduces the potential consequences of failure to follow preventive measures. Often water suppliers may have no direct control over contaminant concentrations, but section 69U of the Health Act 1956 requires them to take “reasonable steps” to protect source water quality.

In this context:

* A **hazard** is a biological, chemical, physical or radiological agent that has the potential to cause harm.
* A **hazardous event** is an incident or situation that can lead to the presence of a hazard in the water supply.
* **Risk** is the likelihood of the hazardous event occurring (in a specified timeframe; for example, likelihood of an event happening today), combined with the severity of the public health consequences of the hazardous event (arising from the hazards in the water). Consequences can be a combination of harm to people in the exposed population and disruption to the water supply system.

The distinction between hazard and risk is important: suppliers need to direct attention and resources to preventive measures selected primarily on the basis of level of risk, rather than the mere existence of a hazard. To give an example, the protozoan parasite *Cryptosporidium parvum* is a hazard; failure at a water treatment plant leading to *C. parvum* passing into the distribution system is a hazardous event. The likelihood of the organism being present in source water and passing through the treatment plant in sufficient numbers to cause illness, combined with the severity of the harm caused by *C. parvum*, determines the overall level of risk.

### Select risk assessment methodology

Suppliers should adopt a consistent methodology for both hazard and hazardous event identification and risk assessment. The methodology needs to be transparent and fully understood by everyone involved in the risk assessment process.

INCLUDE IN THE WSP

Information on risk assessment methodology, including:

* a description of the approach to gathering and assessing risk assessment data
* a list of hazards or hazard groups that will be considered
* a table of qualitative likelihood descriptors of hazardous events occurring
* a table of qualitative public health-based consequence descriptors of hazards and system disruption descriptors
* a likelihood–consequences risk matrix
* details of limitations and uncertainties
* the rationale for acceptable levels of risk.

ACTION

Select the methodology used for the risk assessment, and provide a description of the approach to the overall risk assessment process (eg, data collection and analysis, interviews and workshops).

Develop definitions for the likelihood and consequence descriptors and matrix.

Define the limits of the methodology and any uncertainties.

Define the rationale for acceptable levels of risk.

Suppliers can draw on a range of existing risk identification and management methodologies to form the basis of the WSP; for example, the *Australian Drinking Water Guidelines* (NHMRC, NRMMC 2011), the ‘hazard analysis and critical control points’ approach (CAC 1969), ISO 22000 (ISO 2005), AS/NZS ISO 31000 (AS/NZS 2009) or WHO’s *Water Safety Plan Manual* (WHO 2009). For the purposes of the WSP, suppliers can use any risk management methodology that is relevant to the public health risks associated with drinking-water supplies. Suppliers may combine the assessment of public health consequences into any existing risk assessments they may be using, provided those existing risk assessments are suitable to assess and manage health-based impacts (a financial or environmental-based risk assessment may not address specific public health impacts).

To assess the risk of each hazard and hazardous event identified, suppliers should consider the likelihood of the hazardous event occurring in a specified timeframe (eg, the likelihood of an event happening today), combined with the severity of the consequences the hazard may cause. Tables 1 and 2 provide examples of risk assessment descriptors.

Table 3 provides an example of a qualitative risk analysis matrix, which brings together the dimensions of likelihood and consequence to provide a calculated level of risk.

Relevant data for risk assessment may be drawn from a number of sources (eg, monitoring records, questionnaires, workshops, interviews, site visits). Its analysis and interpretation may involve a number of people with contributing expertise, and be done in a number of ways (eg, expert group elicitation, consensus, numerical calculation). Suppliers need to describe the methods they use in the WSP, partly because each method will have associated uncertainties and limitations, which need to be understood.

Table 1: Example of qualitative descriptors of the likelihood that an event will happen

|  |  |  |
| --- | --- | --- |
| **Level** | **Descriptor (Likelihood it will happened today)** | **Example description** |
| A | Almost certain | Occurs more often than once per week |
| B | Likely | Occurs more often than once per month and up to once per week |
| C | Possible | Occurs more often than once per year and up to once per month |
| D | Unlikely | Occurs more often than once every five years and up to once per year |
| E | Rare | Occurs less than or equal to once every five years |

Table 2: Example of qualitative descriptors of consequences (public health and system disruption)

|  |  |
| --- | --- |
| **Consequence** | **Description** |
| Catastrophic | Major impact on most of the population, complete failure of systems, requirement for high level of monitoring and incident management. Potential acute harm to people, declared outbreak or widespread illness and possible deaths expected. |
| Major | Major impact on a sub-population, significant compromise of systems and abnormal operation, requirement for high level of monitoring and incident management. Potential acute harm to people, declared outbreak or widespread illness expected. |
| Moderate | Minor impact on most of the population, significant (but manageable) disruption to normal operation, requirement for increased monitoring. Potential widespread aesthetic issues, or repeated breach of maximum acceptable value (MAV). |
| Minor | Minor impact on a sub-population, some manageable disruption to normal operation. Potential local aesthetic issues, isolated exceedance of MAV. |
| Insignificant | Insignificant impact, little disruption to normal operation. Isolated exceedance of aesthetic parameter. |

Table 3: Example of a qualitative risk analysis matrix: level of risk

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Consequence** | | | | | | |
| **Likelihood** |  | **Insignificant** | **Minor** | **Moderate** | **Major** | **Catastrophic** |
| Almost certain | *Medium* | *High* | *High* | *Extreme* | *Extreme* |
| Likely | *Medium* | *Medium* | *High* | *High* | *Extreme* |
| Possible | *Low* | *Medium* | *Medium* | *High* | *High* |
| Unlikely | *Low* | *Low* | *Medium* | *Medium* | *High* |
| Rare | *Low* | *Low* | *Low* | *Medium* | *Medium* |

Realistic expectations of hazard identification and risk assessment are important. Rarely will enough knowledge or data be available to complete a detailed quantitative risk assessment. Hazard identification and risk assessment are activities of judgement, albeit informed judgement, so will inevitably contain uncertainty and limitations. Uncertainty arises from factors such as lack of complete knowledge or variability/inconsistency of information. Suppliers need to understand uncertainties and limitations and take them into account when determining responses to unacceptable risks. Uncertainties and limitations can be recorded in the risk assessment table (see section 2.3.2). Table 4 provides examples of uncertainty descriptors, and Table 5 provides examples of acceptable levels of risk. Suppliers should create their own uncertainty descriptors.

Table 4: Example of degrees of uncertainty

| **Level of certainty** | **Description** |
| --- | --- |
| Certain | * At least five years of: * continuous data (eg, FAC), or * daily monitoring data (eg, *E. coli* monitoring), or * monthly monitoring data (chemical), or * inspection records   which have been collated and analysed, and variability is predictable.   * At least five years of continuous/daily/monthly monitoring/inspection data for the duration of seasonal events which have been collated and analysed, and variability is predictable. * The hazardous event and preventive measures/processes involved are thoroughly understood. |
| Confident | * At least two years of: * continuous data (eg, FAC), or * daily monitoring data (*E. coli* monitoring), or * monthly monitoring data (chemical), or * inspection records   which have been collated and analysed, and variability is predictable.   * At least two years of continuous/daily/monthly monitoring/inspection data for the duration of seasonal events, which have been collated and analysed, and variability is predictable. * There is a good understanding of the hazardous event and preventive measures/processes involved. |
| Reliable | * At least one year of: * continuous data (eg, FAC), or * daily monitoring data (*E. coli* monitoring), or * monthly monitoring data (chemical), or * inspection records   which have been collated and analysed, and variability is predictable.   * At least two years of continuous/daily/monthly monitoring/inspection data for the duration of seasonal events have been collated and analysed, but variability is not predictable. * There is a good understanding of the hazardous event and preventive measures/processes involved. |
| Estimate | * There are limited monitoring data available. * There is a reasonable understanding of the hazardous event and preventive measures/process involved. |
| Uncertain | * There are limited or no monitoring data available. * The hazardous events or preventive measures/processes are not well understood. |

Suppliers should not use uncertainties and limitations as a reason to postpone preventive measures when threats to public health are at stake. The precautionary principle, as applied to public health, states that action should be taken to prevent harm even if some cause-and-effect relationships have not been fully established scientifically. The drinking-water supplier must indicate which level of risk (Table 5 identifies four levels) it considers: (i) acceptable, for which it would take no additional actions to further reduce the risk, (ii) unacceptable, for which it must take additional actions, and (iii) unacceptable until the uncertainty is reduced and informs otherwise, and for which it must take at least short-term measures to reduce the risk. Chemical and microbiological hazards may have different levels of acceptability because of differences in exposure periods before they become hazardous.

Table 5: Example showing levels of acceptable microbiological risk and how management actions are influenced by the level of uncertainty in the assessment

|  |  |  |  |
| --- | --- | --- | --- |
| **Risk level** | **Certainty** | **Acceptability** | **Management actions** |
| Low | Certain Confident Reliable | Acceptable | Manage within existing processes, adopting continuous improvement. |
| Estimate Uncertain | Acceptable |
| Medium | Certain Confident Reliable | Unacceptable | Implement short-term measures, and plan and implement longer-term risk reduction measures within x-year timeframe. |
| Estimate Uncertain | Unacceptable | Implement short-term measures, and investigate measures to reduce level of uncertainty as soon as possible. |
| High | Certain Confident Reliable | Unacceptable | Implement short-term measures immediately, and prioritise longer-term risk reduction measures. |
| Estimate Uncertain | Unacceptable | Implement short-term measures immediately, and investigate measures to reduce level of uncertainty as soon as possible. |
| Extreme | Certain Confident Reliable | Unacceptable | Implement short-term measures immediately, put emergency plans on stand-by and give longer-term risk reduction measures top priority. |
| Estimate Uncertain | Unacceptable | Implement short-term measures immediately, put emergency plans on stand-by and immediately investigate measures to reduce level of uncertainty. |

### The risk assessment table

Suppliers should record all the information necessary to estimate the level of risk from identified hazards and hazardous events in a risk assessment table. This table should include:

* the water supply element
* the hazardous event that may lead to the hazard being in the water (see section 2.3.3)
* the cause or causes of the hazardous event – there may be several possible causes, identifying these is important for knowing which preventive measures are needed to reduce the likelihood of the event (see section 2.3.3)
* the hazard being considered (see section 2.3.3)
* the likelihood of the hazardous event **in the absence of any preventive measure** **and** **under conditions when the system would be most challenged**
* the consequence of the hazardous event **in the absence of any preventive measure** **and under conditions when the system would be most challenged**, noting that consequences may be different for different hazards originating from the same hazardous event
* the **maximum risk** for each hazard/hazardous event combination (ie, **in the absence of any preventive measure** **and under conditions when the system would be most challenged**), determined as described in section 2.3.4
* **existing preventive measures** for controlling the hazardous event (see section 3.1)
* the likelihood of the hazardous event **with the existing preventive measures in place** **and under conditions when the system would be most challenged**
* the consequence of the hazardous event **with the existing preventive measures in place** **and under conditions when the system would be most challenged**, noting that consequences may be different for different hazards originating from the same hazardous event
* the **residual risk** for each hazard/hazardous event combination (ie, **with the existing preventive measures in place** **and under conditions when the system would be most challenged**), determined as described in section 3.1.1.

Appendix 3 discusses risk assessment tables in more depth.

### Identify hazards and hazardous events

Suppliers must document hazards and hazardous events, including the causes of hazardous events that could adversely affect water quality, in the WSP, including those affecting the:

* catchment
* abstraction and pre-treatment infrastructure
* treatment plant(s) and processes
* reticulation network, including storage.

INCLUDE IN THE WSP

* Details of the supplier’s approach to hazard and hazardous event identification.
* A list of all hazards and hazardous events for each element of the drinking-water supply. The Ministry of Health’s Water Safety Plan Guides for Water Supplies(Ministry of Health 2014b) provide an extensive, but not exhaustive, list of the hazardous events that could befall each water supply element; Appendix 4 contains a table showing the possible hazards arising from different catchment activities.

ACTION

Determine and document the approach to hazard and hazardous events identification.

Identify and document hazards and hazardous events for each element of the drinking-water supply, as a first step towards populating the risk assessment table.

Suppliers should use information gathered for the water supply system description and analysis (see section 2.1) to inform hazard and hazardous event identification. If a supplier uses additional information sources, it should note these (eg, prompts like the Water Safety Plan Guides for Water Supplies). Analysis and interpretation of the information to extract hazards and hazardous events should involve a number of individuals with contributing expertise, and be done in a number of ways (eg, expert group elicitation, WSP team workshop, site/supply visit, review of previous problems). The WSP needs to describe the methods a supplier uses, partly because each method will have associated uncertainties and limitations, which need to be understood.

Suppliers should identify and document all potential hazards and hazardous events that can lead to the presence of hazards in the drinking-water supply for each element of the water supply system. They should do so regardless of whether the event is under the direct control of the drinking-water supplier. Suppliers should also consider continuous, intermittent or seasonal pollution patterns, as well as extreme and infrequent events such as droughts or floods.

Suppliers must include hazards and hazardous events that they consider to be currently well managed. They should not exclude a hazard or hazardous event simply because there is water treatment or other processes in place to remove it. These processes are preventive measures; they do not eliminate the risk. If the preventive measure fails, the hazardous event returns to being uncontrolled. Suppliers should consider the effects of existing preventive measures on risk as part of their risk assessment in the determination of residual (or mitigated) risk (see section 3.1.1) and additional preventive measures required.

Consistent with the principles of the DWSNZ, the WSP should give highest priority to health risks arising from microbiological contaminants, because they can lead to rapid and major outbreaks of illness. Human and animal waste represent the largest sources of these contaminants in drinking-water. Both can include high numbers of enteric pathogens and large amounts of nutrients. The potential range of pathogens present will vary according to the type of waste involved.

Suppliers must give adequate consideration to plausible combinations of hazards or hazardous events (eg, calving season (because of elevated levels of *Cryptosporidium* in the environment) AND a heavy rain event AND treatment plant failure) that result in an increased level of risk to the water quality.

Suppliers must also consider whole-of-supply hazardous events (eg, an earthquake, a weather event, power failure, a sudden mass influx of people using the water supply). Preventive measures are rarely able to manage risks arising from these events, so contingency and emergency plans are needed (see section 7). Including such events at this stage in the WSP process ensures they will be followed through to the most appropriate risk management response.

In well-managed systems, problems should be rare, making them more challenging to anticipate and possibly to counter. Suppliers can learn constructive lessons from the experiences of other New Zealand and international drinking-water suppliers and water agencies. Many problems are triggered by short periods of sudden change, such as heavy rainfall or equipment failure. Reviews of waterborne disease outbreaks and the events that caused them reveal that some of these events should have been foreseeable, while others are attributable to unusual or rare events (Hrudey & Hrudey 2004). Suppliers should maintain awareness of such incidents to assist implementation of their own preventive measures and to safeguard against similar occurrences.

The Ministry of Health’s Water Safety Plan Guides for Water Suppliesprovides a non-exhaustive list of hazards and hazardous events*.* Appendix 4 identifies possible hazards arising from catchment activities.

### Determine maximum risk

Once suppliers have identified potential hazards and hazardous events, they must estimate the maximum level of risk (the risk in the absence of any preventive measure and under conditions when the system would be most challenged) associated with each hazard (or group of hazards) and hazardous event. This is useful for identifying high-priority risks, determining where to focus attention and preparing for emergencies. It helps to put into perspective the implications for the health of the population if the hazard is not removed or controlled, and identify priorities for risk management.

INCLUDE IN THE WSP

* The maximum risk associated with each hazard/hazardous event combination.
* A prioritised list of hazard/hazardous event combinations that need to be managed.
* Identification of uncertainties in risk assessment, and investigations to reduce uncertainties linked to the improvement plan (see section 6).

ACTION

Determine (or estimate) the level of maximum risk associated with each hazard and hazardous event using the documented risk assessment methodology (see section 2.3.1). Add to the risk assessment table.

Where there is insufficient data or information to complete a reliable assessment, this should be highlighted as an uncertainty and added to the improvement plan (see section 6).

The result of the risk assessment across all water supply elements will be a list of hazard/hazardous event combinations, prioritised from low to extreme. Those in the ‘extreme’ category require priority assessment of existing preventive measures to identify any unacceptable residual risks that require urgent attention: see Table 5.

The next step in the WSP process is to assess existing preventive measures to determine what protection these measures are providing against identified priority risks (see section 3), and subsequently where additional preventive measures are needed to manage unacceptable residual risks.

After suppliers have completed the risk assessment, they should run a sense-making check across the set of results. Do the hazard/hazardous event combinations in the ‘extreme’ risk category make logical sense compared with those in the ‘high’ risk category? If not, reconsider the information used to make the assessment, and how it was analysed.

A likely outcome of risk assessment will be the identification of some specific areas where further information and research is required. Where there are too few data or insufficient information to complete a reliable assessment, suppliers should highlight this as an uncertainty (see section 2.3.1) and added it to the improvement plan (see section 6).

# Preventive measures for drinking-water quality management

Prevention of health-significant levels of contaminants reaching the consumer is an essential feature of effective drinking-water quality management. The identification, evaluation and planning of preventive measures should always be based on system-specific hazard identification and risk assessment (see section 2). The level of protection used to control a hazard should be proportional to the associated risk. For example, significant (high or extreme) risks require multiple-barrier preventive measures to reduce the risks to acceptable levels and regular monitoring. Lower-priority risks may not require mitigation in the short-term; in this case the risk management approach may involve occasional monitoring and visual inspections.

## Assessment of existing preventive measures and multiple barriers

Preventive measures are actions, activities and processes used to prevent hazardous events from occurring, or reduce hazards reaching the consumer to acceptable levels. They include all active measures that protect raw water quality prior to treatment, treatment steps, and measures to protect treated water quality all the way from the treatment plant to the consumer’s gate. Their purpose is to reduce the risk to acceptable levels.

Wherever possible, especially for hazards and hazardous events that pose significant (high or extreme) risks, suppliers should avoid reliance on a single preventive measure. Furthermore, they should employ the multiple-barrier principle, having a range of preventive measures in place from catchment to the point of supply to the consumer. This will ensure the failure of one barrier will be compensated for by the others. Wherever possible, the priority should be to prevent contamination in the catchment, rather than to rely on downstream control. The four types of barrier are:

* preventing hazards entering the raw water
* removing particles and hazardous chemicals from the water
* killing or inactivating pathogens in the water
* maintaining the quality of the water in the distribution system.

INCLUDE IN THE WSP

* Current preventive measures for hazards and hazardous events.
* A description of which of the four types of barrier are present, and what preventive measures constitute them.

ACTION

Identify all existing preventive measures for identified hazards and hazardous events. Add these to the risk assessment table alongside the hazards and hazardous events they address.

Identify which of the four types of barrier are present, and importantly identify any barrier type that is not present. Section 3.2 considers missing barrier types.

As noted in section 2.3.3, the Ministry of Health’s Water Safety Plan Guides for Water Suppliesprovide information to assist in identifying hazardous events, their causes and preventive measures that suppliers can use to reduce the likelihood of hazardous events occurring. These documents provide a wide range of possible preventive measures, but are unlikely to be comprehensive; water suppliers need to identify possible hazardous events, their causes and preventive measures relevant to their own supplies.

### Calculation of residual risk

Residual risk is the level of risk resulting from a hazardous event/hazard combination once the existing preventive measure(s) have been applied. Residual risk provides an indication of the need for additional preventive measures.

INCLUDE IN THE WSP

* The residual risks, by evaluating whether the preventive measures for a particular hazard/hazardous event, **when considered together**, are effective in reducing the risk to an acceptable level.

ACTION

Determine (or estimate) the residual risk for combinations of preventive measures associated with each hazard and hazardous event, using the documented risk assessment methodology (see section 2.3.1 and the microbiological log reduction values in section 2.1.3). Add to the risk assessment table.

Residual risk is determined using the same methodology (likelihood and consequence descriptors) as the initial maximum risk assessment. Changes to the assessed likelihood (or consequence) should reduce the risk score.

Since multiple-barrier risk management is best practice, there will often be several preventive measures associated with a hazard/hazardous event. Residual risk needs to be determined for the combination of preventive measures, and consider the likelihood of all these preventive measures failing at the same time, or causing a cascade failure of preventive measures.

## Identification of additional preventive measures

Suppliers must assess residual risk for each hazard and hazardous event against their predetermined level of acceptable risk. For any risks ‘deemed’ unacceptable (eg, where residual risk is assessed as high and the residual risk that the supplier will accept without taking further action is low), the assessment team must determine what additional preventive measures it will take to manage and reduce these risks to an acceptable level. **These must include interim, or short-term, measures for managing the risk until long-term (permanent) measures are in place. An inability to put permanent measures in place immediately, for whatever reason, is not an excuse for leaving risks unmanaged**.

INCLUDE IN THE WSP

* A list of unacceptable residual risks.
* Interim and long-term preventive measures to manage unacceptable risk described in the risk assessment table.
* A prioritised list of risks requiring additional preventive measures, in the improvement plan.

ACTION

Determine what level of residual risk is acceptable (see Table 5).

Assess residual risk against acceptable risk levels, to identify the acceptability of each risk.

Identify additional interim and long-term preventive measures, to manage unacceptable risk.

Develop a prioritised list of additional preventive measures to include in the improvement plan (section 6.1).

Measures for managing unacceptable risks to safe and secure drinking-water supply may fall under categories such as:

* fixing what is broken
* installing physical infrastructure/treatment
* accessing a new water source (including temporary tankered or bottled water)
* creating and using appropriate operational procedures
* training operational and management staff.

Note: Additional or enhanced intensive monitoring with defined limits to trigger emergency actions is not a preventive measure. Monitoring does not prevent hazardous events from occurring or reduce the concentrations of hazards reaching consumers to acceptable levels. Monitoring assesses the performance of preventive measures, or triggers a preventive action.

# Operational procedures

Even brief failures in contamination barriers can present a significant risk to public health. It is critical that the preventive measures discussed in section 3, which contribute to these barriers, are continuously effective. Robust procedures, monitoring and inspection plans and predetermined corrective actions are integral to the reliability of the preventive measures.

## Operational procedures

Operational (including maintenance) procedures ensure that the entire water supply system remains functional, and that preventive measures and activities associated with their operation, from the catchment to the point of delivery to the consumer, are continuously effective.

INCLUDE IN THE WSP

* A list of the documented operational procedures required to ensure the satisfactory performance of the water supply system and each existing preventive measure identified in the risk assessment.
* A schedule summarising operations and maintenance duties required to ensure the entire water supply system remains functional and preventative measures are continuously effective, with sign-off by the person responsible when each duty is complete (to show the schedule is being followed).
* A training record, listing each operations staff member and the procedures in which they have received training.

ACTION

Refer to the water supply description and risk assessment table for a list of all processes and activities required to ensure that the entire water supply system remains functional and preventive measures are continuously effective, which includes treatment processes, activities before and after treatment, and staff training.

For each of these processes/activities, identify the staff member(s) with responsibility for it, and the competencies this person requires.

For each process/activity, prepare document-controlled operational procedures and maintenance manuals (see section 8.1).

Establish the procedure for recording that the operation or maintenance has been carried out as prescribed.

Ensure staff are trained in the duties needed for the proper performance of each operation or maintenance procedure with which they are involved or for which they have responsibility.

The WSP must note which operational and maintenance procedures have been prepared, but the procedures themselves could be contained in separate operations manuals. Controlled copies (see section 8.1) of these documents must be easily accessible by operations staff. Changes to a procedure must be approved by the person responsible for the manual (or document control).

An operational and/or maintenance procedure must:

* describe the function of each process/activity (or some component of it). Where the process/activity relates to a preventive measure, it must describe:
* the hazard it is designed to control or the hazardous event it is designed to prevent
* briefly, how it works to control a hazard or prevent a hazardous event
* identify the responsibilities and authorities associated with the preventive measure and associated operational and maintenance procedure
* describe the actions that make up the operational and maintenance procedure (ie, what has to be done to ensure the satisfactory working of the preventive measure (or some component of it), and the scheduling of actions)
* describe the monitoring, or observations, undertaken to check that the preventive measure is effective (see section 4.2)
* identify what must be recorded as part of the operation and maintenance procedure
* describe the corrective actions that need to be taken should monitoring/inspection show that the preventive measure is ineffective (ie, when the monitored values are outside their control limits (see section 4.4))
* include a list of the routine materials and chemicals that have been approved for use in contact with the water.

Operational and maintenance procedures are site-specific. Ideally, a procedure must be sufficiently detailed and clear that an operator who is unfamiliar with the water supply is able to understand how to operate and maintain the supply. Staff familiar with a preventive measure should be involved in preparing its associated operational procedure, to ensure the procedure makes sense to those using it.

## Operational monitoring and inspection

Operational monitoring and inspection is a planned series of measurements or observations designed to check that a preventive measure is performing satisfactorily. This type of monitoring is different from drinking-water quality monitoring, which is undertaken to show compliance with the DWSNZ (see section 5.1). Consequently, parameters measured to check that a preventive measure is working effectively may not have an MAV or guideline value, and observations (to assess the state of a bore head, for example) may not be quantifiable.

INCLUDE IN THE WSP

* A list of operational monitoring and inspection plans for assessing the satisfactory operation of preventive measures. These plans may be included in the WSP or kept as separate documents.
* A schedule showing when operational monitoring samples or inspections/observations are to be made.
* A log of the operational monitoring/inspection undertaken, or the location of the log, if kept as a separate document, with signoff by the person responsible when each action is complete.
* Evidence that the operational staff have been trained in operational monitoring.

ACTION

Refer to the water supply description and risk assessment table for a list of all processes and activities required to ensure that the entire water supply system remains functional and preventive measures are continuously effective, which includes treatment processes, activities before and after treatment, and staff training.

For each of these processes/activities, identify the staff member with responsibility for the preventive measure’s satisfactory performance and the competencies this person requires.

Prepare document-controlled (see section 8.1) operational monitoring and inspection plans, which include a monitoring/inspection schedule, for each preventive measure.

Ensure staff are trained in their duties needed for the proper performance of each operational monitoring and inspection plan with which they are involved or for which they have responsibility.

Establish a log to record operational monitoring/inspection has been undertaken.

Plans for operational monitoring/inspection (see example in 0) should:

* encompass each preventive measure from the catchment to the point of water delivery
* identify:
* what is to be measured or observed (the operational parameter)
* where samples are to be collected, or observations are to be made
* the frequency of sampling or observation
* the procedure for sampling or observation
* the criteria to be used to assess the operational effectiveness of the preventive measure, and where necessary, trigger immediate corrective actions (see section 4.2.3)
* who has responsibility for recording measurement and observation results and reporting the results to other appropriate staff
* who has responsibility to act on the results
* who is to receive the reports
* who has responsibility for reviewing and analysing the operational monitoring results
* who has responsibility for preparing and maintaining the plan
* establish a timetable for regular reporting of results and their interpretation
* identify the competencies required by the person with responsibility for analysing the data
* reference the section of the WSP describing the corrective actions required on finding that target criteria or critical limits have been exceeded (see section 4.4)
* describe what ongoing review and interpretation of results is required to confirm operational performance (see also section 10.1).

The operational monitoring/inspection log must include:

* the time and date when the sample was taken or inspection made
* the name of the person who collected the sample or made the inspection
* the sampling/observation location (where appropriate)
* the result of the test or observation
* the name of the person who reviewed and analysed the collected data
* a record of actions taken in response to the result(s).

### Operational parameter selection

The parameter to be measured, or observed, should be indicative of the effectiveness of the preventive measure. It should also be able to be readily measured/observed to allow a timely response to an adverse result. To meet these needs, surrogate measurements are often used. For example, the FAC level is used to determine the effectiveness of chlorination, rather than the *E. coli* concentration.

### Sampling/observation frequency

Suppliers should monitor/observe operational parameters with sufficient frequency to reveal any failures in good time. They should use continuous online monitoring wherever possible; particularly at critical control points (see section 4.3).

### Target criteria, triggers and critical limits

Target criteria and critical limits triggering corrective or emergency action may be quantitative (numerical) or qualitative (descriptive) depending on the nature of the preventive measure. Excursion of an operational parameter outside the critical limits indicates that control of a preventive measure has been lost and an immediate corrective action is needed (see section 4.4).

Target criteria indicate the desirable range of values for the operational parameter when process performance is satisfactory. Ideally, they are more stringent than critical limits. An excursion of the parameter value outside the target criteria does not require the same level of corrective action as exceedance of a critical limit. However, it signals to the operator that action is needed to bring performance of the preventive measure back into an acceptable range.

### Result analysis

The results of operational monitoring/observation must be displayed and recorded to help in identifying trends in the performance of the preventive measure. Suppliers must review results frequently (but less frequently if measurements or observations are made less frequently) to allow checks for completeness and accuracy, and timely responses when target criteria/critical limits are exceeded.

Operational monitoring results feed into the long-term evaluation of results (see section 10.1).

## Critical control points

A critical control point (CCP) is a specific preventive measure at which control can be exercised/applied to reduce the concentration of a hazard in the drinking-water to an acceptable level, or prevent the possibility of a hazard entering the drinking-water. The proper functioning of a CCP is essential for protecting public health. Specifically, a CCP must have defined and measurable limits that clearly distinguish acceptable from unacceptable performance at that point, and be monitored frequently enough that failure in the preventive measure can be detected and action taken in time to prevent harm to consumers. For these reasons, most CCPs are treatment barriers. See Appendix 6 for further guidance.

The fact that CCPs are termed ‘critical’ does not diminish the importance of other preventive measures in the multi-barrier system. Suppliers should identify CCPs for all hazards that pose a significant risk to the safety of the drinking-water.

INCLUDE IN THE WSP

* A list of CCPs identified from the catchment to the point of delivery to the consumer.
* Each CCP, tabled with its control parameter values (target criteria, action limits, critical limits) and predefined corrective actions.

ACTION

Review all preventive measures from the catchment to the point of delivery to the consumer to identify those that meet the requirements for being a CCP, and assign these as CCPs.

Prepare document-controlled (see section 8.1) CCP plans for each CCP (see Appendix 6).

Validate target criteria and critical limits for each CCP (see section 9.2).

The operational requirements for a preventive measure being a CCP (see also Appendix 7) include:

* at least one measurable operational parameter that allows the effectiveness of the preventive measure to be determined and unambiguous critical limits to be set so that an acceptable level of effectiveness can be defined
* operational parameters that can be measured frequently enough to reveal failures before unsafe water is supplied to consumers (continuous online monitoring is preferable)
* associated corrective actions that can be triggered by excursions beyond target criteria or critical limits to bring the system back under control.

Critical limits are key performance criteria that clearly separate acceptability from unacceptability with respect to drinking-water safety. They may include an operational parameter combined with the period for which a certain limit has been exceeded (eg, a minimum chlorine concentration for a specified time).

## Corrective actions

When operational parameters do not meet their target criteria, corrective action procedures are required to return the preventive measure to satisfactory performance.

INCLUDE IN THE WSP

* A list of preventive measures with associated corrective action procedures to be followed if a target criterion or critical limit is exceeded. (Corrective action procedures may be contained in a separate corrective actions manual, or in the control systems manual, in which case, the WSP should reference this.)
* A process for reviewing why a corrective action was needed, the effectiveness of the monitoring/inspection plan and the corrective actions taken, and whether the WSP needs to be updated.
* Records of responses to excursions beyond target criteria.
* Evidence that operational staff have been trained in corrective action procedures.
* Evidence that there is document/version control of corrective action procedures.

ACTION

Identify staff with responsibilities for:

– reviewing operational monitoring/inspection results and taking corrective actions

– preparing corrective action procedures

– preparing the corrective action manual (where appropriate).

Prepare corrective action procedures for each preventive measure.

Carry out staff training in responding to monitoring/inspection results that do not meet target criteria.

Ensure that corrective action procedures are covered by the document control system (see section 8.1).

A corrective action procedure must include:

* where possible, an investigation to try to establish the cause of the excursion
* if the investigation shows it is warranted, making adjustments to the preventive measure to return it to satisfactory performance (eg, process control changes where the preventive measure is a treatment process)
* undertaking additional monitoring to show that the actions taken have been successful in returning the preventive measure to satisfactory performance
* keeping a record of when corrective actions were needed, the steps taken, the findings of the investigation and the overall outcome of the corrective action. These details are important for learning from the incident
* including in the improvement plan any shortcomings found in the corrective action procedure so that they may be subsequently addressed.

A corrective action procedure should not be limited to actions that return the preventive measure to satisfactory performance. It must also consider the potential for consequential impacts on following preventive measures, and ultimately the quality of water reaching the point of delivery to the consumer. These types of corrective action are called public health mitigations. Figures 4.1 and 4.2 of the DWSNZ contain examples of these (eg, issuing of boil water notices). The corrective action procedure must identify:

* specific actions needed to protect public health (where appropriate), such (eg, increasing the disinfectant level, or flushing mains), the circumstances under which these actions are needed and who has responsibility for deciding that they are needed
* who has responsibility and authority for communications regarding the public health mitigation
* who must be informed of:
* the need for the public health mitigation(s) (both internally and externally; eg, drinking-water assessors (DWAs))
* when they need to be informed of the mitigation(s)
* the mitigation’s outcome
* potential sources of external assistance (eg, DWAs) and their contact information.

The operator/water supplier may become aware that corrective action is needed through analysis of operational monitoring results, the activation of an automatic alarm responding to a continuous monitor or some other means.

While planning in advance is important, not all eventualities can be envisaged, and it is important to have identified possible sources of external help before the help is needed.

# Verification monitoring programme

The effectiveness of the WSP is determined by verification monitoring, which assesses the drinking-water quality at the point at which it is supplied to the consumer’s property. The assessment makes use of water quality testing and consumer complaints. The latter provides an important source of information about the aesthetic properties of the water.

Verification monitoring provides another check on the effectiveness of preventive measures, although the information it provides is retrospective.

## Drinking-water quality monitoring

The basis for assessing drinking-water quality in New Zealand is compliance with the DWSNZ, which specify monitoring requirements. A supplier’s WSP must identify how the supplier will meet these requirements in the specific water supply. This should ensure that staff do not misunderstand what needs to be done to achieve compliance.

The DWSNZ require drinking-water quality monitoring of: *E. coli* (all supplies); chemical determinands (Priority 2[[1]](#footnote-1) determinands only); radiological determinands (bore sources that are not equivalent to a surface water) and cyanotoxins (toxins assigned as Priority 2 determinands). For protozoal compliance, where the determinand cannot be measured directly, measurement of treatment efficacy is used as the surrogate method for establishing compliance (eg, turbidity is used to assess filter performance).

INCLUDE IN THE WSP

* A drinking-water quality compliance monitoring plan, or reference to a plan, that shows the supply-relevant requirements of the DWSNZ (see example in Table 6).
* Evidence that staff have been trained in the use of the plan.
* The procedure(s) to be followed in the event of the monitoring identifying a transgression or other non-compliance with the DWSNZ, consistent with the requirements of the DWSNZ.

ACTION

Prepare a document-controlled (see section 8.1) drinking-water quality monitoring plan that:

– identifies which determinands must be monitored

– determines how the monitoring requirements of the DWSNZ will be made specific to the supply (eg, frequency of sampling determined by population)

– establishes a sampling schedule for each determinand

– determines the steps to be taken in the event of a transgression or some other non-compliance.

Identify staff who have responsibilities according to the plan.

Train staff in the use of the plan and sampling procedures.

The drinking-water quality compliance monitoring plan should contain, but not be limited to:

* staff responsibilities for:
* maintenance of the monitoring plan and the sampling schedule
* sample collection, including a list of the training these staff have received
* liaison with the testing laboratory
* collation, recording, assessment and reporting of results
* the population being supplied by each of the treatment plant(s) and in the distribution zone(s)
* the Priority 2 determinands assigned to the supply, and their MAVs
* the testing laboratories to be used, and their contact information
* for each of the determinands that need to be monitored for compliance:
* the sampling location(s), with the rationales for their selection
* a sampling schedule that meets the requirements of the DWSNZ, prepared/updated for each compliance year
* the procedure for sample collection and transport
* test methods provided by the laboratory (this is important where options are possible)
* the procedure for collation, recording, assessment and reporting results (Table 7 provides an example template for summarising verification monitoring data, and Figure 5 gives an example of how a supplier might plot monitoring data for a particular determinand).
* the procedure to be followed in the event of transgression being detected (see section 4.4). This **must** include communication with a DWA.

The WSP must refer to the drinking-water quality monitoring plan, if it is maintained as an external document, and state where the plan is kept.

The drinking-water quality monitoring plan must be a controlled document (see section 8.1).

Table 6: Example of a monitoring plan showing the requirements of the DWSNZ for a specific supply

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Population served** | **Determinand** | **MAV** | **Associated hazard** | **DWSNZ compliance criterion** | **Sampling frequency** | **Maximum days between samples** | **Minimum days of the week to be used** | **Sampling locations** | **Response to exceedances (DWSNZ compliance requirements)** |
| **Monitoring at the treatment plant** | | | | | | | | | |
| Treatment plant ID code: *TP09999* | | | | | | | | | |
| 6,000 | *E. coli* | <1 *E. coli*/ 100 ml | Bacteria | Criterion 1 | Twice weekly | 5 | 6 | Water leaving the contact tank | Section 4.3.9 Figure 4.1 |
| 6,000 | Fluoride | 1.5 mg/L | Fluoride | – | Weekly | 13 | – | Water leaving the treatment plant | Section 8.4 |
| **Monitoring in the distribution zone** | | | | | | | | | |
| Distribution zone ID code: *ABC001AB* | | | | | | | | | |
| 6,000 | *E. coli* | <1 *E. coli*/ 100 ml | Bacteria | Criterion 6B | 10 / quarter | 16 | 4 | Council sampling point Mulberry Street  Council sampling point Orchard Road  Three other random locations | Section 4.4.6 Figure 4.2 |
| 6,000 | Bromodichloro-methane | 0.06 mg/L | Disinfection by-products | – | Monthly | 45 | – | Council sampling point Mulberry Street  Two other random locations at reticulation extremities | Section 8.4 |

Table 7: Example template for summarising verification monitoring data

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Source name and type** | | | | | | | | | | |
| **Determinand** | **Sampling location(s)** | **Time period** | **No of samples** | **Summary of results** | | | **MAV or guideline value** | **Units** | **Number of exceedances** | **Comments** |
| **Maximum value** | **Average value** | **Minimum value** |
|  |  |  |  |  |  |  |  |  |  |  |

Figure 5: Example of a plot of data for a determinand to help identify trends

Figure 2: Example of a plot of data for a determinand to help identify trends

Note that as these results routinely exceed 50% of the MAV, this determinand should be assigned as a Priority 2 determinand to the supply. Because it frequently exceeds the MAV, it should also be documented in the hazard identification section of the plan.

## Consumer satisfaction

The human senses are capable of detecting some water quality problems more readily than instrumental analysis. Consumers provide a network of ‘detectors’ throughout the reticulation, frequently monitoring the water, and are a valuable tool for detecting some forms of water quality problem.

INCLUDE IN THE WSP

* A consumer complaints register, or reference to where it can be found.
* A procedure for maintaining the register.
* A procedure for responding to complaints; particularly in terms of corrective action.
* Evidence of staff training in logging and responding to complaints.
* The supplier’s approach to making consumers aware of how complaints may be made.

ACTION

Establish a complaints register and initiate regular reviews of the information received from consumers.

Identify the details of complaints/complainants to be logged in the register.

Establish, and notify consumers of, ways consumers can make complaints.

Establish a procedure for review of the information contained in the register.

Identify staff with responsibilities for establishing and maintaining the complaints register, reviewing and assessing the information, communicating the findings of the assessment, and responding to complaints.

Train staff in handling and responding to complaints.

To gather potentially useful complaint information:

* establish pathways by which consumers can communicate water quality problems to the water supplier, and advertise them well. These pathways could include:
* an 0800 telephone line
* a council call centre
* an email address
* social media accounts
* assign responsibility to a staff member(s) for:
* regularly monitoring communication pathways
* establishing and maintaining the (preferably electronic) complaints register in a way that allows rapid alert and escalation for a predefined set of complaints or rate of receipt of complaints, and rapid data search and retrieval (for common complaints, for example)
* regularly assessing the complaints received to look for patterns (particularly apparently sudden changes in water quality), to allow identification of genuine concerns requiring a response (especially where the problem may have acute health consequences, such as overdosing of coagulant at the treatment plant) (see section 5.3)
* notifying someone with appropriate authority that a corrective action is needed (see section 5.3)
* taking action in response to a complaint (ie, notifying the person with ‘appropriate authority’)
* encourage consumers to provide the following information when they log a complaint:
* the date, time and location when the problem (or suspected health consequence) was first noticed
* their awareness of neighbours experiencing the same problem
* a description of the problem (eg, taste, odour, appearance), with as much specific detail as possible (eg, ‘smells like solvent’, rather than ‘smells bad’)
* train staff in how they are to respond to complaints, both when there is a need for corrective action and when there is not.

## Short-term evaluation results

Short-term evaluation of results as part of the **verification** monitoring programme entails the frequent and regular review of drinking-water quality monitoring data and consumer complaints to confirm that the water being provided meets required standards. This is in contrast to the review of **operational** monitoring data described in section 4.2, which provides direct information on the performance of a preventive measure.

INCLUDE IN THE WSP

* The schedule for reviewing water quality and complaints.
* The procedure for reviewing the data (including what the data should be compared to) and how it should be responded to (including communication of results internally and externally and the need to update the WSP).
* A list of staff responsibilities.
* Evidence of staff training.

ACTION

Establish a schedule for the review of drinking-water quality data and consumer complaints.

Identify staff with responsibilities for short-term result evaluation.

Train staff in reviewing drinking-water quality monitoring data and consumer complaints and responding to the findings of their review.

For short-term result evaluation, the verification monitoring programme should:

* identify who has responsibility for reviewing and analysing/interpreting data from drinking-water quality monitoring and information from consumers
* identify which results require analysis/interpretation – these will include the determinands requiring monitoring for compliance with the DWSNZ and qualitative information from consumers
* state the tools (eg, graphs, statistical analysis) to be used for analysis of the results and which comparisons should be made in the assessment. These should include:
* previous data
* MAVs
* guideline values in the DWSNZ
* agreed qualitative performance targets, such as the aesthetic properties of the water
* reference the section of the WSP containing the corrective actions to be taken by the person analysing/charting the data on finding a transgression
* establish a schedule for regular analysis and reporting of results. Frequency of analysis and reporting will depend on the determinand and the frequency at which samples for it are taken. For example, if samples are taken daily, results need to be reviewed daily. There should be daily review of the complaints register. When consumers experience an acute major change in water quality, they may be more likely to communicate this by phone. The staff member with responsibility for taking phone complaints needs to be alert to receiving numerous complaints of a similar nature, as this could signal the need for an urgent response, rather than one that can wait until the next scheduled review of the information
* identify who (internally and externally) is to receive the report with the results of the data review. Transgressions **must** be reported to a DWA
* provide training for the person with responsibility for analysing the data.

# Improvement plan

Inclusion of an improvement plan in a WSP is a statutory requirement. Section 69Z(2)(a)(v) of the Health Act 1956 requires that a WSP ‘set out a timetable for managing the public health risks that have been identified as being associated with the drinking-water supply’.

## Drinking-water quality management improvement plan

INCLUDE IN THE WSP

* The improvement plan, which describes what measures will be taken to address each unacceptable **residual** risk identified by section 3.1.1, and the missing operational procedures (see section 4).
* Evidence of endorsement of the improvement plan by senior leadership.

ACTION

Identify improvements needed to address risks to the drinking-water quality identified through the risk assessment process (sections 2.3.4 and 3.1.1), operational procedures (section 4), short-term evaluation of verification monitoring results (section 5.3) and long-term data evaluation (section 10.1).

Identify interim or short-term measures that the supplier will take to temporarily reduce the risk that will eventually be addressed by long-term improvements.

Prepare the improvement plan, stating for each improvement: objective, priority, actions to be taken, accountabilities and timeline.

Have the improvement plan endorsed by senior leadership.

Improvement plans should include, for each improvement:

* the objective (which risk is being addressed)
* the assigned priority
* actions to be taken to achieve the objective
* accountability (this may be a single person for minor improvements, and several people looking after various aspects for large capital improvements, although in this case there should be one person with overall accountability)
* a timeline setting out start and finish dates and, where necessary, intermediary dates
* actions that will be taken to temporarily reduce the risk that will eventually be addressed by long-term improvements
* a cost–benefit analysis for large items in the plan – this will make use of the findings of the risk assessment to express the benefit in terms of the extent to which the risk has been reduced.

An effective improvement plan requires adequate resources. This requires endorsement by the senior leadership and budget.

# Management of incidents and emergencies

When the nature of a threat is known, even if the timing of its occurrence is not, suppliers need a detailed plan to manage the event.

While some incidents or emergencies may result from a failure of a preventive measure, a distinction needs to be made between corrective actions (as discussed in section 4.4) and emergency responses. The failure of corrective actions to provide protection for consumers from hazards associated with the water supply, or the unexpected failure or overwhelming of a preventative measure, can lead to an emergency situation and require an emergency response. To help in making these distinctions, suppliers should develop criteria to guide their response.

Examples of situations requiring an emergency response are:

* accidents that increase levels of contaminants to acutely hazardous levels (eg, chemical spills in catchments, incorrect dosing of chemicals)
* equipment breakdown and mechanical failure
* prolonged power outages
* extreme weather events (eg, flash flooding, cyclones)
* natural disasters (eg, fire, earthquakes, volcanic eruption, lightning damage to electrical equipment)
* human actions (eg, serious error, sabotage, strikes).

## Incident and emergency response plans

Each possible incident or emergency that can be identified requires an *individualised* response plan, which may be included in the water supplier’s emergency plan or referred to a plan outside of the WSP (eg, a civil defence plan, pandemic plan or general business continuity plan).

INCLUDE IN THE WSP

* A response plan for each possible incident or emergency situation identified, identifying who has responsibility for preparing the plan.
* A procedure for reviewing the response to an incident or emergency to determine:

– why it was needed

– how effective the response plan was, and whether it needs to be updated

– whether the WSP needs to be updated to prevent a recurrence.

* Evidence of staff training, including in emergency practices.

ACTION

Review previous incidents and emergencies.

Identify possible incidents and emergencies for which response plans may be needed.

Assign responsibilities for preparing each of the needed plans.

Assign emergency response roles.

Assign a level of emergency to each event and identify the triggers required for activating each response plan (see examples of emergency-level descriptors in Table 8).

Prepare the necessary plans, in consultation with other agencies/stakeholders likely to be involved in the response, and ensure each agency/stakeholder is clear about who has responsibility for which actions.

Compile a list of key contacts for inclusion in each response plan.

Train staff in using the plans, including through regular emergency practices.

Ensure copies of response plans are readily accessible to operational staff who have to implement them.

Table 8: Examples of emergency level descriptors

|  |  |
| --- | --- |
| **Incident / emergency level** | **Description of level** |
| Level 5 | * Widespread outbreak of waterborne disease. * Declared disaster. * Supply unable to be maintained. * Gross exceedances of one or more chemical MAVs (eg, more than five times the MAV). |
| Level 4 | * High level of *E. coli* or any pathogen detected in the reticulation. * Failure of infrastructure resulting in the need for severe restrictions on usage to maintain continuity of supply. * Alert from district health board that its intelligence strongly suggests cases of illness in the community are drinking-water related. |
| Level 3 | * Detection of *E. coli* in the reticulation. * Failure of infrastructure which compromises the ability to supply water, indicating that short-term water restrictions may be required. * Minor exceedances of one or more chemical MAVs (ie, measured concentration is close to the MAV). * Alert from district health board that its intelligence suggests that cases of illness in the community are possibly drinking-water related. |
| Level 2 | * Failure of infrastructure or source supply, where water quality or supply is unlikely to be compromised or an alternative process is available to provide drinking-water. * Exceedance of a DWSNZ aesthetic guideline, possibly resulting in customer complaints. |
| Level 1 | * Exceedance of an operational limit, able to be managed through operational and maintenance procedures. |

Incident and emergency response planning needs to include:

* planning in advance, to ensure efficient operation of the plan by:
* planning the detail to clarify every step of the response. For example, the instruction ‘Provide an alternative source of water’ may prove difficult in an emergency unless the detail of how this might be done has been thought through in advance
* consulting with other agencies likely to be involved in the emergency response – this will help in building trust and an understanding of the operation of other agencies on which the water supplier may depend during an emergency. It is particularly important when the emergency may involve more than simply the water supply, (eg, an earthquake)
* undertaking staff training, including through regular emergency practices
* building awareness of, and integration with, government emergency response arrangements – including the Ministry of Civil Defence and Emergency Management’s response to a large-scale emergency
* pre-preparing communications such as boil water notices and ‘do not drink water’ notices, and other identified key messages
* response actions, including increased monitoring (see Table 9, which provides an example of a plan identifying actions required for responding to a Level 3 incident)
* the responsibilities and authorities of:
* internal parties
* external parties

informed by consultation with other agencies/stakeholders

* plans for emergency water sources that identify the availability of alternative sources (ideally more than one); information about the quality of the alternative sources and plans to adequately treat it; advice to be given to consumers, if the quality is known to be poor; and the contact details of other agencies potentially involved
* communication strategies and plans, including notification procedures (for internal staff, regulatory bodies, the media and the public), and the circumstances under which a boil water notice should be issued and how it should be issued (see section 7.1.1)
* mechanisms for increased health surveillance, informed by consultation with the district health board, and relevant contact details
* a plan to evaluate the response should it be activated, including through a staff debriefing to learn from the experience. The evaluation should seek answers to the following questions:
* What was the initiating cause of the problem?
* How was the problem first identified or recognised?
* What were the most critical actions required?
* What communication problems arose, and how were they addressed?
* What were the immediate and longer-term consequences?
* How well did the emergency response plan function?
* a reporting plan outlining what needs to be reported, to whom and when, including situation reports and debriefs.

Suppliers should consult public health units in preparing the incident and emergency response plan. One of the aims in drafting the plan should be to avoid key steps and the release of key communications being dependent on the availability of particular personnel.

Suppliers must review incident and emergency response plans after every major incident and at least every two years.

Table 9: Example of actions required for responding to a Level 3 incident

|  |  |  |  |
| --- | --- | --- | --- |
| **Level** | **Incident or emergency** | **Summary of actions to be taken (with documented procedure listed)** | **Position/s responsible for action/s** |
| 4 | Detection of >9 *E. coli*/100mL in reticulation | Alert manager of water (phone 027XXXXXXX). | Water quality officer |
| Report detection to DWA by phone (027XXXXXXX) (immediately by phone, written incident report as soon as practicable). | Manager, water quality |
| Determine potentially affected area [details for how to do that need to be included], isolate if possible. Consider boil water notice in discussion with the DWA. Escalate emergency further if situation worsens. | Manager, water quality |
| Resample for *E. coli* and disinfectant residual in potentially affected infrastructure. | Water quality officer |
| Undertake comprehensive investigation to determine the reason for the contamination. | Treatment plant operator and water quality officer |
| Undertake necessary corrective actions. | As appropriate |
| Upon resolution, provide written report to DWA. | Manager, water quality |
| **See Level 4 incident response protocol, pages 5–8 in Emergency Response Plan-0016.** |  |

Although it does not appear in the example, the response plan must give sufficient detail for a specific water supply to ensure that staff can undertake each of the listed steps without unnecessary loss of time.

### Communication

Communication needs during and after incidents and emergencies are of two types, as follows.

#### A. Communication required for management of the incident

##### Key requirements

* Identify internal and external parties with whom communication will be required and develop communication plans for each. The plan should:
* include a contact list of key people, agencies and businesses and their role relevant to the plan
* provide current contact details for those people.
* Share the list of contacts with those who might need to use it.
* Develop communication plans in consultation with other relevant agencies and ensure these are regularly updated (at least annually).
* Develop a reporting plan specifying what needs to be reported, to whom and when (see section 8.2).

#### B. Communication to ensure that consumers have confidence in the management of the response

##### Key requirements

* Develop communications plans for the public and the media.
* Draft notifications for target audiences (eg, boil water notices) in advance.
* Identify and train staff with the specific task of dealing directly with the public/media.
* Keep all staff informed – they are contact points with the community.
* Inform consumers when the incident has ended, expressing remorse (depending on the cause of the incident), and describing the cause and the actions taken to avoid recurrence.
* At an appropriate time after the incident, a survey of the community **could** be undertaken to establish its view of the incident and its management, to inform future responses.
* Develop a reporting plan specifying what needs to be reported, to whom and when (see section 8.2).

# Documenting and reporting

Appropriate documentation provides the foundation for the establishment and maintenance of effective drinking-water quality management systems. Consequently, the documentation of processes and procedures and the keeping of records arise in all components of a WSP. This section sets out the generic requirements for documentation, record-keeping and reporting.

## Management of documentation and records

INCLUDE IN THE WSP

* A system for managing information about all aspects of drinking-water quality management.
* A system for control of the documentation.
* A system for keeping records of all activities pertaining to the performance of drinking-water quality management.
* A system for ensuring that staff regularly read documents relevant to their work.

ACTION

Establish, or link to the water supplier’s overall document management system, a system to be used for managing all documentation associated with all aspects for drinking-water quality management (Table 10 provides a basic example of a record of each document used in the water quality management system and associated information). This should include document control.

Identify who will have responsibility for ensuring

– all procedures are documented

– documents are updated

– document versions are controlled.

Train relevant staff in record-keeping.

Establish a system for ensuring staff regularly read documents relevant to their work.

Table 10: Basic example of a record of each document used in the water quality management system and its associated information

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Information/ document** | **Format (hard copy / electronic)** | **Where stored (at WTP / on electronic system / other)** | **Position responsible / business unit** | **Date last reviewed** | **Comments** |
| Chlorine supply register | Hard copy | WTP – chemical supply file | Senior operator (operations) | 3/5/2017 |  |
| Chlorinator maintenance log | Hard copy | WTP – maintenance logs cabinet | Senior operator (operations) | 6/8/2016 |  |

Good document management requires a document control system, to ensure that current versions are in use and obsolete versions are discarded. Suppliers must assign responsibility for overall operation of the control system, but all staff are responsible to inform the controller of changes to any aspect of the system once the changes have been validated and are in use.

Documents need to be regularly reviewed (eg, six-monthly for large supplies, but less frequently for smaller supplies) and revised, if necessary, to ensure they reflect current practices. Documents should be assembled in such a way that revision is easy.

To encourage staff to refer to the documents, they need to be readily available and kept as simple as possible. Suppliers could consider requiring staff to read the documentation relevant to them every six months (for example), and to sign off that they have done so. The internal audit (see section 10.2.1) could observe staff adherence to the content of documentation.

Suppliers must train staff in proper completion of records. Records concerning the performance of drinking-water quality management must be easily retrievable to allow for review. Suppliers must store records suitably to protect them from damage. Suppliers must implement a plan for frequent back-up of electronic records, and keep two copies of each file: one off-site.

A supervisor must regularly review records of the performance of each preventive measure, and date and sign them on review (see sections 10.1 and 10.2).

## Reporting

Various sections of the WSP require reporting (internal and external). Appropriate sections should set out requirements for reports and procedures for preparing and issuing them, or make reference to one section of the WSP that records all reporting requirements.

INCLUDE IN THE WSP

* The requirements for internal and external reports about the activities and performance of the drinking-water supply.
* The procedures for generating and disseminating internal and external reports about the activities and performance of the drinking-water supply.

ACTION

Identify all reports, internal and external, that need to be generated as part of the operation and management of the drinking-water quality supply.

Specify what the reporting requirements for each are.

Establish the procedure for generating and disseminating each report.

Specification of the requirements for an individual report needs to include:

* the report’s purpose (eg, for information, for decision or approval, a legislative requirement)
* the nature of the information the report is to contain and the frequency at which the report is to be prepared
* who has responsibility for the report’s preparation
* the report’s recipient and their contact information (especially if this is external)
* the report’s primary audience: this (with the purpose) will determine the nature of the material it contains, the way it is written and possibly the structure
* the means by which the report will be disseminated (eg, post, email etc) – consultation with stakeholders will help determine this.

### Internal reporting

Internal reporting supports decision-making on drinking-water quality management. They will generally concern:

* summaries of monitoring data
* performance evaluation
* significant operational problems that occurred during the reporting period
* results of audit and management reviews.

### External reporting

External reports aim to provide transparency of drinking-water quality management. The stakeholder audience for external reports will include regulatory bodies, consumers and other stakeholders.

Water suppliers serving more than 100 people must be able to provide DWAs or designated officers with records of compliance information.

### Annual reports

In addition to regulatory external reporting obligations, suppliers should consider producing an annual report for consumers, regulatory authorities and stakeholders that:

* summarises drinking-water quality performance against the Health Act 1956 and the DWSNZ
* identifies water quality trends and problems
* summarises system failures and the steps taken to resolve them and prevent their recurrence
* specifies accountabilities, statutory or legislative requirements and minimum reporting requirements.

An annual report should contain sufficient information to enable consumers to make informed judgments about the quality of their drinking-water and provide a basis for discussions about the priorities to be given to improving drinking-water quality. Suppliers can use annual reports to explicitly seek feedback from consumers.

# Investigations

## Investigative studies

Other sections (see sections 2.3.4, 4.4, 7.1) of the WSP include the need for an investigation when there is evidence of unsatisfactory performance of some aspect of the drinking-water supply. The ‘Investigations’ section of the WSP guides staff in how to conduct these investigations.

INCLUDE IN THE WSP

* The procedure for activating, planning and carrying out investigations of instances of unsatisfactory performance of the drinking-water supply.

ACTION

Identify situations that may result in the need for an investigation.

Establish a procedure for activating, planning and carrying out an investigation, depending on the purpose of the individual investigation.

For each type of situation requiring an investigation, the procedure should specify:

* the criteria that determine when an investigation is needed (eg, the detection of *E. coli* during water quality monitoring)
* who has responsibility for the investigation
* the steps to be taken in the investigation, to the extent possible in planning ahead
* the actions to be taken at the completion of the investigation
* who is to receive the report containing the investigation’s findings.

In addition to problem-targeted investigations, suppliers could also consider including in the WSP investigations not targeted at a specific problem. Such investigations could be more strategic in nature, aiming to gather information about the supply that allows the supplier to maintain and improve drinking-water quality. These investigations could aim to provide:

* improved understanding of source water quality and its variability
* improved assessment of the effectiveness of treatment processes (or preventive measures more generally) and factors influencing treatment effectiveness
* improved understanding of how contaminants enter the water supply post‑treatment
* improvement in the aesthetic properties of the water
* information to assist with long-term planning, such as new technologies or modelling of water availability and demand.

## Validation of equipment, processes and practice

Validation collects evidence to establish that preventive measures (usually treatment processes) are capable of performing at the level expected. Suppliers must regularly revalidate treatment processes to ensure their effective operation and adequate control, especially if a process or component has been physically changed or an operational setting changed. Operational monitoring (see section 4.2) provides the on-going checks that the performance shown by validation is being maintained.

Verification, on the other hand (see section 5), considers the quality of the water resulting from the operation of the system as a whole, and is a check that the WSP is performing as required (see section 5).

INCLUDE IN THE WSP

* The procedures for routine revalidation of the performance of equipment, processes and practices associated with processes.

ACTION

Identify equipment, processes and practices within the drinking-water supply that require validation.

Prepare a schedule for validations.

Identify who has responsibility for initial and regularly scheduled validations.

Establish what has to be measured for each validation, and the values that distinguish satisfactory from unsatisfactory performance.

Establish what steps are required if the validation shows unsatisfactory performance.

Identify who is to receive the results of the validations.

With respect to validation, the WSP must record, or reference a manual that records:

* what is to be validated:
* equipment – prevalidation (by the manufacturer) is acceptable provided the validation was appropriate for the water quality of the supply
* processes – encompassing:
* equipment and the procedures used to operate the equipment
* control systems and target criteria and critical limits – to determine whether they are set at levels that ensure continuously safe water is produced
* operational determinands (eg, filter run times, filter ripening periods) – bench-scale or pilot-scale experiments may be required to establish suitable operational determinands
* practices (eg, water sampling, water quality field tests)
* determinands to be monitored for each validation
* the frequency of validation, or when each process is to be validated:
* during or just after commissioning of a new/replacement process, but before it is brought online to supply consumers
* at a frequency that matches the possible causes of variation in performance, such as seasonal effects
* who has responsibility for the validation
* to whom the results of the validation are to be reported
* actions to be taken in the event of the validation yielding unsatisfactory results
* the details of each validation procedure.

# Oversight review and continual improvement

## Long-term evaluation of results

Long-term evaluation focuses on extended time series operational, investigative and verification monitoring results. These results will in some way be related to preventive measures.

INCLUDE IN THE WSP

* The procedure for undertaking the long-term evaluation of results, including frequency of evaluation and staff responsibilities.

ACTION

Identify what questions the evaluation is addressing.

Identify who is responsible for the long-term evaluation of monitoring and inspection results.

Identify which preventive measures and data are to be included in the evaluation.

Determine the procedure for the evaluation (to guide those undertaking it).

Establish how frequently long-term evaluations are required.

Identify who (internally and externally) is to receive the evaluation report.

With respect to the long-term evaluation of results, the WSP should:

* state what questions the evaluation is addressing
* state which preventive measures and data need to be included in the evaluation to answer these questions – this can include numerical and non-numerical information about the performance of the selected preventive measures
* state the types of data analysis methods to be used in the evaluation – the reviewer should not limit themselves to these methods if questions arising from the data analysis suggest that analysis of a different type would also be helpful
* summarise records of investigations undertaken at the time, when the requirements of the DWSNZ, target criteria or critical limits were not met
* identify who has responsibility for undertaking the evaluation
* identify who (internally and externally) is to receive the results of the evaluation (see section 8.2) – this person will also inform appropriate people, if further action is required
* state the frequency at which the evaluation should be undertaken (annually or possibly less frequently)
* identify where the evaluation report is to be kept.

## Audit of drinking-water quality management

Auditing is the systematic evaluation of activities and processes to confirm that objectives are being met. Audits can be internal or external.

INCLUDE IN THE WSP

* The procedure for undertaking an internal audit, specifying:

– who is responsible for undertaking the audit

– scheduling of audits

– which components of the drinking-water quality management system the audit will include

– what the audit report is to cover

– who is to receive the audit report.

* The process for commissioning an external audit (if relevant), including how frequently it should occur, its purpose, which aspects of the drinking-water quality management system it would cover and communication of the report.

ACTION

Identify the questions the evaluation is addressing.

Identify who is responsible for undertaking the audit (internally and externally, if relevant).

Identify what is to be audited, and, in the case of external audit, the audit’s purpose.

Establish a frequency/schedule for audits.

Determine a procedure for undertaking the audit and what it is to cover.

Identify who will receive the audit report.

### Internal audits

Suppliers must undertake internal auditing to ensure that the drinking-water quality management system is properly implemented and effective in ensuring that the drinking-water is of satisfactory quality. Internal audits are intended for internal use, and are not reported externally.

An internal audit should be comprehensive, although it can be carried out over a period of time – usually 12 months. The audit should aim to determine whether the WSP is being implemented correctly, and, where it is not, the reasons for non-compliance and the impact on ensuring safe and secure drinking-water.

For internal audits, the WSP must identify:

* the questions the audit is addressing
* who has responsibility for the audit
* the components of the system to be included in the audit; for example:
* the management system (ie, the overall system tasked with ensuring the production of safe water)
* operational procedures
* monitoring/inspection programmes, records and use of corrective actions (the records should provide an indication of how successful the WSP has been)
* the effectiveness of incident and emergency responses
* staff training and competencies
* delivery of the improvement plan
* what the audit is required to do
* the frequency and schedule of audits of the various components of the system
* who is to receive the audit report.

### External audits

Suppliers should also consider external auditing because it is independent of the water supplier/water supply organisation. External release of an external audit report has the benefits of improving consumer confidence in and the credibility of the water supplier. External audits should focus on confirming implementation of the WSP, the achievement of its purpose (ie, provision of continuously safe drinking-water) and the results of internal audits.

Where suppliers plan external audits, the WSP should:

* identify the purpose(s) of the audit, for the auditor
* identify which external agency will undertake the audit
* identify who the auditor will report to
* state which components within the system the audit will cover; for example:
* the water supply management system
* operational activities
* drinking-water quality performance
* the effectiveness of incident and emergency responses, or other specific aspects of drinking-water quality management
* delivery of the improvement plan
* adequacy of resources to deliver on the WSP
* identify how frequently the audit of each of these components should be undertaken
* identify how the report will be communicated to stakeholders, and who has responsibility for this communication.

## Review by senior leadership

Senior leadership should review, at least annually, consolidated information about overall system performance.

INCLUDE IN THE WSP

* The frequency of review of the drinking-water quality management system by senior leadership.
* The content of the consolidated information report.
* A list of information sources to be used as the basis for the review.
* Who has responsibility for preparing the consolidated information report for senior leadership to review.
* Who, in senior leadership, has responsibility for documenting the findings of the review.

ACTION

Assign responsibility for preparing the consolidated information report for senior leadership to review.

In consultation with senior leadership:

– identify the purpose of the senior leadership review

– determine the frequency and scheduling of the review

– agree on the information sources that will inform the review

– identify who, within the senior leadership, will undertake and document the review findings

– determine the target audience for the review’s report, and the procedure for its communication.

As the basis of its review, the senior leadership should consider the findings of, and actions taken as a result of:

* previous management reviews
* audit reports (internal and external)
* long-term evaluation reports
* external reports received from regulators, such as the district health board and other stakeholders
* correspondence from stakeholders, such as DWAs, and including consumers, expressing concerns about water quality
* the suitability of the drinking-water quality policy, objectives and preventive strategies with regard to:
* changes to legislation, expectations and requirements
* changes in the supplier’s activities
* advances in science and technology
* outcomes of drinking-water quality incidents and emergencies
* reporting and communication.

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Appendix 1: Example template for recording source, treatment plant and distribution zone characteristics

| **Component** | | **Detail** | | | |
| --- | --- | --- | --- | --- | --- |
| **Sources** | | | | | |
| Source | Source name |  | | | |
| Unique DW-Online identification code |  | | | |
| Type | Example: dam, weir, river intake, bore field | | | |
| Percentage of supply |  | | | |
| Reliability | Example: it tends to run dry; it is unusable in wet weather | | | |
| Water quality issues | Example: blue-green algae, pesticides, fluoride | | | |
| Source infrastructure | Type (pumped/gravity/ equipped bore/etc) |  | | | |
| Description | Example: intake location, bore depth, variable off-take | | | |
| Does water from this this source undergo disinfection before reticulation? | Yes /No  If **No**, provide the reason why it is not disinfected. For example, ‘the bore water is classified as secure’. | | | | |
| Other sources | Repeat as above | | | | |
| **Treatment plants** | | | | | |
| Treatment plant | Plant name |  | | | |
| Unique DW-Online identification code |  | | | |
| Treatment processes (extend table as required) | Estimated log reduction value for each step | | | |
| Bacteria | Viruses | Protozoa | Chemical (specify) |
| Process 1: |  |  |  |  |
| Process 2: |  |  |  |  |
| Process 3: |  |  |  |  |
| Process 4: |  |  |  |  |
| Process 5: |  |  |  |  |
| Process 6: |  |  |  |  |
| Notes on any of the above processes: | Example: activated carbon is only used during periods of blue-green algae outbreaks in the storage | | | |
| Design capacity | ML/d | | | |
| Daily flow range | ML/d | | | |
| Current loading (percentage of maximum operating limit) |  | | | |
| Chemicals added |  | | | |
| Standby chemical dosing facilities (Y/N) |  | | | |
| Water sourced from and percentage (extend table as required) | Source ID code | | Percentage | |
|  | |  | |
|  | |  | |
|  | |  | |
| Percentage of average day demand provided by this treatment plant |  | | | |
| Percentage of distribution zone area supplied |  | | | |
| Bypasses/variations |  | | | |
| Other treatment plants | Repeat as above |  | | | |
| Disinfection not at the treatment plant | Location | Example: chlorine booster in X Road | | | |
| Type |  | | | |
| Dose rate |  | | | |
| Target residual levels |  | | | |
| Duty/standby |  | | | |
| Dosing arrangements | Example: fixed, flow paced, residual analyser | | | |
| Alarms | Example: failure, low/ high residual | | | |
| Auto shut-off arrangements |  | | | |
| **Distribution zones** | | | | | |
| Zone | Zone name |  | | | |
| Unique DW-Online identification code |  | | | |
| Pipe material |  | | | |
| Age range |  | | | |
| Approximate percentage of total length each pipe material contributes |  | | | |
| Areas where potential long detention periods could be expected |  | | | |
| Areas where low water pressure could be expected during peak or other demand periods |  | | | |
| Reservoirs | Name |  | | | |
| Above or below ground (Y/N) |  | | | |
| Capacity (ML) |  | | | |
| Roofed (Y/N) |  | | | |
| Vermin-proof (Y/N) |  | | | |
| Run-off directed off roof (Y/N) |  | | | |
| Other reservoirs | Repeat as above |  | | | |
| Water quality responsibility changes | Upstream location |  | | | |
| Downstream location |  | | | |
| Other distribution zones | Repeat as above | | | | |

Appendix 2: World Health Organization table of log reduction values for bacteria, viruses and protozoa

The log reduction value (LRV) data in the table below are from the fourth edition of the World Health Organization’s *Guidelines for* *Drinking-water Quality* (2011).

| **Treatment process** | **Enteric pathogen group** | **Minimum removal (LRV)** | **Maximum removal (LRV)** | **Notes** |
| --- | --- | --- | --- | --- |
| **Pretreatment** | | | | |
| Roughing filters | Bacteria | 0.2 | 2.3 | Depends on filter medium, coagulant |
| Storage reservoirs | Bacteria | 0.7 | 2.2 | Residence time >40 days |
| Protozoa | 1.4 | 2.3 | Residence time 160 days |
| Bank filtration | Viruses | >2.1 | 8.3 | Depends on travel distance, soil type, pumping rate, pH, ionic strength |
| Bacteria | 2 | >6 |  |
| Protozoa | >1 | >2 |  |
| **Coagulation, flocculation and sedimentation** | | | | |
| Conventional clarification | Viruses | 0.1 | 3.4 | Depends on coagulation conditions |
| Bacteria | 0.2 | 2 |  |
| Protozoa | 1 | 2 |  |
| High-rate clarification | Protozoa | 0.2 | 2.8 | Depends on use of appropriate blanket polymer |
| Dissolved air flotation | Protozoa | 0.6 | 2.6 | Depends on coagulant dose |
| Lime softening | Viruses | 2 | 4 | Depends on pH and settling time |
| Bacteria | 1 | 4 |  |
| Protozoa | 0 | 2 |  |
| **Filtration** | | | | |
| Granular high-rate filtration | Viruses | 0 | 3.5 | Depends on filter media and coagulation pretreatment; filtered water turbidity of ≤0.3 NTU in 95% of samples (and none to exceed 1 NTU) associated with 1–2 log reduction of viruses and 3 log reduction of *Cryptosporidium* |
| Bacteria | 0.2 | 4.4 |
| Protozoa | 0.4 | 3.3 |
| Slow sand filtration | Viruses | 0.25 | 4 | Depends on presence of schmutzdecke, grain size, flow rate, operating conditions (mainly temperature, pH); filtered water turbidity of ≤1NTU in 95% of samples (and none to exceed 5 NTU) associated with 1–2 log reduction of viruses and 2.5–3 log reduction of *Cryptosporidium* |
| Bacteria | 2 | 6 |
| Protozoa | 0.3 | >5 |
| Precoat filtration | Viruses | 1 | 1.7 | If filter cake is present |
| Bacteria | 0.2 | 2.3 | Depends on chemical pretreatment |
| Protozoa | 3 | 6.7 | Depends on media grade and filtration rate |
| Membrane filtration: microfiltration, ultrafiltration, nanofiltration, reverse osmosis | Viruses | <1 | >6.5 | Varies with membrane pore size (microfilters, ultrafilters, nanofilters and reverse osmosis filters), integrity of filter medium and filter seals and resistance to chemical and biological (‘grow-through’) degradation; maximum reductions associated with filtered water turbidity of <0.1 NTU |
| Bacteria | 1 | >7 |
| Protozoa | 2.3 | >7 |

| **Treatment process** | **Enteric pathogen group** | **Reduction** | **Notes** |
| --- | --- | --- | --- |
| **Primary disinfection** | | | |
| Chlorine | Viruses | 2 (Ct99 2–30 min·mg/l; 0–10 °C; pH 7–9) | Free chlorine × contact time predicts efficacy; not effective against *Cryptosporidium* oocysts. Turbidity and chlorine-demanding solutes inhibit this process; hence, turbidity should be kept below 1 NTU to support effective disinfection. Where this is not practical, turbidities should be kept below 5 NTU with higher chlorine doses or contact times. In addition to initial disinfection, the benefits of maintaining free chlorine residuals throughout distribution systems at or above 0.2 mg/l should be considered |
| Bacteria | 2 (Ct99 0.04–0.08 min·mg/l; 5 °C; pH 6–7) |
| Protozoa | 2 (Ct99 25–245 min·mg/l; 0–25 °C; pH 7–8; mainly Giardia) |
| Chlorine dioxide | Viruses | 2 (Ct99 2–30 min·mg/l; 0–10 °C; pH 7–9) |  |
| Bacteria | 2 (Ct99 0.02–0.3 min·mg/l; 15–25 °C; pH 6–7) |
| Protozoa | 2 (Ct99 100 min·mg/l) |
| Ozone | Viruses | 2 (Ct99 0.006–0.2 min·mg/l) | Viruses are generally more resistant than bacteria |
| Bacteria | 2 (Ct99 0.02 min·mg/l) |  |
| Protozoa | 2 (Ct99 0.5–40 min·mg/l) | Depends on temperature; *Cryptosporidium* varies widely |
| UV | Viruses | 4 (7–186 mJ/cm2) | Effectiveness of disinfection depends on delivered fluence (dose), which varies with intensity, exposure time and UV wavelength. Excessive turbidity and certain dissolved species inhibit this process; hence, turbidity should be kept below 1 NTU to support effective disinfection. Where this is not practical, turbidities should be kept below 5 NTU with higher fluences |
| Bacteria | 4 (0.65–230 mJ/cm2) |
| Protozoa | 4 (<1–60 mJ/cm2) |

Appendix 3: Preparation of risk assessment tables

#### Introduction

This appendix offers an approach to preparing risk assessment tables to help in the management of the public health risk (referred to as ‘risk’ here) arising from the operation of a drinking-water supply. It provides information on risk assessment table construction, a description of the principles followed in the construction of a risk assessment table and examples to illustrate the approach.

Suppliers may take other approaches, provided they can be shown to adequately evaluate the risk.

#### What is the purpose of preparing a risk assessment table?

The primary purpose of a risk assessment table is to determine which combination of hazardous events/hazards are of greatest risk and need to be well managed through existing controls or improvements.

#### What risk is being assessed?

The approach to assessing risk explained in this appendix determines the risk arising from a particular hazardous event (ie, from a particular cause), which results in a particular hazard or group of hazards entering the water supply, or the unavailability of water.

#### What are the features of a risk assessment table?

The *New Zealand Drinking-water Safety Plan Framework* notes that risk assessment of a water supply should:

* assess both the maximum risk (in the absence of preventive measures) and the residual risk (taking account of preventive measures)
* identify all hazards and hazardous events, even if they are presently managed
* provide a rationale for deciding on the level of residual risk that is acceptable
* identify the degree of uncertainty in the risk assessment, as it may influence the selection of preventive measures.

#### Preventive measures

The Framework defines preventive measures as:

… those actions, activities and processes used to prevent hazards from reaching the consumer or reduce them to acceptable levels.

Thus, preventive measures can be classified as being of two types.

##### Type A: Preventive measures aimed at reducing the likelihood of a hazardous event occurring

These measures prevent hazards reaching the consumer, because they disrupt the pathway by which the hazard reaches the consumer. They are not designed to reduce the consequences of the hazard reaching the consumer.

Suppliers may put more than one Type A preventive measure in place to reduce the likelihood of a hazardous event occurring.

##### Type B:preventive measures aimed at reducing hazards to acceptable levels.

These measures reduce the concentrations of hazards in the water, and therefore the consequences to the consumer of the hazardous event occurring. Generally, they are treatment processes (eg, chlorination), and are not designed to influence the likelihood of a hazardous event.

Some hazardous events may cause Type B preventive measures to fail (ie, involve treatment failure). Consequently, Type B preventive measures may themselves entail Type A preventive measures, to ensure their optimum performance.

Type B preventive measures can act as preventive measures for hazardous event/hazard combinations associated with another particular supply element. For example, by chlorinating a supply, a supplier can control the risk arising from bacteria and viruses entering the supply because of contamination of an aquifer.

#### Principles for constructing a risk assessment table

Tables [A1](#TableA1) and [A2](#TableA2) below provide examples of risk assessment tables. This section sets out construction principles.

Type A preventive measures can result in a **modified likelihood** for the residual risk, but do not change consequence.

Type B preventive measures can result in a **modified consequence** for the residual risk, but do not change likelihood.

The **overall modified consequence** is determined from the least severe of the individual modified consequences.

The **overall** **modified likelihood** is determined from the lowest of the individual modified likelihoods.

Suppliers should consider ‘catastrophic’ the **default consequence descriptor for microbiological hazards**, unless a preventive measure mitigates their effect, or the water supplier can justify a lesser descriptor.

The **usual consequence descriptor for chemical hazards**, unless a preventive measure mitigates their effect or there is ample monitoring data to show otherwise, is ‘moderate’. Based on Table 2, this is the descriptor for repeated exceedances of the MAV. Where an elevated concentration of a chemical hazard may lead to acute harm for a sub-group in the population, as in the case of nitrate affecting infants, the descriptor is better set to ‘major’ (see Table 2).

#### Examples

[Table A1](#TableA1) provides an example of a fragment of a risk assessment table for a hazardous event affecting a well or bore source. [Table A2](#TableA2) provides an example of a fragment of a risk assessment table for a hazardous event affecting supply chlorination.

In both tables, the maximum and residual risk ‘calculations’ are included in the one table. Table columns are identified by letter for ease of reference.

##### Explanation of columns in [Table A1](#TableA1)

Column A: The supply element is the physical or operational component of the water supply. The identification code refers to the relevantdocument from Water Safety Plan Guides for Water Supplies. For the particular supply element, the Guide lists hazardous events that may occur, their possible causes and possible preventive measures.

Column B: The hazardous event and its cause are identified here. The same event may have several causes. In the example, the cause is written into the hazardous event column, but the table could be formatted so that the event and the cause are two separate columns, as they are in the Guides.

Column C: The hazardous event may introduce several types of **hazard into the water**. The words ‘reasonably expected’, italicised in the column heading, are important. Four hazards are identified in this table: bacteria, viruses, protozoa and nitrate. Should the hazardous event lead to contamination of the water by animal waste, these hazards are all reasonable possibilities. Pesticides are another class of hazard that could be used on farms in the area of bore. If this were the case, suppliers would need to consider pesticides as ‘reasonably expected’ and include them in the table. For the purposes of this example, pesticides are not used in the area and consequently are not ‘reasonably expected’ to be associated with the event.

Bacteria and viruses are considered together because the preventive measures considered in the example that will manage one will manage the other. Protozoa are considered separately because chlorination, one of the preventive measures, will not inactivate this hazard. Suppliers would also have to consider bacteria and viruses separately should a preventive measure be capable of reducing the risk of one but not the other.

Column D: The consequence descriptor (see Table 2) reflects the severity of the **public health consequences of the particular hazard being in the water at a concentration high enough to cause illness**. This is consistent with the **maximum risk** being assessed, and takes no account of the likelihood of the hazardous event or any preventive measures that might be in place. The nature of the hazard will determine the consequence descriptor used. The consequences of microbiological contamination are considered to be worse than those of chemical contaminants. The recommended default consequence descriptor for microbiological hazard is ‘catastrophic’. This is consistent with the requirement that the risk assessment considers conditions that are most challenging when the level of risk is estimated, for both the maximum and residual risk assessments (see section 2.3.2).

For chemical hazards the default descriptor is ‘moderate’ (ie, unless there is good reason to use another descriptor, ‘moderate’ should be used. This descriptor fits with the description of a ‘moderate’ consequence in Table 2 (‘… repeated breach of MAV’). In this example, the consequence descriptor for nitrate is ‘major’ because of nitrate’s potential to have a major impact on a sub-population (bottle-fed infants). In the second example, the ‘moderate’ default is used for disinfection by-products.

Column E: This is the **likelihood of the hazardous event occurring** from a **specific cause** and introducing a **specific hazard** into the water. Different farming practices or different aquifer depths may affect this likelihood. If stock are grazed in the recharge zone of a shallow aquifer, then, in a worst-case situation, both microorganisms and nitrate are highly likely to arise in the water.

Column F: The **maximum risk** is determined by using the descriptors for consequence and likelihood listed in Columns D and E respectively, together with the risk matrix of Table 3.

That completes the portion of the risk assessment table necessary to estimate the maximum risk. The next section (columns G to L) determines the residual risk.

Column G: Three **preventive measures** are identified in the example, abbreviated to PM1, PM2 and PM3. In determining the residual risk, the distinction between Type A and Type B preventive measures is important. In the example, PM1 and PM2 are measures designed to reduce the likelihood of the hazardous event (contamination of the aquifer) by a specific cause (farm practices) (ie, they are **Type A preventive measures**). PM3 (chlorination) cannot reduce the likelihood of the hazardous event; it controls the concentration of hazards that have entered the water supply because of the event. Therefore, it modifies the consequences of the event, making it a **Type B preventive measure**. All three preventive measures work together to reduce the risk caused by the hazardous event.

Column H: For **each** preventive measure this column identifies the degree to which it modifies the consequence of the hazardous event. Because PM1 and PM2 are Type A preventive measures, they do not change the consequence from that identified in Column D; PM3 is designed to modify consequence. As with the other preventive measures, this assumes that the chlorination is working optimally and that as a result the modified consequence is ‘insignificant’. As chlorination is a separate supply element, [Table A2](#TableA2) separately assesses the risk associated with it not functioning properly. For the other hazards (protozoa and nitrate), the consequences remain the same for each of the preventive measures. PM1 and PM2 are, again, unable to modify the consequences, and PM3, although designed to modify consequence, is ineffective in reducing either protozoa or nitrate concentrations.

Column I: To estimate the residual risk, an idea of the overall modified consequence is needed; that is, all three consequences need to be considered. Logic suggests that the descriptor to be placed in the overall modified consequence column is the **least of the individual consequences for the specific hazard in Column H**, because, if all preventive measures are acting together, the concentration of the hazard will be determined by the measure best able to reduce the concentration.

The same logic applies to the overall consequence descriptor for protozoa and nitrate.

Column J: The ability of the three preventive measures to modify the likelihood of the event is now controlled by the Type A preventive measures (PM1 and PM2). For the example, the effectiveness of PM1 and PM2 in modifying the likelihood of the event are different; this is recorded in Column J. PM3 (chlorine) cannot affect the likelihood of the event, and therefore its modified likelihood remains as it was in the absence of preventive measures (see Column E): ‘almost certain’. The likelihood descriptors for all three hazard groups (bacteria/viruses, protozoa and nitrate) are the same because they are to do with the event rather than the nature of the hazard.

Column K: As with consequence, an overall modified likelihood is required for the residual risk estimation. Again, the preventive measure that is best able to reduce the likelihood of the hazardous event will control the overall modified consequence, because its efficacy is not reduced by the efficacies of the less effective measures. Therefore, the overall modified likelihood across all the hazard groups is ‘unlikely’.

Column L: The residual risk is determined using the overall modified consequence from Column I, the overall modified likelihood from Column K and the risk assessment matrix in Table 3.

The residual risk descriptors in Column L are what might be expected. In a chlorinated system, the bacteria and viruses are controlled by chlorination, while neither the protozoa nor nitrate is controlled. Of the two, the residual risk is greater for protozoa than nitrate, because the health consequences of microbiological hazards in the water are considered to be intrinsically more severe.

The example shows the importance of multiple barriers. Although the chlorine is key to keeping the overall modified consequences of the bacteria/virus hazard ‘low’, without the likelihood being reduced by PM1, the overall risk could be as high as ‘medium’. There is a focus placed on chlorination as a possible CCP, but the importance of other barriers must not be forgotten.

That completes the portion of the risk assessment table necessary to estimate the residual risk. The next section (Columns M to P) records the acceptability of the risk, the priority it should receive for management, the level of uncertainty associated with the risk estimate and comments providing the rationale for the level of uncertainty assigned.

Column M: The supplier needs to have determined and justified what level of residual risk is acceptable. The supplier may consider the level of risk classified as unacceptable to be different for microorganisms and chemicals because of the great difference in timescale over which each type of hazard creates adverse health effects: for microorganisms, exposure to a glass full of water may be sufficient to cause illness, while for chemicals decades of exposure may be required (assuming the contamination is not acute). In this example, a risk above ‘low’ is considered unacceptable for microorganisms, while anything above ‘medium’ is considered unacceptable for chemicals.

Column N records the priority levels that suppliers need to give to the particular hazardous event/cause combination. In this example, the level of risk associated with protozoa from this event is greater than that for nitrate. Consequently, introducing further preventive measures to reduce the risk associated with the hazardous event from protozoa should take priority over that from nitrate. Further examination of the likelihood and consequence descriptors for each of the **individual** preventive measures may also guide suppliers steps towards improvement. In this example, the risk associated with protozoa is unlikely to be satisfactorily managed without the introduction of a Type B preventive measure targeted at protozoa inactivation or removal. Steps to reduce the likelihood of the hazardous event, such as improving PM1 or introducing an additional preventive measure, would also help to reduce the residual risk level.

Column O: This column records the level of uncertainty in the residual risk. This a separate evaluation: it is an estimate independent of the other values recorded in the table except for Column P, which records the basis for the uncertainty estimate. The uncertainty value is another consideration, in addition to the risk level, in reaching decisions about improvement priorities.

Column P: This column records the basis for the level of uncertainty in the risk assessment.

##### [Table A2](#TableA2)

[Table A2](#TableA2) is a fragment of an example risk assessment table. It is constructed following the same principles as [Table A1](#TableA1).

There are three aspects to note.

The difference in the risk assessment table for the chlorination water supply element is that there are no Type B preventive measures. All preventive measures are Type A, designed to reduce the likelihood of a hazardous event that may affect the satisfactory operation of the chlorination system.

Because the preventive measures for a Type B preventive measure (like chlorination) are Type A, only the likelihood of the hazardous event occurring can be modified by the preventive measures. The consequence descriptor for microbiological hazards will always be ‘catastrophic’. Table 3 shows that no matter how unlikely a hazardous event affecting chlorine is, the best risk level that can be achieved is ‘medium’. In other words, because of the severity of the consequences of the chlorine failing, even if such an event occurs rarely, the associated risk can never be low.

Disinfection by-products (DBPs) can arise as a result of the use of chlorine (or other chemical disinfectants). Because chlorine must be present in the water to form DBPs, the absence of chlorine because of a failure of the dosing system, for example, will reduce the exposure of consumers to chlorine, and therefore the chemical risk.

Preventive measures to manage the microbiological risk will reduce the likelihood of the hazardous event (low chlorine concentration) occurring. However, in doing so, they increase the likelihood of DBP formation occurring. Consequently, if the likelihood of there being a low chlorine concentration is ‘rare’, the likelihood of DBP formation is ‘almost certain’. This likelihood in combination with the modified consequence of ‘moderate’ leads to the residual risk categorisation as ‘high’.

**The fact that the risk arising from DBPs is higher when the chlorination system is operating properly should not be taken as an indication that a measure for managing the DBP risk is to cut or reduce the chlorine dose. Protection against microorganisms must never be compromised to reduce DBP formation.**

Table A1: Example fragment of a risk assessment table for a hazardous event affecting a groundwater supply element (well/bore)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | | **Maximum risk** | | | **Residual risk** | | | | | |  | | | |
| **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** | **K** | **L** | **M** | **N** | **O** | **P** |
| **Supply element** | **Hazardous event** | **Hazards reasonably expectedto be associated with hazardous event** | **Consequence of the hazardous event** | **Likelihood of hazardous event occurring** | **Maximum (unmitigated) risk (D x E)** | **Preventive measures** | **Modified consequence of hazardous event** | **Overall modified consequence** | **Modified likelihood of hazardous event occurring** | **Overall modified likelihood** | **Residual (mitigated) risk (I x K)** | **Risk acceptability** | **Priority** | **Uncertainty** | **Comment** |
| P1.3 Ground-waters -– wells/ bores | Contamination of the aquifer, caused by farming practices | Bacteria/ viruses | Catastrophic | Almost certain | Extreme | PM1 Restrict activities in aquifer recharge zone and near the bore head | Catastrophic | Insignificant | Unlikely | Unlikely | Low | Acceptable |  | Certain | Based on weekly indicator monitoring for 5 years, including seasonal data |
| PM2 Gather information about the vulnerability of the aquifer before undertaking development | Catastrophic | Likely |
| PM3 Chlorination | Insignificant | Almost certain |
| Protozoa | Catastrophic | Almost certain | Extreme | PM1 | Catastrophic | Catastrophic | Unlikely | Unlikely | High | Unacceptable | 1 | Estimate | No protozoa monitoring data. Chlorine known to be ineffective against protozoa |
| PM2 | Catastrophic | Likely |
| PM3 | Catastrophic | Almost certain |
| Nitrate | Major | Almost certain | Extreme | PM1 | Major | Major | Unlikely | Unlikely | Medium | Acceptable | 2 | Confident | Based on monthly nitrate for 5 years including seasonal data |
| PM2 | Major | Likely |
| PM3 | Major | Almost certain |

Table A2: Example fragment of a risk assessment table for a hazardous event affecting a treatment process (chlorination)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Assessment of risk** | | | **Maximum risk** | | | **Residual risk** | | | | | |  | | | |
| **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** | **K** | **L** | **M** | **N** | **O** | **P** |
| **Supply element** | **Hazardous event** | **Hazards associated with hazardous event** | **Consequence of the hazardous event** | **Likelihood of hazardous event occurring** | **Maximum (unmitigated) risk (D x E)** | **Preventive measures** | **Modified consequence of hazardous event** | **Overall modified consequence** | **Modified likelihood of hazardous event occurring** | **Overall modified likelihood** | **Residual (mitigated) risk (I x K)** | **Risk acceptability** | **Priority** | **Uncertainty** | **Comment** |
| P7.1 Chlorination | Chlorine concentration too low caused by supply running out | Bacteria/ viruses | Catastrophic | Possible | High | PM1 Place alarm on chlorine supply to indicate supply is close to exhaustion | Catastrophic | Catastrophic | Rare | Rare | Medium | Unacceptable | 1 | Certain | Based on weekly indicator monitoring for 5 years, including seasonal data |
| PM2 Maintain records of chlorine use to provide guide to length of time the supply is likely to last | Catastrophic | Likely |
| Protozoa | N/A – chlorine is not a control for protozoa (protozoa could be omitted from the table) | | | | | | | | | | |  |  |
| Disinfection by-products | Insignificant | Possible | Low | PM1 | Moderate | Moderate | Almost certain1 | Almost certain | High | Unacceptable | 2 | Estimate | Too few data collected when chlorine supply exhausted |
| PM2 | Moderate | Unlikely1 |

Appendix 4: Catchment land use hazards table

The table in this appendix identifies, for each activity within a particular land-use category, the **possible** chemical determinands that may arise from the activity. Not every activity matching the description will necessarily give rise to the full list of determinands. Only determinands for which MAVs exist are listed.

A hazard source in a catchment only presents a threat to the safety of the water supply if there is a pathway by which it can enter the supply upstream or up-gradient of the point of abstraction. When considering what pathways may exist, for groundwater sources suppliers need to take account of bores nearby that may not have secure bore heads, and abandoned wells or bores that remain open and unsealed. Both situations may allow contaminants into the supply aquifer. Contaminant transport pathways may be intermittent, being active under some conditions and not others. Rain events can lead to a transmission pathway being intermittently active.

When identifying catchment hazards, suppliers need to investigate historical activities and associated hazards. The determinands listed for each activity includes those that might arise from activity today and those that might arise from the activity in the past.

Where reasonably possible, the table identifies individual determinands that may arise from the listed activity. In some instances, it is not possible to provide guidance on the specific determinand (eg, pesticides). The availability of multi-determinand chemical screens may assist where a range of unknown determinands in the water needs to be checked. For specific situations, water suppliers should try to discover which determinands are potential contaminants, to allow the appropriate pesticide screen to be selected.

Table A3: Chemical determinands within discreet land use categories

| **Land use category** | | **Activity** | **Contaminating material** | | | **Possible health-significant determinands for which there are MAVs** | | **Comment** | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1. Agriculture | | Use of pesticides | Range of pesticides, metals | | | Pesticides, copper | |  | | |
| Use of artificial fertilisers | Range of artificial fertilisers | | | Nitrate, cadmium, arsenic | | Cadmium is a contaminant of superphosphate | | |
| Use of manure as fertiliser | Manure | | | Nitrate, copper, pathogens | |  | | |
| Fuel storage and use | Petrol, diesel | | | Benzene, toluene, xylene, ethylbenzene, lead | |  | | |
| Land farming | Oil industry waste | | | Benzene, toluene, xylene, ethylbenzene, benzo(α)pyrene, lead, nickel, copper, cadmium, chromium | |  | | |
| Silage production | Silage leachate | | | Nitrate | |  | | |
| Sewage sludge application | Sewage | | | Nitrate, antimony, cadmium, chromium, copper, lead, nickel, mercury, pathogens | |  | | |
| Compost application | Compost | | | Arsenic, antimony, cadmium, chromium, copper, lead, nickel, nitrate, pesticides | | The nature of the contaminants depends on the materials used to produce the compost | | |
| Dairy shed operation | Washwater | | | Nitrate, pathogens | | Chlorine and monochloramine may also be present | | |
| Spray irrigation of effluent | Effluent | | | Nitrate, copper, pathogens | | Levels of contaminants from well-operated effluent ponds should be low | | |
| Effluent pond operation | Effluent | | |
| Grazing animals | Manure deposited in pasture | | |
| 2. Forestry | | Sewage sludge application | Sewage | | | Nitrate, antimony, cadmium, chromium, copper, lead, nickel, mercury, pathogens | |  | | |
| Use of pesticides | Range of pesticides | | | Pesticides | |  | | |
| Use of poisons (feral animal control) | Poisoned baits | | | Cyanide, 1080 | | Determine which poisons are in use before selecting determinands to monitor  Events involving 1080 should be treated as a chemical spillage. Preventive measures need to be taken as soon as contamination is believed to have occurred, and sampling for 1080 needs to be undertaken as soon as possible after the contamination event. 1080[[2]](#footnote-2) decomposes relatively rapidly – its half-life in water is about 24 hours  Forestry slash presents a possible physical hazard to supply infrastructure during heavy rain events | | |
| Use and maintenance of vehicles | Petrol, diesel, oil | | | Benzene, toluene, xylene, ethylbenzene | |  | | |
| Fuel storage | Petrol, diesel | | |  | | |
| 3. Mining and quarrying | | Use and maintenance of vehicles | Petrol, diesel, oil | | | Benzene, toluene, xylene, ethylbenzene | |  | | |
| Fracking |  | | | These contaminants can be found near fracking sites from activities associated with fracking. Suppliers should make checks for other chemicals in use if fracking is carried out in the catchment or capture zone | | |
| Fuel storage | Petrol, diesel | | |  | | |
| Ore extraction | Extraction chemicals | | | Cyanide, arsenic, antimony, cadmium, chromium, copper, lead, nickel, mercury | | The metals of concern will depend on the composition of the ore. The presence of cyanide will depend on the nature of the extraction process(es) in use. Find out from the mine operator what chemicals are in use | | |
| Backfilling | Backfill | | | Arsenic, chromium, nickel, lead, benzo(α)pyrene | | A wide range of contaminants may arise, depending on the source of the backfill and the geochemistry of surrounding geology | | |
| Collection and treatment of acid mine drainage | Mine drainage | | | Antimony, cadmium, chromium, copper, lead, nickel, mercury | | The metals of concern will depend on the composition of the ore and extraction processes | | |
| 4. Industry and commerce (heavy and light industry) | | Ceramics | Glazes | | | Antimony, cadmium, copper, lead, nickel, mercury, boron | |  | | |
| Cold storage | Refrigerants | | | Nitrate | | Possibly formed from the oxidation of ammonia | | |
| Drum reconditioning | Range of organic and inorganic chemicals, degreasers, detergents | | | Benzene, toluene, xylene, ethylbenzene, antimony, cadmium, chromium, copper, lead, nickel, mercury | |  | | |
| Electronics | Alkalis, acids, cyanides, solvents, metals | | | Cyanide, antimony, cadmium, chromium, copper, lead, nickel, mercury, barium, selenium, tetrachloroethene, trichloroethene, toluene, dichloromethane | |  | | |
| Fertiliser/ agrichemical production | Fertilisers and pesticides | | | Nitrate, pesticides | |  | | |
| Foundries | Acids, metals, fluxes | | | Antimony, cadmium, chromium, copper, lead, nickel, mercury | | Nitric acid may give rise to nitrate | | |
| Furniture production | Glues, polishes, paints | | | Toluene, dichloromethane, formaldehyde | |  | | |
| Gas works | Product, solid residues and tar | | | Cyanide, nitrate, antimony, arsenic, barium, boron, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, benzo(α)pyrene, benzene, ethyl benzene, toluene xylenes | |  | | |
| Meat and milk processing | Processing effluent including cleaning chemicals | | | Nitrate, chlorine, monochloramine, pathogens | |  | | |
| Metal cleaning/ electroplating | Cleaning and plating chemicals, metals, acids | | | Cyanide, antimony, cadmium, chromium, copper, lead, nickel, mercury, nitrate, ethylenediaminetetraacetic acid (EDTA), , carbon tetrachloride, tetrachloroethene, trichloroethene | | Nitric acid may give rise to nitrate | | |
| 4. Industry and commerce (heavy and light industry) (continued) | | Paper making | Bleaching chemicals, caustic soda | | | Barium, chlorite, chlorate, Trihalomethanes (THMs), haloacetic acids, EDTA nitrilotriacetic acid | | In this situation, DBPs may be formed in the source water before chlorine at the water treatment plant comes in contact with the water. The quantities of chlorinated organic compounds (eg, DBPs) should be small in a well-run plant | | |
| Printing | Solvents, inks, dyes | | | Dichloromethane, toluene, xylene, antimony, cadmium, chromium, lead, mercury | |  | | |
| Product storage | Fumigants | | | 1,3-dichloropropene, cyanide | | The nature of the fumigation will determine which fumigants are a concern | | |
| Resins | Range of organic chemicals | | | Formaldehyde, THMs, di(2-ethylhexyl)phthalate, epichlorohydrin, styrene, toluene | | Members of the THM family can be used as solvents for resins | | |
| Rubbers and plastics | Solvents, plasticisers, paints and other organic substances | | | Formaldehyde, di(2‑ethylhexyl)phthalate), cyanide | |  | | |
| Tanning | Tanning chemicals | | | Arsenic, chromium, pentachlorophenol, organochlorine pesticides | |  | | |
| Wood processing | Preservatives and other treatment chemicals | | | Pentachlorophenol, copper, chromium, arsenic, boron, chlorpyriphos, benzo(α)pyrene | |  | | |
| Wool scouring | Degreasing agents, pesticides | | | Pesticides (including chlorpyriphos, diazinon), pentachlorophenol, copper | | The classes of pesticides likely to be derived from wool are organophosphates, synthetic pyrethroids and insect growth regulators | | |
| 4. Industry and commerce (commerce and community) | | Car washes | Soaps, detergents, waxes, oil | | | Benzo(α)pyrene, nitrilotriacetic acid, EDTA | |  | | |
| Cemeteries | Embalming fluids, bodies, coffin construction materials, fertilisers | | | Formaldehyde, arsenic, mercury, lead, copper, nitrate | | The properties of the soil and age of the cemetery, among other things, will influence the nature of contaminants in the groundwater | | |
| Dental clinics | Filling materials | | | Mercury | |  | | |
| Defence establishments | Disinfectants, human waste, chemical dumps, fuel and oil, fire-fighting foams | | | Chlorine, benzene, toluene, xylene, ethylbenzene, benzo(α)pyrene, lead, cadmium, poly-fluoroalkyl substances (PFAS), perfluorooctanesulfonic acid (PFOS), pesticides, pathogens  Chemical dumps may contain a wide range of chemicals. Ask defence authorities for a list of chemicals disposed of in the greatest quantity. Use these as markers of contamination. Once it is confirmed that there is contamination, consider testing for other specific contaminants | |  | | |
| Dry cleaning | Dry cleaning chemicals | | | Tetrachloroethene, trichloroethene | |  | | |
| Hospital | Disinfectants, biological waste, radiological waste, other miscellaneous chemicals | | | Formaldehyde, chlorine, mercury, pathogens  A wide range of contaminants may arise from hospital sources. Identify the most-used chemical contaminants, and use these are markers of contamination. Once it is confirmed that there is contamination, consider testing for other specific contaminants | | Reticulated waste disposal should reduce the likelihood of contamination with hazards associated with this activity | | |
| 4. Industry and commerce (commerce and community) (continued) | | Laboratories (school, medical and research) | Disinfectants, biological waste, other miscellaneous chemicals | | | A wide range of contaminants may arise from laboratory sources. Identify the most-used chemical contaminants, and use these are markers of contamination. Once it is confirmed that there is contamination, consider testing for other specific contaminants | | Chlorine and monochloramine may be present  Reticulated waste disposal should reduce the likelihood of contamination with hazards associated with this activity | | |
| Laundromats | Detergents, bleaches, dyes | | | Nitrilotriacetic acid, EDTA, chlorine, monochloramine | |  | | |
| Offices | Detergents, solvents | | | Dichloromethane, toluene, xylene, 1,2 dichloroethane | |  | | |
| Photographic processing | Photographic processing chemicals | | | Cyanide, selenium, chromium, copper, nitrilotriacetic acid, EDTA, nitrate | | Cyanide was used in an early photographic process and is unlikely to be a concern in modern photographic laboratories. Ammonium salts may be oxidised to nitrate | | |
| Prisons | Disinfectants, human waste | | | Chlorine, monochloramine, nitrate, pathogens | | This is only a possible concern if sewage is treated and discharged on-site | | |
| Scrap yards | Petroleum products, solvents, metals, acids, alkalis | | | Benzene, toluene, xylene, ethylbenzene, benzo(α)pyrene, antimony, cadmium, chromium, copper, lead, nickel, mercury, tetrachloroethene, trichloroethene, carbon tetrachloride | |  | | |
| Swimming pools | Disinfectants, other pool treatment chemicals, human waste | | | THMs, haloacetic acids, chlorine, monochloramine | | In this situation, DBPs may be formed in the source water before chlorine at the water treatment plant comes in contact with the water. The quantities of chlorinated organic compounds (eg, DBPs) should be small in a well-run plant  Disposal of backwash water to a reticulated sewer will minimise the likelihood of contamination from this source | | |
| 4. Industry and commerce (transport, storage and utilities) | | Airport operation | Fuels, fire-fighting foams, solvents, de‑icing substances, fumigants | | | Benzo(α)pyrene, cyanide, formaldehyde, antimony, cadmium, chromium, copper, lead, nickel, PFAS, PFOS, tetrachloroethene, trichloroethene, carbon tetrachloride | | The range of contaminants will depend on whether the airport has maintenance facilities | | |
| Fuel storage and sale | Fuel storage and sale | | | Benzene, toluene, xylene, ethylbenzene, benzo(α)pyrene | |  | | |
| Railway operation | Spraying of tracks, diesel and oil leaks, human waste (if toilet effluent is vented onto tracks) | | | Pesticides (herbicides), benzo(α)pyrene, nitrate, arsenic, pathogens | | Spills of cargo carried by rail may result in a wide range of contaminants being introduced into water if there is a pathway to the source water | | |
| Road transport | Asphalt, fuel and oil leaks, chemicals for roadside weed control, tyre and brake wear | | | Benzo(α)pyrene, benzene, toluene, xylene, ethylbenzene, herbicides, antimony, cadmium, chromium, copper, lead, nickel | | Spills of cargo carried by road may result in a wide range of contaminants being introduced into water if there is a pathway to the source water | | |
| Sewerage reticulation | Sewage (human waste, trade waste) | | | Nitrate, antimony, cadmium, chromium, copper, lead, nickel, mercury, pathogens | | A wide range (in addition to what is listed) of industrial and domestic contaminants may be present in sewage | | |
| Sewage treatment |
| Stock effluent and camper van effluent disposal facilities | Animal and human waste | | | Nitrate, antimony, cadmium, chromium, copper, lead, nickel, mercury, pathogens | |  | | |
| Tyre storage | Tyres | | | Benzo(α)pyrene | |  | | |
| 5. Open space | | Car parks | Fuel and oil leaks, asphalt surface | | | Benzene, toluene, xylene, ethylbenzene, benzo(α)pyrene, antimony, cadmium, chromium, copper, lead, nickel, pathogens | |  | | |
| Clay target clubs | Lead shot | | | Arsenic, antimony, lead, benzo(α)pyrene | |  | | |
| Disposal of stormwater run‑off | Fuel and oil spills and other contaminants on asphalt road surfaces, faecal material from animals, weed and pest control chemicals, fertilisers, metals | | | Nitrate, pesticides, industrial solvents (benzene, toluene, xylene, ethylbenzene), antimony, cadmium, chromium, copper, lead, nickel, mercury, pathogens | |  | | |
| Golf courses | Chemicals used for course upkeep (fertiliser, pesticides), fuel storage | | | Nitrate, pesticides, benzene, toluene, xylene, ethylbenzene, benzo(α)pyrene, lead, arsenic, cadmium, copper | |  | | |
| Recreational parks | Fertilisers, weed control chemicals, fuel and oil from vehicles | | |  | | |
| Sports fields | Fertilisers, weed control chemicals, fuel and oil from vehicles | | |  | | |
| 6. Residential (urban, lifestyle block, rural) | | Disposal of household waste | Household chemicals, garden chemicals, petrol, diesel and oil | | | Arsenic, antimony, cadmium, chromium, copper, lead, nickel, mercury, benzene, toluene, xylene, ethylbenzene, nitrate, pesticides, benzo(α)pyrene | | The contamination risk associated with this activity is likely to be small because of the small scale | | |
| Use of fertilisers | Fertilisers | | | Nitrate, cadmium | |  | | |
| Keeping pets or livestock (lifestyle blocks) | Animal waste, pest control chemicals | | | Nitrate, pesticides, pathogens | |  | | |
| Fuel storage | Petrol, diesel, oils | | | Benzene, toluene, xylene, ethylbenzene, benzo(α)pyrene | |  | | |
| On-site disposal of sewage | Human waste, detergents | | | Nitrate, pathogens | |  | | |
| Weed and pest control | Pesticides | | | Pesticides | |  | | |
| 7. Vacant land | | Illegal dumping | Wide range of possible chemicals | | | Arsenic, antimony, cadmium, chromium, copper, lead, nickel, mercury. In addition to these metals, a screen for semi-volatile organic compounds may be the best check on possible contamination. | | Measurement of water conductivity in the vicinity of the activity and comparison with groundwater from the area known not be contaminated | | |
| 8. Landfill | Disposal of industrial waste | | Leachate containing a wide range of possible chemicals | | Arsenic, antimony, cadmium, chromium, copper, lead, nickel, mercury, nitrate pesticides, cyanide.  In addition to these determinands, a screen for semi-volatile organic compounds may be the best check on possible contamination. | |  | | | |
| Disposal of waste from water and wastewater treatment systems | | Leachate from waste sludge (which includes treatment chemicals) | | Antimony, cadmium, chromium, copper, lead, nickel, mercury, acrylamide, epichlorohydrin, nitrate (derived from ammonia which may be high), pathogens | |  | | | |
| Disposal of household waste | | Household chemicals, garden chemicals, petrol, diesel and oil | | Arsenic, antimony, cadmium, chromium, copper, lead, nickel, nitrate, pesticides.  In addition to these metals, a screen for semi-volatile organic compounds may be the best check on possible contamination | | | | Which contaminants are present will depend on how well the landfill system is controlled | |
| 9. Fishing | Onshore aquaculture | | | Faecal matter, pesticides | | Pesticides, nitrate | | | |  |
| 10. Conservation land | On-site sewage disposal | | | Human waste | | Nitrate, pathogens | | | |  |
| Feral animal control | | | Poisons | | Cyanide, 1080 | | | | Check to determine which poisons are in use before selecting determinands to monitor  Events involving 1080 should be treated as a chemical spillage. Preventive measures need to be taken as soon as contamination is believed to have occurred, and sampling for 1080 needs to be undertaken as soon as possible after the contamination event 1080 decomposes relatively rapidly[[3]](#footnote-3) |

Appendix 5: Example of an operational procedure

|  |  |
| --- | --- |
| Operating procedure number: | **OP12345** |
| Operating procedure title: | **Microbiological water sample collection and despatch** |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Name** | **Title** | **Signature** | **Date** |
| Author |  |  |  |  |
| Reviewer |  |  |  |  |
| Authoriser |  |  |  |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | | | Effective date: |  |
|  | | | Review date: |  |
| **Read by** | | | | |
| **Name** | **Title** | **Signature** | | **Date** |
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#### Purpose

The purpose of this operational procedure (OP) is to ensure that microbiological water quality samples required to demonstrate achievement of the Drinking-water Standards for New Zealand 2005 (Ministry of Health 2018) (the Standards) are taken in a way that ensures that the test results are an accurate indication of the quality of the water at the time and place the sample was taken.

#### Introduction

Operational monitoring is in place to ensure that preventive measures are functioning as they should. Verification monitoring, which determines the quality of the water after treatment or in the distribution system, provides a further check that the preventive measures in place are continuing to provide water that meets the requirements of the Standards. This OP contributes to ensuring the verification monitoring is undertaken correctly.

Any samples taken for assessing water quality, whether as part of demonstrating achievement of the Standards or additional sampling undertaken at the water supplier’s initiative, must follow this procedure.

#### Scope

Within scope:

* sampling for routine bacteriological (eg, *E. coli* and total coliforms) determinands
* all actions relevant to sample collection and despatch of the sample to the testing laboratory
* samples taken from the treatment plant and the distribution zone.

Out of scope:

* samples from water prior to the treatment plant (source or raw water).

#### Definitions

[Include a list of definitions for terms used in the OP. Acronyms and abbreviations should be explained at the point of use.]

#### Responsibilities

The water quality officer has responsibility for ensuring that staff are trained in the use of this procedure and that the procedure is followed when any sample (within the scope of this OP) is collected.

#### Specific procedure

1. Prepare a sampling plan for compliance monitoring, if not already prepared under a different section of the water safety plan. This must include proposed sampling dates and the locations for sampling (eg, street address), preferably marked on a map.
2. Check with the drinking-water assessor that the plan meets the requirements of the Standards.
3. Ensure that correct bacteriological sampling containers are available. If not, obtain a supply from the laboratory. Containers for bacteriological sampling from a chlorinated supply MUST contain thiosulphate to neutralise the chlorine.
4. Obtain an insulated container that can be chilled to 4°C and used to store microbiological samples between sampling and their delivery at the laboratory.
5. Arrange a suitable delivery time with the laboratory, unless a routine arrangement has been agreed. Ensure that the laboratory will be open and able to undertake analysis of the sample within the required interval between sampling and testing.
6. At, or before, reaching the sampling location, complete as much of the Sample Form as possible before taking the sample. A dry form is easier to write on. Also complete as much as possible of the label on the sampling bottle.

##### Sampling

Before taking a bacteriological sample, the sampling point must be disinfected/ sterilised, using either a spray of 70% ethanol or sodium hypochlorite solution, or with a flame (eg, run a cigarette lighter flame around the rim of the tap).

Unscrew the sampling container lid, taking care not to contaminate the lip of the container, and place the lid upside down on clean surface where it cannot be contaminated.

Flush the sampling point, letting the water run to waste, for several minutes before collecting the sample, to ensure the sample is representative of the water in the reticulation system.

Fill the container with slightly more than 100 ml of water. This should leave an air space between the sample and the lid.

Carefully, so as not to contaminate the lip of the container or the inside of the lid, screw the lid firmly back onto the container.

When turbidity, FAC or pH measurements are also required, make them directly after taking the sample.

After sample collection, take or send the sample to the laboratory as quickly as possible. It is preferable that the sample reach the laboratory in time for the test to be started within six hours, but no later than 24 hours, after the sample is taken. The container must be chilled so that the temperature of the sample on reaching the laboratory is not above 10°C. The sample must not be frozen.

#### Forms or templates to be used

Record the sampling details using form BCS 123.

#### Internal and external references

[Use this section to list all controlled internal references (eg, OPs) and external references referred to within the text of the OP only.]

#### Change history

|  |  |  |  |
| --- | --- | --- | --- |
| **OP number** | **Effective date** | **Significant changes** | **Previous OP number** |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

Appendix 6: Critical control points

#### Introduction

Water supplies should have multiple barriers to prevent hazards reaching consumers. Some of these barriers are passive (such as confined aquifers); others are active (such as treatment processes). Active barriers are also termed control points (or critical points). Control points whose functioning is essential for protecting the consumers from hazards are critical control points (CCPs).

The supply operator cannot apply controls to a passive barrier; consequently, this type of barrier, while important, cannot be classified as a CCP.

This appendix provides information to help suppliers in:

determining which water supply elements in a water supply could be classified as CCPs

managing CCPs.

#### Attributes of a critical control point

Critical control points formalise control over water supply elements that provide important controls over hazards (contaminants). For a water supply element to be classifiable as a CCP, it needs to have the following attributes:

at least one operational parameter that can be monitored to provide a check on the performance of the supply element

at least one operational parameter that can be sampled, or read, frequently enough that suppliers can make a timely response to prevent harm to consumers in the event of loss of control at that CCP (monitoring should be continuous)

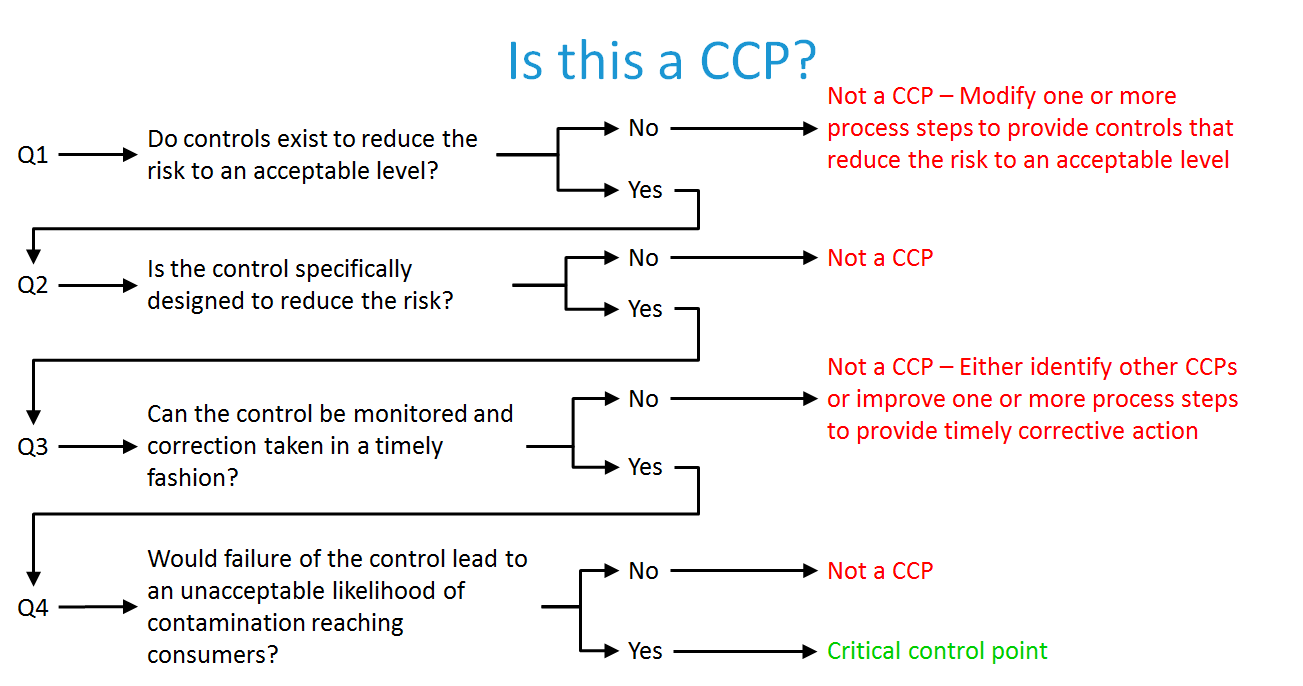
performance limits can be set to show when optimum control is lost and corrective action needed

corrective actions defined so that in the event of performance limits not being met the operator knows how to respond to the situation

critical limits on the operational parameter(s) that if exceeded, because corrective actions have failed to regain control and maintain safe water, signal the need to shut down the supply (and/or initiate ‘contingency plans’).

Figure A1 outlines a decision tree to help suppliers determine when a water supply element can be classified as a CCP.

Figure A1: Decision tree for identifying critical control points



#### Critical control point control plan summaries

A CCP control plan summary is designed to provide suppliers with the key information needed to manage the operation of a specific CCP.

The control plan summary needs to contain:

process objectives, identifying which hazards the CCP is designed to manage and (briefly) the nature of the process being used

information on operational day-to-day monitoring of the control process, as follows:

what – which operational parameter(s) is to be monitored to provide a check on the performance of the CCP

when – how frequently readings of the operational parameter(s) are to be made, or samples taken

where – at what point in the system the operational parameter is to be monitored (ie, the specific sampling point)[[4]](#footnote-4)

how – what method or instrumentation is to be used to monitor the operational parameter

who – who has responsibility for monitoring the operation parameter(s)

records – where the results from the monitoring are to be stored (eg, a logbook, SCADA, or propriety third-party compliance platform system, including WaterOutlook, ID and Drinking Water Online).

a table identifying:

performance criteria

corrective actions

supporting programmes (eg, calibration, reagent check, training).

Illustrative examples follow.

#### Example: Primary disinfection by free chlorination

##### Process objectives

1. Provide a **primary disinfection CCP** to inactivate bacterial and viral pathogens that may have entered upstream of dosing point.
2. Provide a **residual disinfection quality control point** to help inactivate pathogens entering downstream of the dosing point.

|  |  |
| --- | --- |
| **Operational day-to-day monitoring of control process** | |
| What[[5]](#footnote-5) | Free available chlorine (FAC) concentration in mg/L pH in pH units |
| When | Continuously online |
| Where | At designated primary disinfection analyser for each chlorinator[[6]](#footnote-6) |
| How | Online pH and Cl meter |
| Who | Operator |
| Records | SCADA historian |

|  |  |  |
| --- | --- | --- |
| **Process performance criteria at the operational monitoring point** | | **Correction if performance criteria are not met** |
| Target range | * FAC: 1–1.2 mg/L * pH: 7.0–8.0 * Turbidity: <0.3 NTU | * Operator to adjust dosing system to achieve target range if identified as outside of target range during routine checking procedures or if system indicates outside of target range. |
| Action limits | * FAC: * <0.5 mg/L (>15 m) * >2 mg/L (>1 h) * pH: * >8.5 (>1 h)[[7]](#footnote-7) * Turbidity: >0.5 NTU (>15 min) | * Duty operator to respond by adjusting dosing to within targets. * Duty operator to notify duty supervisor. |
| Critical limits[[8]](#footnote-8) | * FAC: * <0.2 mg/L (>15 m) * >5 mg/L (>1 h) * pH: * >9.0 (>15 m) * Turbidity: >1 NTU (>15 m) | * Duty operator to isolate the supply and run off storage until rectified and back within critical limits. * Duty operator to notify duty supervisor. * Duty supervisor to trigger chlorine exceedance protocol and notify executive and district health board if inadequately disinfected water needs to be supplied or has been supplied. |

##### Supporting programmes

Daily[[9]](#footnote-9) monitoring instrument checking and calibration by operator as necessary.

Monthly operator check of currency of reagents and discarding of outdated reagents.

Training and competency assessment of operator in free chlorination of drinking-water.

Use of only potable water grade chlorine stock solution from an approved supplier.

Laboratory verification checks for *E. coli* and total coliforms at least weekly and chlorate at least monthly, with transgression reporting to operator and district health board if results are outside the DWSNZ.

#### Example: Rapid sand filtration

##### Process objectives

Provide a **primary particle removal CCP** to physically trap pathogens that may have entered the system.

Provide a **primary particle removal CCP** to separate material that will compromise the efficacy of subsequent disinfection barriers.

|  |  |
| --- | --- |
| **Operational day-to-day monitoring of control process** | |
| What | Filtrate turbidity in NTU |
| When | Continuously online |
| Where | At designated filtered water sample point for each rapid sand filter[[10]](#footnote-10) |
| How | Online NTU meter |
| Who | Operator |
| Records | SCADA historian |

|  |  |  |
| --- | --- | --- |
| **Process performance**[[11]](#footnote-11) **criteria at the operational monitoring point** | | **Correction if performance criteria are not met** |
| Target range[[12]](#footnote-12) | * NTU: <0.15 NTU | * Operator to adjust raw water intake, flow control and coagulant/polyelectrolyte system to achieve target range if system indicates outside of target range. |
| Action limits | * NTU 0.2 (>15 min) | * Duty operator to respond by adjusting coagulant dosing, restricting raw water intake, checking headloss and/or initiating filter backwash. Take grab sample to verify readings. |
| Critical limits[[13]](#footnote-13) | * NTU: 0.3 NTU (>15 min) | * Duty operator to shut down affected filter and conduct filter backwash procedure before bringing filter back online. * Verify correct operation of pre-filter CCPs (eg, coagulation). * Supervisor to initiate transgression incident response if water has entered reservoir/distribution. |

##### Supporting programmes

Daily[[14]](#footnote-14) monitoring instrument checking and verification by operator as necessary.

Monthly operator check of currency of reagents used in turbidity meter calibration and verification.

Training and competency assessment of operator in operation of rapid sand filtration.

Filter maintenance plan, including review of media condition and materials.

Online analyser operation and maintenance plan.

Performance transgression incidence response protocol.

#### Example: Membrane filtration

##### Process objectives

Provide a **primary particle removal CCP** to physically trap pathogens that may have entered the system.

Provide a **primary particle removal CCP** to separate material that will compromise the efficacy of subsequent disinfection barriers.

|  |  |
| --- | --- |
| **Operational day-to-day monitoring of control process** | |
| What | Filtrate turbidity in NTU |
| When | Continuously online |
| Where | At designated filtered water sample point for each membrane bank[[15]](#footnote-15) |
| How | Online NTU meter |
| Who | Operator |
| Records | SCADA historian |

|  |  |  |
| --- | --- | --- |
| **Process performance**[[16]](#footnote-16) **criteria at the operational monitoring point** | | **Correction if performance criteria are not met** |
| Target range[[17]](#footnote-17) | * NTU: <0.05 NTU | * Operator to adjust raw water intake, flow control and coagulant system to achieve target range if system indicates outside of target range. |
| Action limits[[18]](#footnote-18) | * NTU: >0.05 NTU (>15 min) | * Duty operator to respond by undertaking integrity testing of membrane, restricting feed water or initiating CIP procedure.[[19]](#footnote-19) * Check calibration of turbidity meters. |
| Critical limits[[20]](#footnote-20) | * NTU: 0.1 NTU (>15 min) * NTU: filtrate>feed | * Duty operator to shut down affected membrane unit filter and conduct filter backwash and/or CIP procedure plus integrity testing before bringing filter back online. * Verify correct operation of pre-filter CCPs (eg, coagulation). * Duty officer to notify supervisor. * Supervisor to initiate transgression incident response if water has entered reservoir/distribution. |

##### Supporting programmes

Monthly[[21]](#footnote-21) monitoring instrument checking and calibration by operator as necessary.

Monthly operator check of currency of reagents used in turbidity meter calibration and verification.

Training and competency assessment of operator in operation of membrane filtration.

Membrane filtration maintenance plan, including review of membranes and materials.

Performance transgression incidence response protocol.

#### Example: Ultraviolet disinfection

##### Process objectives

Provide a **primary disinfection CCP** to inactivate bacterial, viral[[22]](#footnote-22) and protozoan pathogens.

|  |  |
| --- | --- |
| **Operational day-to-day monitoring of control process** | |
| What[[23]](#footnote-23) | * UV dose in mJ/cm2 * Turbidity in NTU |
| When | * Continuously online |
| Where | * At designated filtered water sample point and dose meter for each reactor[[24]](#footnote-24) |
| How | * Online UV sensor * Online NTU meter |
| Who | * Operator |
| Records | * SCADA historian and logbook |

|  |  |  |
| --- | --- | --- |
| **Process performance criteria at the operational monitoring point** | | **Correction if performance criteria are not met** |
| Target range | * UV dose: 40 mJ/cm2 * NTU: <1.0 * UVT: >98% | * Operator to check pre-filtration operating normally and adjust flow or correct/replace filters. Perform reactor sensor and lamp checks during routine checking procedures. Check UVT and or raw water quality. |
| Action limits | * UV dose: <40 mJ/cm2 * NTU: >1.0 (>15 min) * UVT: <98% AND >85% | * Duty operator to respond by adjusting/maintaining reactor so that target dose is achieved. Adjust/maintain pre‑filtration barrier to achieve target NTU. Reduce flow. * Duty operator to notify duty supervisor. |
| Critical limits[[25]](#footnote-25) | * UV dose: <40 mJ/cm2 * NTU >2.0 (>3m) * UVT: <85% | * Duty operator to shut down affected reactor and switch to standby. Service lamp pre-filter. * Duty operator to notify duty supervisor. * Supervisor to initiate transgression incident response if water has entered reservoir/distribution. |

##### Supporting programmes

Monthly[[26]](#footnote-26) monitoring instrument[[27]](#footnote-27) checking and calibration by operator as necessary.

Monthly operator check of currency of reagents and discarding of outdated reagents.

Training and competency assessment of operator in UV reactor performance and turbidity monitoring of drinking water.

Laboratory verification checks for *E. coli* and total coliforms, with transgression reporting to operator and public health unit.

Raw water chemistry sampling programme (colour, iron, manganese, hardness).

Response protocol for standby chlorination.

Appendix 7: Example of a plan for operational monitoring

This appendix provides an example of an operational monitoring plan. It is based on the template for critical control point (CCP) process control summaries, and it is consistent with the 2017 World Health Organization document *Operational Monitoring Plan Development: A guide to strengthening operational monitoring practices in small- to medium-sized water supplies* (URL: <http://apps.who.int/iris/bitstream/handle/10665/255753/9789290225379-eng.pdf?sequence=1&isAllowed=y> (accessed 1 February 2019)).

Operational monitoring may be based on *either* online continuous data or on manual sampling (or operator observations). In both instances suppliers may use either monitoring approach for the operational management of a treatment process.

*Examples* of operational parameters include:

* **manual parameters** – floc (blanket) formation, turbidity, chemical monitoring (such as heavy metals), conductivity, UV transmissivity, total coliforms and heterotrophic plate counts
* **continuous parameters** – UV transmissivity, UV lamp hours, flow, differential pressure, headloss, reticulation pressure, reservoir level sensors and direct integrity tests (or membrane integrity tests).

It should be noted that there are instances where analytical parameters may be both a ‘verification of compliance’ monitoring requirement (as required by the *Drinking Water Standards for New Zealand 2005* (DWSNZ) (Ministry of Health 2018) and an ‘operational’ parameter.

Note: It is important to adequately keep and maintain records for all operational parameters and regularly assess the results (see section 2.2).

The specific examples this appendix provides are for rapid sand filtration and coagulation, respectively.

#### Rapid sand filtration

The rapid sand filter might also be regarded as a CCP. The CCP process control summary would be based on turbidity measurement, as this parameter provides an indication of how well the filter is removing protozoa and providing water quality that allows efficacious disinfection downstream.

Monitoring of parameters other than turbidity is needed for the satisfactory functioning of the filtration process. This example sets out the procedure for monitoring dirt accumulation in the filter bed and responding to indications of filter bed overloading.

##### Coagulation

Coagulation aids in the effective removal of particulates including pathogens such as protozoa. While coagulation itself may not be considered a CCP, it does contribute to the efficacious operation of sand filtration in terms of improving particulate removal. Turbidity would be the main monitoring parameter for determining successful coagulation; however, physical observation of floc formation and blanket development are also beneficial operational monitoring tools.

#### Example: Preventative measure: rapid sand filter inspection

##### Process objectives

Provide **primary particle removal**, including pathogens.

**Improve efficacy** ofsubsequent disinfection barriers.

|  |  |
| --- | --- |
| **Operational day-to-day monitoring of control process** | |
| What | Indication of filter overloading – clogging, reduced filter flow-rate |
| When | Daily |
| Where | At both treatment plant filters |
| How | Visual inspection of both filters and measurement of flow rates |
| Who | Operator |
| Records | Treatment plant logbook |

|  |  |  |
| --- | --- | --- |
| **Process performance criteria at the operational monitoring point** | | **Correction if performance criteria are not met** |
| Target range[[28]](#footnote-28) | * Headloss within normal[[29]](#footnote-29) range | **Business as usual**   * No additional action required. |
| Action limits | * Individual filter headloss above target range, but below critical limit | **Corrective action to regain control** (**refer to corrective action procedures in WSP)**   * Shut down affected filter and conduct filter backwash procedure. * Check raw water turbidity, performance of coagulation/sedimentation processes and treated water turbidity. Respond to these operational monitoring/inspections if required. * If backwash is ineffective, consider the need to replace filter material. |
| Critical limits | * Individual filter headloss above critical limit * Filter headloss above action limit for **all filters** at same time | **Emergency response (refer to emergency response procedures in WSP)**   * Shut down affected filters and conduct filter backwash procedure. * If individual filter backwash is ineffective, consider the need to replace filter material. * Consider inspecting (and replacing) filter bed nozzles if determined to be an issue. * Initiate transgression incident response if water with turbidity above CCP critical limit has entered reservoir/distribution. |

##### Supporting programmes

Daily[[30]](#footnote-30) monitoring instrument checking and verification by operator as necessary.

Monthly operator check of currency of reagents used in turbidity meter calibration and verification.

Monthly operator check of calibration of filter flow rate gauges.

Training and competency assessment of operator in operation of rapid sand filtration.

Filter maintenance plan, including review of media condition and materials.

Performance transgression incidence response plan.

|  |  |
| --- | --- |
| **Actions** | **Responsibilities** |
| * Carrying out and recording monitoring/inspection * Daily reviewing and interpreting results * Acting on target range and trigger limits results * Reporting trigger limits and critical limits results to supervisor | Operator |
| * Receiving reports and acting on trigger limits and critical limits results, reporting to senior leadership when required * Monthly reviewing and interpreting results, or when operator identifies anomalies * Annual review of monitoring/inspection plan | Supervisor |

#### Example: Preventative measure: coagulation

##### Process objectives

Provide a coagulation **CCP** to physically enlarge particles to facilitate the removal of protozoan pathogens that may have entered the system.

Provide a coagulation **CCP** to separate particles that will compromise the efficacy of subsequent filtration and disinfection barriers.

|  |  |
| --- | --- |
| **Operational day-to-day monitoring of control process** | |
| What[[31]](#footnote-31) | Turbidity in NTU[[32]](#footnote-32) |
| When | Continuously online |
| Where | At designated filtered water NTU sample point |
| How | Online NTU meter |
| Who | Operator |
| Records | SCADA historian |

|  |  |  |
| --- | --- | --- |
| **Process performance**[[33]](#footnote-33) **criteria at the operational monitoring point** | | **Correction if performance criteria are not met** |
| Target range[[34]](#footnote-34) | * Optimum floc size range * Stable floc blanket[[35]](#footnote-35) | * Operator to adjust coagulant dosing system[[36]](#footnote-36) to be optimised against new jar test information. Jar tests used to determine optimum doses every time raw water characteristics change. * Adjust (stop/reduce) raw water intake to account for changes in raw water NTU and adjust plant flow. * Adjust/control pH. * Adjust polyelectrolyte. |
| Action limits | * Floc size not optimal * Unstable floc blanket | * Duty operator to respond by adjusting dosing to within targets. * Adjust plant flow and raw water intake to optimise floc. * Adjust/control pH. |
| Critical limits[[37]](#footnote-37) | * Floc not forming | * Duty operator to close intake and revert to raw water storage. * Duty operator to notify duty supervisor. * Supervisor to initiate transgression incident response if water has entered reservoir/distribution. |

##### Supporting programmes

Daily[[38]](#footnote-38) monitoring instrument checking and verification by operator as necessary.

Monthly operator check of currency of reagents used in turbidity meter calibration and verification.

Training and competency assessment of operator in operation of coagulation dosing and jar testing of drinking-water.

Laboratory verification checks for colour, coagulant (Fe/Al) and polyelectrolyte in filtered water.

Performance transgression incidence response protocol.

1. Priority 2 determinands are designated for each supply. Refer to DWSNZ (sections 8.2 to 8.4) for further information. [↑](#footnote-ref-1)
2. The primary route of degradation is microbiological defluoridation. Laboratory studies of 1080 have shown half-lives from very much less than 24 hours to eight days: see Appendix C of the ERMA review of 1080 (2007). (Application for the Reassessment of a Hazardous Substance under Section 63 of the Hazardous Substances and New Organisms Act 1996. Application Number: HRE05002). URL: www.epa.govt.nz/assets/FileAPI/hsno-ar/HRE05002/HRE05002-059.pdf (accessed 31 January 2019). [↑](#footnote-ref-2)
3. The primary route of degradation is microbiological defluoridation. Laboratory studies of 1080 have shown half-lives from very much less than 24 hours to eight days: see Appendix C of the ERMA review of 1080 (2007). (Application for the Reassessment of a Hazardous Substance under Section 63 of the Hazardous Substances and New Organisms Act 1996. Application Number: HRE05002). URL: [www.epa.govt.nz/](http://www.epa.govt.nz/) assets/FileAPI/hsno-ar/HRE05002/HRE05002-059.pdf (accessed 31 January 2019). [↑](#footnote-ref-3)
4. Steps ii and iii should be developed in accordance with requirements specified in the Drinking-water Standards for New Zealand 2005 (DWSNZ) (Ministry of Health 2018). [↑](#footnote-ref-4)
5. Chlorination efficiency is influenced by turbidity; this parameter should also be considered in line with the DWSNZ. [↑](#footnote-ref-5)
6. Although knowledge of plant layout is inherent to daily operations, a general description of where and how these are identified is recommended. This will be referenced more formally elsewhere (eg, P&IDs/asset register). [↑](#footnote-ref-6)
7. As per the DWSNZ if the pH exceeds 8 the FACe is required to be calculated for efficacy of disinfection, and therefore your CCP limits should reflect this characteristic. [↑](#footnote-ref-7)
8. Refer to the validation section of the WSP for justification and explanation of these critical limits. [↑](#footnote-ref-8)
9. Or as per manufacturer recommendations. [↑](#footnote-ref-9)
10. Although knowledge of plant layout is inherent to daily operations, a general description of where and how these are identified is recommended. This will be referenced more formally elsewhere (eg, P&IDs/asset register). [↑](#footnote-ref-10)
11. Although values relate to filtrate turbidity, a more complete understanding of filter performance can be obtained when the difference between pre- and post-filter water NTU is measured. [↑](#footnote-ref-11)
12. As measured at each individual filter. [↑](#footnote-ref-12)
13. Refer to the WSP for justification and explanation of these critical limits. Also refer to relevant DWSNZ thresholds and compliance criteria. [↑](#footnote-ref-13)
14. Or as per manufacturer recommendations. [↑](#footnote-ref-14)
15. Although knowledge of plant layout is inherent to daily operations, a general description of where and how these are identified is recommended. This will be referenced more formally elsewhere (eg, P&IDs/asset register). [↑](#footnote-ref-15)
16. Although values relate to filtrate turbidity, a more complete understanding of filter performance can be obtained when the difference between pre- and post-filter water NTU is measured. [↑](#footnote-ref-16)
17. As measured at each individual filter. [↑](#footnote-ref-17)
18. Membrane integrity also monitored by SCADA permeability alarm. [↑](#footnote-ref-18)
19. Could include chemically enhanced backwash. [↑](#footnote-ref-19)
20. Refer to the validation section of the WSP for justification and explanation of these critical limits. Also refer to relevant DWSNZ thresholds and compliance criteria. [↑](#footnote-ref-20)
21. Or as per manufacturer recommendations. [↑](#footnote-ref-21)
22. Although viral control/standards are not part of the DWSNZ, some reactors may refer to virus log reduction in their validation process. [↑](#footnote-ref-22)
23. Control process monitoring should consider all UV reactor performance requirements needed to demonstrate that operation is in accordance with certification/validation specifications (ie, inclusion of flow and transmittance). These levels should align with the operational validation testing results. [↑](#footnote-ref-23)
24. Although knowledge of plant layout is inherent to daily operations, a general description of where and how these are identified is recommended. This will be referenced more formally elsewhere (eg, P&IDs/asset register). [↑](#footnote-ref-24)
25. Refer to the WSP for justification and explanation of these critical limits. Also refer to relevant DWSNZ thresholds. [↑](#footnote-ref-25)
26. Or as per manufacturer recommendations. [↑](#footnote-ref-26)
27. In the longer term the SCADA system also needs to be frequently checked. [↑](#footnote-ref-27)
28. As measured at each individual filter. [↑](#footnote-ref-28)
29. Supply-specific: need to set normal range. [↑](#footnote-ref-29)
30. Or as per manufacturer recommendations. [↑](#footnote-ref-30)
31. For some supplies, natural organic matter will influence coagulation; this may be a better parameter to measure. [↑](#footnote-ref-31)
32. Increased turbidity across all filters (rather than individual filters) is indicative of an upstream issue including coagulation failure; filtrate NTU can therefore be a monitoring tool for confirming optimisation of coagulation. Successful coagulation is marked by a number of other indicators, which can be quantitatively or qualitatively measured depending on treatment methodology (eg, pH or alkalinity may be measured to determine if target range is being maintained at a specific control point; visual assessment of floc and sedimentation performance). [↑](#footnote-ref-32)
33. Filter performance criteria may also be used to judge coagulation performance (eg, filter run times). [↑](#footnote-ref-33)
34. Performance values mirror filtered water targets and action level. [↑](#footnote-ref-34)
35. Not applicable to direct filtration. [↑](#footnote-ref-35)
36. Dosing system may involve manual controls, feed forward controllers and streaming current detectors. [↑](#footnote-ref-36)
37. Refer to the validation section of the WSP for justification and explanation of these critical limits. [↑](#footnote-ref-37)
38. Or as per manufacturer recommendations. [↑](#footnote-ref-38)