

Chapter 19: Small, individual and roof water supplies

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19.1 Introduction

Providing safe drinking-water for all is a cornerstone of protecting people from illness, and it is the responsibility of the water supplier/operator to ensure that the drinking-water they provide is safe regardless of the number of people served and the type of population.

Generally, the larger water supplies have more resources and lower costs per customer, so can more readily comply with the DWSNZ. In the US, small supplies (<10,000 population) account for over 90 percent of 'violations' (USEPA 2003). In New Zealand, water supplies serving <5,000 people predominate the 'non-compliances', which led to the assistance programme, see Chapter 1: Introduction, sections 1.4.6 and 1.5.

In 2002 the New Zealand Water and Wastes Association (NZWWA) in conjunction with the New Zealand Water Environment Research Foundation (NZWERF) conducted a survey of New Zealand small water systems (systems that supply water to fewer than 500 people). The survey attempted to identify how well the systems were being managed, and what difficulties the industry experienced in meeting the requirements as set out in the *Drinking-water Standards for New Zealand 2000* (DWSNZ). The objective of the report was to highlight the trends and issues facing small water systems. The interviewers undertook a visual inspection of the systems and rated the plant in the majority of systems (85 percent) as in excellent or satisfactory condition; although 'satisfactory' does not mean that they were DWSNZ compliant. The 15 percent of the systems that were rated as unsatisfactory were given this rating mainly for having no (or an inadequate level) of treatment. Only 40 percent of surface water sources were reported to be fenced, at least 20 percent of the groundwater sources had insecure head works, and 47 percent of roof water sources had no flushing points. The storage tanks for 33 percent of the systems were considered to have inadequate vermin protection or were incorrectly sealed, NZWWA (2002).

The Drinking-water Standards for New Zealand 2005, revised 2008 and 2018 (DWSNZ) describe safe drinking-water in terms of maximum acceptable levels of contaminants (MAV), and describe how to demonstrate that drinking-water is safe. The DWSNZ include a specific section for small water supplies (section 10). Section 10 covers small and neighbourhood drinking-water supplies as defined in the Health (Drinking Water) Amendment Act 2007. Rural agricultural drinking-water supplies (RADWS) are covered by the *Rural Drinking-water Supply Guideline* (Ministry of Health 2015). See section 19.6.

Specific actions are required to be carried out and documented for small and neighbourhood drinking-water supplies. This chapter of the Guidelines provides references to a range of resources (including those available from the Ministry of Health's web page) and information to assist these water suppliers manage their supplies to ensure safe drinking-water, and to meet their obligations under the DWSNZ (see sections 19.2 and 19.3 for small and individual water supplies, respectively).

Reticulated community supplies that serve fewer than 1,500 person days (eg, fewer than 25 persons for 60 days) per year do not have to demonstrate compliance with the DWSNZ, but must still provide safe (potable) drinking-water as described in the Building Act 2004 and its amendments.

Section 19.3 provides information to assist individual household water suppliers produce safe drinking-water at a reasonable cost. Section 19.4 covers roof water, and section 19.5 covers tankered water supplies.

Readers should refer to other chapters of these Guidelines for additional information. Some helpful information also appears in AWWA (1999) *Design and Construction of Water Systems, an AWWA Small System Resource Book*.

Other chapters discuss some of the treatment processes covered in this chapter. For example, Chapter 13 Treatment Processes: Coagulation and Filtration includes lime softening and ion exchange processes, and Chapter 14 Treatment Processes: Filtration and Adsorption covers cartridge and bag filtration, and adsorption processes such as activated alumina and activated carbon.

DWI (2001) is an extensive manual on water treatment for small water supplies. It includes an interesting procedure for risk assessment in Appendix E.

WHO (2011a) discusses issues related to water quality in buildings, while WHO (2009a) addressed water supplies to schools.

WHO (2012) gives step-by-step guidance for the planning, design and implementation of water safety plans by and for rural and remote communities, including communities with piped schemes, those served by point sources and community-wide water supply services using various technical options. WHO (2014) contains short explanations of the water safety planning process (including practical templates and tips) that support WSP development and implementation in small communities. Chapter 2 of these Guidelines also covers WSPs.

The DWSNZ do not cover private water supplies. The Ministry of Health has prepared a lot of material to assist owners and operators of small water supplies. Go to www.health.govt.nz and click on Environmental Health, Drinking-water. The NSW Government published *NSW Private Water Supply Guidelines* in 2015; see <http://www.health.nsw.gov.au/environment/water/Pages/NSW-private-water-supply-guidelines.aspx>. The Victorian Government published *Guidelines for private drinking water supplies at commercial and community facilities* in 2010.

DWI (2016) notes that larger water supplies are increasingly choosing UV disinfection for protozoa compliance, using modern validated appliances with adequate instrumentation, monitoring and maintenance. Previously this process was not always understood resulting in inadequately disinfected water entering the distribution system. DWI found this can still be the case with smaller water supplies. They observed that:

There was a general lack of understanding amongst users regarding the treatment of their private supplies. This was compounded by the lack of information provided by equipment providers/installers.

There was no indication that UV equipment had been selected correctly for the flow or water quality.

UV equipment was generally serviced by specialist companies, plumbers or the users, with quartz sleeves cleaned at intervals between 2-12 months and lamps changed around every 12 months; the frequency of maintenance of other equipment and replacement of cartridge filters was less clear. Maintenance logs are generally not kept by users.

Monitoring and control of UV equipment is inadequate. Failure of a UV lamp may go undetected for some time because a lack of a prominent alarm, and will generally not prevent flow and the possibility of the consumption of non-disinfected water.

A UVI sensor is stipulated by all standards where UV is installed for disinfection applications in larger applications. Unfortunately such a sensor is considered desirable, but not necessarily essential, for private supply applications.

The potential for contamination of stored UV-treated water may not be well understood by users.

There is currently no licensing or approved contractor scheme applicable to the installation of equipment for private water supplies.

As a result, DWI recommends that:

- a licensing or approved contractor scheme should be implemented for installers of equipment for private water supplies
- copies of manufacturers'/suppliers' operating and maintenance instructions should be provided and retained by the supply owner. In addition, a maintenance log should be maintained by the owner to record details of maintenance carried out and schedules for future maintenance
- audible and visual alarms should be more prominent, particularly where the UV system is sited away from the user's premises

- UV systems should include automatic shutdown of the water supply in the event of power or lamp failure. An emergency valved by-pass line could be incorporated with instructions to boil drinking water prior to consumption (whilst the UV system awaits repair).

19.2 Small water supplies

19.2.1 Key requirements of the DWSNZ

A risk management approach has been adopted in the DWSNZ for small drinking-water supplies, placing the emphasis on taking action to prevent contamination in the first place and on water quality monitoring/testing as a check that the risk management actions are working.

There are two options for demonstrating that small water supplies comply with the DWSNZ:

- 1 comply with the requirements in sections 4, 5 and 7 to 9 of the DWSNZ, or
- 2 follow a Water Safety Plan (WSP – formerly known as a Public Health Risk Management Plan, PHRMP) approach to compliance (section 10 of DWSNZ). Although it is not necessary to comply with all the requirements in sections 4, 5 and 7 to 9 of the DWSNZ, any issues relating to these need to be addressed in the WSP. Water suppliers following this approach were called participating supplies.

Compliance with section 10 of the DWSNZ requires that:

- a WSP must have been approved by a drinking-water assessor (DWA) and is being implemented
- appropriate bacterial and chemical treatment, as determined from the catchment assessment in the WSP, must be in use
- appropriate protozoal treatment must be in use, following the manufacturer's instructions
- water quality must be monitored and meet specified requirements
- the remedial actions that have been specified in the WSP must be undertaken when a MAV is exceeded or treatment process controls are not met.

Reticulated community supplies serving fewer than 1500 person days (eg, 25 people for fewer than 60 days) each year are exempt from having to demonstrate compliance with the DWSNZ, but must have safe (potable) water. This means the drinking-water must not contain any contaminants that exceed the MAVs in the DWSNZ.

Section 19.2.5 provides information to assist these water suppliers produce safe drinking-water.

19.2.2 Preparing a water safety plan

Preparing, implementing and updating a WSP are requirements of ongoing compliance with the DWSNZ. WSPs and quality management for larger supplies are discussed in Chapter 2: Management of Community Supplies. The WHO has now adopted the principle of WSPs, which they also call water safety plans (see WHO 2012, 2014).

Risk management recognises that sometimes things will not go as planned, and aims to identify the causes of these problems and to recognise early warnings that these events are starting, and to put in place measures to control their impact. Emphasis is placed on developing plans that detail how to prevent events occurring and to respond to events when they do occur.

Why prepare a plan

Water, whether it comes from a river, stream, lake, reservoir, rain, spring or groundwater, may be unsafe to drink. What makes water safe is the care and consideration people have for activities and actions in the areas from where the water is obtained (the catchment), and in the treatment, storage and distribution of the water.

Water suppliers have a public health responsibility to ensure that the drinking-water supplied to their communities is safe. Following a well thought-out WSP designed specifically for the supply will provide consumer confidence of consistently safe drinking-water. A WSP provides direction for improvements and expenditure, is a safeguard against changing operations staff and management, and is a learning resource for new staff.

What is covered by the plan

A WSP is a systematic assessment of every aspect of providing safe drinking-water, identifying the events that could cause water quality to deteriorate and become unsafe to drink, and developing plans to manage these.

The WSP covers three parts of a water supply: catchment and intake; treatment; storage and distribution. It helps to identify whether any of the following four barriers to contamination are missing:

- preventing contaminants entering the source water
- removing particles from the water (where many of the pathogens/germs hide)
- killing or inactivating pathogens/germs
- preventing recontamination after treatment.

The WSP covers the following questions:

- 1 what could happen to cause the water quality to deteriorate and become unsafe to drink
- 2 which of these factors needs urgent attention

- 3 how to know when the water quality is deteriorating to a point where action is needed
- 4 how to respond if action is needed
- 5 what to do to stop deterioration happening in the future.

How to prepare the plan

A kit has been developed to help water suppliers prepare a supply-specific WSP (*Small Drinking-water Supplies Public Health Risk Management Kit*, February 2008, available from the Ministry of Health's website <http://www.health.govt.nz>). See also Ministry of Health (2014a and b).

- Step 1 describes the drinking-water supply. A good description of the water supply starts the process of identifying what could cause the water to become unsafe to drink.
- Step 2 is based on the description of the water supply, and assesses in detail what is being managed well and where improvements are needed to ensure safe drinking-water.
- Step 3 focuses on what needs attention and develops a plan to manage these. The plan covers monitoring and inspections, emergency and incidents, standard operating and maintenance procedures and an improvement schedule. WHO (2011b) provides technical notes covering a range of emergency situations.

A range of resources are available from the Ministry of Health's website <http://www.health.govt.nz> to assist you. For a list of DVDs, go to http://www.health.govt.nz/publications?page=2&f%5B0%5D=im_field_category%3A39. These include:

- Don't Bug Me! Pathogens and pathways in drinking water supplies, 2006, DVD.
- Making it Safe! Principles and methods of treatment for small drinking-water supplies, 2007, DVD.
- Checking it Out. Sampling and monitoring of small drinking-water supplies, 2007, DVD.
- Tanks, Pumps and Pipes. Small drinking-water supply reticulation systems, 2007, DVD.
- Pathogens and Pathways, and Small Drinking-water Supplies. Resources for the Drinking-water Assistance Programme, 2007, booklet.
- Treatment Options for Small Drinking-water Supplies. Resources for the Drinking-water Assistance Programme, 2007, booklet.
- Sampling and Monitoring for Small Drinking-water Supplies. Resources for the Drinking-water Assistance Programme, 2007, booklet.
- Optimisation of Small Drinking-water Treatment Systems. Resources for the Drinking-water Assistance Programme, 2007, booklet.
- Sustainable Management of Small Drinking-water Supplies. Resources for the Drinking-water Assistance Programme, 2007, booklet.

What to do with the plan

The WSP will guide both day-to-day actions and long-term planning. It will identify regular monitoring and inspections that signal deteriorating water quality and prompt action. It will identify regular on-going maintenance to reduce the chance of failure of any of the four barriers to contamination. It will list where to get help, who needs to know what about the status of the WSP and drinking-water quality, and how quickly they need to know. It will provide direction and priorities for improvements and expenditure.

Risk management is an ongoing process, so the WSP should be reviewed at least annually. It should also be reviewed after any significant change in the catchment or to the water supply, or in response to finding a weakness in the plan. The review process should incorporate appropriate document control.

For supplies wishing to comply with section 10 of the DWSNZ, the completed WSP needs to be approved by a DWA (contact the local District Health Board). The DWA will assess the WSP and return it with a report within 20 working days. They may visit the supply periodically to see progress in using the WSP.

19.2.3 Sanitary inspection

A sanitary inspection of the water supply system is a necessary part of preparing, implementing and updating a WSP. It is the physical/visual assessment component of the water supply assessment step. The broader water supply assessment gathers recent and historical information about the supply to identify what could cause the water to become unsafe to drink. It reminds the supplier about previous problems, things that have been slowly changing, or sudden but short-lived changes, and extreme events that have impacted on water quality and delivery.

The Ministry of Health's *Small Drinking-water Supplies Public Health Risk Management Kit* provides useful checklists of things to consider about the catchment and intake, the treatment process, storage and distribution, and the people-aspects of water supply management.

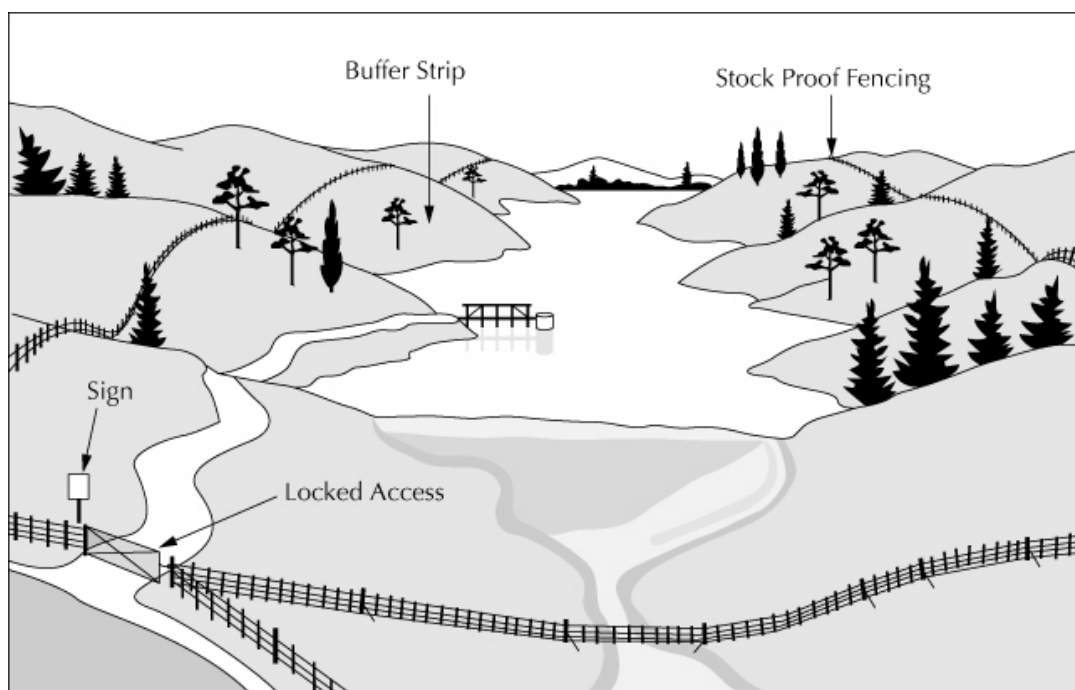
Every effort should be made to prevent contaminants entering the source water. The catchment and intake sanitary inspection should consider:

- access to catchment by people, human excrement
- access to catchment by animals, animal excrement
- discharges to catchment such as effluent from farm practices, septic tanks and wastewater treatment plants, pesticide and fertiliser run-off or seepage, industrial waste, stormwater, seepage from landfills, underground tanks and pipes – all of which can affect surface water, springs and groundwater
- land use changes
- access and discharges to pretreatment storage
- natural events (eg, algal blooms, floods, drought and other natural disasters)
- condition of intake structure and accumulation of debris

- saltwater intrusion
- entry of contaminants to poorly constructed wells or bore heads
- deliberate damage and sabotage.

As an example, Figure 19.1 schematically shows the elements for minimising contamination of open reservoirs (pretreatment storage). Note that the water will still attract birds, and the trees will attract possums. There will, therefore, always be a certain amount of pollution of surface waters even in controlled catchments.

Figure 19.1: Reducing the contamination of open reservoirs



The treatment process needs to be operated in a manner that assures removal of contaminants, kills or inactivates pathogens/germs, and does not add contaminants. The treatment sanitary inspection should consider:

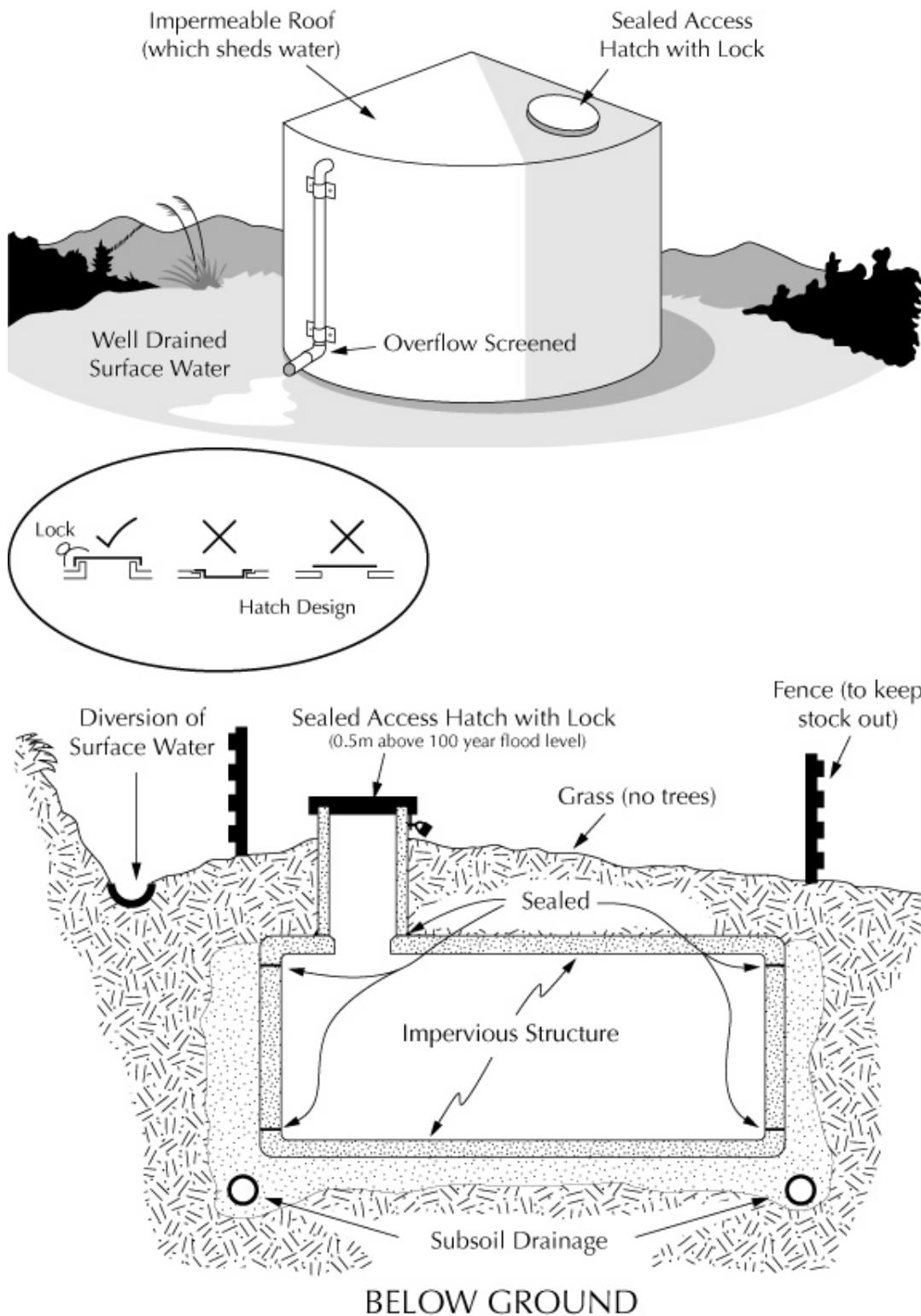
- condition of treatment units and parts
- the training of water supply staff
- the suitability of the treatment process for the likely contaminants
- the suitability of the operational procedures for the equipment used
- the monitoring system, alarm indication and backup equipment if faults occur
- use of approved parts and certified chemicals
- maintenance, cleaning and personal hygiene practices while working at the treatment plant
- appropriate record keeping to assist in management and troubleshooting
- security against access and vandalism or deliberate damage.

Storage/distribution needs to be protected from contamination; see Ministry of Health (2010d). The storage/distribution inspection should consider:

- maintenance, cleaning and personal hygiene practices while working on the reservoirs/tanks and distribution system
- condition of reservoirs/tanks
- security against access and deliberate damage
- interconnections between this supply and a supplementary lesser quality supply (eg, an untreated stream supply that tops up a groundwater supply)
- illegal connections
- maintenance of consistent pressure in the system
- leakage control
- use of backflow prevention devices, particularly for high-risk connections (toxic chemicals or pathogens) such as stock troughs, chemical dosing tanks and irrigation systems
- condition of pipes and fittings, releasing any build-up of corrosion products or material that have settled out from poor quality water, or allowing ingress of sub-surface water from the surrounding area into the pipes.

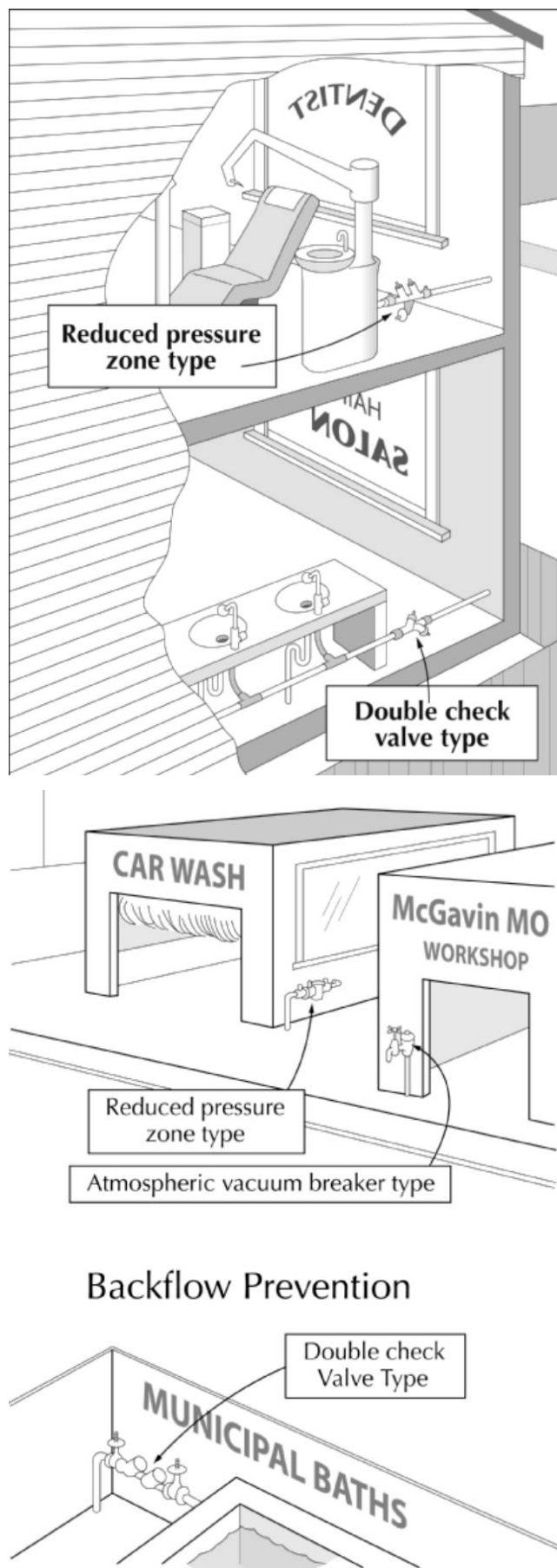
As an example, access of birds and animals to storage tanks has caused a number of contamination incidents. Refer to Figure 19.2 for methods of preventing contamination of storage tanks.

Figure 19.2: Prevention of contamination of storage tanks



As an example, Figure 19.3 shows how potential sources of backflow can be eliminated. Backflow prevention is also discussed in Chapter 16: The Distribution System, section 16.3.2.

Figure 19.3a and b: Backflow prevention device installations



Although Figures 19.3a and b provide examples of how potential sources of backflow can be eliminated they also show examples of errors that can occur and these are listed below (details in brackets relate to clause G12 of the New Zealand Building Code):

- water supply systems must be installed in a manner that allows the system and any backflow prevention devices to be isolated for testing and maintenance (page 4, G12.3.7d and page 23 3.7.1a and b). Isolation valves are shown on the swimming pool and carwash but not on the other installations
- the hair salon is high hazard (page 18, section 3.3.1 comment c) and as such a double check valve is not sufficient (page 19, Table 2)
- all backflow prevention installations should be fitted with a line strainer upstream (page 21, 3.6.3a). None of the diagrams shows a strainer
- the atmospheric vacuum breaker on the garage hose tap is incorrectly installed; the tap/valve should be on the upstream side of the vacuum breaker and the outlet from the system should be a minimum of 150 mm above the outlet from the vacuum breaker (page 21 3.6.3d (i)–(iii))
- the double check valve in the hair salon diagram is installed backwards, ie, it would allow backflow from the sinks to enter the mains but would not allow water from the mains to flow to the sinks.

19.2.4 Water quality monitoring

Regular water quality monitoring and a satisfactory response to any contamination event or when the MAV of a contaminant is exceeded is a requirement of compliance with the DWSNZ. These monitoring requirements provide the check on planning and the actions taken to prevent contamination in the first place. The monitoring requirements are based on the principle that it is more effective to test for a narrow range of key contaminants frequently than to conduct comprehensive testing less often. The monitoring requirements are also based on the principle that the microbiological quality of the water is by far the most important factor in determining how safe water is from a health perspective. The Small Water Supplies section of the DWSNZ provides, or refers to, general requirements (details are to be included in the WSP) of:

- how often to take samples
- where to take samples
- who should take the samples
- who should test the samples
- for what the samples need to be tested
- what to do with the results.

From time to time there are other reasons for carrying out additional water testing. These reasons are for:

- source water assessments
- treatment selection and enhancement
- process control and operational issues

- consumer complaints
- troubleshooting.

There is no set time or place that this additional testing should be done and each individual supply has its own requirements. Most of this type of testing should be identified in the WSP. The Ministry of Health's *Sampling and Monitoring for Small Drinking-water Supplies* booklet provides useful information.

Process monitoring of chlorine disinfection

Disinfection of a drinking-water supply by chlorination is common for small water supplies. Generally, a chlorine residual throughout the distribution system of between 0.2 and 0.5 mg/L is adequate. The amount of chlorine required to achieve this free disinfectant residual varies with the flow rate, the composition of the raw water, the water temperature, time in the distribution system, and the type of treatment.

Testing of chlorine residuals should be carried out at least weekly, preferably daily. This can be done using a simple diethyl-phenylenediamine (DPD) tablet and colour comparator or Nessleriser. Portable spectrophotometers are becoming increasingly popular. Online monitoring is highly recommended. Regular testing for residual chlorine will:

- serve as a check on the continuous satisfactory operation of the chlorinator
- indicate when the chlorine demand has increased, requiring dose adjustment
- allow savings to be made in the quantity of chlorine used
- reduce the level of complaints of strong chlorine odours, which may result from excessive or insufficient dosing.

If the water has a low turbidity and colour, and a free chlorine residual is maintained, consumers can be reasonably confident that most (if not all) pathogenic organisms will have been destroyed after a 30-minute period. Some pathogens (eg, oocysts of the protozoan *Cryptosporidium*) are more tolerant of chlorine and require removal by filtration or inactivation by another disinfection system, but chlorination is still regarded as the most appropriate key defence against contamination by bacteria and viruses. If there are perceived problems related to disinfection by-products, colour/turbidity or taste/odour, these must be addressed rather than turning off the disinfection process; see chapters 5, 6 and 15.

In addition, and provided the dose is adequate, chlorine will prevent slimes and other organisms from growing within the pipeline system so minimises the loss of hydraulic capacity and reduces the potential for biological slimes to cause tastes, odours, turbidity and colour in the water.

Process control of other treatment

Based on the outcome of the catchment assessment (section 10.3.2 of DWSNZ), water treatment may be needed (Table 10.1 in DWSNZ) to inactivate or remove protozoa, or to remove excess colour or turbidity, or to reduce the concentration of any chemicals to below their MAV. Cartridge filtration and UV disinfection will be popular treatment options; some technical requirements are specified in the notes to Table 10.1.

A continuous UV monitor (intensity meter) is required and an alarm or fail-safe device is strongly recommended, and although not usually fitted as standard on point-of-use units, they are usually available as an extra (DWI 2001).

Section 10.3.1 of DWSNZ states that as a minimum requirement, treatment processes must be operated and monitored according to the manufacturer's instructions. That means that the water supplier must demonstrate with appropriate confidence that the UV lamp is working within specification, and the UV dose is satisfactory (which in some cases implies UVT is being measured), and the turbidity is suitable (ie, prefiltration in operation if needed). If using cartridge filtration, note 5 to Table 10.1 requires the vendor to guarantee the system will meet defined performance standards. That means the vendor must supply a test procedure for the water supplier to follow that demonstrates that the equipment is performing to specification, and will indicate when maintenance, servicing, and replacement is required. To be able to do that, the vendor must be aware of the quality of the water being disinfected.

In summary

Instead of prescriptive compliance criteria being detailed in section 10 of the DWSNZ, individual participating water suppliers must cover these in their WSP. Water suppliers will match treatment requirements (see Table 10.1) with the results of their catchment assessment (section 10.3.2). Monitoring the effectiveness of the treatment plant is a balance between source water quality, treatment practices, network protection, and treatment plant suppliers' specifications (section 10.4.3). *E. coli* and total coliform monitoring is specified in section 10.4.2.

The WSP should address issues related to treatment plant performance, either from a compliance perspective or safety. An operator should be alerted when the treated water quality begins to deteriorate, ideally before non-compliance is reached. A system of alarms is normally incorporated into the treatment process, triggering different levels of response. A minor alarm (eg, visual or audible) could indicate some action is required within say 24 hours. A major alarm (eg, a pager) could indicate a plant inspection is required urgently or within a few hours. A critical alarm can be designed to shut down the treatment plant or part thereof.

The MoH prepared Operation and Maintenance of a Small Drinking-water Supply, see Ministry of Health (2010b), and Managing Projects for Small Drinking-water Supplies (Ministry of Health 2010c).

19.2.5 Supplies not required to demonstrate compliance with DWSNZ

Reticulated community supplies serving fewer than 1,500 person days (eg, 25 people for fewer than 60 days) each year are exempt from having to demonstrate compliance with the DWSNZ, but this does not absolve suppliers from the responsibility of producing safe (potable) drinking-water, as required by the Building Act 2004 and its amendments. This means the drinking-water must not contain any contaminants that exceed the MAVs in the DWSNZ.

The cost of treatment, maintenance, and water quality monitoring per consumer may be a concern for some small communities, but it is considered unwise that the health of people in the community or those visiting the community should be compromised. These very small community supplies are encouraged to adopt a WSP approach to provide adequate assurance of safe drinking-water. The processes and resources described in sections 19.2.2 and 19.2.3 are equally applicable to very small communities as they are to the fewer than 500 people communities. Useful information can also be found in section 19.3: Individual Supplies.

Responsible management of these very small community drinking-water supplies includes:

- the skills and knowledge of the people responsible for operating and maintaining the supply are adequate for the type of system operated
- raw water sources and storage are inspected regularly for any source of contamination (see section 19.2.3)
- all equipment and plant are maintained in good condition, inspected regularly, and a maintenance routine is in place
- treatment is provided where the quality of raw water is poor, and appropriate treatment selection is based on known source water quality and variability. The Ministry of Health's *Treatment Options for Small Drinking-water Supplies* booklet provides useful information
- disinfection should be considered for water entering the distribution system, preferably with chlorine or using technology that is effective for removing or inactivating microbiological contamination
- the level of attention to water quality should be increased during periods when water quality is known to be poor. Indicators of poor water quality are turbidity (murkiness), the absence of a free available chlorine residual and the presence of *E. coli*. The indicators will help in deciding whether the barriers to contamination are adequate at times of greatest need. They will also assist in assessing the need for action and the extent of action required
- distribution pipes are cleaned/flushed to remove any build-up of corrosion products or material that has settled out from poor quality water
- treatment and storage facilities are secure and cleaned regularly
- potential sources of backflow are eliminated and reasonably constant pressure in the distribution system is maintained

- funds are set aside to ensure that repairs/maintenance can be carried out when required
- plans are in place to manage deteriorating drinking-water quality before the water becomes unsafe to drink, including knowing the signs of deteriorating water quality or treatment plant performance, knowing when to take action, knowing what actions to take, and who will take the actions.

Where water quality or quantity problems occur, they must be investigated thoroughly and the risks to the community assessed. The options may then be to:

- inform the community of the problem, the actions being taken, and advise what actions individual households should take while the problem is being attended to, eg, boil water:¹ see section 3.1 of WHO (2009) for a discussion on issues related to boiling
- if a permanent 'Boil Water' notice is issued, approved signage must be displayed next to all taps connected to the supply
- check the operation of the existing system to ensure that the complete system is working as designed
- thoroughly clean the system and flush the system to waste
- seek an alternative source of raw water or upgrade the existing source
- upgrade the barriers to contamination in order to achieve potable drinking-water
- as a last resort, declare the supply non-potable and recommend alternatives.

Microbiological quality and monitoring

The microbiological quality of water is by far the most important factor in determining the safety of water supplies from a health perspective. Good microbiological quality in very small water supplies can be achieved by:

- regular sanitary inspections
- routine system maintenance
- adequate disinfection
- monitoring/testing for microbiological indicator organisms.

Barriers for preventing contamination must be effective. Routine sampling and analysis of the microbiological quality of the water during periods of higher risk can help in detecting contamination problems, and in determining whether these have arisen at the water source, during treatment, or in the distribution system. As a minimum, these very small community drinking-water supplies should be monitored for the four determinands that best establish the sanitary state of the water:

- *E. coli* and total coliforms
- pH
- disinfectant residual (may not be relevant for secure bore water supplies, or for ultraviolet light irradiated water)
- turbidity (monitoring frequency will be less for secure bore water supplies).

¹ Chapter 6 includes an Appendix: Boil Water Notices.

Note that secure bore water is defined in the DWSNZ, and is explained in Chapter 3 of the Guidelines.

Except for the indicator micro-organisms, the above determinands can be tested on-site using relatively simple testing equipment. This is essential for disinfectant residuals, which must be measured at the time of sampling. It is also important for the other determinands where laboratory support is lacking or where transportation problems would render conventional sampling and analysis difficult or impossible.

Test kits are available for rapid microbiological examination of water, but the results obtained may be variable and require careful interpretation. A coliform presence/absence test (P/A) may be used for process control monitoring, and for testing the water supply for compliance with the DWSNZ. But when total coliforms or *E. coli* are found when using presence/absence kits, the correct response should be to consider that the drinking-water supply is contaminated; a more rigorous method must be used for repeat tests so that a numerical result (the number of organisms can be counted) can be obtained. Although microbiological test kit analyses are relatively simple and cheap, expertise in their use and strict compliance with the instructions are required.

To enable a small drinking-water supply to be monitored adequately, the water supplier may wish to consider using the services of a volunteer from the community. Suitable personnel can be selected after consideration of where their premises are, and whether they have previous experience such as operating a swimming pool. The water supplier should call periodically to cross-check results and to replace reagents and equipment as required. Advice can be obtained from drinking-water assessors.

Any person undertaking the monitoring or operation of a community water supply should receive adequate training, reference material, and contact personnel to enable them to perform their functions responsibly, with a full understanding of the requirements and purpose of their duties.

19.2.6 Water supplies operated under the Building Act

Many drinking-water supplies in New Zealand are self-supplied drinking-water systems, eg, rural schools, marae, and camping grounds. The water is not delivered to individual buildings via a distribution system, but distributed across the owner's property by their own plumbing system. Self-supplied drinking-water systems are subject to the requirements of the *Building Act* 2004.

Section 19.2.5 (Small Community Supplies not Required to Demonstrate Compliance with DWSNZ) should be used as a guide for these self-supplied drinking-water supplies.

Refer to section 19.3 for matters related to individual household drinking-water supplies.

19.3 Individual household drinking-water supplies

An individual household drinking-water supply is a stand-alone system that is not connected to a community drinking-water supply. Individual household supplies have a responsibility to produce safe (potable) drinking-water as described in the *Building Act* 2004 and its amendments. Approved Document G12 Water Supplies requires premises to be provided with potable water for oral hygiene, utensil washing and food preparation. Bathing, showering, and toilet flushing can use non-potable water such as salt water or stream water, provided it is not detrimental to health. Under section 39 of the *Health Act* 1956, it is illegal to let or sell a house unless there is a supply of potable water.

Water, whether it comes from a river, stream, lake, reservoir, rain, spring or groundwater, may be unsafe to drink. What makes water safe is the care and consideration people have for activities and actions in the areas from where the water is obtained (the catchment), and in the treatment, storage and distribution of the water, affecting the raw water quality and the safety of the final product. This section provides information to assist individual household water suppliers produce safe drinking-water at a reasonable cost. For further information on design of individual household drinking-water supplies refer to (available from district health board offices):

- *Household Water Supplies*, Ministry of Health, 2001, revised 2016
- *Water Collection Tanks and Safe Household Water*, Ministry of Health, 1999, revised 2014
- *Secure Groundwater Bores and Wells for Safe Household Water*, Ministry of Health, 2000.

Further useful information can be found in the resources listed in section 19.2.2 for small community supplies. MoH drinking water publications can be found at <http://www.health.govt.nz/our-work/environmental-health/drinking-water/drinking-water-resources>.

The WHO published *Managing Water in the Home: Accelerated health gains from improved water supply* and is available on the internet (WHO 2002).

19.3.1 Water sources other than rainwater

Waters from different sources tend to have different qualities. These are summarised in Chapter 4: Selection of Water Source and Treatment, Table 4.1: Source Water Quality. This table may be used as a guide in determining how much risk is associated with a particular source, and therefore what degree of treatment and vigilance is necessary to ensure safe drinking-water. The characteristics listed in the columns headed Chemical Quality and Aesthetic Quality are sometimes interrelated. For example, soft corrosive waters can cause high concentrations of some metals due to corrosion of plumbing materials.

Apart from some chemicals in geothermal or hydrothermal waters (most frequently boron, arsenic and fluoride), and corrosion metals such as lead, the principal health risk is usually from the presence of illness-causing micro-organisms. Therefore microbiological quality should be given the most attention.

Groundwater

Groundwater as a source for drinking-water is discussed in Chapter 3: Source Waters, section 3.2. Also, see *Design and Operation of Bores for Small Drinking-water Supplies* (Ministry of Health 2010a).

The key points about groundwater are:

- most groundwater used for individual household supplies is likely to be from bores drawing from shallow systems
- these shallow systems should be treated as if they were surface sources, ie, susceptible to contamination from surface activities, and therefore likely to require treatment, particularly disinfection
- a properly constructed and protected bore head, and an adequate separation between the bore and any septic tank or other wastes, are important in preventing contamination from surface activities, see Chapter 3: Source Waters, Figure 3.2: sanitary protection of a typical bore
- groundwater can contain elevated levels of nitrate from farm run-off and seepage (fertiliser application and stock effluent), and from septic tank effluent; health effects from nitrate at or above the MAV of 50 mg/L as NO₃ are restricted to infants, see datasheet
- some groundwater can contain elevated levels of iron and manganese, which when exposed to the atmosphere or are chlorinated, can appear as brown/orange and black staining or particles
- some groundwaters contain high levels of carbon dioxide which can cause metallic corrosion eg, copper pipes, see Chapter 10
- some groundwater can also occasionally have odours and tastes associated with them, usually H₂S, however these are not necessarily indicators of any health risk.

Surface water

Surface water as a source for drinking-water is discussed in Chapter 3: Source Waters, section 3.3. Surface water is water from streams, rivers, ponds, lakes, reservoirs, springs and shallow unconfined groundwater systems. Roof water is discussed in section 19.4. In areas where roof water may offer an inadequate supply, surface water can be used for non-potable purposes such as garden watering. Taps providing non-potable water should have suitable signage.

The key points about surface water are:

- it is necessary to regard surface water as unsafe for use in a household unless reliable treatment is provided because it is susceptible to contamination from surface activities
- surface water from streams, rivers and lakes draining catchments that are highly modified by human and animal impacts will have higher turbidity (murkiness). These sources are likely to be contaminated by animal effluent, sewage effluent, agricultural fertilisers, and possibly industrial waste discharges. They may also have high algae concentrations during summer. In some parts of the country, surface waters can be affected by geothermal activity which can cause health effects over a long period of exposure
- a controlled surface water catchment is one where animals or people are prevented (unless a permitted entry is allowed) from entering. Such a catchment is often well-vegetated and the water usually has a low turbidity, but may have moderate to high colour, depending on the vegetation and soil type. These sources may undergo rapid increases in turbidity and colour following heavy rainfall. Feral animals (eg, possums) and birds (eg, scavengers such as seagulls and ducks) are often present, introducing illness-causing micro-organisms.

19.3.2 Sanitary inspection

A sanitary inspection is the physical/visual assessment of a drinking-water supply from catchment to tap that identifies what could happen to cause water quality to deteriorate and become unsafe to drink. The processes described in section 19.2.3 are equally applicable to individual household supplies as they are for small community supplies.

19.3.3 Water quality and monitoring

The microbiological quality of water is by far the most important factor in determining the safety of water supplies from a health perspective. Good microbiological quality in individual household drinking-water supplies can be achieved by:

- regular sanitary inspections
- routine system maintenance
- adequate disinfection
- monitoring/testing for microbiological indicator organisms.

Common contaminants, the problems they cause, and their likely origins, are shown in Table 19.1.

Table 19.1: Common contaminants, related problems, and their likely sources

Cause	Problem	Likely source
Aggressiveness	Corrosion, taste and staining	Soft low pH water (eg, rainwater) and bore water containing CO ₂
Arsenic	Poisonous to humans	Water containing geothermal fluids
Bacteria	Waterborne disease	Human and animal wastes
Boron	Possible health problems	Water containing geothermal fluids
Colour	Appearance, taste, staining	Natural decaying vegetative matter, or high manganese/iron
Copper	Possible health problems. Taste and staining (blue water) can occur at lower concentrations	Corrosive water and plumbing materials
Hardness	Scale, excessive soap use and increased maintenance of water heating elements	Dissolution of limestone-type rocks
Iron	Staining, taste, pipe clogging	Soluble iron salts produced by reduction in oxygen-free conditions, usually bore water
Lead	Poisonous to humans, especially infants, young children and unborn babies	Corrosive water and older plumbing materials/roof paints
Manganese	Possible health problems if above 5 mg/L. Taste and staining can occur at lower concentrations	Soluble manganese produced by reduction in oxygen-free conditions, usually bore water
Nitrate	Bottle fed infants can have breathing problems (blue baby syndrome)	Fertilisers, sewage, animal effluent, clover pasture
pH	When less than 6.5, corrosion of plumbing materials, possibly causing copper or lead to be dissolved into the water	Soft water, CO ₂ rich groundwaters
	When greater than 8.5, scale formation in hot water cylinders and on heating elements causing reduced efficiency and premature failure. Also can cause excessive scale build-up in pipes	Many groundwaters
Protozoa	Waterborne disease	Human and animal wastes
Taste and odour causing substances	Taste, odour	Many causes including algae, minerals, chlorination by-products, leaching of organic materials from plumbing materials, corrosion products
Turbidity	Appearance, and interference with disinfection	Suspended particles of natural and human or animal origin
Viruses	Waterborne disease	Human and animal wastes

Water supply owners should have the water being used for drinking, cooking and food preparation tested for microbiological indicator organisms (eg, *E. coli*) at least once every six months.

A specialist water testing laboratory should be used, and can give advice on the correct procedures and container to be used when taking samples (see Laboratories – Analytical, and Laboratories – Testing in the Yellow Pages; but check that they routinely carry out water quality analyses). The laboratory used should be on the list of analytical laboratories recognised by the Ministry of Health as suitable for carrying out compliance testing related to the DWSNZ. Advice is also available from Drinking-water Assessors (contact your local public health protection unit through your District Health Board). IANZ accredited and MoH recognised laboratories are listed in <http://www.ianz.govt.nz/>.

Other contaminants should be tested when there is a change in the source or treatment process, or every two to three years, or when there is some cause for concern. Cause for concern may arise because of a new or worsening problem with the water (see Table 19.1 for some of the more common contaminants and their related problems). If analysis shows that a particular contaminant has reached or is greater than 50 percent of its MAV (refer to DWSNZ), the cause should be investigated and it should be monitored every three months until it has dropped below the 50 percent level, and/or the source of the contamination is removed or controlled.

19.3.4 Water treatment

The purpose of treating water is to ensure reliable safe (potable) water for the household or buildings. Anything less than microbiological safety is placing members of a household at risk. Only the water used in drinking, washing, cooking, and food preparation is required to be both microbiologically and chemically safe. This typically represents only two to three percent of household consumption. It is recommended that, if the whole supply is not being treated, to ensure safe drinking-water, as an absolute minimum, the water used for the above purposes should be treated to the required standard using a point-of-use or point-of-entry device (see below). Labelling of pipes and outlets is extremely important especially for visitors and future owners (refer New Zealand Building Code Approved Document G12: Water Supply). Labelling of pipes helps prevent cross-connections between potable and non-potable waters. When the water is unsafe, a notice at points of use should advise consumers to boil water for all water used for drinking.

Bore water proven to be secure should not need any treatment, at least for microbiological contamination. However, for some groundwater, treatment of the whole supply may be necessary to remove or control specific chemical contaminants, eg, carbon dioxide (see Chapter 12: Pretreatment Processes), iron and manganese (see Chapter 18: Aesthetic Considerations). Proving bore water is secure can be very expensive so it is recommended to assume that it is equivalent to surface water.

Treatment selection should be based on known source water quality and its variability. This requires repeated testing over a period of time to select a treatment process that will be effective over the range of source water quality. In particular, a sample should be tested when the source water is considered to be at its worst quality and at its best. A specialist water testing laboratory should be used, and the results made available to a drinking-water treatment specialist/consultant (see Table 19.1 for some of the more common contaminants and their related problems).

Table 19.2 summarises the common contaminants found in water, and some possible methods of treatment (suitable for individual supplies) for these contaminants. The Ministry of Health's *Treatment Options for Small Drinking-water Supplies* booklet provides additional information. The discussions that follow provide further detail on some of these treatment options. Refer to Chapters 12–15 for a more in-depth discussion about methods for water treatment and disinfection. Chapter 18 includes some treatment processes for the control of aesthetic determinands.

Water treatment systems for individual households fall into two main groups:

- point-of-entry (POE), where the water is treated 'at the gate' or boundary
- point-of-use (POU), which is usually associated with the kitchen tap, commonly installed under the sink. Sometimes they are installed under the bathroom basin as well. If POU rather than POE is used, the potential risk exists of drinking water from the wrong tap.

The World Health Organization (WHO 2016) has begun evaluating household water treatment technologies. After their first round of testing they concluded:

- only half of the 10 products evaluated were found to provide comprehensive protection against all three pathogen classes
- two of the products evaluated were found to not meet any of the minimum performance targets
- two of the products evaluated (a membrane ultrafiltration device and a solar disinfection indicator) did not consistently meet the required performance targets across all samples
- manufacturer testing, in some cases, is insufficient to support claims as testing does not cover all three classes of pathogens
- existing testing is often conducted under ideal conditions that are not reasonably reflective of actual use in the field
- unclear instructions and product labelling were observed in two products
- national regulations are generally weak.

Membrane filters are split into categories depending on the size of the pores. In decreasing order of pore size, the categories are microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO); they are discussed individually. For small supplies they are usually in the form of a cartridge.

Section 19.4 discusses rainwater/roof water systems and their treatment options. Section 19.3.5 covers plumbing considerations.

Table 19.2: Contaminants and treatment methods

Contaminant	Treatment
Arsenic	Cartridge filtration if arsenic is particulate; strong base anion exchange or reverse osmosis if soluble. Activated alumina
Bacteria	Ultraviolet light (only effective in low turbidity/low colour waters and while lamps performing near full efficiency) Ozone, chlorine, reverse osmosis, boiling, nanofiltration
Boron	Ion exchange
Carbon dioxide	Aerate; add calcium carbonate, marble, dolomite granules or chips
Colour	Activated carbon, reverse osmosis
Copper	Make water less corrosive, treat as for carbon dioxide. If copper present in source water (unlikely) other treatment will be necessary so seek specialist advice
Hardness	Ion exchange, water softening, reverse osmosis
Iron	Aerate and filter, chlorinate and filter, ion exchange (if soluble)
Lead	Remove source of lead. Use approved fittings. Make water less corrosive, treat as for carbon dioxide. If present in source water (unlikely) other treatment will be necessary so seek specialist advice
Manganese	Aerate, chlorinate and filter, potassium permanganate and filter, ion exchange (if soluble)
Nitrate	Ion exchange or reverse osmosis; use alternative source for infants
pH	If too low, treat as for carbon dioxide; if too high, treat by ion exchange (but rarely necessary)
Protozoa	Boil, cartridge filter (1.0 µm nominal pore size), ozone, ultraviolet light, reverse osmosis, nanofiltration, ultrafiltration, microfiltration
Taste and odour (many causes)	Activated carbon, boil, reverse osmosis
Turbidity	Cartridge filter, reverse osmosis, nanofiltration, ultrafiltration, microfiltration
Viruses	Chlorine, reverse osmosis, boil, nanofiltration

Point-of-entry systems

POE systems usually treat all the water entering a property or a cluster of buildings, for domestic purposes. Capital costs are usually higher but the plumbing may be simpler. The larger treatment units can incorporate some degree of automation such as routine backwashing, water quality monitoring becomes more cost-effective, and they can be operated by trained staff.

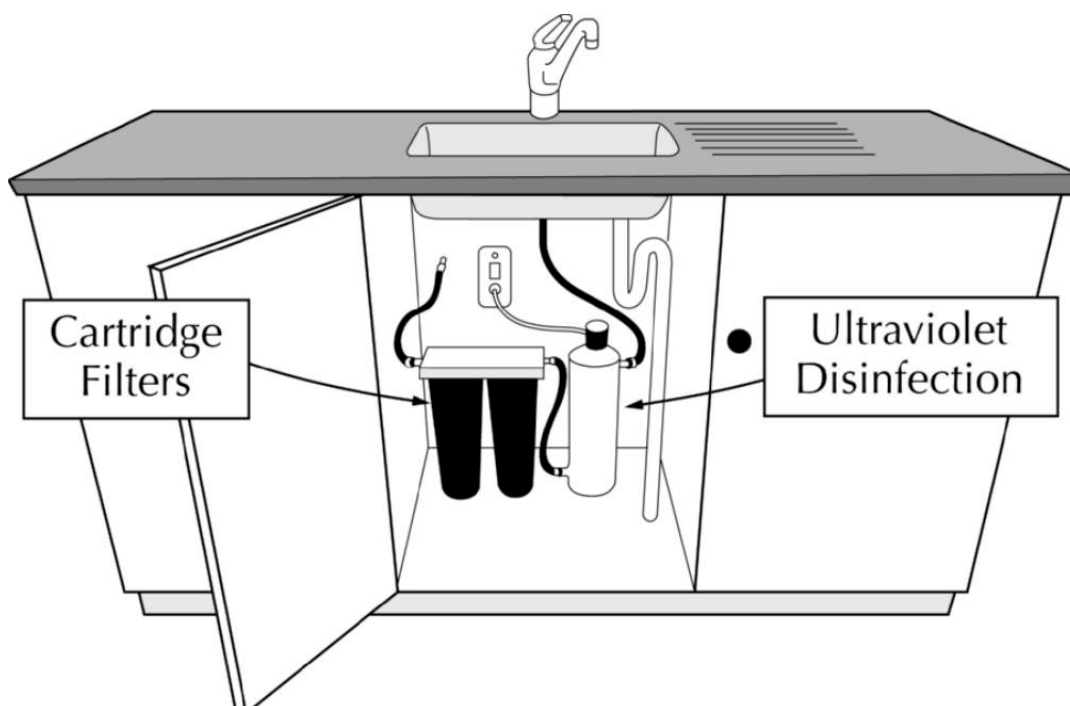
POE systems have been used where a non-potable supply (eg, irrigation water) passes a village or cluster of buildings; the local authority installs or supervises an approved POE system, and then monitors the water and maintains the equipment. POE systems can feed into a storage tank.

Point-of-use devices

Many people use the cheap, effective point-of-use (POU) device found in most kitchens: an electric kettle. If water is boiled for a minute, all biological (including *Cryptosporidium* oocysts and *Giardia* cysts) and most gaseous contaminants will be removed or destroyed; most chemicals will be unaltered.

Other POU devices are like a miniature water treatment plant and can be used to treat all household water, or even be put on the end of a tap, for producing drinking-water only (see Figure 19.4). A potentially serious limitation with POU devices is that there will invariably be other taps in a dwelling without a POU device and people will need to be able to identify these, and accept that they should not be used for drinking.

Figure 19.4: Typical point-of-use installation



There is a wide range of POU devices on the market. They are available as plumbed-in, tap mounted, and stand-alone units. The POU devices available vary widely in quality, type and performance. Their effectiveness has a number of considerations, such as knowing:

- the quality of water that the device needs to treat
- the device can cope with this incoming quality
- the device can cope with the anticipated quantity and flow rate
- the device is being operated, maintained and serviced appropriately
- when the device has failed, either physically, or is no longer producing potable water. Preferably there should be a warning that this state is approaching because these systems usually do not include any (or much) treated water storage so there is very little time to remedy the situation.

It is important to get clear written specifications from the vendor about what determinands the device will treat, and perhaps more importantly, what it will not treat. This should then be compared with the source water quality and its variability. It is also advisable to ask for validated New Zealand tests for the performance claimed by the manufacturer and vendor. In the event of the purchased device not being suitable for its purpose there may be a remedy available under the *Consumer Guarantees Act 1993*.

Where communities rely on household water treatment, WHO (2006a) considers water authorities should initiate programmes and work to ensure that a range of these technologies or systems are available, such that consumers can choose what is acceptable, affordable and appropriate for their household. As a minimum they should work to ensure that the training and information that consumers need to make good decisions is available. Authorities should also monitor these situations to be sure that the household treatment is functioning successfully.

With recent research indicating that household-based approaches to managing water are cost effective, WHO has taken the lead in coordinating the International Network to Promote Household Water Treatment and Safe Storage (WHO 2006b). WHO (2002) describes many household treatment and storage techniques.

Neglected maintenance is one of the biggest problems with POU devices (the other being selection of an inappropriate system for the contaminants of concern). For example, many micro-organisms can accumulate and grow in or on poorly maintained devices, or systems designed to remove tastes/odours (eg, activated carbon filters). It is important to be familiar with the maintenance and replacement requirements of each treatment unit. Some units require more maintenance than others. All POU units should be maintained according to the manufacturer's recommendations. Some units have dealer or manufacturer maintenance contracts available to ensure proper operation over the life of the unit. One of the major problems is the difficulty of knowing when a point-of-use device has ceased to function effectively. Use-by dates or the manufacturer's instructions as to the maximum volume of water that can be treated should be strictly adhered to. It could be helpful to install a water meter or to measure pressure loss across the device. Once again, reputable suppliers should offer sound advice.

Table 19.3 shows the different types of POU and POE devices and their effectiveness against various contaminants when used and maintained properly. A POU device should state clearly and permanently on its casing, what type of unit it is and what it will and will not achieve.

NSF/ANSI have published the following standards (note: these are updated frequently):

Point-of-entry and point-of-use systems designed for the removal of aesthetic determinands are covered by NSF/ANSI 42-2005e. Determinands included are chloramines, chlorine, hydrogen sulphide, iron, manganese, zinc, particulates, and pH adjustment.

NSF/ANSI 44-2004 *Residential Cation Exchange Water Softeners* is designated as an ANSI standard. See Chapter 13: Coagulation Processes, section 13.6: Lime Softening and Ion Exchange for further information. Some discussion related to water softening also appears in Chapter 18: Aesthetic Considerations, section 18.3, under the heading of Hardness.

NSF/ANSI 53-2006 *Drinking water treatment units – Health effects* (with Addendum No. 1) is a standard that establishes minimum requirements for design and construction, and performance of drinking-water treatment systems that are designed to reduce specific health-related contaminants in public or private water supplies.

- Clauses 7.2.1 and 7.2.4 cover organic chemical reduction
- Clause 7.2.2 covers inorganic chemical reduction (fluoride, nitrate)
- Clause 7.2.3 covers radon reduction (POU activated carbon)
- Clause 7.3.2 covers (oo)cyst reduction
- Clause 7.3.3 covers turbidity reduction
- Clause 7.4.1 covers arsenic reduction (RO)
- Clause 7.4.2 covers general metals reduction
- Clause 7.4.3 covers lead reduction
- Clause 7.4.4 covers mercury reduction.

NSF/ANSI 55-2004 *Ultraviolet Microbiological Water Treatment Systems* is designated as an ANSI standard for point-of-use units. This specifically covers point-of-entry and point-of-use systems.

NSF/ANSI 58-2006 *Reverse Osmosis Drinking Water Treatment Systems* is designated as an ANSI standard for point-of-use units.

NSF/ANSI 61-2017 *Drinking Water System Components – Health Effects*.

NSF/ANSI 62-2004 *Drinking Water Distillation Systems* is designated as an ANSI standard.

NSF/ANSI 419-2015 *Public Drinking Water Equipment Performance – Filtration*.

Discussion of point-of-use systems appeared in the July and November 1995 issues of *Water and Wastes in New Zealand*, nos. 86 and 88. See USEPA (2006) for an extensive discussion on POU/POE treatment systems. Section 7 in USEPA (2003) discusses point-of-use and point-of-entry (POU/POE) units too. WHO (2012a) produced a Toolkit to help assess correct and consistent use of household water treatment and safe storage by those most at risk.

Three very good handbooks have been published in recent years, see CRC (2007), British Columbia (2007) and USEPA 2006a). Costs are discussed in USEPA (2007).

See also: Ministry of Health. 2010e. *UV Disinfection and Cartridge Filtration: Resources for Drinking-water Assistance Programme*.

Chlorination

Individual household supplies may use chlorination to disinfect the water. Disinfection by chlorination must be controlled carefully – both the dose and the contact time, before using the water. The chlorine should be dosed to give a free available chlorine (FAC) level of at least 0.2 mg/L in the water 30–60 minutes after mixing. Enough FAC needs to be added to destroy the pathogens/germs, but too much may cause consumers to complain about taste and odour. Disinfection using chlorine can be done on either a batch basis, or by using a proprietary chlorinator that doses chlorine into the water as it is drawn and stored, as used at school swimming pools. The FAC can be measured using a test kit based on the DPD colorimetric method or by a combination test kit that includes pH measurement. These kits come with all necessary test tubes, chemicals, colour chart and instructions, and are available from swimming pool chemical suppliers and some pharmacies.

The compounds of chlorine most commonly used for batch dosing are sodium hypochlorite (ordinary, unscented, uncoloured, fresh, household bleach, a liquid) or calcium hypochlorite (swimming pool chlorine, powder or granules). For water that comes from very safe to reasonably safe sources a dose of either:

- 4 to 7 mL of sodium hypochlorite bleach per 100 litres of water; make sure it is fresh stock (at 3 percent available chlorine this is equivalent to a dose of 1 to 2 mg/L) or
- 0.15 to 0.3 g of calcium hypochlorite (65 percent available chlorine) per 100 litres of water

will generally give the required free available chlorine residual. The disinfected water should be left to stand overnight before use. The Ministry of Health's *Household Water Supplies* booklet has tables of chlorine dose (sodium hypochlorite bleach and calcium hypochlorite) for other tank volumes. CDC (2009) discusses emergency disinfection of drinking water, including disinfecting wells.

It is advisable to keep records of the disinfection, eg, dates, doses and volumes, so the process can be fine-tuned as experience accumulates. Records will be helpful when different people treat the water, when the raw water quality varies, and for troubleshooting.

WHO (2011) discusses some household water treatment options.

Table 19.3: Point-of-use and point-of-entry devices and an indication of their effectiveness against various contaminants

Contaminant	Activated carbon (1)	Boiling (4)	Ceramic candle (2)	Cartridge filtration (2)	Home distillation (13)	Reverse osmosis (8)	Water softener (7, 8)	Ultra-filtration (8)	Ultraviolet light (6)	Calcium filtration (9)	Oxidising systems (16)
Arsenic (11)	P	N	N–G	N–G	M–Ex	G–Ex	G (7)	N–G	N	P–G	
Bacteria	N (1)	Ex (4)	P–G	P	Ex	M	N–P	M	Ex (6)	P	
Boron	N	N	N	N	Ex	N	Ex	N	N	N	
Carbon dioxide/corrosivity	P	G	N	N	M	P	P	N	N	G–Ex	
Colour	M (3)	N	N	N	Ex	G	P	P–M	N	N	
Hardness	P	M (5)	N	N	Ex	P–M	G (7)	P	N	N	
Iron, soluble	P	N	N	N	Ex	G	G–Ex (7)	M	N	P–M	G
Manganese, soluble	P	N	N	N	Ex	G	G (7)	M	N	P–M	G
Nitrate	P	N	N	N	Ex	G	G (7)	P	N	N	
Protozoa cysts/oocysts	G (2)	Ex (4)	G–Ex	G (2)	Ex	Ex	N	Ex	G (15)	P (10)	
Taste and odour	G–Ex (3)	M (12)	N	N	M	M	P	P	N	P	M
Turbidity (14)	M	N	P–M	P–G	Ex	Ex	M	Ex	N	P	
Viruses	N (1)	Ex (4)	P	P	Ex	Ex	P–M	Ex	P–Ex (15)	P	

Terms used in table:

Ex excellent removal, where equipment is in good condition

G good removal to an acceptable level

M moderate removal, constituent may still give a problem

P poor performance, most of constituent levels unaffected

N no removal at all

Notes:

Activated carbon filters can be either POE or POU.

Boiling, ceramic candle, cartridge filtration, home distillation, reverse osmosis tend to be used as POU systems.

Water softening, ultra-filtration, ultraviolet light, calcium filtration, and oxidising systems tend to be used for POE treatment.

See Chapter 9, section 9.7.2.4 for brief comments related to removal of cyanotoxins.

Explanatory notes for Table 19.3:

- 1 Activated carbon filters should not be used for water containing biological contaminants unless there is a subsequent reliable disinfection stage. Activated carbon can act as a growth medium for micro-organisms. WHO (2003) states in Chapter 12.4 that Health Canada, the US Environmental Protection Agency (EPA), the US Consumer Product Safety Commission and the Italian government have all, at one time or another, proposed banning activated carbon filters used in home drinking-water treatment devices because of the growth of HPC bacteria on the carbon media and subsequent rises in HPC counts in the filtered water. After further study, however, all four decided against banning the filters. At Health Canada, the decision was made following consultations with stakeholders and was based on the absence of evidence of any illness linked to such devices. This decision was taken with the proviso that the manufacturers and distributors of activated carbon filters agree to take steps to help prevent the use of these devices on microbially unsafe waters or waters of unknown quality. In addition to growth on the carbon filter, it was shown that the filter media of some new commercial filters were already contaminated with bacteria and moulds even before being installed in homes.
- 2 Either plain or activated carbon cartridge-type filters or ceramic candles can remove protozoa (oo)cysts, provided the nominal particle retention size of the filter is 1 micron or less. However, see note 1 above. Some candle filters are impregnated with a bactericide. NZS 4348 (1995) covers the requirements for protozoa removal. WHO (2009) discusses ceramic filters, and some other treatment processes.
- 3 Activated carbon will eventually become saturated with contaminants. The carbon must then be replaced or the contaminants will start returning to the water, often at a higher concentration than in the original water.
- 4 Jugs with automatic cut-out are suitable; do not hold the cut-out switch down manually. Non-automatic jugs should be allowed to boil for a minute.
- 5 Boiling hard water removes some of the hardness (the carbonate, or temporary hardness). The hardness not removed forms a scale on the heating element making the element less efficient and advances its time of failure.
- 6 Ultraviolet disinfection becomes less effective if anything shields the microbiological contaminants from the ultraviolet light. Dissolved iron, manganese, natural organic matter (colour), or turbidity will all make UV disinfection less effective. Keep these constituents low or remove them before the water passes through the UV appliance. Treating dirty water also necessitates a lot of lamp cleaning.
- 7 Water softeners use ion exchange resins that can selectively remove specified chemicals from a range of chemical contaminants if the appropriate resins are chosen. They are available as cation, anion and mixed bed exchangers. Cation exchangers usually remove calcium hardness, replacing it with sodium. General purpose resins (mixed bed) are often not suitable for drinking-water treatment, and they tend to remove everything from the water (see note 13). A resin has been developed that removes tannin, so can be used for colour removal. See Chapter 13 for further information.
- 8 While some treatment methods work well for some contaminants, they can be upset by the presence of others. For example, ion exchange, reverse osmosis, and nanofiltration, are capable of effectively removing a range of contaminants. However, when fouled with excess turbidity and bacterial growths, their performance efficiency can fall off dramatically and they can break down. Bacteria can grow in these systems when they are not in regular use, thereby contaminating the drinking-water. Reverse osmosis and nanofiltration need daily flushing to prevent this. Reverse osmosis nearly always has an activated carbon filter upstream, and this can grow bacteria too. RO may not be appropriate in water-short areas because up to 80 percent may be wasted.
- 9 The calcium in the filter device is in the form of calcium carbonate, marble or dolomite; these dissolve, quite rapidly in some waters. Akdolite (a heat-treated dolomite) is a common brand used in New Zealand.
- 10 These calcium filter devices are of variable effectiveness depending upon exact details of filter.
- 11 Filtration processes remove arsenic if it is particulate; soluble forms require strong-base anion exchange or reverse osmosis. The ion exchange process removes most anions, replacing them with chloride; this could make the water corrosive.
- 12 Boiling will remove odours, but not necessarily taste. The chemicals that give rise to taste are not as volatile as odour chemicals.
- 13 Most people consider distilled water (and deionised water) to be insipid, and it does not provide many of the common minerals that are needed in the daily diet. Distillation requires considerable electricity usage, nearly 1 kilowatt-hour per litre.
- 14 Turbidity removal usually depends on the size of the particles that give rise to the turbidity. These can range from visible particles to very fine colloids.
- 15 The effectiveness of disinfection of viruses by UV light depends on the type of virus that is in the water. UV light only inactivates bacteria effectively if the dose is reliably high and the water clean. UV disinfection installations can inactivate protozoa effectively if they have been tested to NSF55 or DVGW. UV systems that meet the NSF standard (Class A) can be found at the website: <http://nsf.com/Certified/DWTU/>.
- 16 Oxidising systems cover a range of products from small ozone generators, greensand filters, to a variety of propriety products. Most oxidising systems will cause the iron and manganese to become particulate, so that they can then be filtered out. Most cells in Table 19.3 have not been filled in because of the variety of products available. They will range from being not very effective, to products like ozone that can also inactivate bacteria, viruses, protozoa, remove taste and odours, and maybe even reduce the colour. Small-scale package ozonation equipment is available that could be suitable for treatment of small water supplies. However, ozone is not widely used because of the high power requirements, complexity of the equipment, and relatively high capital cost.

19.3.5 Plumbing considerations

Plumbing requirements are covered by the Building Act 2004 and its relevant Building Codes.

See Chapter 10: Chemical Compliance, section 10.2.6 re plumbosolvency, and section 10.3.4 re discretionary monitoring which includes some discussion related to corrosion of pipes and fittings.

Chapter 16: The Distribution System, section 16.2.6 discusses permeation and leaching of chemicals into or from water pipes (mostly plastic).

MoH (2011) includes some discussion of hot water systems as they relate to the control of legionellae.

AS/NZS 3497:1998 (which was reissued in 2001 to incorporate Amendment No 1) covers plumbing requirements related to drinking-water treatment units. This will soon only be an Australian standard.

WHO (2006a) has produced a publication on health aspects of plumbing. The following paragraph is an extract from the section in Chapter 12 on domestic roof tanks:

There is considerable debate over the desirability in distributed water systems of domestic storage tanks or cisterns. An argument in favour of domestic storage is that it provides an air break that virtually excludes the possibility of back-siphonage and contamination of the public mains. Without this air break it is possible for contamination to occur whenever the mains pressure is reduced. In the event of temporary stoppage of mains supply (due to planned stoppages, breakdown or repairs), sufficient water is stored in the tank to provide domestic supply for a short period. The major disadvantage is that these tanks can become contaminated. Where distribution systems work without intermittency and the authority ensures a continuous positive pressure, fixtures connected directly to the incoming water service pipe should be preferred, avoiding the need for a tank.

DWI (2002) stated:

In Southern England it has been common practice to provide drinking water directly from the supply main at the kitchen sink only. All other taps, both hot and cold, are supplied from storage within the premises. The practice in Northern England is different where all water comes directly from the supply mains. The Water Supply (Water Quality) Regulations will require that drinking water taps in domestic premises and public buildings deliver water that is wholesome. The regulations include detailed standards for the definition of wholesome water. Storage within premises represents a risk of potential deterioration in bacterial quality. Since it is not feasible for a householder to implement a monitoring and maintenance regime similar to that carried out by water companies for their service reservoirs, compliance with quality standards cannot be reliably maintained if water is stored within consumer's premises.

Because of the risk of deterioration in drinking water quality from storage within premises, it is recommended that all supplies to the cold water taps and other cold water services in domestic premises normally used for drinking or cooking purposes should be supplied directly from the water company distribution network or from a rising main pumped either directly or indirectly from the distribution network. Where ground level storage is deemed necessary, it should be designed, sized and maintained to ensure that any stored drinking water remains wholesome at all times. Where the plumbing arrangements in existing domestic premises are renovated, the premises owner should be encouraged to design the plumbing arrangements so that all cold water supplies used for drinking or cooking purposes are connected directly to the incoming main.

19.4 Roof-collected rainwater supplies

19.4.1 Introduction

In New Zealand more than 10 percent of the population is on roof-collected rainwater systems, mostly in areas not served by municipal town supplies. Roof-collected rainwater consumption is also popular because of the general public's perception that rainwater is pure and safe to drink. The risk of disease arising from roof-collected rainwater consumption can be low, providing the water is visibly clear, has little taste or smell and, importantly, the storage and collection of rainwater is via a properly maintained storage tank and roof catchment system.

Section 19.4.2 summarises a number of national and international studies that have shown that the microbiological quality of roof-collected rainwater can be poor, often failing to meet standards.

Section 19.4.3 introduce some of the problems that can result from chemical issues.

Section 19.4.4 covers problems with rainwater catchment systems and components such as lack of maintenance, inadequate disinfection of the water, poorly designed delivery systems and storage tanks, and failure to adopt physical measures to safeguard the water against contamination. This may reflect the notion that rain is a relatively pure source of water and it may be related to the fact that in many rural areas, the availability of sufficient water for households seems to be a bigger issue than water quality. Irrespective of how roof-collected rainwater is used, the water quality is dependent on implementing a sensible maintenance programme.

Section 19.4.5 provides guidance on managing rainwater collection and storage in order to maximise the quality of water supplied from storage tanks.

Section 19.4.6 lists some readily available publications offering technical advice.

19.4.2 Microbiological problems

Rainwater collected and stored in domestic tanks will contain a range of micro-organisms from one or more sources. While many will be harmless, the safety of roof-collected rainwater will depend on excluding or minimising the presence of enteric pathogens. Enteric pathogens include types of bacteria such as *Salmonella* and *Campylobacter* and protozoa such as *Cryptosporidium* and *Giardia*. The likely sources of these pathogens can be faecal material deposited by birds, frogs, lizards, rodents, possums, insects, and dead animals, either in the gutters or in the tank itself, or arriving as wind-blown aerosols.

The microbiological quality of drinking-water is commonly measured by testing for *Escherichia coli* (*E. coli*), or alternatively thermo-tolerant coliforms (sometimes referred to by the less accurate term, faecal coliforms), as indicators of faecal contamination and hence the possible presence of enteric pathogens, see Chapter 5: Microbiological Quality for further information.

The following references are included to help dispel the belief that roof water is potable, therefore requiring no attention.

A study by Dennis (2002) on 60 roof-collected rainwater samples from South Wairarapa, where approximately 60 percent of the households use roof water, revealed *E. coli* transgressions in all samples on at least one occasion during a three-month period. Most samples had total coliform counts of more than 500 per 100 mL, and in two samples *E. coli* counts of greater than 550 per 100 mL were found. In a study by Sedouch (1999) on 100 roof-collected rainwater samples from the lower half of the North Island, only 18 percent of samples were found to comply with the *Drinking-water Standards for New Zealand* (DWSNZ) and 40 percent of samples were found to have failed badly with very high *E. coli* counts (> 150 per 100 mL).

Of 125 roof-collected rainwater samples from rural Auckland districts analysed between 1996 and 1998, 56 percent had faecal coliform levels that would have exceeded the 1993 WHO drinking water guidelines (Simmons et al 2001a). Significantly *Aeromonas* spp. was found in 16 percent of the samples leading the authors to conclude that this organism has potential as an alternative indicator of water quality and health risk.

In a survey of the water quality of 100 private farm rainwater supplies in Australia, varying levels of total coliforms were found in 52 percent of the water samples and 38 percent showed the presence of *E. coli* as well (Verrinder and Keleher 2001). An intensive monitoring programme in southeast Queensland showed that while roof water and *in situ* tank water exceeded the *Australian Drinking Water Guidelines* for total and faecal coliforms by a considerable margin (average tank counts of 830 and 120 per 100 mL respectively), the water quality from the hot water systems consistently produced zero levels of total and faecal coliforms (Coombes et al 2000). This study also revealed that in rainwater cisterns, the highest counts occurred immediately after major rainfall events (≥ 50 mm) that washed organic material from the roof gutters into the tanks.

Several investigations in the 1980s also revealed that in many instances stored rainwater did not meet WHO, USEPA or other standards with respect to one or more bacteriological water quality indicators. In northeast Thailand, where several million people use rainwater tanks, a major study of rainwater quality by Wirojanagud et al (1989) on 189 rainwater storage tanks, revealed that only around 40 percent met WHO drinking-water standards. The faecal coliform and faecal streptococci levels in the water samples taken from roofs and gutters demonstrated that the faecal contamination was from non-human sources such as animals, birds and rodents.

Koplan et al (1978) postulated roof-collected rainwater as the possible cause of a 63-case outbreak of salmonellosis in Trinidad, West Indies, after detecting the organisms in rainwater samples and in food prepared using the rainwater.

Eight roof tank water samples were tested from rural areas near Auckland during 1975–1986. Three of the eight samples contained faecal coliforms: 17, 25 and 25 per 100 mL. Two of the three samples tested for faecal streptococci were positive (2 and 30 per 100 mL), one being in the absence of faecal coliforms. Most samples had high numbers of heterotrophic bacteria (two had more than 1000 per mL grown at 37°C for two days), probably living on the detritus washed off the roofs (Ogilvie 1994).

Simmons and Smith (1997) reported roof-collected rainwater as the probable source of *Salmonella* Typhimurium infections in a family of four in New Zealand. An investigation of an outbreak of *Salmonella enterica* serotype Typhimurium DT160 infections in humans in New Zealand (Thornley et al 2003) found that five of the 170 case-patients had consumed roof-collected rainwater in which the pathogen was also detected. In an investigation of 28 cases of gastroenteritis among 200 workers at a construction site in Queensland, *Salmonella* Saintpaul was isolated from both cases and rainwater samples (Taylor et al 2000). Animal access was suggested as source of the contamination with several live frogs being found in one of the suspect tanks.

Savill et al (2001) found the presence *Campylobacter* in 5 percent of roof water samples collected from rural locations in the North Island. In a 621 case-control multi-centre analysis of gastroenteritis induced by *Campylobacter* study in New Zealand, Eberhart-Phillips et al (1997) found that consumption of roof-collected rainwater was associated with a threefold greater risk of campylobacteriosis than that of non-consumers. In New Zealand an estimated 237 cases (2 percent) of campylobacteriosis was likely to be explained by the consumption of rainwater. Contamination of an open-topped water storage tank by faecal material from birds and bats was the most likely source of infection in an outbreak of *Campylobacter* gastroenteritis that affected 234 pupils and 23 staff at a UK boarding school over a period of eight weeks (Palmer et al 1983). An outbreak of 23 cases of *Campylobacter enteritis* on a resort island in North Queensland was probably due to the consumption of contaminated rainwater (Merrit et al 1999).

In a study on 45 water samples of roof water cisterns in the United States, Crabtree et al (1996) revealed that 48 percent were positive for *Cryptosporidium* (mean = 2.4 oocysts/100 L) and 26 percent positive for *Giardia* (mean = 1.09 cysts/100 L). In contrast, in a New Zealand study by Simmons et al (2001a) on 50 roof-collected rainwater samples, *Cryptosporidium* oocysts were detected in only two (4 percent) of the samples and no *Giardia* cysts were found in any of the samples. The authors of the latter study suggest that the difference in the results of the two studies may reflect differences in the prevalence of the protozoa in the animal reservoirs, the sources, and

the degree and frequency of faecal contamination of the catchment or rainwater storage tank. An underground rainwater storage tank was associated with a mixed outbreak of cryptosporidiosis and giardiasis in Australia in which 89 people supplied with the drinking water became ill (Lester 1992). Investigations revealed that the tank had been contaminated by an overflow from a septic tank.

Despite the fact that relatively few roof-collected rainwater-linked disease outbreaks have been reported, the indications are that there could well be under-reporting of illnesses associated with contaminated roof-collected rainwater (see Chapter 1, section 1.1.3). High levels of faecal indicator organisms are frequently detected in roof-collected rainwater as well as range of bacterial and protozoan pathogens known to cause gastroenteritis in humans. The lack of reports linking communicable disease outbreaks to roof-collected rainwater may in part be due to the fact that while rainwater use is extensive, most systems serve individual households of only a few persons. Residents experiencing sporadic gastrointestinal illnesses are less likely to seek medical attention unless the illnesses are severe and/or life threatening. Furthermore, contaminated rainwater is also more likely to be a source of sporadic disease episodes because of possible immunity in a proportion of those exposed, together with asymptomatic infection in others (Abbott 2004, Simmons et al 2001b).

In March 2006 three cases of legionella (causing one death) in a small community in south Auckland (Beachlands) were identified, resulting from three different household water supplies. These were found to have been contaminated with *L. pneumophila* SG1. The water supplies were all untreated roof-collected rainwater systems. Filters attached to taps were also contaminated. *Legionella* bacteria affect the respiratory system, often due to inhaling organisms with water vapour in a shower box. *Legionella* bacteria can grow in water when the temperature is in the range 25–60°C (approximately). Roof tank water can be kept cooler by installing the tanks on the south side of the house and selecting tanks with a light colour. The bacteria are unlikely to grow if the hot water cylinder operates at >60°C. Strictly speaking, problems due to *Legionella* bacteria (they also cause problems in some air-conditioning systems) are covered by the Building Act. Further information is included in the Datasheets 1.1: Bacteria, *Legionella*. See the Ministry of Health's 2011 publication "*The Prevention of Legionellosis in New Zealand: Guidelines for the Control of Legionella Bacteria*".

A South Korean study (Lee et al 2011) found that turbidity was the highest five minutes after the initial precipitation, and ranged from 240 to 570 NTU in all events. In the first flush of rainfall runoff at five minutes, there were significant levels of total coliforms, *E. coli*, and heterotrophic plate count organisms recorded in all events; the quality of the rainfall runoff was good after 10 minutes however.

WQRA (2010) reported the prevalence and counts of bacterial contaminants in stored rainwater in a survey in Adelaide.

Bacterial parameter	Samples analysed	Prevalence n (%) ¹	Median	Range
Heterotrophic plate count/mL (35°C/48 h)	974	961 (98.7)	1200	0–32,000
Total coliforms/100 mL ²	973	802 (82.4)	180	0–22,000
<i>E. coli</i> /100 mL	974	293 (30.1)	0	0–2,400
Enterococci/100 mL	974	696 (71.5)	6	0–3,200
<i>Salmonella</i> spp ³	486	1 (0.21)	NA	NA
<i>Campylobacter</i> spp ⁴	486	0	NA	NA
Pathogenic <i>E. coli</i>	273	43 (15.8)	NA	NA

1 Prevalence = 100 x (number of positive samples / total number of samples).

2 One sample was not tested for total coliform.

3 Samples (1 L) were tested weekly for *Salmonella*.

4 *Campylobacter* was tested weekly using a semi-quantitative MPN method <4 orgs/L.

The rainwater samples tested contained either *E. coli* only (2.5 percent), enterococci (43.8 percent) only, both (27.6 percent) or neither (26.1 percent). When both *E. coli* and enterococci were detected, 31.6 percent (85 of 269) of the samples had higher *E. coli* counts. Where *E. coli* was present, 33.5 percent of the samples had counts of 1 *E. coli* / 100 mL, 29.6 percent had counts of >1–10 *E. coli* / 100 mL, while 36.9 percent had levels of >10 *E. coli* / 100 mL.

19.4.3 Chemical problems

Rainwater chemistry

Rainwater is nothing like distilled water! During 1982/1983 the Auckland Regional Authority Water Laboratory collected a series of monthly rainwater samples at urban sites. The rainwater had passed through a glass fibre filter so that no dry deposition was collected. During a windy month the chloride content averaged as high as 55 mg/L, the total hardness reached 20 mg/L as CaCO₃ and the ammonia concentration was high in the sample collected near a sewage treatment plant (Ogilvie 1994).

Urban and rural rainwater can become quite impure. Rural roofwater has been contaminated with chemicals in spray drift. The median monthly lead content of nine samples collected at Mt Eden (in Auckland) was 0.01 mg/L (ie, equalled the DWSNZ MAV), and the highest monthly result was 0.033 mg/L. Most of this lead will have resulted from motor vehicle fumes. The Mt Eden site was the most urban site but not beside a busy road. The concentration of lead was analysed in Christchurch rainwater (just rain, no dry deposition) by Stevenson (1980). Results varied from 0.005–0.031 mg/L Pb, with a mean of 0.017 mg/L, whereas rain from the Main Divide contained only 0.002 mg/L. The Christchurch and Auckland results were similar, and would have been even higher had dry deposition been included. In New Zealand about 1,500 tonnes of lead were being added to petrol per annum in the early 1980s; by 1994 it was down to around 500 tpa. The Ministry of Economic Development stated in 2005 that:

New Zealand has used lead-free petrol since 1996; only a contamination level of 13 mg/L is allowed, and this is proposed to be reduced to 5 mg/L.

The limit of detection (0.0002 mg/L) was exceeded on five of the six occasions arsenic was analysed in the Mt Eden rainwater; the maximum was 0.0022 mg/L As. Boron reached 0.2 mg/L. Arsenic and boron levels are fairly high in New Zealand coal, and both are used in wood preservation.

The ARC (2004) concluded from an Auckland study that roofs within 100 m of busy roads are likely to generate increased amounts of road transport contaminant loads. However, Adachi and Kobayashi (1992) described the results of their analysis of 117 samples of rainwater collected 1,500 m from a motorway near Kobe in Japan. Some mean values include:

- nitrate: 3.69 mg/L N
- cadmium: 0.0003 mg/L Cd
- copper: 1.52 mg/L Cu
- lead: 0.12 mg/L Pb
- nickel: 1.82 mg/L Ni
- zinc: 0.43 mg/L Zn.

The lead and nickel concentrations are well above the MAVs in the DWSNZ. Some organic chemicals such as benzene, toluene, ethylbenzene and xylene will find their way into roof tank water from motor vehicle fumes too; maybe their volatility will limit the amount that reaches water storage tanks. PAHs will deposit on roofs from chimney smoke and motor vehicle exhaust.

WQRA (2010) found 2 percent of roof water supplies in Adelaide exceeded the health-related parameter for lead (0.01 mg/L), and 26 percent exceeded the aesthetic parameter for zinc.

Roof water chemistry

Once the rainwater lands its quality will be affected by the roof, guttering and storage system, and how these are operated and maintained.

Generally water does not sit around for long on a roof that is not flat, so the material it is constructed of probably should not have a marked effect on water quality. Two exceptions will be a new, unpainted galvanised steel roof, which will lose zinc for months, and newly painted roofs that leach detergent and other organic substances for months, causing frothing and astringent tastes in tank water.

In 1977 TJ Sprott & Associates tested four roof water samples from bitumastic-type roofs in Rodney County. They found phenolic substances that they assumed were tar derivatives in each sample at about 0.4 ppm measured as phenol. Their report concluded that the water would taste too foul to drink before it became a health risk. Some were even highly coloured.

Simmons et al (2000) found 16 percent of rural Auckland roof waters exceeded the DWSNZ MAV for lead (0.01 mg/L as Pb), despite the very low nearby traffic densities.

ARC (2004) compared the levels of copper, lead and zinc that ran off new artificial roofs made from colour steel tiles, concrete tiles, decramastic, and long run colour steel. All produced very low concentrations, <0.002 mg/L Cu, <0.001 mg/L Pb and <0.06 mg/L Zn.

ARC also examined the composition of water running off existing galvanised roofs, in conditions ranging from excellent to very poor, and unpainted. The mean concentrations of copper and lead tended to be lower on the well-painted roofs, while zinc was much lower (usually <0.2 mg/L, compared with many samples over 2 mg/L for roofs other than well-painted. Maximum total lead levels exceeded the DWSNZ MAV for all roofs in the study. The mean total lead from the fair, poor and very poor condition roofs exceeded the MAV of 0.01 mg/L Pb. One sample from a poor condition roof almost reached the MAV for cadmium of 0.004 mg/L.

Smoke from the chimney and external fires

The discussion above referred to elevated levels of arsenic and boron, both of which can arise from the burning of coal and treated timber. Some of the smoke and soot settles on to the roof, to be washed off later by rain. Chromium was not analysed in the Auckland study; copper levels never exceeded 0.01 mg/L Cu (Ogilvie 1992).

Dungal (1961) related the high incidence of stomach cancers in a part of Iceland to the presence of polyaromatic hydrocarbons in the rainwater that was gathered from the house roofs into barrels. The houses were heated with coal and oil. The soot settled on the roofs and is washed with the rainwater into their barrels of drinking water. Quite frequently the water tasted of soot.

ARC (2004) reported fluoranthene and benzo[a]pyrene median levels commonly exceeded their (then) MAVs. Several other PAHs were reported at quite high levels too. Combustion is a common source of dioxins too.

Smoke from external fires can also affect rainwater supplies. See section 1.8 of these Guidelines re forest fires. Ash and debris deposited on a roof should be removed and the first flush of water after a fire should not be collected. Care should be taken to ensure that hatches or openings in the tops of rainwater tanks are closed or covered/sealed. If material has been washed into a tank in sufficient quantities to affect taste or appearance of rainwater, the tank will need to be drained and cleaned, or alternatively the water could be used for non-potable purposes.

Where rainwater tanks are used in bushfire-prone areas, consideration should be given to ensuring that the rainwater can be easily and quickly disconnected from the roof area for the tank. The disconnection should occur as early as possible when a bushfire is in the area so as to avoid windblown ash or debris landing on the roof area and possibly entering the tank. Reconnection of the tank to the catchment area should only occur after the fire has past and the roof area has been clear of ash and debris.

Fire retardants and foams may also be deposited on roofs. This material can be washed into tanks when water is hosed on to the roof as part of fire protecting activities, or when it rains after a bushfire. The recommended concentrations of the commonly used retardants and foams should not present a risk to health, but they may affect the taste of the water if washed into the tank. Fire retardants also contain detergents that may cause the water in the tank to froth.

The effect of storage materials

Water from a galvanised steel roof tank near Auckland was found to contain 7 mg/L zinc (Ogilvie 1992). At this level zinc can impart a taste to the water.

Concrete tanks raise the pH, calcium and alkalinity of the water, so it is quite common to find water with a pH greater than 9.5. At this level it can kill goldfish. Water with a pH above 9 can spoil the taste of tea and coffee, and drunk on its own, can have a drying effect in the mouth.

Water from some fibreglass tanks has been associated with taste and odour problems due to organic chemicals leaching out.

A manufacturer of stainless steel and galvanised iron rainwater tanks in Tasmania had used a 50:50 lead:tin solder. Concentrations of lead from the 64 stainless steel tanks were significantly higher than from the galvanised iron tanks, with median concentrations of 121 µg/L compared with 1 µg/L respectively. The maximum lead concentration found in water from a stainless steel tank was 2030 µg/L. All stainless steel tanks had water lead concentrations above the ADWG health-related limit of 10 µg/L, only four of the 60 galvanised tanks exceed this limit; all of these four had lead flashing on roofing or lead in plumbing materials (Lodo et al 2018).

The effect of nearby trees

Leaves falling on the roof can cause a low pH (less than 6) in the stored water, and has been implicated in the corrosion of copper service pipes. Trees can also give animals access to the roof. Generally, the main water quality problem caused by trees is the detritus that enters the tank to support large populations of bacteria, fungi and build-up the sludge layer. They can also cause the water to become coloured.

19.4.4 Maintenance problems

The following surveys highlight the fact that many rainwater supplies in New Zealand are designed and/or managed inappropriately. Contamination of rainwater can be minimised and even eliminated so that, with appropriately protected roof catchments and well-maintained storage tanks, high quality water can be collected.

A study by Walker (1997) of 40 private dwellings using roof water supplies in the Pauatahanui district revealed deficiencies by property owners in the use of rainwater catchment systems and components. These deficiencies included lack of maintenance, inadequate disinfection of the water, poorly designed delivery systems and storage tanks, and failure to adopt physical measures to safeguard the water against contamination.

A study on risk perception and domestic roof-collected rainwater supplies of 20 households on Waiheke Island (Fleming 2000) found that 55 percent of participants maintained their systems in terms of cleaning but the frequency of maintenance varied; only 45 percent of those participants who actually cleaned their systems had done so within the previous six months. This study also found that while 55 percent of participants did have some type of filtration system, none chemically disinfected their supplies.

A study by Breach (1996) of 20 rainwater water supplies of rural schools in South Auckland showed that only 20 percent of the schools cleaned their roofs and while 65 percent of the schools cleaned their gutters either yearly or every two to three years; only 42 percent of the schools regularly cleaned their rainwater storage tanks. Seventy-three percent of the schools did not monitor the microbiological and chemical quality of their supplies and only 9 percent of the schools disinfected their supplies with either chlorine, UV light, or filtration.

A study of 125 domestic roof-collected rainwater supplies from four rural Auckland Districts (Simmons et al 2000) showed that only 35 percent of households ever cleaned their storage tanks, and 25 percent never cleaned their catchment guttering. Forty-three percent of supplies had some type of water filtration system but only 3 percent ever used any disinfection, and then only intermittently. In 19 percent of the supplies foliage was found to overhang the roof surface.

19.4.5 Design and operation

Design of collection and storage systems to minimise water quality issues

BRANZ (accessed 2014) has published a note which lists roofing materials that are suitable for rainwater collection and a list of those which are not recommended. They also offer other advice on their website, eg, at <http://www.level.org.nz/water/water-supply/mains-or-rainwater/>.

Roof materials suitable for water collection for human consumption include:

- unpainted zinc/aluminium-coated or galvanised steel
- factory-coated or painted zinc/aluminium alloy-coated or galvanised steel
- zinc
- stainless steel
- aluminium
- concrete or terracotta (clay) tiles

- copper
- PVC (without lead stabilisers) or fibreglass sheet
- untreated timber shingles (usually imported western red cedar)
- butyl rubber.

Do not use collected water for drinking if it has come into contact with:

- uncoated lead flashings (lead flashings on existing roofs should be coated with a suitable paint; coated lead is available for new roofs)
- treated timber where chemicals leaching out might contaminate the water
- bitumen-based (asphalt) roofing (note however, that BRANZ do approve some brands)²
- asbestos (although no longer used in building, existing asbestos roofs should not be used for collection of rainwater); note that the DWSNZ do not consider asbestos particles from materials used for water supply present health concerns when consumed.

Roof catchments are vulnerable to microbiological contamination by droppings of birds, frogs, lizards, rodents, possums, and contamination from dead animals and insects, either on the roofs or in the gutters. Unpleasant material can be brought to the roof by animals for feeding. Physical contamination of roof catchments can occur from windborne material, and chemical contamination from the soft corrosive water, and by leaching from inappropriate roof paints (eg, lead based) or lead flashings or some plastic gutters. Most paints and gutters are lead-free these days, but it is still advisable to check before purchasing. While roofs are being painted and for some time thereafter, disconnection of the tank is recommended during preparation and paint application and for a period immediately following application. Most reputable roof paint manufacturers provide advice on the paint container label. The lead content of paint used on roofs used for drinking-water collection should not exceed 0.1 percent and 0.2 percent (percentage based on the non-volatile content of the paint) for lead and lead compounds and lead and lead compounds occurring as an impurity in zinc based paint, respectively (MoH 2012). Care is required if fungicides or other chemicals are used for cleaning a roof.

Gutters should have sufficient and continuous fall to down pipes to prevent ponding, which can increase the accumulation of material, result in algal or slime growth, and provide a site for mosquito breeding. A fall of 1:100 should suffice. Gutter shielding devices will substantially reduce the amount of larger debris such as leaves but small particles will not be removed. Periodic cleaning of gutters will still be needed but at a lower frequency than for gutters without shielding.

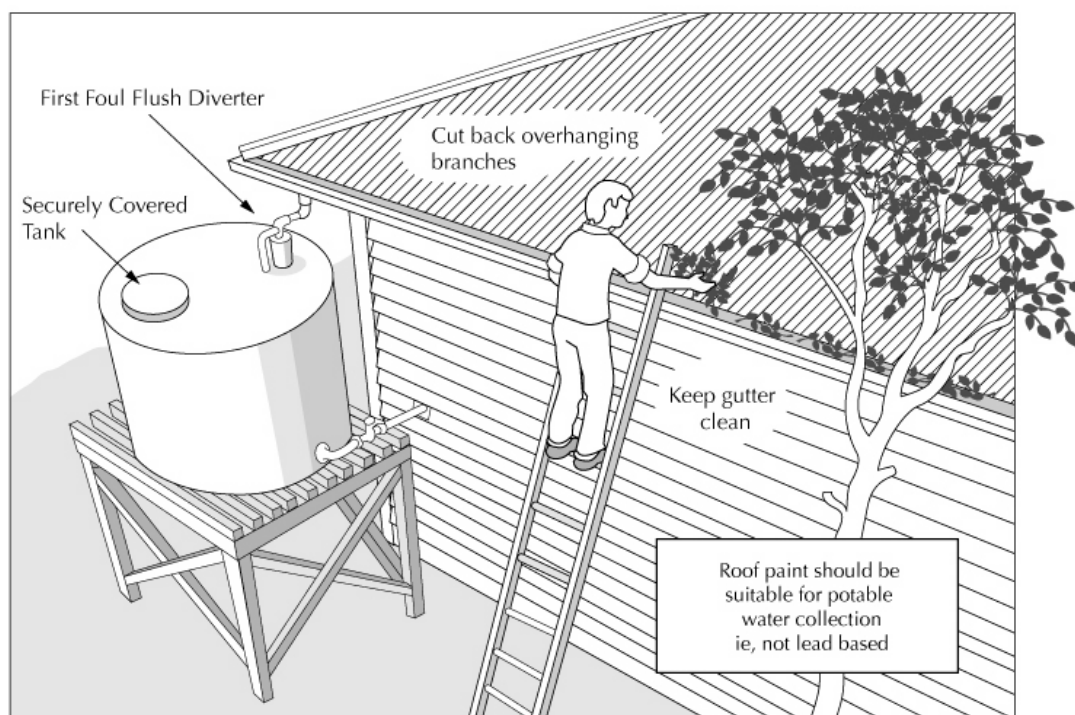
² On 5 October 2015 The Ministry of Business, Innovation & Employment issued Determination 2015/056 which included: 10. The Decision. 10.1 In accordance with section 188 of the Building Act 2004 I hereby determine that asphalt roofing shingles used as part of a potable water supply system, if verified as set in paragraphs 9.4.2 to 9.4.5 of this determination, comply with Clause G12 of the Building Code in respect of chemicals or particulates leaching from the asphalt.

Before installing a rainwater tank the roof catchment should be checked for overflows, discharges and bleed-off pipes from roof-mounted appliances such as hot water systems and solar heaters. These appliances should not discharge on to the roof catchment area. Flues from slow combustion wood, coal or oil burners should be installed in accordance with the AS/NZ standards (1999).

Entry by small animals and birds to rainwater tanks can lead to direct faecal contamination, even if the animals escape from the tank. In some cases, animals become trapped in the tanks and drown, leading to high levels of contamination. In the case of larger animals such as possums, ducks and cats, this will almost certainly have an impact on the taste and odour of the water as well. Rainwater tanks can provide excellent habitats for midge and mosquito breeding, and certain types of mosquitoes can be vectors of arboviruses. Arbovirus is short for arthropod-borne virus. Arboviruses are a large group of viruses that are spread by certain invertebrate animals (arthropods), most commonly blood-sucking insects like mosquitoes and ticks. Of particular concern are species of mosquito that can be vectors of dengue fever virus, which occurs in tropical and sub-tropical regions of the world. The inlet to the tank should incorporate a screen to prevent material such as leaves and dirt that may have collected on the roof or in the gutters being washed into the tank, as well as a mesh covering to prevent access of mosquitoes and other insects. Overflows should be covered with an insect-proof mesh. The tank's contents should be inspected regularly and a cleaning programme should be established. See Figure 19.5.

A range of tanks made from different materials is available in New Zealand. Concrete and ferro-cement tanks are strong and long lasting. New tanks may impart tastes and leach lime thereby increasing the pH of water. These tanks may need to be flushed several times before use. Tanks manufactured from synthetic polymers and polyethylene are also available for rainwater storage. Plastic tanks and liners should be constructed from materials that are at least of food-grade standard, eg, compliant with AS 2070 (1999) and preferably that comply with the requirements of AS/NZS 4020 (2002).

Figure 19.5: Minimising contamination of roof water



Fibreglass tanks are suitable for collecting rainwater but must be manufactured with a food grade coating on the interior surface. The coating must be cured before the tanks are offered for sale. Fibreglass and plastic tanks should be manufactured to prevent the entry of light which could encourage the growth of algae.

According to the principle of first order kinetics, tanks operating in series should reduce considerably the levels of microbial contamination of stored rainwater. Ashworth (2002; 2005) recommends that at least two tanks operating in series should be installed, including a removable drop inlet pipe arrangement and a floating arm draw off in the first tank. Free discharge of water into second or sequential tanks should result in the majority of dirt and micro-organisms being confined to the first tank. Water should exit the drop inlet pipe horizontally, 500 mm above the tank floor so as to reduce the resuspension of any sediment, and the floating arm draw off will siphon the surface water from the first tank into the second tank.

Sometimes water storage tanks are buried or partly buried. This is not a good practice. Concrete and plastic tanks can split or crack and metallic tanks can corrode, allowing contaminated groundwater or septic tank effluent to enter the tank causing illness, as pointed out in section 19.4.2 (Lester 1992). Also, unless the tank has been installed to prevent it, a high water table can push a near empty tank out of the ground.

Preventive measures and corrective actions for minimising contamination of roof-collected rainwater include:

- use a clean impervious roof made from non-toxic material
- remove and replace with approved materials any items containing toxic products (eg, lead paints, flashings, nails, etc)
- keep roof catchments clean and clear of moss, lichen, debris and leaves

- keep roof catchments clear of overhanging vegetation as branches provide roosting points for birds and can provide access for small animals such as rodents, cats and possums
- inspect gutters regularly and clean if necessary. Disconnect the pipe(s) that feed the water tank before cleaning the gutters. Exercise care when cleaning gutters; ensure the ladder is secure and avoid going anywhere near overhead power lines or better still have the power disconnected before cleaning the gutters
- if appropriate, install removable gutter guards and/or screens as well
- ensure that chimneys within or adjacent to roof water collection areas are of sufficient height to minimise the settlement of ash or residues on the roof and in the gutters
- use a coarse filter (leaf slide) and first foul flush device to intercept water entering the tank. Any roof water collection area, by virtue of its location, susceptible to undue contamination with organic material, dust, ash, sand, salt or airborne chemical residue, should have a first flush diversion system installed
- clean gutters, tank inlets and screens every three to four months
- in the event of any weed or chemical spraying in an adjacent location, advise the contractor that the roof is used to collect drinking water, and that there must be no over-spraying. Obtain a guarantee from the contractor that pesticides that present a health risk will not be used
- prevent access by small animals, birds and mosquitoes into rainwater storage tanks by screening all tank inlets as well as overflows, and keep access hatches closed
- prevent entry of surface run-off from areas other than roof catchment into below-ground tanks (see below). Tank roofs must be secure and the sides and bottom of the tank should be sealed to prevent egress
- inspect tanks annually and if necessary have tanks cleaned out professionally. See section on tank desludging, cleaning and replenishing below
- if tank contamination by faecal material is apparent the supply should be disinfected
- ensure that tank taps or draw-off pipes are at least 100 mm above the tank floor, or use a floating arm draw off valve
- do not use roof water if it is likely to be contaminated by smoke, soot or fumes from a nearby industrial process without checking its safety.

Tank desludging, cleaning and replenishing

Accumulated sediments can be a source of microbiological and chemical contamination and can cause off-tastes and odours. Desludging water storage tanks should ideally be done by tank cleaning contractors (see telephone directory). Sludge can be removed without emptying the tank by siphoning the sludge with an inverted funnel attached to the end of a hose. Sludge can also be pumped from the tank with minimum loss of water by using a suitable pump and attachments. Alternatively, draining out and cleaning the tank can remove the sludge. Sludge can be removed continuously by installing a tank vacuum system in the tank that automatically siphons the overflow water from the bottom of the tank instead of from the top.

If it is necessary to enter the tank for cleaning, care should be taken to ensure that there is adequate ventilation and that there is an additional person in attendance. Working in a confined space such as a water tank can be dangerous because of the possibility of carbon dioxide, methane and other gases at lethal concentrations being present in the tank. Cleaning should ideally be performed by tank cleaning contractors. Cleaning should generally be limited to removing accumulated sediments and leaf litter. Cleaning agents that might release hazardous fumes should be avoided. After cleaning, the internal walls and floor of the tank should be rinsed with clean water. Rinse water and sediment should be run to waste. Further details on tank cleaning procedures can be found in the Ministry of Health's *Water Collection Tanks and Safe Household Water* booklet.

When water is delivered to replenish a storage tank, written assurance must be obtained from the water carrier that the water is from a registered source meeting the requirements of section 11 of the DWSNZ and that the water has been loaded, transported, and delivered in accordance with the requirements of the tankered drinking-water guidelines (Ministry of Health 2008). Transfer of water from the supply vehicle must not cause undue agitation of any sediment on the bottom of the tank. Water should not be transferred to any tank that is in bad state of repair or to any tank in which the residual water or sediments could adversely affect the quality of the water being transferred to the tank.

Treatment methods

Roof-collected rainwater can be affected by contaminants that will make it undesirable or even unsafe to drink. The rainwater source needs to provide sufficient quantity to meet the requirements of the household (normally 300 litres per person per day). The water quality should be checked by an accredited laboratory. Testing will reveal the quality of the water and the treatment needed to make the water safe to use. See the Ministry of Health's *Household Water Supplies: The selection, operation, and maintenance of individual household supplies* book for full details of the contaminants, their sources, the problems they can cause, and the treatments that can be used to remove or reduce the contaminants. Some of the methods that can be used to treat roof-collected rainwater follow.

A point-of-use device is like a mini-treatment plant. It can be used to treat all the household water, or it can be put on the end of a tap for treating drinking-water only. They are effective if operated correctly. See section 19.3.4 and Table 19.3. Some common approaches include:

- boiling water in an electric kettle is an effective point-of-use technique. Boiling for one minute will remove or destroy all microbiological and most gaseous contaminants. Electric jugs with automatic cut-off are suitable especially if the water is left to cool for some minutes before use
- an under-the-bench filter at the kitchen sink is another example of a point-of-use device. There is a wide range of filters on the market that can remove micro-organisms, chemicals, and even bad tastes and taints. Before installing a point-of-use device, ensure that there is a written statement from the manufacturer as to what the device will achieve and what it will not achieve in the way of purification. The device should provide some means of indicating when it will no longer function

according to specification. It is important to adhere rigidly to the manufacturer's maintenance instructions. Check that it complies with AS/NZS 3497 and has been tested to AS/NZS 4348 for the purpose which the appliance is to be used. Ultraviolet light can be used to disinfect rainwater by treating microbiological contaminants so that they are unable to reproduce. The UV disinfection unit can be installed in the pipework delivering water from a storage tank to a dwelling, or selectively to taps used to supply water for drinking and food preparation. An ultraviolet light point-of-use device must be used with relatively clean water to enable the light beam to penetrate with sufficient intensity throughout the reaction chamber. The lamps degrade with time and must be replaced on a six-monthly to yearly basis. The intensity of UV radiation emitted decreases with lamp age; typical lamp life is about 10 to 12 months after which the output is about 70 percent of that of a new lamp, and lamp replacement is required. If UV light is used, it is important to install a system incorporating a sensor that indicates when the device is or is not operational. See Chapter 15: Disinfection Processes, section 15.5.5 for further information.

Chlorination

Regular chlorination of roof-collected rainwater stored in domestic household tanks is not considered appropriate in most cases and is generally only recommended as a remedial action. The effectiveness of chlorine is short-lived and will only act on water in the tank at the time of dosing. Fresh rain run-off into the tank after chlorination will probably not be disinfected.

The Ministry of Health's *Household Water Supplies: The selection, operation, and maintenance of individual household supplies* book provides full details on how to calculate the dosages required for disinfection using sodium hypochlorite (plain household bleach, usually about 3 percent available chlorine) or calcium hypochlorite (swimming pool chlorine).

To achieve effective disinfection, it is necessary to add sufficient chlorine to provide a free chlorine residual of at least 0.5 mg/L after a contact time of at least 30 minutes. This can be measured using a suitable chlorine test kit (eg, a swimming pool kit) if available.

As a guide, the addition of 40 mL of liquid sodium hypochlorite (12.5 percent available chlorine) per 1,000 L of water or 7 g of granular calcium chloride (75 percent available chlorine) per 1,000 L of water will give a reasonable assurance of effective disinfection. Both methods will provide chlorine doses of approximately 5 mg/L. Sodium and calcium hypochlorite can be purchased from large supermarkets, hardware stores or swimming pool stockists. When handling and storing strong chemical compounds it is important to follow safety instructions given on the package label.

When adding the chemical solution to the tank, spread it as widely as possible across the surface to promote mixing (this will often be limited by restricted access) and let it stand for at least one hour before using the disinfected water. The chlorine will impart a distinct taste and odour that should dissipate in a few days. Boiling the water will remove most of the taste and odour associated with chlorination.

19.4.6 Information resources

A number of information resources on the safe collection and storage roof-collected rainwater systems have been published including material available on the internet:

- *Water Collection Tanks and Safe Household Water*. Ministry of Health 1999; Code 10148. This booklet outlines the steps involved the safe collection and storage of rainwater.
- *Household Water Supplies: The selection, operation, and maintenance of individual household supplies*. Ministry of Health 2004 Code 4602. This book presents information on the supply of safe drinking-water to households not connected to town supplies. Information on water sources and treatment options are included.
- *Public Health Risk Management Plan Guide: Roof water sources*. Ministry of Health 2001 Ref S1.2. This guide covers many of the causes of contamination of roof water and the preventive measures and corrective actions that are necessary to ensure the safety of the water supply. Included are contingency plans such as when roofs are contaminated by spray drift, volcanic ash, and contingencies for water shortage events. See also the worked example, Ref W1.
- *Codes of Practice for Private Rainwater Supplies*. Sarfai 1997. This non-mandatory code was developed for the Southland District Council for use as a building compliance guidance document for the potable water requirement of the Building Act.
- *Tank Water Supply Design Guide*. Ashworth 2002. This book is intended to help householders or small businesses that collect roof rainwater or surface water, to improve their water quality.
- *Rainwater Tank Supply Best Practice*. Ashworth 2005. This book simplifies the above design guide, putting forward the preferred systems to achieve a wholesome water supply to serve communities of fewer than 25 people.
- *Guidance on the Use of Rainwater Tanks*. EnHealth 2010, third edition. This Australian monograph consolidates the most up-to-date information and advice as a resource for Environmental Health Officers and other professionals, and for those members of the public seeking detailed guidance on safe rainwater collection and storage.
- The NSW Government published the *NSW Guideline on use of rainwater where a public water supply is available*. See <http://www.health.nsw.gov.au/environment/water/Pages/rainwater.aspx>.
- *Rainwater Catchment Systems for Domestic Supply: Design, construction and implementation*. Gould and Nissen-Petersen 1999. This very detailed book focuses on technical options for improving rainwater collection and storage. It provides an extensive review of recent developments and lessons learnt with respect to rainwater catchments systems for domestic supply.
- *Sustainable Water from Rainwater Harvesting*. Wade 2003. This is an information booklet about simple, cost effective and revolutionary designed products for leaf and debris diversion/exclusion/removal systems for household and industrial use.

- *Public Health Aspects of Rainwater Tanks in Urban Australia*. CRC 2005. Recent drought and ongoing concerns about the sustainability of water supplies have resulted in increased interest in the installation of rainwater tanks in urban areas. Given the potential that this may lead to increased consumption of rainwater even in areas where a treated public drinking water supply is available, health authorities are concerned that the potential health risks should be better documented and understood, particularly with respect to any differences in rainwater quality that may exist between urban and rural settings.

19.5 Tankered drinking-water supplies

The tankered drinking-water carriers formed a voluntary group: the Tankered Drinking Water Carriers Association Incorporated (TDWCAI). In July 2008 the Ministry of Health, in conjunction with the TDWCAI, published the *Guidelines for the Safe Carriage and Delivery of Drinking-water*. The latest version of that publication is available at <https://www.health.govt.nz/publication/guidelines-safe-carriage-and-delivery-drinking-water>.

By following the Guidelines, applying best practice, and implementing a water safety plan, tankered drinking water suppliers can demonstrate that they have taken all practicable steps to comply with the Health Act 1956.

WHO (2011b) includes Technical Note 12 titled *Delivering Safe Water by Tanker*. The NSW Government published the *NSW Guidelines for Water Carters* in 2012, see <http://www.health.nsw.gov.au/environment/water/Pages/nsw-guidelines-for-water-carters.aspx>.

19.6 Rural agricultural drinking-water supplies

The drinking-water provisions of the Health Act 1956 include a new category of water supply: Rural Agricultural Drinking-water Supplies (RADWS). The *Rural Agricultural Drinking-water Supply Guideline* was published in March 2015 (<https://www.health.govt.nz/publication/rural-agricultural-drinking-water-supply-guideline>). The Guideline includes a decision tree that determines if a water supply is a RADWS.

This Guideline gives water suppliers flexibility in demonstrating compliance with the requirements of the drinking-water provisions of the Act. By following the Guideline, applying best practice, and implementing a water safety plan, rural agricultural water suppliers can demonstrate that they have taken all practicable steps to comply with the Health Act 1956.

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