



Guidance on use of
rainwater tanks



ISBN: 978-1-74241-325-9
Online ISBN: 978-1-74241-326-6
Publications Approval Number: D0042

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Preface

This third edition of *Guidance on use of rainwater tanks* has been produced by the Environmental Health Committee (enHealth) of the Australian Health Protection Committee to revise the monograph produced in 2004. The revision was thought timely in response to the ongoing interest in using rainwater tanks by householders and the commercial sector in both rural and urban areas. This increased interest has arisen because of widespread drought conditions, predictions of worldwide shortages of fresh water as populations continue to grow, and increased water restrictions. The number of agencies offering incentives for installation of domestic tanks has also increased.

The edition has been formatted to ensure consistency with the framework for drinking water quality management incorporated in the *Australian Drinking Water Guidelines 2004 (ADWG)*. The framework advocates implementation of a preventive risk management approach for assuring water quality.

The guidance document 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. Information is provided on the range of potential hazards that can threaten water quality, preventive measures that can be used to prevent these hazards from contaminating rainwater, straightforward monitoring and maintenance activities, and, where necessary, corrective actions.

Collection and storage of rainwater involves relatively simple systems. A reasonably low level of management can ensure provision of good quality water that can be used for a wide range of purposes including drinking, food preparation, bathing, laundry, toilet flushing and garden watering.

This guidance document includes information on design and installation as well as the potential contribution of rainwater tanks to improved water conservation.

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Acknowledgements

A large number of people, including representatives from many of the agencies represented on the Environmental Health Committee (enHealth) of the Australian Health Protection Committee, provided comments during the revision of this guidance document. The final form of the document was shaped by these invaluable contributions.

enHealth would especially like to thank the project steering committee consisting of Stuart Heggie (Chair), Xavier Schobben, David Cunliffe, Andrew Langley and Steve Galloway (Project Officer) for contributing their time and expertise to update this valuable resource.

Sources of information

Rainwater tanks – Information used in preparing this guidance document was obtained from a range of published and unpublished reports, as well as from the accumulated experience of health agencies in dealing with rainwater tanks. Copies of unpublished material were very kindly provided by a range of state and territory government agencies, as acknowledged in the bibliography.

Household water use data – Total household usage of water in each state was taken from the Water Account for Australia (Australian Bureau of Statistics 2007). The proportions of water used for different purposes were taken from a number of sources including the Water Services Association of Australia Water Consumption fact sheet (2001), *Planning for Perth's water needs* (Water Corporation, Western Australia 2002) and *Planning for the future of our water resources: discussion starter* (Water Resources Strategy Committee for the Melbourne Area 2001).

1. Introduction

Water is a limited natural resource and a public good fundamental for life and health. The human right to water is indispensable for leading a life in human dignity. It is a prerequisite for the realization of other human rights.

(United Nations 2002)

Australia has a generally hot, dry climate and fresh water is a limited and valuable commodity. Over 90% of Australians receive their domestic supply from mains water but there are vast areas with very low population densities with few reticulated supplies (Australian Bureau of Statistics 2001). Living and surviving in these areas depends on the use of local sources of water such as rainwater collected in tanks and groundwater. Even in areas that receive mains water, many households collect rainwater in domestic tanks to augment supplies or provide an alternative and renewable source of water. Widespread water restrictions commenced in 2002-03 and involved several capital cities, large urban areas and hundreds of rural centres highlighted the importance of water conservation measures, including use of rainwater tanks. A number of agencies have offered cash rebates to support installation of rainwater tanks.

Collection of rainfall from roof run-off is an ancient practice that dates back over 3000 years. In Australia the use of domestic rainwater tanks is an established and relatively common practice, particularly in rural and remote areas. In 2007, 19% of Australian households used rainwater tanks, with 10% of households using tanks as their main source of drinking water (see Table 1). Use of tanks as the main source of water for gardens (5.5%), bathing, showering and washing (6%) or toilet flushing (4.5%) is less common.

Not surprisingly, the driest state, South Australia, had the highest rate of usage, with 45% of households (ABS 2007) having a rainwater tank and 22% using them as the main source of drinking water. The Northern Territory (5.5%) and the ACT (6.7%) recorded relatively low rates of use (see Table 1). Use of rainwater tanks is more common outside capital cities with 33.5% of households having a rainwater tank, compared to 11.2% of city households.

Table 1: Domestic use of rainwater tanks in Australia

State/Territory	Households with rainwater tanks (%)	Rainwater tank as main source of drinking water	Capital city households with rainwater tanks (%)	Non-capital city households with rainwater tanks (%)
NSW	15.8	7.3	6.9	29.9
VIC	16.7	8.2	7.8	38.7
QLD	22.1	13.2	15.2	28.0
SA	45.4	22	37.0	69.2
WA	13.6	9.2	6.9	34.2
TAS	21.4	14.9	12.5	27.8
NT	5.5	nd	5.5*	0.0
ACT	6.7	nd	6.7	0.0
Total	19.3	10.1	11.2	33.5

Source of data: Australian Bureau of Statistics (ABS) 2007

* NT data largely from urban areas



Although there has been some debate about the volumes of water that can be provided from rainwater tanks, tanks can be a significant source of drinking water even in arid regions. The 2007 ABS survey found that 80% of households with rainwater tanks considered the volume of water supplied sufficient for their needs. The main reason given for not installing a rainwater tank was cost (47.5%), followed by lack of time (28%), and lack of room (15%). Only 1.4% of those who had considered installing a tank had decided not to because of health concerns.

As well as using tanks as a conservation measure, some choose to install them as a means of independently collecting a relatively pure product (at least before collection) and using it without treatment, and in particular, without the addition of chemicals.

The general public perception is that rainwater is safe to drink. In most areas of Australia, the risk of illness arising from consumption is low, providing it is visually clear, has little taste or smell and, importantly, the storage and collection of rainwater is via a well maintained tank and roof catchment system. While the risk from consuming rainwater is low in most areas of Australia, the water from domestic tanks is not as well treated or managed as the major urban water supplies. The microbial quality of water collected in tanks is not as good as that in urban supplies. In a limited number of areas, specific industries or very heavy traffic emissions may affect the chemical quality of rainwater.

Where a treated, disinfected public drinking water supply is available, rainwater can be used as a source for hot water services, bathing, laundry, toilet flushing, or gardening. These uses represent lower risks to public health than drinking rainwater.

Irrespective of how tank rainwater is used, water quality is dependent on implementing a sensible maintenance program. However, while maintenance requirements are not particularly onerous, in practice most roof catchments and rainwater tanks are poorly maintained. 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 water is a bigger issue than quality.

The aim of this guidance document is to consolidate information and advice on rainwater tanks in one document. It presents a description of the issues and provides guidance on managing rainwater collected in domestic tanks in a way that should maximise the quality of water. The information on management and water quality is consistent with the general advice provided in the *Australian Drinking Water Guidelines (ADWG)*.

2. Uses of rainwater

Rainwater tanks have historically been used as an essential means of supplying drinking water in many rural and remote parts of Australia. The location, style, construction and use of rainwater tanks have changed significantly over time.

There has been a steady and acceptable progression from rainwater being used in urban areas for irrigation to its modern use in a dual household reticulation system complete with associated controls to prevent backflow or contamination of the high quality regulated mains supply. The use of rainwater tanks is increasing as communities adjust to the reality of life with water restrictions and drought.

While the use of rainwater tanks in urban areas has previously been debated, it is now strongly encouraged by all levels of government and supported by some with offers of rebate. The Australian Government offers a significant rebate on the installation of a rainwater tank under the long term *Water for the Future Plan* and the associated *National Rainwater and Greywater Initiative*. Other rebates are provided from time to time in various states/territories and regions.

The use of rainwater tanks has become a major strategy to enhance water conservation, reduce the burden of water restrictions and address the increasingly dramatic impacts of drought and climate change. Rainwater tanks now provide for a multitude of uses, including:

- drinking water
- garden watering
- toilet flushing
- laundry usage
- replenishing domestic pools or spas
- car washing
- supplying the hot water system
- thermal buffers to insulate houses
- ventilation for buildings
- protecting homes from bushfires.

While there is versatility in the uses of rainwater, there is also a corresponding risk. Microbiological quality is not as reliable as high quality mains water, particularly after rain events that follow long dry spells. The risk of contracting illness from rainwater supplied from well-maintained roof catchments and tanks is very low, although it should be noted that the risk increases with less maintenance and cleaning, and in the absence of a first flush diverter. If in doubt about the microbiological quality of rainwater, the water should be either disinfected or boiled prior to use.

There are also a number of chemical risks associated with rainwater. For example, impacts from major industrial emissions, such as lead in Port Pirie, may result in tank rainwater not being suitable for drinking and food preparation by particular vulnerable groups, such as pregnant or breastfeeding women and young children. Refer to local health authorities for further advice.

The water quality requirements for non-potable uses of rainwater are lower than those for drinking water, while higher quality water may be required for some medical procedures, such as kidney dialysis.



The *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks 2008* provide an assessment of the likely risks associated with the intended use and exposures for alternative water supplies. If there are concerns about the risks associated with the end use of rainwater the default values established in the above national guidelines can be used to establish microbial and chemical risks through ingestion and frequency factors. Consumption or ingestion from showering is generally less than 100 mL per day, while ingestion associated with laundry use is estimated at 0.1 mL at 100 times per year, and toilet flushing is estimated at 0.1 mL at 1100 times per year, with gardening much lower. It should be noted that aerosol volumes are less for activities inside the house than those produced by garden irrigation. Risks associated with the use of rainwater for drinking are higher because of the volumes of water consumed. Guideline values cited in the ADWG are based on a daily consumption of 2 L of water per day for an adult and 1 L for a child.

The use of rainwater to supply hot water services has attracted increasing interest as the hot water infrastructure is already a separate supply. Rainwater may cause corrosion in water heating systems and advice should be sought from suppliers on the use of rainwater in these devices. It is not recommended that water from the hot water tap be used for drinking or cooking. Other uses of hot water in the home result in lower exposures and therefore less risk from microbial or chemical contamination.

3. Managing rainwater quality – an ounce of prevention

Health and aesthetic hazards for rainwater collected in tanks can be minimised by sensible management procedures.

With the possible exceptions of urban traffic emissions in very highly populated centres, and industrial emissions, these hazards are amenable to individual action. Some preventive measures are associated with design and installation, while others are associated with ongoing maintenance. Well-designed systems are low maintenance.

In most cases roof catchments, guttering, piping and rainwater tanks are relatively simple systems. Implementation of a low-key management approach will generally prevent problems occurring, so corrective action to restore water quality will be needed infrequently, if at all. One complication can be the installation of buried or below ground pipework which will require additional attention.

As discussed in the ADWG, a preventive risk management approach is the most effective way of ensuring safe, high quality drinking water. This applies to all types of water supply, including rainwater collected in domestic tanks. The ADWG include the Framework for Management of Drinking Water Quality. The Framework addresses four general areas, and while each is important for community-based supplies, the area of system analysis and management is of prime importance for owners of domestic rainwater tanks.

'System analysis' involves identifying and assessing the hazards that can compromise rainwater quality while 'system management' deals with applying preventive measures to minimise risks to health, supported by monitoring and, where necessary, corrective action. For domestic rainwater tanks, monitoring mainly takes the form of visual inspection. These issues will be discussed in the following sections.



4. Identifying potential hazards and health risks (systematic analysis)

Assessment of the health risk of rainwater tanks requires consideration of whether a hazard to human health is present and whether the dose of the hazardous material is sufficient to cause illness.

Both the concentration of the hazard and the degree of exposure determine the dose (of hazardous chemicals and pathogenic microorganisms).

The most common use of rainwater tanks in Australia is to provide a private source of drinking water to individual households. This use provides the highest level of exposure compared to other domestic and gardening uses. Use of rainwater for purposes other than drinking is discussed in Section 2.

Rainwater tanks are also used as a source of public or community-based drinking water supplies. This type of use requires consideration of broader legislative or duty-of-care requirements and is discussed in Section 11.

Collection and storage of rainwater introduces the potential for chemical, physical and microbial contamination. The most common hazards in water sources obtained from surface catchments worldwide, including roof run-off, are microbial pathogens of faecal origin (enteric pathogens). In most of Australia (exceptions are discussed below) chemical and physical quality of rainwater is relatively easy to maintain, but microbial quality is more difficult to manage. This is supported by investigations of rainwater quality as discussed below.

Systems incorporating buried pipework (so called 'wet systems') are becoming increasingly popular to maximise yields from multiple gutters and where rainwater is plumbed into homes. Buried pipes can be susceptible to cross-connection and external contamination as well as potential impacts on aesthetic quality due to stagnation.

Rainwater tanks can also represent a health risk by providing breeding sites for mosquitoes.

Microbial hazards

Rainwater collected and stored in domestic tanks will contain a range of microorganisms from one or more sources. While most will be harmless, the safety of rainwater will depend on excluding or minimising the presence of enteric pathogens. Enteric pathogens include types of bacteria, viruses and protozoa. These organisms do not grow or survive indefinitely in water environments and are introduced into drinking water supplies by contamination with faecal material.

Tank rainwater can contain organisms referred to as opportunistic pathogens such as *Aeromonas* spp and *Pseudomonas aeruginosa* (Sinclair et al. 2005). Except for the severely immunocompromised these organisms are not considered to represent a significant risk through normal uses of drinking water supplies (WHO 2008).

Most domestic rainwater tanks are installed above ground and collect run-off from roofs via guttering. Likely sources of enteric pathogens include:

- faecal material (droppings) deposited by birds, lizards, mice, rats, possums and other animals
- dead animals and insects, either in gutters or in the tank itself.

Less commonly, rainwater is collected in underground tanks. If these tanks are not fully sealed or protected against ground run-off, then microorganisms associated with human and animal excreta may also contaminate stored rainwater.

More recently new houses being built in Australia have rainwater tanks fed by buried pipe work (so-called 'wet systems') in order to maximise yield while minimising the number of separate tanks. This also reduces the need for house walls to have 'unsightly' sloping, external downpipes. However, there are risks from this design approach.

Rainwater systems incorporating buried pipe can be susceptible to inadvertent cross-connections or contamination from external sources such as septic systems. In South Australia one outbreak of gastroenteritis was attributed to buried rainwater pipework being installed in the same trench as pipework to a septic system (SA Health, unpublished).

Microbial quality of drinking water is commonly measured by testing for *Escherichia coli* (*E. coli*), or alternatively thermotolerant coliforms (sometimes referred to by the less accurate term faecal coliforms), as indicators of faecal contamination and the possible presence of enteric pathogens. In the past, the broader total coliform group has also been used for this purpose. However, this group includes non-pathogenic organisms that can grow in water environments and be present in the absence of faecal contamination. Accordingly, total coliforms are no longer recognised as being a suitable indicator of faecal contamination or having health significance (ADWG).

Thermotolerant coliforms or *E. coli* have been commonly identified in domestic tanks (Fuller et al. 1981; Dillala & Zolan 1985; Fujioka & Chin 1987; Haeber & Waller 1987; Wirojanagud 1987; Gee 1993; Edwards 1994, Thurman 1995; Victorian Department of Natural Resources and Environment 1997; Simmons et al. 2001; Sinclair et al. 2005; Chapman et al. 2006 and 2008; Evans et al. 2007; Abbott et al. 2007; Rodrigo et al. 2009). This implies that enteric pathogens could often be present in rainwater tanks.

However, when surveys have included testing for specific pathogens, detection has been relatively infrequent (Sinclair et al. 2005; Chapman et al. 2008; Rodrigo et al. 2009). In Australia *Salmonella* and *Campylobacter* have been detected in small numbers of samples (Sinclair et al. 2005; Chapman et al. 2006; Rodrigo et al. 2009). Atypical enteropathogenic *E. coli* were detected in a survey of metropolitan Adelaide tanks (Rodrigo et al. 2009). In contrast, studies using PCR-based analyses detected relatively high frequencies of *Salmonella*, *Campylobacter* and *Giardia* in rainwater tanks in Queensland (Ahmed et al. 2008, 2009). A quantitative microbial risk assessment based on these analyses calculated risks of disease that are higher than the currently reported incidence of disease in Queensland (Ahmed et al. 2009). As indicated by the authors, further investigations into the significance of these results are required.

In New Zealand, *Campylobacter* was identified in nine of 24 tanks, but the maximum concentrations were less than one organism per 100 mL (based on average concentrations) and it was concluded that the risk of illness from drinking this water was low (Savill et al. 2001). A second New Zealand survey found faecal coliforms in 70 of 125 rainwater tanks but *Salmonella* was only detected in one tank. *Cryptosporidium* oocysts of unknown species were detected in two of 50 tanks that contained at least 30 faecal coliforms or 60 enterococci per 100 mL (Simmons et al. 2001). *Campylobacter* or *Giardia* was not detected in any tanks. Similarly Wirojanagud (1987) reported the detection of faecal coliforms in 43 of 156 samples from rainwater tanks in Thailand, but *Salmonella* was only detected in one sample and *Shigella* in none.

An exception to this trend was the detection of *Cryptosporidium* and *Giardia* in 400 L samples, collected from a large number of rainwater cisterns in the Virgin Islands, where installation of rainwater storage is compulsory due to a lack of fresh water resources (Crabtree et al. 1996). The health significance of this finding was not established.

Legionella

There has been increasing interest in potential risks associated with *Legionella* in rainwater tanks. *Legionella* causes disease through inhalation and not through drinking contaminated water. Rainwater tanks have been proposed as potential sources of organisms that could be amplified in hot water systems in buildings (Chapman et al. 2008).

Legionella is a common environmental organism which survives and grows in sludges and slimes. Risks of waterborne legionellosis (Legionnaires' disease and Pontiac Fever) are typically associated with amplification in water between 25°C and 50°C (WHO 2007). Above ground rainwater tanks have been identified as a potential source of *Legionella* because they tend to accumulate sludges and in Australian summers are likely to contain water between 25°C and 50°C.

Legionella has been detected by culture or PCR in rainwater tanks (Sinclair et al. 2005; Chapman et al. 2008; Ahmed et al. 2009).

In New Zealand there was a reported outbreak of Legionnaires' disease that may have been associated with rainwater fed hot water tanks (Simmons et al. 2008). Using sequence-based typing, it was concluded that aerosols from a nearby marina water blaster was a likely source of contamination of nearby rooftops and rainwater tanks. Nearly two-thirds of the rainwater tanks investigated had never been cleaned, providing environments to support survival and growth.



While rainwater tanks can provide environments for *Legionella*, they are common environmental organisms. Infection normally follows amplification in warm water and dissemination in aerosols. There is little evidence that rainwater tank supplies are associated with increased public health risk. Tanks should be kept clean and the rainwater, when used in hot water systems, stored and delivered to reduce the likelihood of the growth of *Legionella* bacteria, and also reduce the likelihood of burns and scalds.

Illness and rainwater tanks

The relatively frequent detection of faecal indicator bacteria is not surprising, given that roof catchments and guttering are subject to contamination by bird and small animal droppings. However, despite the prevalence of indicator organisms, reports of illness associated with rainwater tanks are relatively infrequent. Although traditional under-reporting of gastrointestinal illness will contribute to a lack of evidence, epidemiological investigations undertaken in South Australia have failed to identify links between rainwater tanks and illness (Heyworth et al. 1999; Heyworth 2001; Rodrigo et al. 2010).

Investigations in the late 1990s compared rates of gastrointestinal illness in South Australian children who drank rainwater collected in domestic tanks, compared to those who drank filtered and disinfected mains water that was fully compliant with the ADWG. Overall, the investigations found no measurable increase in illness associated with drinking rainwater. In the first part of the investigation, a questionnaire was supplied to the parents of about 9500 children undertaking a general health check before enrolling at school for the first time. There was a slightly higher, but non-significant, incidence of gastrointestinal illness reported for rural children who drank rainwater rather than mains water (Heyworth et al. 1999).

There was no difference in rates of illness between children drinking rainwater or mains water in urban areas.

The second part of the investigation expanded on the results through use of a diary with parents of about 1000 rural children. The results were reversed and the study found a small but significant decrease in illness associated with consumption of rainwater compared to mains water (Heyworth 2001). The investigations included questions about rainwater tank maintenance. As found in most surveys, maintenance was generally poor.

A double-blind controlled study was conducted in 2007-2008 in South Australia to compare rates of gastrointestinal illness between filtered and unfiltered rainwater (Rodrigo et al. 2010). Three hundred households that drank untreated rainwater were selected for the study from metropolitan Adelaide and adjacent hills suburbs with a total of 1352 participants. All households included at least two children. Half of the households had an active water filter fitted and the balance had an inactive filter. Householders recorded incidence of illness weekly with the exception of 5 weeks over the Christmas period. Two hundred and seven households completed the study with similar dropout rates for both groups.

The overall trend was that the inactive filter group had a slightly lower rate of illness. The study found that untreated rainwater does not contribute significantly to community gastrointestinal illness for either adults or children (Rodrigo et al. 2010).

Water quality testing was also performed and 30% of 974 samples were positive for *E. coli* with levels ranging from 1 to 2400 cfu/100 mL. There was no relationship between water quality and illness.

There have been a few reports of illness associated with *Campylobacter* and *Salmonella* in rainwater tanks. In four of these reports the contaminating organisms were detected in both those infected and their rainwater sources (Koplan et al. 1978; Brodribb et al. 1995; Simmons & Smith 1997; Taylor et al. 2000). Brodribb et al. (1995) reported on an investigation into recurrent infections of an elderly immuno-compromised woman by *Campylobacter fetus*, where the organism was also isolated from the patient's rainwater tank, which served as her sole source of drinking water. No further infections occurred after the patient started boiling the tank water before consumption. It was postulated that an outbreak of 23 cases of campylobacteriosis at a Queensland island resort was probably associated with contamination of rainwater tanks, even though *Campylobacter* was not isolated from rainwater samples (Merritt et al. 1999). A study of risk factors for campylobacteriosis in New Zealand associated consumption of rainwater with increased risk in a small number of cases (23 cases, 11 controls; odds ratio 2.2) (Eberhart-Phillips et al. 1997).

An investigation of an outbreak of *Salmonella* infections in a church group in Trinidad, Jamaica led to detection of the organism in rainwater samples and in food prepared using the rainwater (Koplan et al. 1978). It was reported that the roof catchment was covered with dried and fresh bird droppings. Similarly, *Salmonella* was isolated from a rainwater tank used by a family of four in New Zealand that had suffered from recurrent infections by the same organism (Simmons & Smith 1997). In an investigation of 28 cases of gastroenteritis among 200 workers at a construction site in Queensland, *Salmonella saintpaul* was isolated from both the cases and rainwater samples (Taylor et al. 2000). Animal access was suggested as being the source of contamination with several live frogs being found in one of the suspect tanks.

An underground rainwater tank was associated with the only drinking water borne outbreak of cryptosporidiosis/ giardiasis recorded in Australia to date (Lester 1992). Eighty-nine people supplied with drinking water from the tank became ill. Investigations revealed the tank had been contaminated by an overflow from a septic tank.

Two explanations have been suggested for the apparent disparity in frequency of faecal contamination and the prevalence of illness. The first is the likely source of contamination. For most rainwater tanks, particularly those installed above ground, faecal contamination is limited to small animals and birds. While faecal contamination from these sources can include enteric pathogens, there is a degree of host group pathogen specificity. Enteric viruses are the most specific; in general, human infectious species only infect humans and animal (non-human) infectious species only infect animals.

The host range for protozoa is a little broader, but except for the severely immuno-compromised, human infections with *Cryptosporidium* are predominantly associated with genotypes of *C. hominis* carried by humans and *C. parvum* carried by livestock (McLauchlin et al. 2000; Chappell & Okhuysen 2002, Hunter & Thompson 2005, Xiao & Fayer 2008). The livestock genotype can be transmitted to some other animals, but the human genotype is very specific for humans. *C. meleagridis* carried by birds has been associated with low numbers of cases (McLauchlin et al. 2000; Pedraza-Diaz et al. 2001). The evidence for the zoonotic transmission of *Giardia* is limited (Hunter & Thompson 2005, Xiao & Fayer 2008).

Bacterial pathogens are the least specific and birds, for example, are known to carry and excrete potentially human infectious *Campylobacter* (Koenrad et al. 1997; Whelan et al. 1983). Birds that live in close proximity to human populations can also transport *Salmonella* (Hernandez et al. 2003; Refsum et al. 2002).

These limitations are important, as enteric illness mediated by waterborne bacteria requires ingestion of much higher numbers of organisms than enteric illness mediated by protozoa or viruses. Dosing studies have found that while ingestion of between one and 10 virus particles or protozoan cysts can lead to infection, at least 1000 and often more than 100,000 bacteria are required (Haas 1983; Regli et al. 1991; Gerba et al. 1996; Okhuysen et al. 1999).

The second explanation is that ongoing exposure to organisms in rainwater could result in increased immunity (Heyworth 2001, Rodrigo et al. 2010). The protective effect of acquired immunity can last from months to years and for such partially immune people it is possible that larger doses of contaminating organisms may be required to trigger illness (Eisenberg et al. 2001).

In summary, the study conducted in South Australia found no measurable difference in rates of gastrointestinal illness in children who drank rainwater compared to those who drank mains water. However, there are examples of *Campylobacter* and *Salmonella* enteritis associated with rainwater tanks and one example of cryptosporidiosis/ giardiasis associated with an underground tank. Faults in tank design or poor maintenance were identified as contributory factors in some of the investigations of illness.

Dead animals

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 tanks and drown, leading to very high levels of contamination. In the case of larger animals, such as possums and cats, this will almost certainly have a distinctive impact on the taste and odour of the water.

Mosquitoes

Rainwater tanks can provide excellent habitats for mosquito breeding. In addition to causing nuisance, certain types of mosquito can be vectors of arboviruses.

Of particular concern are species of mosquito that can be vectors for dengue virus, which occurs in tropical and subtropical areas of the world. Rainwater tanks have been identified as potential breeding sites for vectors of dengue virus and the World Health Organization (WHO) recommends all tanks have screens or other devices to prevent adult mosquitoes from emerging (WHO 1997).

In Queensland it has long been suggested that rainwater tanks are associated with breeding of the mosquito *Aedes aegypti*, the primary vector of dengue virus (Kay et al. 1984). This was confirmed in an outbreak of dengue in the Torres Strait Islands in 1996-1997 (Hanna et al. 1998). In addition, a survey conducted in the Torres Strait Islands in 2002 detected adult mosquitoes, including *Aedes aegypti*, in rainwater tanks with missing or faulty insect screens (Ritchie et al. 2002).

Both the Northern Territory and Queensland have regulations relating to prevention of mosquito breeding in rainwater tanks (Northern Territory 1998; Queensland 2005).



Other mosquitoes that breed in rainwater tanks may also be vectors of arbovirus infections. For example, *Aedes notoscriptus* could be a vector of Ross River and Barmah Forest viruses (Doggett & Russell 1997). This species is widespread in Australia.

- development and implementation of standards relating to materials that can be used in contact with drinking water or food
- reduction of lead concentrations in paint from up to 50% before 1950 to a maximum of 0.1% from 1997

Notwithstanding these results, there may be localised areas where tank rainwater quality is affected by specific industries. Relatively high concentrations of lead (mean 61 µg/L) were detected in surveys of tank rainwater collected in Port Pirie, South Australia (Fuller et al. 1981; Body 1986). The source of this contamination is considered to be a very large smelter, and Port Pirie residents have been advised not to use rainwater collected in domestic tanks for drinking or food preparation.

When in doubt about the possible impact of local industry, advice should be sought from the local water authority, environmental health agency or environment protection agency.

Chemical hazards

Sources of chemical hazards can be divided into two types:

- Those arising from off-site sources beyond the control of the owner/resident, including urban traffic, industrial emissions and poor agricultural practices (for example, pesticide overspraying). In urban areas, potential contamination by lead has attracted most concern, due to its relatively common use, while in rural areas contamination from pesticides has been the major issue.
- Those arising from on-site sources in the immediate vicinity of the tank, and controllable by the owner/resident. These sources include characteristics of the roof catchment; materials used in construction of the roof, gutters, piping and tanks; flues from wood heaters etc.

Measures introduced to reduce the potential for contamination from both off- and on-site sources of chemical contamination including:

- off-site
 - introduction of lead-free petrol in the 1980s and lead replacement petrol in 2002
 - tighter controls on industrial emissions
 - increased surveillance and control of pesticide use
- on-site
 - advances in design and construction of tanks and associated equipment

Industrial and urban traffic emissions

In most parts of Australia, industrial and traffic emissions are unlikely to cause significant impacts on the quality of rainwater collected in domestic tanks.

In addition, as discussed above, several measures have been introduced to reduce levels of airborne contamination and potential impacts on the quality of rainwater collected in tanks.

Analyses of rainwater from domestic tanks in Adelaide (Fuller et al. 1981, South Australian Department of Human Services unpublished results 1999-2002), Newcastle (Coombes et al. 2000, 2002a) and overseas (Haeber & Waller 1987) did not detect an impact on lead concentrations in tank rainwater from urban emissions.

In Adelaide, the testing of rainwater from household tanks near industrial precincts was undertaken as part of two investigations into the impacts of contaminants associated with local emissions. Lead, manganese, nickel, zinc and hydrocarbon concentrations in the rainwater samples were consistently below the guideline values cited in the ADWG (South Australian Department of Human Services, unpublished results 1999-2002).

Huston et al. (2009) investigated the atmospheric deposition of contaminants on roofs at 13 sites in Brisbane. The conclusion of the study was that elevated lead levels were most likely caused by roofing materials and only partially due to atmospheric deposition.

Pesticides – agricultural pollution

Use of pesticides and potential drift from agricultural areas has been the subject of increasing public concern, and one of the issues commonly raised has been potential contamination of roofs used as catchments for rainwater tanks. There have been complaint investigations but pesticides are rarely detected and, where they are, concentrations are well below health-related guideline values (South Australian Department of Human Services, unpublished results).

In surveys of rainwater quality in rural areas, most samples did not contain detectable concentrations of pesticides (Victorian Department of Natural Resources and Environment 1997; Fuller et al. 1981; Paskevich 1992; New South Wales Environment Protection Authority and Northern Districts Public Health Unit 1996; Chapman et al. 2008). Endosulfan, profenofos, chlorpyrifos and dieldrin were detected in some samples, but all at concentrations well below health-related guideline values cited in the ADWG.

If in doubt about the use of pesticides in a particular area, advice should be sought from the relevant agriculture, environmental health or environment protection agency.

Bushfires

Bushfires generate large amounts of smoke, ash and debris that can settle on roof catchment areas. In addition, it is possible that fire retardants or foams may also be deposited on roofs.

Such material can be washed into tanks, either when water is applied to the roof as part of fire protection activities, or when it rains after a bushfire. Although the presence of ash and debris in rainwater does not represent a health risk, it could affect colour, turbidity and taste. The recommended concentrations of the commonly used retardants and foams should not represent a health risk, but they may affect the taste of the water if washed into a rainwater tank.

Contaminants identified as a risk to health after a bushfire event include polycyclic aromatic hydrocarbons (PAHs) from burnt organic matter and arsenic, released during the combustion of wood treated with arsenic-based preservatives. A pilot study of 49 tanks in north-eastern Victoria after the 2003 bushfires found that levels of PAHs and arsenic were below the ADWG values (Spinks et al. 2006). Elevated levels of cadmium, iron and zinc were recorded however it was unclear if this was due to roof materials or the bushfire debris. There are no health-related guideline values for iron or zinc.

Slow-combustion heaters

Concerns have been expressed about the potential impact of emissions from slow combustion wood fires on rainwater collected in domestic tanks. Public complaints have ranged from reports of a slight burnt wood taste to tainting with creosote. However, in a survey of rainwater collected from roofs incorporating wood heater flues, polyaromatic hydrocarbon (found in combustion products) concentrations did not exceed guideline values in the ADWG (Victorian Department of Natural Resources and Environment 1997).

Roof materials

Roofs may be constructed from a variety of materials such as cement or terracotta tiles, Colorbond®, galvanised iron, Zinalume®, asbestos/fibro cement, polycarbonate or fibreglass sheeting and slate. All of these should be suitable for collecting rainwater.

Lead

Surveys of rainwater from domestic tanks have identified lead contamination as a potential problem. Results have been variable with exceedances of the ADWG health-related guideline value of 10 µg/L (NHMRC & NRMCC 2004) ranging from 0% to 15% of samples collected (SA Health unpublished results 1999-2009; Simmons et al. 2001; Chapman et al. 2006 and 2008; Morrow et al. 2007; Huston et al. 2009; Rodrigo et al. 2009). In addition to these results a survey in Melbourne recorded a particularly high exceedance frequency of 33% (Magyar 2008).

As discussed in other sections the reduction of lead concentrations in paint and the introduction of lead free petrol have decreased the risk from paint and general traffic emissions. However, roof materials and uncoated lead flashing in particular remain a potential source of contamination (Simmons et al. 2001; Chapman et al. 2006; Magyar et al. 2008; Huston et al. 2009), as rainwater tends to be acidic and may mobilise lead, and possibly other metals, into solution. The increasing availability of lead-free or coated lead flashing is expected to reduce future concentrations of lead in rainwater tanks.

Roof catchments used in the collection of rainwater for drinking should not include uncoated lead flashing. Alternative materials should be used in new roofs or when renovating or extending roofs. In existing roofs, painting of uncoated flashing will reduce the risk of contamination. Lead may also enter rainwater from lead washers for roofing screws. These can be replaced with plastic washers.

Leaching of lead into roof run-off may be more of a problem from poorly maintained roofs and gutters, where the process could be increased by the action of water made acidic with organic substances from materials such as leaf litter.

Preservative-treated wood

Preservative-treated wood could be a source of chemical contamination if there is direct contact with rainwater that is to be collected in a domestic tank. Examples of timber preservatives used in Australia are:

- water-based preservatives, such as copper chrome arsenates (CCA) and boron compounds
- oil-type or oil-based preservatives, such as creosote
- light organic solvent preservatives, such as solutions containing pentachlorophenol.

Cement-based or terracotta tiles

The coloured surface of cement-based or terracotta tiles will oxidise over time through natural weathering. This oxidised coating may break down and be washed into rainwater tanks, thus colouring the water.

The coating is non-toxic and, if left undisturbed, will settle to the bottom of the tank. The colour may reappear after rain, if settled material is stirred up by water flowing into the tank.

It is possible to purchase colour-through tiles that have colour impregnated throughout the tile, which is a more stable type of tile.

Asbestos/fibro-cement roofing

Although no longer used in new houses, asbestos may be present in some pre-1970s roofs. Although asbestos fibres are dangerous to health when inhaled in sufficient quantities, it is not believed that asbestos in drinking water poses a risk (ADWG). Asbestos is incorporated into some types of pipe used in distribution of public water supplies.



Note: Asbestos roofing material should, as far as is practicable, be left undisturbed since fibres can be released into the air by actions such as cutting, grinding or drilling. High-pressure roof cleaning methods should not be used on asbestos roofs. Where the roof catchment area has deteriorated badly, it should be replaced with asbestos-free substitutes.

Paints and coatings

Before purchasing materials or paint for roofs used to collect rainwater, read and observe the manufacturer's recommendations on labels and brochures. Look for warnings. If in doubt, check with the manufacturer. Three types of paints and coatings are:

- lead-based paints (including primers) – concentrations of lead in paints have been substantially reduced over the last 50 years, but care should still be taken to ensure that paints used are suitable for use in association with collecting rainwater for human consumption
- acrylic paint – will leach dissolved chemicals, including detergents, in the first few run-offs after application and these run-offs should not be collected
- bitumen-based (tar) materials – are generally not recommended, as they may leach hazardous substances or cause taste problems.

Some roof sealant materials contain mercury and this has been a cause of contamination of a rainwater supply. It is advisable to check the MSDS for any paint or coating to be used on a roof catching rainwater for drinking.

Tank materials

Rainwater tanks are available in a range of suitable materials including galvanised steel, Aquaplate®, Zinalume®, fibreglass, plastic and concrete. All can be suitable, providing the materials used are at least of food-grade standard (for example, plastics should comply with AS 2070) and preferably comply with the requirements of AS/NZS 4020 Testing of products for use in contact with drinking water.

Guidance on use of rainwater tanks

New rainwater tanks can impart specific tastes and odours. For example, galvanised tanks can impart a metallic taste when first filled, due to leaching of excess zinc.

New concrete tanks can release excess lime, leading to a high pH (Gee 1993; Simmons et al. 2001) and possibly a bitter taste. Rainwater from other types of tanks tends to be slightly acidic (Simmons et al. 2001). Although results outside the recommended pH range of 6.5-8.5 (ADWG) have been recorded, they are unlikely to have a direct health impact, but low pH in particular could cause increased corrosion and result in dissolution of metal tanks, pipes and fittings. By way of comparison, orange juice and some soft drinks have a pH below three.

Other types of tanks can also impart tastes related to their manufacture or the materials that they are made of but, providing the materials are of food or potable water grade, these will not represent a health hazard and will diminish over time as the tank ages. If tastes make the water unpleasant to use, new tanks may need to be flushed with water from the first fill and used for non-potable purposes until the taste of the water improves.

It has been suggested that galvanised metal can include low levels of lead, but, as discussed in the section on roof materials above, specific surveys have not detected elevated concentrations of lead associated with metal tanks.

Australian and Australian/New Zealand Standards that apply to tanks and their associated fixtures and fittings are:

- AS 2070 Plastics materials for food contact use
- AS/NZS 2179 Specifications for rainwater goods, accessories and fasteners
- AS 2180 Metal rainwater goods – selection and installation
- AS/NZS 3500 National plumbing and drainage code
- AS/NZS 4020 Testing of products for use in contact with drinking water
- AS/NZS 4130 Polyethylene (PE) pipes for pressure applications.

Further information on the various types of tanks, their installation and capacity is provided in Section 7.

Pipework

Pipes that may be in contact with rainwater for extended periods of time should comply with AS/NZS 4020. In general, this does not apply to guttering or downpipes that deliver rainwater directly into the top of tanks because the contact with the rainwater is transient. However, underground pipework delivering water to the tank, between tanks or from tanks to houses should comply with AS/NZS 4020. Polyethylene pipes that are used in situations where the pipework is operating under pressure should comply with AS/NZS 4130.

Irrigation piping should not be used as it can contain and release lead into water at concentrations exceeding those specified in the ADWG.

The slight acidity of rainwater and its lack of buffering can make rainwater quite corrosive to plumbing. A long-term unpublished study by NSW Health showed that the water standing in metal pipework overnight frequently showed lead and copper concentrations above ADWG values. Flushing the water for three minutes removed this problem, except where lead was present in the catchment area. Shorter flushing times would probably work for smaller buildings.

Accumulated sediments

Sediments accumulated below good quality rainwater can contain high concentrations of chemicals, including lead (Gee 1993; Scott & Waller 1987; Coombes et al. 2002b). In a survey of water and sediment samples from tanks along the rail corridor used to transport lead ore to Port Pirie, very high concentrations of lead were detected in the sediments, while most of the water samples (25 of 33) contained less than 10 µg/L (Body 1986).



Sediments could be particularly significant in the absence of regular cleaning, as taps are typically close to the bottom of tanks. There have been examples where elevated concentrations of lead have been detected in samples taken from tank taps, due to the presence of small amounts of re-suspended sediment from the bottom of poorly maintained tanks (South Australian Department of Human Services, unpublished results).

Dangerous plants

Most plants are harmless but there are some plants in Australian gardens that produce toxins. Examples include:

- fruits of the nightshade family such as *Solanum rantonnetii* and *Solanum nigrum*
- the common oleander (*Nerium oleander*) and yellow oleanders (*Thevetia peruviana*)
- lantanas such as *Lantana camara* and *Lantana montevidensis*
- flowers and berries of white cedar (*Melia azadirach* var '*australasica*')
- wintersweet (*Acokanthera oblongifolia*).

Most of these plants are low-growing and would be unlikely to affect above-ground tanks. In addition, there is little evidence of poisoning from plant material in rainwater tanks. However, there are anecdotal reports that flowers of the white cedar falling into tanks can cause diarrhoea (Campbell 2001).

As a general rule, roof catchments should be kept clear of overhanging tree branches and vegetation, and leaf filters should protect inlets to rainwater tanks. These practices will minimise the risk from plants.

Further advice on the potential toxicity of plants could be sought from local nurseries or operators of botanic gardens.

Injury and drowning/accidental death

Any water body can cause death through drowning and rainwater tanks are no exception. The greatest risk is to young children playing on or near rainwater tanks. In recent years three children have drowned in rainwater tanks (Gibson 2008). A study by Byard (2008) identified the need to identify any access points to rainwater tanks including nearby trellises, trees and ladders which could be used by children to climb onto tanks.

All rainwater tanks should be roofed and access points should be child proofed.

Aesthetic quality – tastes, colours and odours

The absence of distinctive tastes, colours and odours is a feature of good quality rainwater, but there is a range of factors and/or conditions that can cause deterioration of these characteristics during collection, storage and piping. Other than dead animals (see Section 4) the principal sources of taste, colour and odour are:

- sediments and slimes at the bottom of tanks or in pipework that can hold stagnant water
- soil and decaying vegetation that is allowed to accumulate in guttering
- algal growth in pipework or open tanks
- pollen
- tannins from leaf materials.

Odours from sediments and slimes are the most commonly reported. Sediment can accumulate in the bottom of tanks that have not been cleaned frequently enough. In warm to hot weather, anaerobic conditions can develop, leading to growth of microorganisms that produce sulfides, with a distinctive sewage or rotten egg-like smell.

Pipework that does not completely self drain (for example, u-bends or underground piping from roof catchments to tanks, between tanks or from tanks to buildings) can also be a source of off-tastes and odours, particularly where stagnant water can develop and be retained between rain events. In these environments, slimes and biofilms can be formed and in the same manner as for tank sediments, anaerobic growth can occur, leading to production of sulfides.

Decaying vegetation and soils accumulated in guttering can also release taste, colour and odour compounds into the water, particularly if the gutters are not kept clean and do not fully drain between rain events.

Open tanks are fairly uncommon but exposure of stored rainwater to light will lead to algal growth. Most algae are not a human health risk, but growth can adversely affect the taste, odour and appearance of rainwater. Piping that is not impervious to light can also support algal growth.

Some pollens have very distinctive tastes and odours and if allowed to accumulate on roof catchments or in gutters, they can affect the quality of stored rainwater.

Off-tastes associated with roof catchments that include flues from wood heaters have been reported. Deposits could occur if the heater is not operated efficiently and the flue is not installed and operated in accordance with Australian/New Zealand Standards (see SAA/SNZ HB170 Wood heating resource handbook). The burning of preservative-treated wood could exacerbate the problem, and in any event, such wood is not a suitable fuel due to health and environmental concerns associated with production of toxic fumes and ash.

5. Preventive measures and corrective actions

Health and aesthetic hazards for rainwater collected in tanks can be minimised by sensible preventive management procedures.

The possible exceptions are the impacts of urban traffic emissions in highly populated centres, and industrial emissions. Some of the preventive measures are associated with design and installation while others are associated with ongoing maintenance. Well designed systems are low maintenance.

Implementation of a relatively low-key management approach will generally prevent problems occurring so corrective action to restore water quality will be needed infrequently, if at all.

Potential sources of hazards, preventive measures and corrective actions are summarised in Table 2 (Sources of potential health hazards and preventive measures) and Table 3 (Sources of aesthetic hazards and preventive measures).

Minimising contamination by harmful microorganisms

Preventive measures to reduce contamination by potentially harmful microorganisms are predicated on minimising the impact of faecal waste. As indicated in Table 2 measures could include:

- keeping 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

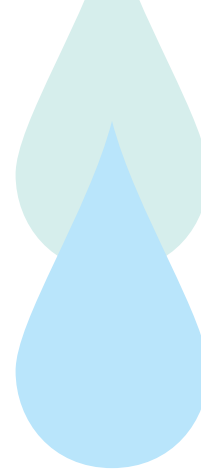
- preventing access by small animals and birds into rainwater tanks by screening all tank inlets and overflows, keeping access hatches closed and by maintaining the integrity of tank roofs
- preventing entry of surface run-off from areas other than the roof catchment into below-ground tanks. Roofs should be secure and the sides and bottom of tanks should be sealed to prevent ingress
- ensuring that buried pipework is impervious and suitable for contact with water. It should be separated from pipework carrying septic waste or sewerage.

Swimming in storage tanks should be prevented, as this type of human access can greatly increase risks of contamination.

Table 2: Sources of potential health hazards and preventive measures

Health hazard	Cause	Preventative measure	Monitoring	Corrective action
Faecal contamination from birds and small animals	Overhanging branches on roof	Prune tree branches. Install first flush device.	Check tree growth every six months. Check device after rainfall.	Prune branches. Empty contents of device after rainfall.
	Animal access to tank	Protect all inlets, overflows and other openings to prevent entry by small animals and birds.	Check access covers are kept closed. Check inlets, overflows and other openings every six months.	Repair gaps. Secure access cover. If animal access suspected disinfect tank using chlorine.
		Maintain integrity of tank roof and body to prevent access points.	Check structural integrity of tank.	If a dead animal is found, empty and clean tank. If this has to be delayed, remove animal remains and disinfect tank using chlorine.
Faecal contamination from humans (above-ground tanks)	Human access to tank	Prevent access. Ensure tank is roofed and access hatches are secured.	Check access covers are secured, particularly in hot weather.	Secure access cover.

Health hazard	Cause	Preventative measure	Monitoring	Corrective action
Faecal contamination from humans and livestock (below-ground tanks)	Surface water ingress into tank	Ensure tank is protected from overground flows and tank walls are intact.	Check structure annually and that surface water does not enter during storm events.	Repair or increase barrier to surface water flow. Repair or line inside of tank.
Faecal contamination from humans (buried pipework)	Ingress of contaminated water, potential cross-connections	Ensure that pipework is protected from cross-connections, that pipework is impervious and is separated from septic and sewage pipes.		Remove cross-connections, repair or replace pipework.
Mosquitoes	Access to stored water	Protect all inlets, overflows and other openings with mosquito-proof mesh.	Inspect water for presence of larvae at least every six months (in northern areas of Australia this should be done more often).	Repair screening of inlets and openings to prevent access and if larvae are present, to prevent escape of mosquitoes. Treat tanks with a small amount of kerosene or medicinal paraffin.
Lead contamination	Lead based paints and primers on roofs	Do not collect rainwater from roofs painted with products containing high lead concentrations (for example, pre-1970s paint). When painting roof, check suitability with paint retailer.		
	Uncoated lead flashing on roofs	Paint existing material or use pre-coated products.	Inspect roof and gutters every six months.	Use coated lead flashing or alternative materials on new roofs. Paint existing uncoated flashing.
	Increased corrosion of metals due to low pH from long periods of contact between rainwater and leaves	Keep gutters clean. Install leaf protection devices on gutters.	Inspect gutters every six months.	Clean gutters. If large amounts of leaves are detected on regular inspections clean more often.
Chemical contaminants from tanks, pipework etc	Water standing in metal pipes overnight or longer periods	Use plastic pipes	Inspect plumbing to identify pipe materials	Flush pipes in the morning for long enough to bring new water from the tank (several minutes).

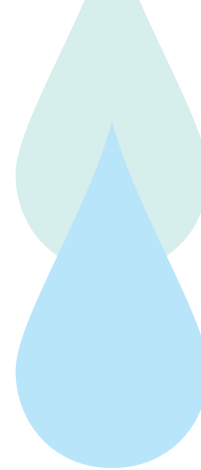


Health hazard	Cause	Preventative measure	Monitoring	Corrective action
	Re-suspension of accumulated sediment	Regularly clean tank to remove accumulated sediment. Reduce amount of sediment by keeping roof catchments and gutters reasonably clean. Protect inlet to tank using a leaf filter. Install a first flush diverter.	Inspect tank every 2-3 years. Inspect roof and gutters and inlet filter every six months.	Clean tank if required. Clean roof, gutters and inlet filter as necessary. Ensure filter is in place.
Other contamination from roof materials	Preservative-treated wood Bitumen based materials	Do not collect rainwater from roofs covered with exposed treated wood. Do not collect rainwater from roofs with bitumen-based products.	Inspect roof before installing tank.	If treated wood present it could be sealed or covered to prevent exposure to rainwater.
Chemical contaminants from tanks, pipe work etc.	Inappropriate material that does not comply with Australian or Australian/New Zealand Standards relating to food grade products or products for use in contact with drinking water	Use only approved materials.	Check suitability of product with retailer or supplier.	Remove or replace product.
Dangerous plants	Overhanging branches (check identity of suspect plants with horticulturist)	Prune tree branches.	Check tree growth every six months.	Prune or remove plant.
Drowning	Access to tank roof Hatches open or roof in poor state of repair	Prevent access to tank roof by children.	Check access covers are kept closed and roof is intact. Ensure that trellises and trees do not allow ready access to tank roofs.	Repair gaps. Secure access cover. Prune tree branches.



Table 3: Sources of aesthetic hazards and preventive measures

Aesthetic hazard	Cause	Preventative measure	Monitoring	Corrective action
Sulfide/rotten egg/ sewage odours	Anaerobic growth in accumulated sediment at the bottom of tanks	Regularly clean tank to remove accumulated sediment.	Inspect tank every 2-3 years.	Clean tank if required. If cleaning not practical (for example, in the middle of summer) disinfect tank with chlorine and flush chlorinated water through all pipework. If practical, pumping air into the tank, to add oxygen to the water, may also help to minimise tastes and odours.
	Slimes and stagnant water in pipe work	Avoid u-bends or underground pipework that can hold stagnant water. Install drainage points on buried pipe work.		
Musty or vegetable type taste and odours (no light penetration)	Accumulated material on roofs and gutters. May possibly include pollen	Remove overhanging branches from trees. Keep gutters clean. Install leaf protection devices on gutters.	Inspect gutters at least every six months.	Clean gutters. If large amounts of leaves (or pollen) are detected on regular inspections clean more often. If practical, pumping air into the tank, to add oxygen to the water, may also help to minimise tastes and odours.
Coloured water	Accumulated damp leaves in gutter	Keep gutters clean. Install leaf protection devices on gutters.	Inspect gutters at least every six months.	Clean gutters. If large amounts of leaves are detected on regular inspections clean more often.
Coloured water, particularly after rain (tiled roof)	Coloured coating from tiles washed into tanks. Re-suspension from sediments when fresh intake	Use colour-through tiles.	Inspect water after rainfall.	Remove sediment by cleaning the tank.
Musty, vegetable or fishy type taste and odours (light penetration)	Algal growth due to light penetration into tank or pipe work	Make sure tank is completely roofed and is impervious to light.	Inspect water every six months.	Repair roof. If practical, pumping air into the tank, to add oxygen to the water, may also help to minimise the tastes and odours.



Aesthetic hazard	Cause	Preventative measure	Monitoring	Corrective action
		Ensure pipework, including inlets to tanks, are impervious to light (white pipes can allow light penetration).		Paint pipework with dark colour.
Bitter taste (concrete tanks) Metallic taste (galvanised tanks) Plastic taste (plastic tanks)	New tank	Use water from first fill for non-potable purposes. Taste will diminish in subsequent fills.	Water quality/taste will improve with tank age.	Use water from first fill of new tanks, or water collected from newly painted roofs for non-potable purposes. Problem will diminish with time.
Detergent taste or water frothing	Newly painted roof	Do not collected water from first 2-3 rain events after painting.	Water quality/taste will improve with paint age.	Use water from first fill of new tanks, or water collected from newly painted roofs for non-potable purposes. Problem will diminish with time.
Hydrocarbon or preservative taste	Deposits from wood combustion heater flue	Install flue in accord with Australian Standards. Operate heater correctly. Use appropriate fuel (not preservative treated).	Check flue installation. Check operation of heater and choice of fuel.	Repair flue. Discard inappropriate fuel.
Insects/water boatmen etc.	Access to stored water	Protect all inlets, overflows and other openings with insect proof mesh.	Inspect water for presence of insects and/or larvae every six months.	Repair screening of inlets and openings to prevent further access. Use simple coarse filter to remove remaining insects.
Small white flakes in water	Microbial growth	Keep gutters clean. Growth encouraged by nutrients contained in plant and soil material accumulated in gutters or at the bottom of tanks. Install leaf protection devices on gutters	Inspect gutters at least every six months. Inspect tank every 2-3 years.	Clean gutters and tank if necessary. Disinfect tank using chlorine.



Aesthetic hazard	Cause	Preventative measure	Monitoring	Corrective action
Slime on the inside of tanks	Microbial growth	All containers that continuously hold water will develop biofilms on surfaces below the water level.	None required.	None required. These are naturally occurring and not harmful to the general population.
White deposits on the surface of metal tanks (slimy or waxy feel)	'White rust'. A corrosion product containing zinc-rich oxide	Not required.	None required.	None required, the deposits are not harmful. Physical removal could damage the surface of the tank and increase the potential for corrosion.

Disinfection

The most common methods for disinfecting rainwater are chlorination, ultraviolet light irradiation or heat (boiling).

Chlorination

Regular chlorination of rainwater held in domestic 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 it will only act on water in the tank at the time of dosing. Fresh run-off into the tank after chlorination will probably not be disinfected.

Chlorination is effective against harmful bacteria, many viruses and *Giardia* but it has limited effect against *Cryptosporidium*. Chlorination can also remove odours from rainwater by oxidising the responsible chemicals. When chlorine is added to water, it reacts with organic matter and other impurities in the water – the amount of chlorine needed for disinfection will depend on the concentrations of these impurities.

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 30 minutes. This can be measured using a suitable chlorine test kit (for example, a swimming pool kit) if available.

As a general guide, the addition of 40 mL of liquid sodium hypochlorite (12.5% available chlorine) per 1000 L of water or 7 g of granular calcium hypochlorite (75% available chlorine) per 1000 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. Stabilised chlorine (chlorinated cyanurates) is not effective in enclosed tanks and should not be used.

Methods for calculating the volume of water in a tank are provided in Appendix A.

The chlorine will not make the water unsafe to drink, but it will impart a distinct taste and odour that should dissipate in 10 to 14 days (depending on temperature). Boiling the water, or leaving water in an open jug in the fridge overnight, will remove most of the taste and odour associated with chlorination.

Calcium hypochlorite should be dissolved in rainwater, in a clean plastic bucket, in the open air, before adding it to the tank. Always add the disinfectant to the water rather than vice versa. When adding the concentrated chemical mixture to the tank, spread it as widely across the surface as possible to promote mixing (this will often be limited by restricted access) and let the water stand for at least one hour before use (or overnight if possible).

Note: When handling and storing chemical compounds, it is important to carefully read and follow the safety directions given on the package label, particularly advice in relation to the wearing of appropriate personal protective equipment (such as gloves or goggles).

Ultraviolet light irradiation

Ultraviolet (UV) light irradiation can be used to provide continuous assurance of water quality. UV light systems require relatively low maintenance and have the advantage of not involving the addition of chemicals. The UV light could be installed in pipework delivering water from a tank to a dwelling or selectively to taps used to supply water for drinking and food preparation. UV light systems could be particularly suitable for community supplies (see Section 11). It is important to note that typical UV doses for drinking water only provide limited inactivation of viruses.



If UV light irradiation is used, it is important to install a system incorporating a sensor that indicates when the device is or is not operational. UV lamps have a limited effective life and most need to be replaced after between nine and 12 months.

Boiling

While rainwater should be safe for most people to drink, at times the microbial quality may not be as high as mains water supplies. People with lower immune responses, such as the very young or very old, cancer patients, people with diabetes, organ transplants or those who are HIV positive, should talk to their doctor about potential risks and consider boiling the water before consumption. If gastric upsets are being experienced, boiling the water prior to use should also be considered.

Bringing water to a boil can disinfect rainwater (WHO 2008). Boiling does not have to be maintained for any length of time – kettles with automatic shut-offs are suitable for this purpose. Boiling water will kill any harmful bacteria, viruses and protozoa including *Giardia* and *Cryptosporidium*. The water can then be cooled and stored in a clean container until use. To improve the taste of boiled water, allow water to cool then pour it back and forth from one clean container to another. Alternatively, let it stand for a few hours to increase the dissolved oxygen concentration.

Hot water supplies

The use of rainwater to supply hot water systems has attracted growing interest. This water is used for household purposes such as washing and laundry. Irrespective of the source, water from hot water systems is not recommended for drinking and cooking. Vegetative bacteria, including those that cause enteric illness, are sensitive to heat and Pasteur's original studies indicated that inactivation occurs between 55 °C and 60 °C.

The original low temperature method for pasteurising milk was holding it at 61.7 °C for 30 minutes; this was increased in 1957 to 63 °C to include inactivation of *Coxiella burnetii*, the causative agent of Q fever (Adams & Moss 2000).

Campylobacter, the most commonly detected cause of enteric illness in Australia, is particularly sensitive to heat with inactivation occurring at temperatures above 48 °C. At 60 °C (minimum storage temperature required for hot water storage by AS/NZS 3500 Part 4.2) 99% inactivation of *Campylobacter*, *Salmonella* and *E. coli* populations are achieved in minutes (D'Aoust et al. 1988; Feacham et al. 1983). The protozoa *Cryptosporidium* and *Giardia* are also susceptible to heat (Harp et al. 1996; WHO 2008).

In field testing in Newcastle, Coombes et al. (2000) demonstrated that although faecal coliforms, total coliforms and pseudomonads could be detected in rainwater storages, none were present in hot water samples. Total bacterial counts were also substantially reduced by heating. In one case an instantaneous heater was used. Although further investigation on the effectiveness of these units is needed, microorganisms are sensitive to rapid changes in temperature.

Where heating is used as a mechanism to reduce risks from microbial hazards, attention will need to be paid to reliability of heating systems in achieving required temperatures.

Corrective action to improve microbial quality

Uncertainty over microbial quality

Although there have been isolated reports of illness associated with consumption of tank rainwater, for most people rainwater from well maintained roof catchments and tanks represents a relatively low risk of illness.

Rainwater is not the most likely source of any of pathogens that cause gastrointestinal illness such as *Giardia*, *Cryptosporidium*, *Campylobacter* or *Salmonella*. Transmission of these organisms by person to person contact or contaminated food is far more common.

If it is suspected that rainwater is contaminated or if additional precautions are sought in the event of illness, water used for drinking and food preparation should be boiled or the tank rainwater should be disinfected.

Animal access

Where a rainwater tank has become contaminated by a dead animal, such as a bird or rodent, it is recommended that the tank be drained and cleaned as soon as possible (see Section 5). If the animal is large, such as a possum or a cat, and badly decayed, impacts on taste and odour will be strong and distinct.

If it is not practical to drain and clean the tank immediately, carefully remove as much as possible of the animal carcass and then chlorinate the water as discussed above.

The point of entry for the animal should be located and repaired.

Filtration

Rainwater collected in tanks is usually soft, clear and of good chemical quality.

Water filters should not be necessary as a method for maintaining microbial, chemical or physical quality of rainwater. If problems occur, the preferred approach is to instigate remedial action to prevent contamination (as discussed above) rather than installing a system to treat symptoms of inadequate maintenance.

If water filters are installed, they should be maintained to manufacturer's specifications to avoid problems associated with microbial growths on the filters.

First flush diverters

There is some evidence that the first flush of water in a rain event washes the roof catchment and hence may contain higher than average amounts of accumulated dust, bird and animal droppings, leaves and other debris (Coombes et al. 1999, 2002b; Yaziz et al. 1989). Yaziz et al. (1989) showed that, for a small roof, water quality improved once the first 5 litres of water passed through the down-pipe from the roof guttering.

Although further investigations are needed to determine how effective first flush diverters are in reducing chemical and microbial contamination in all areas of Australia (for example, in temperate, subtropical and tropical zones), installation of simple devices designed to reduce collection of accumulated debris is still supported. For an average roof catchment it is suggested that the first 20-25 L could be diverted or discarded. First flush devices are commercially available.

First flush devices should be regarded as an additional barrier to reduce contamination and should not be used to replace normal maintenance activities designed to keep roof catchments reasonably clean.

First flush devices need to be empty when a rain shower begins. If water remains standing in the diverter from the last shower then the diverter cannot do its job. Many commercially available first flush diverters are designed to empty themselves. However, the devices employed to empty them are not always reliable. First flush diverters need to be inspected frequently and when necessary, emptied manually.

The inlet pipe to all rainwater tanks should be easily detachable so that, when necessary, the tank can be bypassed. Manual detachment could be used as an alternative to an engineered first flush device, although the level of control will not be as good.

Preventing mosquito breeding

Mosquitoes and other nuisance insects need to be excluded from rainwater tanks. Water ponding in gutters also needs to be prevented as it can provide breeding sites for mosquitoes and could lead to eggs being washed into tanks (Northern Territory Public Health Regulations 2007 require that gutters should be installed and maintained to prevent ponding).

Unless in use, all access points, excluding the inlet and any overflows, should be kept shut with close fitting lids that will prevent mosquito access. Inlets and overflows should be covered with closely fitting removable insect-proof screens. Queensland (2005) and Northern Territory (2007) Regulations specify the characteristics of the screens as follows:

- Queensland – brass, copper, aluminium or stainless steel gauze not coarser than 1 mm aperture measure
- Northern Territory – brass or bronze wire not coarser than 7 meshes to the centimetre (each way) and of 33 gauge wire.

Mosquito control

By far the preferred approach for managing mosquitoes and other insects is to keep them out of tanks. In addition, rainwater should not be allowed to pool in containers or on surfaces below tank outlets or taps, as this can also provide a breeding site.

Detection of mosquito larvae (wigglers) in rainwater tanks indicates the presence of an opening through which female mosquitoes can enter and lay eggs or the entry of eggs laid in ponded water collected in roof gutters. Gaps can occur:

- in mesh used to protect inlets and overflows
- around inspection and access points
- between the roof and main body of the tank
- in the tank itself due to corrosion or physical damage.

If mosquitoes or other insects are found in rainwater tanks, the point of entry should be located and repaired. As well as preventing further access, this will prevent the escape of emerging adults. Gutters should be inspected to ensure they do not contain ponded water, and cleaned if necessary.

There is no ideal treatment to kill mosquito larvae present in rainwater. The two commonly recognised treatments involve adding chemicals (medicinal or liquid paraffin or kerosene) to tanks, which defeats one of the advantages of collecting rainwater. In addition, problems have been reported with both types of treatment.

As a last resort, tanks can be treated by adding a small quantity of medicinal or liquid paraffin or domestic kerosene. The recommended dose of kerosene is 5 mL or one teaspoon for a 1 kL tank up to 15 mL or 3 teaspoons for a 10 kL tank. When using paraffin the dose is double that used for kerosene.

Note: Commercial or industrial kerosenes, for example, power kerosene for tractors etc., **should not** be used in rainwater tanks.

Paraffin can be used in all types of tanks, but there have been reports of coagulation after a time and of deposits forming on the sides of tanks.

Kerosene is not suitable for use in tanks coated with Aquaplate® and may not be suitable for use in tanks constructed of, or lined with, plastic. If in doubt, consult the manufacturer of the tank. Used carefully, kerosene will not result in risks to human health, but excess quantities can taint the water and very high doses can be poisonous to humans. Kerosene added to the surface will not mix through the body of rainwater in the tank and it will either evaporate or be washed out of the tank by overflow. Kerosene should not be added to tanks when water levels are low.



If excess quantities of kerosene are added to the point that taste is affected, the only solution is to drain and clean the tank.

Internationally, it has been suggested that larvicides, such as temephos, s-methoprene and Bti (*Bacillus thuringiensis*), could be used in rainwater tanks (WHO 1997). However only the larvicide s-methoprene is registered for use in rainwater tanks by the Australian Pesticides and Veterinary Medicines Authority.

Note: Vegetable oils **should not** be used as they can become rancid after a while.

Preventing chemical contamination from on-site sources

Chemical risks from on-site sources can be minimised by sensible management. Preventative measures can include:

- ensuring that pipework in constant or prolonged contact with water complies with AS/NZS 4020, and is flushed regularly.
- not collecting rainwater from roofs coated with bitumen-based materials or painted with lead-based paints
- not collecting rainwater from parts of roofs that include exposed preservative-treated wood
- ensuring that wood-based heaters and associated flues are designed, installed and operated in accordance with relevant Australian/New Zealand Standards
- not using wood treated with preservatives or painted for fuel in slow combustion heaters
- keeping the use of uncoated lead flashing to a minimum (as a precaution existing lead flashing could be painted)
- replacing lead washers for roofing screws with plastic washers

- inspecting tanks every 2-3 years for the presence of accumulated sediments and, if the bottom of the tank is completely covered, cleaning the tank
- keeping gutters clean to prevent long-term retention of leaf litter and prolonged contact with rainwater. Gutter shields can be used to stop the collection of larger tree and plant material. Gutters should have a sufficient and continuous fall to prevent pooling of water. Prolonged contact of water with leaves can lower pH resulting in increased corrosion and the release of metals.

Preventing impacts on aesthetic quality

The presence of suspended material or the generation of off-tastes and odours from accumulated material or algal growth can affect aesthetic quality. The possible presence of suspended material can be minimised by keeping the roof catchment reasonably clear of accumulated debris, including leaves and twigs, and by keeping gutters clean. Roofs and gutters should be cleaned twice a year or more frequently in areas subject to large amounts of windborne dust or leaves.

Generation of tastes and odours can be prevented by:

- keeping gutters clean and ensuring they drain quickly between rain events
- preventing entry of light into tanks or pipe work; some types of white pipes allow transmission of light and should be painted a dark colour
- removing accumulated sediment
- installing pipe work so it is self-draining or installing drainage points to enable pipes to be emptied and flushed.

Removing odours and suspended material

If rainwater has a distinctive odour or contains suspended material, the most likely sources are accumulated material in gutters, or at the bottom of tanks, or stagnant water in pipe work that does not self-drain.

Corrective action should include inspecting gutters and the bottom of tanks and determining whether there is pipe work that can contain stagnant water. If necessary, gutters and tanks should be cleaned and pipe work drained. Where possible, a drainage point should be fitted in pipe work that does not self-drain.

It is not always practical to clean a tank immediately, particularly if it is the only source of drinking water. In addition, off-odours from pipe work and accumulated tank sediments are more common in hot or warm weather in the absence of likely replenishing intakes of water. In this case, chlorinating the tank can provide a temporary solution until cleaning can be undertaken (for example, at the beginning of winter or the wet season). Any pipe work, including inlets to tanks, that does not completely drain, should be flushed with chlorinated water. The dose rates in Section 5 are suitable.

Many of the taste and odour issues associated with tank water are caused when dissolved oxygen levels in the water become low, and anaerobic processes begin to dominate. In some cases the taste and odour issues can be resolved by pumping air into the water to increase the amount of dissolved oxygen in the water. This will require access to a pump and the ability to insert an air hose into the tank. Care should be taken to avoid adding the air at such a rate, or at such a depth, that it disturbs or stirs up sediment on the bottom of the tank.



Bushfire debris

Ash and debris deposited on a roof should be removed and the first flush of water after a bushfire should not be collected. 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 the 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.

Rainwater in tanks that have not been affected by ash and debris, and has no taint or odour can still be used for normal purposes.

Tank desludging

All tanks should be examined for the accumulation of sediments every 2-3 years, or if sediment is evident in the water flow. As discussed in Section 4, accumulated sediments can be a source of chemical contamination and off-tastes and odours.

Sludge can be removed by siphoning without emptying the tank. To do this, use an inverted funnel in the end of a hose and move it carefully across the bottom of the tank. The sludge, plus the lower portion of water in the tank, can be released to waste. If leaves and coarser debris are present in the sludge, a siphon hose of approximately 50 mm diameter should be used.

Sludge may also be pumped from the tank with minimum loss of water by using a suitable motor-operated pump and attachments.

Finally, sludge can also be removed by draining and cleaning the tank. If a drain plug is provided at the base of the tank, water can be run to waste to discharge the sludge. Once the tank is empty, the remaining sludge can be scooped up and removed through the access opening. Care should be taken not to disturb the protective film on the inside surface of the tank.

Tank cleaning businesses (generally listed in telephone directories) may also be available to desludge tanks.

Organic material removed from the tank may be disposed of in the garden by spreading and digging into garden beds. Environment protection agencies should be consulted about off-site disposal.

Tank cleaning

Where cleaning necessitates entering the tank, take care to ensure adequate ventilation is provided and an additional person is in attendance. Advice on working in confined spaces should be available from occupational health and safety authorities in each state and territory.

It is important to check the structural condition of the tank before choosing a method of cleaning. Cleaning should generally be limited to removing accumulated sediments, leaf litter etc. Harsh cleaning methods may accelerate deterioration, for example, by removing the protective layer on the inside walls of a steel tank which will lead to tank corrosion. So called 'white rust' caused by zinc-rich oxides on the inside of metal tanks is not a health risk and does not need to be removed.

Cleaning agents that might release hazardous fumes or adversely affect water quality after cleaning should not be used. After cleaning, it is recommended that the internal walls and floor of the tank be rinsed with clean water. Rinse water and sediment should be run to waste.

Discarded water should be diverted away from tank foundations, buildings and other structures. Water containing cleaning agents should not be allowed to flow into street guttering.

6. Monitoring and maintenance

In a similar fashion to all drinking water supplies, rainwater systems need to be monitored. Monitoring of domestic rainwater tanks consists of a range of visual inspections rather than laboratory testing of rainwater quality.

The recommended regime of inspections and associated maintenance is not particularly onerous, but it is necessary for quality assurance. A proactive approach will prevent the development of problems that can lead to the deterioration of water quality. Tables 2 and 3 provide an overview of monitoring requirements and corrective actions.

Once a rainwater tank is installed, it is recommended that the following components of the roof catchment and tank be inspected at least every six months:

- Gutters – they generally will need cleaning as well as inspection. If inspection finds large amounts of leaf material or other debris, then the inspection and cleaning frequency may need to be increased.
- Roof – check for the presence of accumulated debris including leaf and other plant material. Accumulated material should be cleared. If tree growth has led to overhanging branches these should be pruned.
- Tank inlets, insect-proofing and leaf filters – if necessary these should be cleaned and repaired.

- Tank and tank roof – check structural integrity of the tank including the roof and access cover. Any holes or gaps should be repaired.
- Internal inspection – check for evidence of access by animals, birds or insects including the presence of mosquito larvae. If present, identify and close access points. If there is any evidence of algal growth (green growth or scum on or in the water), find and close points of light entry.
- Pipework – check for structural integrity. Sections of pipework that are not self-draining should be drained. Buried pipework, such as with ‘wet systems’, can be difficult to drain or flush. Where possible drainage points should be fitted.

In addition to six-monthly inspections, tanks should be inspected every 2-3 years for the presence of accumulated sediments. If the bottom of the tank is covered with sediment the tank should be cleaned.

Rainwater tanks can become a significant mosquito breeding site when they are no longer required or when they fall into disrepair. Tanks that are no longer required should be drained, cut up and removed to an appropriate waste disposal site.

In addition to six-monthly inspections, tanks should be inspected every 2-3 years for the presence of accumulated sediments. If the bottom of the tank is covered with sediment the tank should be cleaned.



Initial inspection on moving into a house with a rainwater tank

On moving into a house with a rainwater tank all the above steps should be undertaken. In addition, a wider inspection should be conducted to gain an understanding of the physical characteristics of the roof catchment area, storage tank and any associated pipework including whether:

- the tank and tank roof are in reasonable condition with no obvious holes or gaps that would allow ingress of small animals, insects or light
- water in the tank is clear and has no obvious odours
- the tank inlet is protected by a leaf litter guard and that all permanent openings (inlet, overflows etc.) are covered by mosquito-proof screens
- pipework is either self-draining or has drainage points installed
- there are no cross connections with the public mains water. If there are, it should be confirmed that this has been done in accordance with local requirements (check with the water supply authority – see Section 7)
- there is no exposed preservative-treated timber, large amounts of uncoated lead flashing or lead washers used with roofing screws on the roof area supplying the tank
- there is a flue from a slow combustion heater and, if there is, that it is installed in accordance with Australian Standards.

Any remedial action should be instituted as soon as possible.

Local, regional and state/territory health authorities can be a valuable source of advice and/or information on rainwater tanks including local and state/territory requirements.

Water quality testing

Regular chemical or microbiological testing of domestic rainwater tanks is not needed, but rainwater used for any commercial purpose or for community-based supplies will require testing to verify suitability for drinking (see Section 11).

Microbial testing of rainwater from domestic tanks is rarely necessary and in most cases is not recommended.

Water quality in rainwater tanks can change rapidly during wet weather and, during dry periods, the concentrations of indicator bacteria (*E. coli*) and faecal pathogen numbers decrease due to die-off (Edberg et al. 2000). Testing for specific pathogens is often expensive and is generally only warranted as part of an outbreak investigation. If there are strong concerns about water quality, chlorination of tank water is a suitable alternative to testing. If microbial testing is undertaken, the parameter of choice is *E. coli* as an indicator of faecal contamination. Tests for total coliforms or heterotrophic plate counts are of little value as indicators of the safety of rainwater for drinking.

Chemical testing should only be required in exceptional circumstances, such as in specific areas where there are concerns about impacts from major industrial or agricultural emissions. In these circumstances the chemicals of concern need to be identified before testing or large costs can be incurred with limited likelihood of successful detection.

Advice on the need for testing and analytical laboratories should be sought from local water or environmental health authorities; alternatively, information on testing and analytical laboratories in the local area can be found in the business telephone directory by looking under 'analyst'. When testing is performed, results should be compared to the values contained in the ADWG.

7. Construction material, size and installation

Galvanised steel tanks

The most common material used in the manufacture of rainwater tanks is galvanised steel. Galvanised steel is not inherently resistant to corrosion but it is available with rust-resistant coatings such as Zinalume® or Aquaplate® (see below). Initial corrosion of galvanised steel normally leads to the production of a thin adherent film that coats the surface of the tank and provides protection against further corrosion. It is important when cleaning such tanks not to disturb this film.

New tanks may leach excess concentrations of zinc, which could affect the taste of the stored rainwater, but is not a health risk. These tanks may need to be flushed before use.

Aquaplate® steel has a food-grade polymer skin that complies with Australian Standard AS 2070, bonded to a corrosion-resistant galvanised steel base. A number of precautions need to be taken with tanks manufactured using Aquaplate®:

- the polymer coating is not resistant to prolonged exposure to sunlight so tanks must have a top cover in place at all times
- kerosene or similar chemicals used as mosquito larvicides can cause degeneration of the polymer coating and should not be added to water in the tank
- the polymer coat should not be damaged when cleaning or installing the tank. If the coating is damaged, it should be repaired immediately using an appropriate sealant to prevent corrosion of the metal portions of the tank.

Additionally, copper or copper alloy fittings (brass and bronze) should not be connected directly to steel tanks as this causes corrosion. A minimum of two metres of plastic pipe should be used between the tank and copper fittings.

Concrete tanks

Concrete and ferro-cement tanks are strong and long lasting and can be installed underground.

New tanks may impart tastes and may leach lime, thereby increasing the pH of water. These tanks may need to be flushed before use.

Fibreglass tanks

Fibreglass tanks suitable for collecting rainwater are available. These tanks are manufactured with a food-grade coating on their interior surface. The coating is cured before the tanks are offered for sale. The tanks should also be manufactured to prevent the entry of light, which could encourage algal growth.

Plastic tanks and tanks with plastic liners

Increasing ranges of tanks manufactured from synthetic polymers including polyethylene are becoming available. Plastic tanks and plastic liners should be constructed of materials that are at least of a food-grade standard (compliant with AS 2070) and preferably that comply with the requirements of AS/NZS 4020. Plastic tanks should be manufactured to prevent the entry of light.

Size of tanks

Where a rainwater tank is intended to provide a supplementary source of water, the size of the tank will be determined by balancing cost against the range of uses required (drinking, food preparation, bathroom, laundry, toilet etc.).

If the rainwater tank is to represent the only source of drinking or domestic water, cost will be less important than the size of tank needed to provide security of supply. In this circumstance the size of the tank will depend on:

- the volume of water needed
- the amount and pattern of rainfall
- the area of the roof catchment
- the security of supply required.

The amount of rain combined with the area of the roof catchment will determine the maximum volume of water that can be collected. If this is not sufficient, then either a greater catchment area will be needed (for example, garage or shed) or water demand will need to be reduced.

A number of water conservation measures could be applied, including dual flush toilets or dry toilets (if permitted), and water efficient devices, such as reduced-flow shower heads and washing machines with suds saver cycles. If, after implementing these measures, the volume of rainwater that can be collected is still not sufficient to meet demand, water will need to be obtained from an additional source (see Section 9).



Experience is always a useful guide and advice should be sought from neighbours particularly in areas where reliance on rainwater tanks is common. Some state and territory government departments have tables of calculated tank sizes based on local rainfall patterns. In Queensland this information is available from Water Wise (Department of Environment and Resource Management), in South Australia from the South Australian Water Corporation or the Department for Water and in Western Australia from the Department of Agriculture. Other departments with responsibilities for water resources or water supply may also be able to provide this information.

In some areas local authorities specify minimum requirements for water storage and there may also be storage requirements associated with firefighting. The local council or local fire authority should be contacted to determine whether such requirements apply.

Volume of water needed

The volume of water needed may vary from one area to another. Water demand will depend on:

- the number of people using the water
- average consumption per person
- the range of uses (drinking, food preparation, bathroom, laundry, toilet etc.)
- the use of water conservation devices.

In areas supplied with mains water, the average indoor use per household is estimated to be in the range of 300-740 L per day or alternatively about 100-200 L per person per day. These volumes are steadily decreasing with the application of water conservation measures. Advice on water usage could be sought from the local water or water resources authority.

Average rainfall

In general, the most accurate source of rainfall information is the Bureau of Meteorology. In addition to average rainfall (annual and monthly) it is important to consider yearly variations, seasonality of rainfall, and the occurrence and length of recent dry spells.

Area of roof catchment

Calculate the area covered by the parts of the roof from which the water is to be collected. It is the flat or plan area (including eaves) that should be determined. The slope or pitch of the roof and the actual area of tiles or metal is not important.

The average roof area for a small house is about 100-150 m², for a medium house about 150-200 m², and for a large house it can be 200 m² or greater.

Security of supply

The size of the tank needed will be influenced by the degree of security required. As used in this guidance document, securities of 90% or 99% mean the rainwater tank should supply the demand of water calculated for 90% or 99% of the time, respectively.

Maintaining water supply under almost all conditions, including extended dry spells (high security), will require a larger tank than that needed to maintain supply under normal or average conditions (lower security). Lower security will mean water rationing or alternative sources of supply (see Section 9) may have to be used more frequently.

Calculation of tank size

Methods for determining the maximum amount of water that can be collected as a function of rainfall, and the roof size and tank size needed to provide security of supply throughout the year are provided in Appendix B.

Installation

Rainwater tanks should be installed in a manner that will minimise the risk of contamination from industrial pollutants, dust, leaves, pollens, pesticide sprays, fertilisers, debris, vermin, birds, small animals and insects. Tanks should not be allowed to provide breeding sites for mosquitoes.

Underground tanks require additional protection against entry of surface run-off or groundwater, animal or human faecal material (including septic tank waste) and soil. These tanks need to be properly sealed and access points need to be protected against the ingress of surface run-off. Maintenance and cleaning of underground tanks might be more difficult.

Interconnection with mains water supplies

Rainwater tanks should never be interconnected with mains water supplies without determining local requirements. Protection of mains water distribution systems from other sources of water is an extremely important public health requirement and inappropriate cross-connections have been identified as sources of waterborne disease outbreaks (Craun & Calderon 2001).

Water authorities do not allow direct connection of rainwater systems with mains water supplies. The use of backflow prevention devices, or similar are required to stop rainwater siphoning back into the mains supply.

Information should be sought from the local water authority.

Covers and lids

Tanks should have impervious covers and all access points, except for the inlet and overflow, should be provided with close-fitting lids which should be kept shut unless in use. The inlet to the tank should incorporate a screen to prevent material, such as leaves etc., which may have collected on the roof or in gutters, being washed into the tank and a mesh covering to prevent access of mosquitoes and other insects. Overflows should also be covered with an insect-proof mesh.

Tanks should be light-proof to minimise algal growth. Most algae will not make water unsafe for human consumption but can adversely affect the taste, odour and appearance of the water.

Bypass or overflow water

Run-off that is not collected in the tank and/or overflows should be diverted away from tank foundations, buildings or other structures. This water should be directed onto gardens or into the stormwater drain; it should not be allowed to pool or to cause nuisance to neighbouring properties or to areas of public access. Local authorities may have regulations or requirements that apply to diverted or excess rainwater flows.

Inlet pipes

Wherever possible, all sections of inlet pipes should be directed down and rainwater should flow into the top of the tank. The inclusion of rising sections will provide potential traps for sediments, biofilms and stagnant water and these should be avoided. Modifications to existing downpipes should not restrict existing water flows from roof gutters. To maximise the collection of rainwater, the downpipes should be of sufficient diameter to accept all water flow from roof gutters, even in heavy rains.

Catchment

Before installing a rainwater tank, the roof catchment should be checked for:

- overhanging vegetation – if vegetation is overhanging the roof it should be pruned
- a flue from a slow combustion heater – if possible this section of roof should be avoided; if not ensure the flue is installed in accord with Australian/New Zealand Standards
- overflows/discharges/bleed-off pipes from roof-mounted appliances, such as evaporative air conditioners, hot water services, and solar heaters – the overflows/discharges/bleed-off pipes should not discharge onto the rainwater catchment area
- uncoated lead flashing – if it is present it should be painted
- exposed preservative-treated timber – exposed timber should be sealed or the section of roof containing the timber should not be used for the collection of rainwater
- solar hot water systems – if possible this section of roof should be avoided or sealed off when maintenance is carried out. Solar systems contain fluids that are hazardous in rainwater tanks.

Gutters should have sufficient and continuous fall to downpipes to prevent pooling of water, which could increase accumulation of material, lead to algal growth and possibly provide a site for mosquito breeding. A fall of one in 100 should be sufficient.

Gutter shielding devices will substantially reduce the amount of larger debris (bark, larger leaves, etc.) but small particles will not be removed. Periodic cleaning will still be needed but at a lower frequency than for gutters without shielding.



8. Tank rainwater to sustain development

There are two common justifications for installing rainwater tanks. The first and most important is one of necessity in areas that are not served by mains water and where safe supplies of water are not readily or reliably available. The second is to provide a source of water that can be used as an alternative to mains water.

In areas without mains water

Rainwater tanks can provide a valuable source of drinking water in areas not supplied by mains water. Even in arid regions with low rainfall, tanks can provide a valuable resource. Conway et al. (1999) examined rainwater harvesting in an arid location (Giles) in central Australia where the median rainfall is only 119 mm per year. In an average year, a house with a 266 m² roof area could collect 61.25 kL of water in a 27 kL tank and provide 168 L of water per day. In the worst rainfall year in 40 years, 9.5 kL could have been collected to provide 26 L per day. While these volumes would not be sufficient as a total resource, they could represent a substantial source of drinking water to augment a secondary source, such as groundwater used for other domestic purposes. This could be particularly important in areas where groundwater is too saline to drink.

At Mutitjulu (in the Northern Territory), with an average yearly rainfall of 300 mm, rainwater tanks have been installed to provide a minimum of 100 L of rainwater per day to seven houses (Grey-Gardner 2002). The community initiated the project to supply a better-tasting alternative to the local groundwater supply. The system was designed to provide ease of management in a remote area with limited access to water. To provide greater assurance of water quality each house was fitted with a point-of-use filter. However water quality tests have showed a very low prevalence rate of E.coli in the pre-filtered rain water (Chapman et al 2008, Grey-Gardner et al 2005).

In areas with mains water

Mains water is used for purposes ranging from drinking and food preparation, to toilet flushing and garden watering. The use of rainwater tanks as an alternative source of water for any of these purposes has the potential to reduce pressure on the limited surface and groundwater resources used to supply mains water to urban and rural communities. Reduced pressure on the mains supply provided by rainwater tanks could alleviate the need for additional dams in growth areas and the costs associated with producing water for all uses to drinking water standard.

One constraint that has been raised is that the lack of space in large urban centres limits the size of the tanks that can be installed. This problem is being exacerbated by the trend to higher density living. In these circumstances, at best, only small-capacity tanks can be installed but recent changes in tank design and shape provide a greater selection of choices.

Although small tanks will overflow during wet seasons, modest 1-2 kL tanks, which require little room, can capture a significant proportion of roof run-off. The proportion able to be collected is largely a function of volume and frequency of use. A household using rainwater for all domestic purposes will empty a small tank more often and hence increase the available storage when a rain event occurs. On the other hand, less storage will be available in households using rainwater just for drinking and food preparation. Garden watering is a high volume use, but it mostly occurs in drier months when replenishing rain is relatively infrequent, leading to long periods when small tanks may contain no rainwater.

Across Australia, average rainfall, patterns of rainfall, and residential water usage vary. In the capital cities rainfall ranges from 550-1670 mm per year (Bureau of Meteorology¹), while indoor water usage varies from an estimated 150 kL to 350 kL. Hot water represents about 30%-35% of indoor use. These data have been used to calculate volumes that could be collected in 1 kL and 10 kL tanks and where the water is either used to supplement mains water for all indoor uses or just for hot water uses (see Table 4).

In Adelaide, for example, which has an average rainfall of just above 500 mm, about 57 kL of water would flow from a medium-sized roof of 150 m² each year (see Table 4). Using data on rainfall patterns over the past 10 years, a 10 kL tank would be of sufficient size to ensure that most of the 57 kL was captured and available for use. A volume of 57 kL represents about 36% of annual use (160 kL). A small tank of 1 kL could still collect and contribute 39 kL (24%) to total household use.

If rainwater was used just to supply hot water, a 10 kL tank could contribute 37 kL, and a 1 kL tank 25 kL per year, or 65% and 44%, respectively, of the available roof run-off. Potential volumes of water that could be collected in 1 kL and 10 kL tanks in all Australian capital cities are shown in Table 4.

Other combinations of use would provide different proportions of collection. Mitchell et al. (1997) determined that for a house with a roof area of 203 m² and with three occupants, use of rainwater from a 13 kL tank for laundry, toilet and outdoor use could achieve use of 49-56% of available roof run-off and a 30-40% reduction in mains water use.

Table 4: Indicative volumes of water collected in rainwater tanks in Australian capital cities

City	Potential volume of water collected per year (kL)*			
	1 kL tank		10 kL tank	
	for hot water supply	total indoor supply	for hot water supply	total indoor supply
Adelaide	25	39	37	57
Brisbane	33	48	54	110
Canberra	32	52	44	82
Darwin	35	67	53	135
Hobart	37	48	47	78
Melbourne	40	56	54	87
Perth	26	51	40	87
Sydney	38	49	55	97

* from a 150 m² roof.

Source of data: M Allen, Department of Water, Land and Biodiversity Conservation (SA). Figures were derived from a daily water balance model using long-term rainfall data for each capital city and estimates of water use based on consumption for each city by a household with three occupants.

1. Data accessed on May 2010 from <http://www.bom.gov.au/lam/climate/levelthree/ausclim/zones.htm#two>



In practical examples, the 'Healthy House' in Queensland used a 22 kL tank to collect rainwater from a 120 m² roof. In 2000-2001 the tank supplied 165 kL (36%) of 458 kL used for total indoor use by a family of five (Gardner et al. 2002). The 'Sustainable House' in Sydney uses a 10 kL tank to collect rainwater from a small roof of 70 m² to supply 230 L of water per day for all internal uses, except toilet flushing (Mobbs 1998). Coombes et al. (2000) showed that use of rainwater for hot water and toilet flushing from shared storages in the 'Figtree Place' development could result in up to a 45% reduction in mains water use. In a subsequent study at Maryville, Newcastle, where rainwater was collected in a 9 kL tank and used for hot water, toilet flushing and limited outdoor use, 28 kL of rainwater was used from the tank over 24 weeks (which represents 39% of available roof run-off) (Coombes et al. 2002c). During this period, only 25 kL of mains water was used in the house, representing a 52% reduction.

In addition to reducing consumption of mains water, household use of rainwater also reduces flows of stormwater into street gutters and then to receiving waters. Although house roofs only provide a fraction of the total urban surface run-off, even small tanks reduce these flows (for example, see Mitchell et al. 1997; Coombes et al. 2002a). A detailed discussion of this issue is beyond the scope of this guidance document.

Costs and benefits of rainwater tanks

There are several issues to consider when installing a rainwater tank. As well as the cost of the tank itself these can include:

- transportation
- installation
- alterations to gutters and downpipes
- a tank stand or foundation
- additional plumbing
- a first flush device
- insect-proof screening and gutter guards
- a pump (if necessary)
- maintenance
- development approval (if required).

Estimates of the cost of rainwater from domestic tanks have varied from \$0.30 to \$12.30 per kL (Van der Wel 2000; Coombes et al. 2002c; National Water Commission 2007). In 2006-2007 the average cost of mains water was about \$1 per kL (National Water Commission 2007). However, since then costs of mains water have risen sharply with the result that the cost differential between mains water and rainwater is decreasing.

To a certain extent, a degree of variation in rainwater costs is to be expected, as a range of factors will influence costs. These factors include:

- whether the rainwater tank is to be the sole source of supply or a supplementary supply (the former requires a larger storage capacity)
- the range of uses, for example, using rainwater to supply hot water in a house will require less additional plumbing compared to substituting rainwater for parts of the cold water supply in an existing house
- whether installation is part of new construction or is a retrofit to an existing dwelling
- amount and seasonality of rainfall.

Most estimates have been limited in scope to determining the cost to the householder or installer of the tank. This approach reflects the general situation where the choice or decision to install a rainwater tank has largely been an independent and individual process. However, this excludes the potential benefits to the community of installing rainwater tanks, particularly if it was done in a coordinated way (for example, Coombes et al. 2002a). It has been suggested that installation of rainwater tanks in all new and redeveloped dwellings could provide community savings through reducing demands on mains water supplies, delaying the need for new water supply infrastructure and reducing the need for spending on stormwater infrastructure (Coombes et al. 2002a; Pezzaniti 2003).



There is evidence of increased recognition of potential community-wide benefits of installing rainwater tanks. In 2002-2003, when water restrictions were widely imposed in many parts of Australia, the potential benefits of rainwater tanks received greater attention. Offers of financial support, in the form of rebates, have been provided by the Australian Government, some state and territory governments and local councils.

In a few areas, local councils require installation of rainwater tanks with new dwellings and some developments are being designed with rainwater tanks included for all dwellings. Most of these programs have promoted outdoor use, together with indoor use for toilet flushing, laundry and, in some cases, hot water supply.

One note of caution is that householders have a poor record of maintaining rainwater tanks. In developments where rainwater tanks are included for all dwellings, depending on the nature of use of the water, it may be necessary to institute a centralised management system. This would increase costs.

In addition, in areas where rainwater tanks potentially provide breeding sites for mosquito vectors or viruses, such as dengue fever, the potential for inadequate maintenance has cost implications. Queensland and the Northern Territory have specific legislation relating to mosquito control, and monitoring and enforcement of compliance imposes costs. In the worst case scenario, illness and intervention programs associated with rainwater tanks would also have cost implications.

9. Other sources of water

In some cases it may be necessary to augment rainwater in tanks with water from other sources such as bores, dams, rivers and creeks or with carted water.

Only water that is suitable for the intended purpose should be used. If the water is to be used for drinking and food preparation, it should comply with the guideline values cited in the ADWG (possibly after chlorination). If there are any doubts about the suitability of a water source, consult the relevant local or state/territory water or environmental health agency and, if necessary, have the water tested before adding it to the tank.

Surface water

Water subject to potential contamination from human or livestock waste, such as dams, rivers and creeks, can contain a wide range of pathogenic organisms including chlorine-resistant *Cryptosporidium*. Water of this type may not be suitable for drinking even after disinfection.

Surface water that is protected from human and livestock waste can be used. Water should be added to the tank in one action, then chlorinated and allowed to stand for at least one hour before use.

Chlorination should be performed as described in Section 5 using a test kit to measure chlorine residuals. If, 30 minutes after chlorination, the free chlorine is not at least 0.5 mg/L, a second equal dose should be added. If a kit is not available, use double the amount of chlorine recommended in Section 5.

Deep groundwater, confined aquifers

Water from a deep, encased and well maintained bore and/or from a confined aquifer will generally not need disinfection after addition to a rainwater tank, but the chemical quality of some groundwater is not suitable for drinking. Only groundwater that is compliant with guideline values cited in the ADWG should be used. Key health parameters for groundwater are arsenic, nitrate, fluoride and health-related heavy metals. Salinity is an important aesthetic parameter.

State or regional water resource agencies may be able to provide general information on local groundwater characteristics.

Shallow groundwater

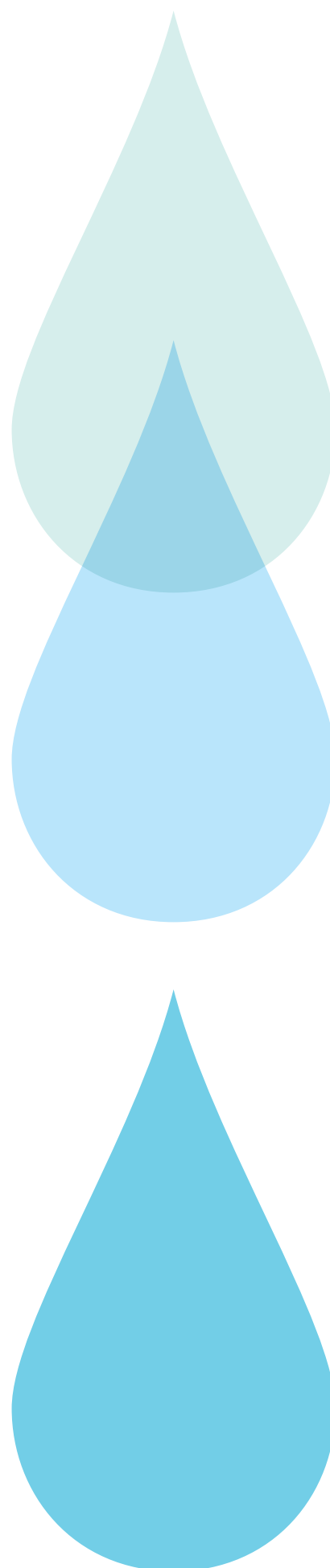
Groundwater from shallow or unconfined aquifers is readily contaminated by agricultural, industrial or urban activities and generally should not be used as a source of drinking water unless it has been recently tested for microbial and chemical quality (for example, for arsenic, nitrate, fluoride, health-related heavy metals, petroleum hydrocarbons and other organic chemicals).

Carted water

Drinking water is recognised in Australia as a food and, depending on state/territory legislation, water carters/carriers may need to be registered as a food business. If the supply of additional drinking water is needed, local authorities should be able to provide names of suitable water carters that are registered or that the authorities are satisfied will provide water suitable to drink. In the absence of information from local authorities, make sure the water carter can provide evidence that water supplied will be safe to drink.

This evidence could include:

- any authorisations issued for the purpose of supplying drinking water
- compliance with state/territory food legislation including, where required, that they have notified the local council or appropriate health authority that they are a food business
- the identity and quality of the source water
- proof that tankers used are suitable for the purpose of carrying drinking water (for example, not likely to have carried other materials that would contaminate drinking water)
- a record of a chlorine residual.



10. Legislation

While there is increasing government support for using rainwater tanks in Australia, there are legislative requirements in many areas relating to their installation and design.

In some areas, where mains water is not available, there are requirements associated with the supply of water for firefighting. In addition, as discussed in Section 5, both Queensland and the Northern Territory have regulations relating to the prevention of mosquito breeding.

Cross-connection of a rainwater tank with a mains water supply should never be undertaken without consulting the local water authority. There are generally restrictions in place including mandatory use of back-flow prevention devices to prevent the possibility of water from tanks entering mains water supplies.

Discharge of treated water or disposal of accumulated sludge may also be subject to local or state/territory regulations.

There are additional legislative requirements relating to tanks used as a source of community supplies (see Section 11).

Before purchasing or installing a rainwater tank, it is important to establish whether there are any local health, building or planning regulations associated with rainwater tanks. The local council or regional authority with jurisdiction over these regulations should be consulted.

Before purchasing or installing a rainwater tank, it is important to establish whether there are any local health, building or planning regulations associated with rainwater tanks.



11. Community-based supplies

Community-based drinking water supplies need a higher level of management than those to individual dwellings.

Operators/managers of community-based supplies need to implement more formal documented management plans to assure quality. In addition, in Australia, drinking water is regarded as a food and may be subject to either general food legislation or specific drinking water legislation. Operators of community supplies should contact relevant health authorities to determine requirements under state/territory legislation.

If rainwater is supplied for purposes other than drinking and food preparation, this must be clearly indicated on all taps.

The principles discussed in Section 3 are relevant to community-based supplies, but compared to the management of rainwater tanks used in individual dwellings, a greater surety is required due to the potential exposure of larger numbers of people. The need for surety is further increased if rainwater tanks are used in facilities such as nursing homes, hospitals or in food premises. Use of continuous disinfection, for example, through installation of a monitored ultraviolet light system could be required to provide assurance of water quality.

Documented management plans for community supplies should include a flow diagram of the system (catchment area, storage tanks, pipework, tap locations) together with a description of preventive measures, monitoring and corrective actions, as well as evidence that these requirements have been met. In addition, while preventive management and maintenance procedures should always remain the primary focus for assuring water quality there is a need for some verification that the overall plan works effectively.

A traditional approach to verification is regular testing for the faecal indicator, *E. coli*. The frequency of testing (for example, weekly or monthly) will depend on the size of the population serviced by the supply, whether water supplied from tanks is treated, the costs and logistics involved in getting samples to a testing laboratory, and the risk management procedures that are in place. For example, installation of a monitored ultraviolet light disinfection system could lessen the required frequency of testing. If *E. coli* is detected, remedial action will be required. This could include chlorination of the rainwater tank. The presence of *E. coli* in a disinfected supply indicates inadequate treatment and the need for improved performance.

If a community-based supply is in an area subject to industrial emissions or high levels of urban traffic, chemical testing could also be warranted.

Further information on requirements for management of water quality is available in the ADWG.



12. Fluoride

Many mains water supplies are fluoridated to help protect against dental caries (decay). This practice is supported by the National Health and Medical Research Council, the Australian Dental Association, Australian Medical Association and the Public Health Association of Australia.

Rainwater collected in domestic tanks will not contain fluoride, nor is it recommended that tank water be fluoridated as it can be difficult to maintain the correct dosage. People relying on tank water for drinking and food preparation should seek advice concerning fluoride requirements from their local dental professional, school dental service, community dental service or from the Australian Dental Association.

People using rainwater for drinking and food preparation will gain some dental benefits when they consume food and beverage products processed in nearby fluoridated centres or work and study in fluoridated areas. Another source of fluoridated water for people who rely on rainwater tanks for drinking and food preparation is packaged (bottled) water with added fluoride.





13. Further advice

Public health units

New South Wales

Environmental Health Branch
New South Wales Health Department
PO Box 798
Gladesville NSW 2111
Phone: (02) 9816 0589
Facsimile: (02) 9816 0377

Victoria

Environmental Health Unit
Department of Health
GPO Box 4541
Melbourne VIC 3001
Phone: 1300 761 874
Facsimile: 1300 768 874

Queensland

Environmental Health Branch
Queensland Health
PO Box 2368
Fortitude Valley QLD 4006
Phone: (07) 3328 9310
Facsimile: (07) 3328 9354

Western Australia

Environmental Health Directorate
Health Department of Western Australia
PO Box 8172
Perth Business Centre WA 6001
Phone: (08) 9388 4999
Facsimile: (08) 9388 4955

South Australia

Public Health Directorate
SA Health
PO Box 6
Rundle Mall
Adelaide SA 5000
Phone: (08) 8226 7100
Facsimile: (08) 8226 7102

Tasmania

Environmental Health Services
Department of Health and Human
Services
GPO Box 125
Hobart TAS 7001
Phone: (03) 6222 7724
Facsimile: (03) 6222 7407

Northern Territory

Environmental Health Program
Department of Health and Families
PO Box 40596
Casuarina NT 0811
Phone: (08) 8922 7152
Facsimile: (08) 8922 7334

ACT

Health Protection Service
Locked Bag 5
Weston Creek ACT 2611
Phone: (02) 6205 1700
Facsimile: (02) 6205 1705

Advice on water quality and testing

Advice on water quality and testing could be obtained from the local health or water authority. The latter could be a government or local government agency or a water corporation.

Advice on tank size

Advice on determining the required size of rainwater tanks should be sought from the state/territory or local agency responsible for management and control of water resources.



A. Determining the size of installed tanks

Tank sizes range from small modular tanks of 750 L (~165 gallons) to over 50 000 L (~11 000 gallons). To convert a volume in gallons to a volume in litres, multiply the number of gallons by 4.5.

Methods to calculate the volume of tanks are given below.

To calculate the volume of a **rectangular** tank, use the formula:

Volume (in litres) = depth (cm) x width (cm) x length (cm) ÷ 1000

For example, the volume of a 1.6m by 0.5m by 2.4m tank in litres would be:

Volume = 160 x 50 x 240 ÷ 1000 = 1920 L

To calculate the volume of a **cylindrical** tank either use the formula:

Volume (in litres) = π x diameter (cm)² x depth (cm) ÷ 4000
(π = 3.142)

For example, the volume in a tank with a diameter of 2m and a depth of 2.6m would be:

Volume = 3.142 x 200 x 200 x 260 ÷ 4000 = 8169 L





B. Determining the required size of tank to be installed

Maximum volume

The maximum amount of rainwater that can be collected can be calculated using the formula:

$$\text{run-off (litres)} = A \times (\text{rainfall} - B) \times \text{roof area}$$

'A' is the efficiency of collection and values of 0.80-0.85 (that is, 80-85% efficiency) have been used (Martin 1980).

'B' is the loss associated with absorption and wetting of surfaces and a value of 2 mm per month (24 mm per year) has been used (Martin 1980).

'Rainfall' should be expressed in mm and 'roof area' in square metres (m²).

For example, the run off from a 200m² roof which receives 750 mm of rain per year, with an efficiency of collection of 80% (A = 0.80) and loss of 2 mm per month (B = 24) would be:

$$\text{Run-off} = 0.8 \times (750-24) \times 200 = 116,160 \text{ Litres (or 116.2 kL)}$$

The maximum volumes of rainwater that can be collected from roofs of various areas and at a range of average annual rainfalls are shown in Table B1. If the maximum volumes are less than the annual water demand, then either the catchment area will need to be increased or water demand will need to be reduced.

Table B.1: Maximum volumes of water that can be collected depending on roof size and annual rainfall

Maximum volumes of rainwater per year (kl)*							
Annual rainfall (A) (mm)	Roof area (m ²) (B)						
	100	150	200	250	300	400	500
150	10	15	20	25	30	40	50
200	13	21	27	35	42	53	70
250	18	27	36	45	54	72	90
300	22	33	44	55	66	88	110
400	30	45	60	75	90	120	150
500	38	57	76	95	114	152	191
600	46	69	92	115	138	184	230
800	62	93	124	155	186	248	310
1000	78	117	156	195	234	312	390
1200	94	141	188	235	282	377	470

* These volumes were calculated using a value of 0.8 for A and 24 mm for B.

Security of supply

Where a tank is the sole source of supply, determining the maximum volume of water that can be collected is only the first step to determining whether the available tank capacity provides adequate security of supply. The next step is to calculate the size of the tank needed to ensure the volume of water that is collected and stored will be sufficient to meet demand throughout the year, including during the drier months or through periods of low or no rainfall.

There are several mathematical models available for determining the size of tank needed to provide a defined level of security of supply. In some cases, state and territory government departments have used computer-based models to prepare tables of calculated required tank size (see Section 7).

The simplest way of checking the tank size that is estimated to provide sufficient water throughout an average year is to use monthly rainfall data and assume that at the start of the wetter months the tank is empty. The following formula should then be used for each month:

$$V_t = V_{t-1} + (\text{Run-off} - \text{Demand})$$

V_t = theoretical volume of water remaining in the tank at the end of the month.

V_{t-1} = volume of water left in the tank from the previous month. Run-off should be calculated as discussed above ($A = 0.8$, $B = 2$ mm).

Starting with the tank empty then $V_{t-1} = 0$. If, after any month, V_t exceeds the volume of the tank, then water will be lost to overflow. If V_t is ever a negative figure then this indicates that demand will exceed the available water. Providing the calculated annual run-off exceeds the annual water demand, V_t will only be negative if periodic overflows reduce the amount of water collected so it is less than the demand.

Tank size is not necessarily based on collecting total roof run-off. For example, from Table B1 the maximum water that can be collected from a roof area of 200 m², with an annual rainfall of 1000 mm, is about 156 kL. If the water demand is less than this, some overflow may occur while demand is still met. If water demand is to be met throughout the year, the tank should be large enough so that V_t is never negative.

Calculations should be repeated using various tank sizes until V_t is ≥ 0 at the end of every month. The greater the values of V_t over the whole year, the greater the security of meeting water demand when rainfalls are below average or when dry periods are longer than normal. The greater the security, the larger the size and cost of the tank.

For example, if the theoretical volume left in the tank from the previous month is 5000 L (5 kL), the annual run-off is 116.2 kL and the annual demand is 98 kL, then the theoretical volume in the tank would be:

$$V_t = 5 + (116.2 - 98) = 23.2 \text{ kL}$$



Table B.2: Tank sizes to provide 99% security of supply

Tank size (kilolitres)*								
Volume required (L/day)	Annual rainfall (mm)	Roof area (m ²)						
		100	150	200	300	400	500	600
60	150					43		
	200				24			
	300		20	12	10			
	400	14	8	7				
	500	8	6	5				
	600	6	5	4				
	900	5	4	3				
100	200						40	–
	250				33	22		
	300				20	17		
	400			15	12			
	500		13	11	9			
	600	9	12	10	8			
	900	11	9	8				
1200	10	8	7					
200	300							47
	350					40	29	26
	400					30	26	24
	500				28	24	22	20
	600			36	26	22	20	18
	900		29	23	18	16	14	
	1200	34	23	19	16	14		
400	500							51
	600							47
	700						49	44
	900					50	44	39
	1200				47	39	34	31

* The tank sizes shown were determined from summarised data provided by the South Australian Water Corporation and the Department of Water, Land and Biodiversity Conservation (SA). The original data were estimated using a computer simulation based on averaged rainfalls and rainfall patterns and using a value of 0.8 for A and 2 mm per month for B.

Table B.3: Tank sizes to provide 90% security of supply

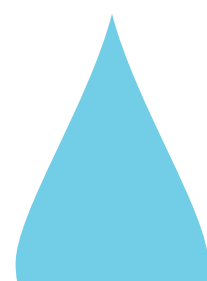
Tank size (kilolitres)*								
Volume required (L/day)	Annual rainfall (mm)	Roof area (m ²)						
		100	150	200	300	400	500	600
60	150				20	14		
	200			15	10			
	300	14	6	4				
	400	6	3	3				
	500	4						
	600	3	2					
100	150						34	27
	200				33	19	17	-
	300			18	10	8		
	400		10	6	6			
	500	11	6	5	4			
	600	8	5	4	3			
	900	6	4					
200	250						26	21
	300					29	20	17
	350				26	17	13	12
	400				19	14	11	10
	500			20	12	10	8	
	600		25	15	10	8	7	
	900	26	13	10	7			
	1200	18	10	8	6			
400	350							44
	500					42	30	24
	600					30	22	19
	700				39	27	21	18
	900				27	19	16	13
	1200			34	21	16	13	12
600	500							
	600							
	700							47
	800						50	40
	900						43	34
	1200				50	37	28	24

* The tank sizes shown were determined from summarised data provided by the South Australian Water Corporation and the Department of Water, Land and Biodiversity Conservation (SA). The original data were estimated using a computer simulation based on averaged rainfalls and rainfall patterns and using a value of 0.8 for A and 2 mm per month for B.



Table B.4: Water demands per day, month or year

Water demands (litres)		
Per day	Per month (30.5 days)	Per year (365 days)
60	1830	21900
100	3050	36500
150	4575	54800
200	6100	73000
300	9150	109500
400	12200	146000
500	15250	182500
600	18300	219000
800	24400	292000





Bibliography

- Abbott S, Caughley B and Douwes J (2007) The microbiological quality of roof-collected rainwater of private dwellings in New Zealand. *Rainwater and Urban Design Conference* 21-23 August 2007 Sydney, Australia.
- ACTEW 1994, ACT future water supply strategy: Our water our future, ACT Electricity and Water, Canberra.
- Adams, MR & Moss, MO 2000, Food Microbiology (2nd ed), Royal Society for Chemistry, United Kingdom.
- Ahmed W, Huygens F, Goonetilleke A and Gardner T (2008). Real-time PCR detection of pathogenic microorganisms in roof-harvested rainwater in South East Queensland, Australia. *Applied and Environmental Microbiology* 74, pp. 5490-5496.
- Ahmed W, Vieritz A, Gardner T and Goonetilleke A (2009). Microbial risks from rainwater tanks in South East Queensland. *Water* 36 (8), pp. 80-85.
- ABS 2007, Environmental issues, people's views and practices, Australian Bureau of Statistics, cat. no. 4602.0, Canberra.
- ABS 2000, Water account for Australia, Australian Bureau of Statistics, cat. no. 4610.0, Canberra.
- Bannister R, Westwood J, McNeill A (1997) Investigation of microbiological and chemical quality in rainwater tanks in Victoria, Melbourne, Water ECOscience, Report No. 139/97 – Victorian Department of Natural Resources and Environment, unpublished draft report.
- Body P 1986, The contamination of rainwater tanks at Port Pirie, South Australia Department for Environment and Planning, Adelaide.
- Brodribb R Webster P & Farrell D 1995, 'Recurrent Campylobacter fetus subspecies fetus bacteraemia in a febrile neutropaenic patient linked to tank water', *Communicable Disease Intelligence*, vol. 19, pp. 312-13.
- Byard RW (2008) Rainwater tank drowning *Journal of Forensic and Legal Medicine* 15 (8), pp. 533-534.
- Campbell M 2001 'Toxic shock'. *Gardening Australia* February 2001, pp. 32-36.
- Centre for Disease Control and Prevention 1995, 'Assessing the public health threat associated with waterborne cryptosporidiosis: report of a workshop', *Morbidity and Mortality Weekly Report*, vol. 44 no. RR-6, pp. 1-15. Report Mortality Report.
- Chapman H, Cartwright T, Huston R, and O'Toole (2008). Water quality and health risks from urban rainwater tanks. Cooperative Research Centre for Water Quality and Treatment, Research Report 42.
- Chapman H, Gardner T, Huston R, Chan A and Shaw G (2006) Chemical water quality and health risk assessment of urban rainwater tanks *7th International Conference on Urban Drainage Modelling and the 4th International Conference on Water Sensitive Urban Design* 2006 Sydney, Australia.
- Chappell CL & Okhuysen PC 2002, 'Cryptosporidiosis', *Current Opinion in Infectious Diseases*, vol. 15, pp. 523-27.
- Coombes PJ, Dunstan H, Spinks A, Evans C and Harrison T (2006) Key Messages from a Decade of Water Quality Research into Roof Collected Rainwater Supplies 1st National HYDROPOLIS Conference 2006 Perth, Australia.
- Coombes PJ, Kuczera G, Argue JR, Cosgrove F, Arthur D, Bridgeman HA & Enright K 1999, 'Design monitoring and performance of the water sensitive urban development at Figtree Place in Newcastle', *Proceedings of the 8th International Conference on Urban Storm Drainage*, Sydney, Australia pp. 1319-26. (www.newcastle.edu.au/~cegak/coombes)
- Coombes PJ, Argue JR & Kuczera G 2000, 'Figtree Place: A case study in water sensitive urban development', *Urban Water*, vol. 1 (4), pp. 335-43.
- Coombes PJ, Kuczera G, Argue J & Kalma JD 2002a, 'An evaluation of the benefits of source control measures at the regional scale', *Urban Water*, vol. 4 (4), 307-320.
- Coombes PJ, Kuczera G & Kalma JD 2002b, 'Rainwater quality from roofs, tanks and hot water systems at Fig Tree Place', *Proceedings of the 3rd International Hydrological and Water Resources Symposium*, Perth, Australia pp. 152-57, (www.newcastle.edu.au/~cegak/coombes)
- Coombes PJ, Kuczera G & Kalma JD 2002c, 'Economic, water quantity and quality results from a house with a rainwater tank in the inner city', *Proceedings of the 27th Hydrological and Water Resources Symposium*, Melbourne, Australia, (www.newcastle.edu.au/~cegak/coombes)
- Conway C, Nicholson C, Bammer G, Wade A & Henderson G 1999, 'Rainfall harvesting for Indigenous health in Australia', *Ninth International Rainwater Catchment Systems Conference Proceedings*, (www.eng.warwick.ac.uk/ircsa/)
- Crabtree KD, Ruskin RH, Shaw SB & Rose JB 1996, 'The detection of Cryptosporidium oocysts and Giardia cysts in cistern water in the US Virgin Islands', *Water Research*, vol.30, pp. 208-16.
- Craun G & Calderon RL 2001, 'Waterborne disease outbreaks caused by distribution system deficiencies', *Journal of the American Waterworks Association*, vol. 93(9), pp. 64-75.
- D'Aoust JY, Park CE, Szabo RA, Todd EC, Emmons DB, McKeller RC 1988, 'Thermal inactivation of Campylobacter species, Yersinia enterocolitica and hemorrhagic Escherichia coli 0157:H7 in fluid milk', *Journal of Dairy Science*, vol. 71, pp. 3230-36.
- Dillaha TA & Zolan WJ 1985, 'Rainwater catchment water quality in Micronesia', *Water Research*, pp. 741-46.

- Doggett, SL & Russell, RC 1997, 'Aedes notoscriptus can transmit coastal and inland isolates of Ross River and Barmah Forest viruses from New South Wales', *Arbovirus Research in Australia*, vol. 7, pp. 79-81.
- Edwards R 1994, 'A microbiological investigation into the degree of contamination of water in domestic rain water storage tanks with residents of Noosa Shire solely supported by tank water, 1993', 54th Annual State Conference of the Australian Institute of Environmental Health (Qld Division), Ipswich, Queensland, pp. 308-25.
- Eberhart-Phillips J, Walker N, Garrett N, Bell D, Sinclair D, Rainger W & Bates M 1997, 'Campylobacteriosis in New Zealand: results of a case-control study', *Journal of Epidemiology and Community Health*, vol. 51, pp. 686-91.
- Edberg SC, Rice EW, Karlin RJ and Allen MJ (2000) *Escherichia coli*: the best biological drinking water indicator for public health protection. *Journal of Applied Microbiology Symposium Supplement* 88, 106S-116S.
- Eisenberg JNS, Bartram J and Hunter PR (2001) *A public health perspective for establishing water-related guidelines and standards* In L Fewtrell and J Batram eds *Water Quality: Guidelines, Standards and Health*. Published for the World Health Organization by IWA Publishing, London, UK.
- Evans C, Coombes P, Dunstan H, Harrison T, Martin A and Morrow A (2007) Roof harvested rainwater – indicator organisms, water quality and risk assessment. *Rainwater and Urban Design Conference* 21-23 August 2007 Sydney, Australia.
- Feachem RG, Bradley DJ, Garelick H & Mara DD 1983, *Sanitation and disease: Health Aspects of Excreta and Wastewater Management*, World Bank. John Wiley & Sons, New York.
- Fujioka RS & Chin RD 1987, 'The microbiological quality of cistern waters in the Tantalus area of Honolulu', Third International Rainwater Catchment Systems Conference Proceedings. (www.eng.warwick.ac.uk/ircsa/)
- Fuller CO, Martin TJ & Walters RP 1981, Quality aspects of water stored in domestic rainwater tanks (a preliminary study), Engineering and Water Supply Department, South Australia.
- Gardner T, Hyde R, Millar G & Vieritz A 2002, 'The healthy home – a step towards greening paradise', 4th Queensland Environmental Engineering Conference. (www.ees.ieaust.org.au)
- Gee L 1993, Pilot survey of the microbiological and chemical aspects of water stored in domestic rainwater tanks, Western Sector Public Health Unit, New South Wales, Department of Health.
- Gerba CP, Rose JB, Haas CN & Crabtree KD 1996, 'Waterborne rotavirus: a risk assessment', *Water Research*, vol. 30, pp. 2929-40.
- Gibson C (2008) *Rainwater tanks pose risk for toddlers*, Media Release, The University of Adelaide, accessed 8/02/2010 (www.adelaide.edu.au/news/news28961.html)
- Grey-Gardner R 2002, 'Mutitjulu rainwater tank and point of use water treatment system trial', Fourth National Indigenous Environmental Health Conference Proceedings, Adelaide.
- Grey-Gardner R, Wright, A and Boyce S (2005) Harvesting water that falls on country; Planning for rainwater tanks in remote Australia, Centre for Appropriate Technology, Alice Springs. (www.icat.org.au/media/Resources/water/CAT-CRCWQT2006-Harvesting-water-that-falls-on-country-Guidance%20Manual.pdf)
- Haas CN 1983, 'Estimation of risk due to low doses of microorganisms: a comparison of alternative methodologies', *American Journal of Epidemiology*, vol. 11118, pp. 573-82.
- Haeber RH & Waller DH 1987, 'Water quality of rainwater collection systems in the Eastern Caribbean', Third International Rainwater Catchment Systems Conference Proceedings, (www.eng.warwick.ac.uk/ircsa/)
- Hanna, JN, Ritchie SA, Merrit AD, van den Hurk AF, Phillips DA, Serafi n IL, Norton RE, McBride WJH, Gleeson FV & Poidinger M 1998, 'Two contiguous outbreaks of dengue type 2 in north Queensland', *Medical Journal of Australia*, vol. 168, pp. 221-25.
- Harp JA, Fayer R, Pesch BA & Jackson GJ 1996, 'Effect of pasteurisation on infectivity of *Cryptosporidium parvum* oocysts in water and milk', *Applied and Environmental Microbiology*, vol. 62, pp. 2866-68.
- Hernandez J, Bonnedahl J, Waldenstrom J, Plamgren H & Olsen B 2003, 'Salmonella in birds migrating through Sweden', *Emerging Infectious Diseases*, vol. 9, pp. 753-54.
- Heyworth JS, Glonek G & Maynard EJ 1999, 'The prevalence of gastroenteritis amongst young children and the potential role of drinking water', Proceedings of the 18th Federal Convention, Australian Water and Wastewater Association.
- Heyworth JS, Glonek G, Maynard EJ, Baghurt PA and Finlay-Jones J (2006) Consumption of untreated tank rainwater and gastroenteritis among young children in South Australia *International Journal of Epidemiology* vol. 35(4) pp. 1051-1058.
- Heyworth JS 2001, 'A diary study of gastroenteritis and tank rainwater consumption in young children in South Australia', Third International Rainwater Catchment Systems Conference Proceedings. (www.eng.warwick.ac.uk/ircsa/)
- Heyworth JS, Maynard EJ & Cunliffe D 1998, 'Who drinks what: potable water consumption in South Australia', *Water*, vol. 25, pp. 9-13.
- Hunter PR and Thompson RCA (2005) The zoonotic transmission of *Giardia* and *Cryptosporidium*. *International Journal of Parasitology* 35, pp. 1181-1190.
- Huston R, Chan YC, Gardner T, Shaw G and Chapman H (2009) Characterisation of atmospheric deposition as a source of contaminants in urban rainwater tanks *Water Research* 43, pp. 1630-1640.



- Kay BH, Barker-Hudson P, Stallman ND, Wiemers MA, Marks EN, Holt PJ, Muscio M & Gorman BM 1984, 'Dengue fever. Reappearance in Northern Queensland after 26 years', *Medical Journal of Australia*, vol. 140, pp. 264-68.
- Koenrad PMFJ, Rombouts FM & Notermans SHW 1997, 'Epidemiological aspects of thermophilic *Campylobacter* in water-related environments: A review', *Water Environment Research*, vol. 69, pp. 52-63.
- Koplan JP, Deen RD, Swanston WH & Tota B 1978, 'Contaminated roof-collected rainwater as a possible cause of an outbreak of salmonellosis', *Journal of Hygiene*, vol. 81, pp. 303-309.
- Lester R 1992, 'A mixed outbreak of cryptosporidiosis and giardiasis', *Update*, vol. 1(1), pp. 14-15.
- Magyar MI, Mitchell VG, Ladson AR and Diaper C (2008) Lead and other heavy metals: common contaminants of rainwater tanks in Melbourne *Water Down Under* 14-17 April 2008.
- Martin TJ 1980, Supply aspects of domestic rainwater tanks, South Australian Department for the Environment, Adelaide.
- McLauchlin J, Amar C, Pedraza-Diaz S & Nichols GL 2000, 'Molecular epidemiological analysis of *Cryptosporidium* spp. in the United Kingdom: results of genotyping *Cryptosporidium* spp. in 1705 fecal samples from humans and 105 fecal samples from livestock animals', *Journal of Clinical Microbiology*, vol. 38, pp. 3984-90.
- Merritt A, Miles R & Bates J 1999, 'An outbreak of *Campylobacter* enteritis on an island resort north Queensland', *Communicable Disease Intelligence*, vol. 23, pp. 215-19.
- Mitchell VG, Mein RG & McMahon TA 1997, 'Evaluating the resource potential of stormwater and wastewater; an Australian perspective', *Australian Journal of Water Resources*, vol. 2(1), pp. 19-22.
- Mobbs M 1998, *Sustainable House*, Choice Books, Australia.
- Morgan-Ryan U, Fall A, Ward LA, Hijawi N, Sulaiman I, Fayer R, Thompson RCA, Olson M, Lal A & Xiao L 2002, '*Cryptosporidium hominis* n.sp. (Apicomplexa: Cryptosporidiidae) from *Homo sapiens*', *Journal of Eukaryotic Microbiology*, vol. 49, pp. 433-39. ', *Journal of Eukaryotic Microbiology* National Research Council 1998, *Issues in Potable Reuse*, National Academy Press, Washington DC.
- National Water Commission (2007) The cost effectiveness of rainwater tanks in urban Australia. Commonwealth of Australia.
- New South Wales Environment Protection Authority and Northern Districts Public Morrow A, Coombes P, Dunstan H, Evans C and Martin A (2007) Elements in Tank Water – Comparisons with mains water and effects of locality and roofing materials *Rainwater and Urban Design Conference* 21-23 August 2007 Sydney, Australia.
- Health Unit, New South Wales, Department of Health 1996, 'Rainwater tank pesticide sampling survey – Namoi Valley April-May 1996', unpublished report.
- NHMRC 1991, The effectiveness of water fluoridation, National Health and Medical Research Council, Australian Government Publishing Service, Canberra.
- NHMRC/ARMCANZ 1996, Australian drinking water guidelines, National Health and Medical Research Council/Agricultural and Resource Management Council of Australia and New Zealand, Commonwealth of Australia.
- Northern Territory of Australia 1998, Public Health (General Sanitation, Mosquito prevention, rat exclusion and prevention) Regulations 1998.
- Okhuysen PC, Chappell CL, Crabb JH, Sterling CR & DuPont AL 1999, 'Virulence of three distinct *Cryptosporidium parvum* isolates for healthy adults', *Journal of Infectious Diseases*, vol. 180, pp. 1275-81.
- Paskevich V 1992, Rainwater tank pesticide survey, 1991-1992, Orana and Far West Region Public Health Unit, New South Wales, Department of Health.
- Pedraza-Diaz S, Amar CF, McLauchlin J, Nichols GL, Cotton KM, Godwin P, Iversen AM, Milne L, Mulla JR, Nye K, Panigrahi H, Venn SR, Wiggins R, Williams M & Youngs ER 2001, '*Cryptosporidium meleagridis* from humans: molecular analysis and description of affected patients', *Journal of Infection*, vol. 42, pp. 243-50.
- Pezzaniti D 2003, Drainage system benefits of catchment-wide use of rainwater tanks. Urban Water Resources, University of South Australia, Consultancy report, Department of Environment and Heritage.
- Queensland Health Public Health Regulation 2005.
- Refsum T, Handeland K, Baggesen DL, Holstad G & Kapperud G 2002, 'Salmonellae in avian wildlife in Norway from 1969 to 2000', *Applied and Environmental Microbiology* Applied , *Microbiology* vol. 68, pp. 5595-99.
- Regli S, Rose JB, Haas CN & Gerba CP 1991, 'Modeling the risk from *Giardia* and viruses in drinking water', *Journal of the American Water Works Association*, vol. 83(11), pp.76-84.
- Ritchie S, Montgomery B & Walsh I 2002, 'Production of mosquitoes in rainwater tanks and wells on Yorke Island, Torres Strait: preliminary study', *Environmental Health*, vol. 2(2), pp. 13-14.
- Rodrigo S, Leder K and Sinclair M (2009) Quality of stored rainwater used for drinking in metropolitan South Australia. Water Quality Research Australia.
- http://www.wqra.com.au/publications/report_84_quality_rainwater.pdf (accessed May 2010).
- Rodrigo S, Sinclair M, Forbes A, Cunliffe D and Leder K (2010) A double-blinded randomised controlled trial investigating the use of untreated rainwater for drinking *American Journal of Public Health* Accepted for publication.

- Rose JB & Gerba CP 1991, 'Use of risk assessment for development of microbial standards', *Water Science Technology*, vol. 24(2), pp. 29-34.
- SAA/SNZ HB170 Wood heating resource handbook, Guide to the selection, installation and operation of wood heaters, Standards Australia, Standards New Zealand.
- Savill MG, Hudson JA, Ball A, Klena JD, Scoles P, Whyte RJ, McCormick RE & Jankovic D 2001, 'Enumeration of Campylobacter in New Zealand recreational and drinking waters', *Journal of Applied Microbiology*, vol. 91, pp. 38-46.
- Scott RH & Waller DH 1987, 'Water quality aspects of a rain water cistern system in Nova Scotia, Canada', Third International Rainwater Catchment Systems Conference Proceedings, (www.eng.warwick.ac.uk/ircsa/).
- Sinclair MI, Leder K and Chapman H (2005) Public health aspects of rainwater tanks in urban Australia. *Cooperative Research Centre for Water Quality and Treatment, Occasional Paper 10*.
- Simmons G, Hope V, Lewis G, Whitmore J & Gao W 2001, 'Contamination of potable roof-collected rainwater in Auckland, New Zealand', *Water Research*, vol. 35, pp. 1518-24.
- Simmons G, Jury S, Thornley C, Harte D, Mohiuddin J and Taylor M (2008) A Legionnaires' disease outbreak, a water blaster and roof-collected rainwater systems *Water Research* 42(6-7) pp. 1449-1458.
- Simmons GC & Smith J 1997, 'Roof water probable source of Salmonella infection', NZ Public Health Report, vol. 4(1), p. 5.
- Spinks J, Phillips S, Robinson P and Van Buynder P (2006) Bushfires and tank rainwater quality: A cause for concern? *Journal of Water and Health* Vol. 4(1), pp. 21-28.
- Standards Australia 1999, AS 2070: Plastics materials for food contact use, Standards Australia, Sydney.
- Standards Australia 1994, AS/NZS 2179.1: Specifications for rainwater goods, accessories and fasteners, Standard Australia, Sydney.
- Standards Australia 1986, AS 2180: Metal rainwater goods – selection and installation, Standards Australia, Sydney.
- Standards Australia 2003, AS/NZS 3500: National plumbing and drainage code, Standards Australia, Sydney.
- Standards Australia 2002, AS/NZS 4020: Testing of products for use in contact with drinking water, Standards Association of Australia, Sydney.
- Taylor R, Sloan D, Cooper T, Morton B & Hunter I 2000, 'A waterborne outbreak of Salmonella Saintpaul', *Communicable Disease Intelligence*, vol. 24, pp. 336-40.
- Thurman R 1995, 'Evaluation of rainwater stored in collection tanks', *Australian Microbiologist*, March, pp. 20-22.
- United Nations Committee on Economic, Cultural and Social Rights 2002 General Comment No. 15. The right to water (articles 11 and 12 of the International Covenant on Economic, Social and Cultural Rights). Twenty-ninth Session, Geneva E/C.12/2002/11.
- Van der Wel B 2000, 'Increasing the viability of urban runoff and sewage effluent as supplementary sources of water in country towns of South Australia', *Australian Journal of Water Resources*, vol. 4(2), pp. 89-97.
- Victorian Department of Natural Resources and Environment 1997, 'Investigation of microbiological and chemical quality in rainwater tanks in Victoria', unpublished draft report.
- Water Corporation (Western Australia) 2002, Planning for Perth's water needs, Water Corporation, Perth.
- Water Resources Strategy for the Melbourne Area Committee 2001, Discussion starter: Stage 1 in developing a water resources strategy for the Greater Melbourne area.
- Water Services Association of Australia 2001, Water consumption fact sheet.
- Whelan CD, Monaghan P, Girdwood RWA & Fricker CR 1983, 'The significance of wild birds (*Larus* sp.) in the epidemiology of Campylobacter infections in humans', *Epidemiology and Infection*, vol. 101, pp. 259-67.
- Wirojanagud W 1987, 'Rainwater contamination', Third International Rainwater Catchment Systems Conference Proceedings. (www.eng.warwick.ac.uk/ircsa/)
- WHO 1997, Dengue haemorrhagic fever: diagnosis, treatment, prevention and control, control (second edition), World Health Organization, Geneva.
- WHO 2002, Heterotrophic plate count measurement in water safety management World Health Organization, Geneva.
- WHO 2007, Legionella and the prevention of Legionellosis Eds Bartram J, Chartier Y, Lee JV, Pond K and Surman-Lee S. World Health Organization, Geneva.
- WHO 2008, Guidelines for drinking-water quality (third edn including the first and second addenda), World Health Organization, Geneva.
- Xiao L and Fayer R 2008 Molecular characterization of species and genotypes of *Cryptosporidium* and *Giardia* and assessment of zoonotic transmission. *International Journal of Parasitology* 38, pp. 1239-1255.
- Yaziz MI, Gunting H, Sapari N & Ghazali AW 1989, 'Variations in rainwater quality from roof catchments', *Water Research*, vol. 23, pp. 761-65.



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