

Guidance on the Use of Rainwater Harvesting Systems

For Rain Harvesting

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By

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Introduction

Rain Harvesting Pty Ltd, a supplier of components for rainwater harvesting systems, are currently developing guidelines for the management of rainwater harvesting systems. Mr. Sandy Murdoch from Rain Harvesting has sent information for review to Associate Professor Peter Coombes from the University of Newcastle in Australia and has requested a commentary on rainwater harvesting guidelines based on Australian science and experience.

Associate Professor Coombes has a long involvement in research, development and application of rainwater harvesting systems in Australia. His research group at the University of Newcastle has conducted over a decade of water quality, health and operational research into the operation of rainwater harvesting systems. He has written a large number of guidelines and has been instrumental in the development of government policy for management of alternative water sources. A/Prof Coombes is the chair of the organising committee and scientific panel for the 13th International rainwater catchment systems and 5th water sensitive urban design conference.

This report provides an overview of water quality, health and operational aspects of rainwater harvesting systems, and proposes a set of guidelines for the installation and operation of these systems.

The Australian Situation

Australia is an island continent that has a generally dry climate with highly variable rainfall. A majority (85%) of Australia's total population of about 20 million people reside on the coastal fringe of the continent that has higher rainfall. The vast interior areas of Australia are arid and have low population densities with limited access to reticulated water supplies.

In Australia the use of domestic rainwater harvesting has a long history that commenced with early white settlement. A 1994 survey by the Australian Bureau of Statistics showed that about 16% of all Australian households (3.2 million people) use rainwater. About 13% of all Australian households (2.6 million people) use rainwater harvesting systems as a primary source of drinking water. The use of rainwater harvesting systems was far more common outside the capital cities with 30% of rural Australians using rainwater compared to 7% in the capital cities.

It was a paradox that, prior to the 1990s, the use of rainwater harvesting systems was virtually illegal in urban areas that had reticulated (mains) water supplies. It is commonly claimed by authorities that rainwater tanks were removed from urban areas due to health concerns. In contrast, historians explain that rainwater tanks were removed to increase the economic viability of water utilities.

More recently, in response to droughts with consequent water shortages and to improved science, local authorities throughout Australia encourage the use of rainwater harvesting systems in urban areas to supplement mains water supplies and to manage urban stormwater runoff. Increased frequency of droughts and water shortages has motivated improvements in the science of rainwater harvesting and resulted in development of government policy that integrates domestic rainwater harvesting into frameworks that includes multiple water sources. The recent New South Wales Government initiative, BASIX, is a planning requirement for all new housing to reduce mains water consumption by 40% using rainwater harvesting, water efficient appliances and wastewater reuse. An emerging interest in rainwater harvesting for water supply and stormwater management has resulted in many Australian state and local governments implementing a diverse range of policies that facilitate use of rainwater tanks in urban areas.

An emerging trend in the urban development industry in Australia is to develop water resources solutions for new housing that includes multiple water sources in an integrated water cycle management framework. For example, the Pimpama Coomera Water Futures project in the Gold Coast area of Queensland utilises domestic rainwater tanks, wastewater reuse and water efficient appliances to mitigate increasing deficits in availability of water from traditional water supply catchments. This is a

major departure from conventional water management practices that requires development of new governance, economic and infrastructure provision regimes.

Water Quality and Health

It is commonly perceived by the community that rainwater collected from roofs in rainwater storages is safe to drink. Experience has shown that health risks resulting from the consumption of rainwater are low throughout Australia [Cunliffe, 2004]. The majority of potential albeit infrequent health risks involved with the consumption of rainwater is linked with the design, installation and maintenance of rainwater harvesting systems. Well designed rainwater harvesting systems require little or no maintenance. The use of rainwater for purposes other than drinking such as hot water, laundry, toilet and outdoor uses significantly reduces any potential risks associated with a rainwater harvesting system [Coombes et al., 2005; 2003; 2002].

An assessment of the human health risk associated with rainwater harvesting systems should consider the likelihood of the presence of hazards to human health and whether the hazardous material is available in sufficient concentrations to cause illness. All rainwater catchment surfaces can be subject to physical, chemical and microbial contamination and the collection of contaminants in rainfall runoff is mostly dependent on the catchment surface and surrounding environment [Evans et al., 2006; 2006a]. Nevertheless, the focus for health risk assessment should be on the quality of rainwater at the point of supply to the household. This will properly account from the action of the “rainwater treatment train” that includes incidental processes (such as destruction of bacteria on roofs due to UV exposure from sunlight; settlement, flocculation and the action of biofilms in storages) and the action of various appliances [Coombes et al., 2005; 2003; 2002; 2000; Spinks et al., 2006; 2004; 2004a; 2003].

It has also been established that the quality of water will vary with depth in rainwater storages from the water surface micro layer with a relatively high bacterial content near the water surface, to the point of supply with improved water quality at about 0.1 to 0.4 metres above the base of the storage and the sludge layer at the base of the storage that accumulates a wide range of contaminants. Water should be drawn from the rainwater storage at 0.1 to 0.4 metres above the base of the rainwater storage thereby accessing the highest quality water.

Microbial issues

Rainwater captured from roofs in domestic storages will contain a range of micro-organisms that will be dominated by mostly harmless environmental sources [Evans et al., 2006]. The safety of rainwater catchment systems is, mostly, dependent on minimising the presence of enteric pathogens that include types of bacteria, protozoa and viruses. These organisms can be introduced to water supplies via contamination with fecal material and they do not grow or survive indefinitely in aquatic environments.

Most Australian domestic rainwater catchment systems include above ground storages that collect rainwater directly from roofs. The possible sources of enteric pathogens in this situation include fecal material deposited on roofs by birds, lizards and small animals or from dead animals located in the roof gutter or the stored rainwater. Rainwater from roofs can also be captured in underground storages although this practice is less common. Under ground storages that are not adequately sealed can allow entry of rainfall runoff from soil surfaces that may include fecal material from humans and larger animals that are the source of the majority of human pathogens.

The potential for fecal contamination and the possible presence of enteric pathogens in drinking water is usually indicated by tests to isolate *E. Coli* in water. Total coliform counts are no longer used for this purpose because the wider Coliform group also includes a number of environmental bacteria that do not indicate fecal contamination or health concerns (NHMRC, 1996). In addition, Heterotrophic Plate Counts are seen as a more complete measure of the general water quality in rainwater harvesting systems (Coombes et al., 2000).

Coliform Bacteria or *E. Coli* are commonly found in domestic rainwater harvesting systems indicating that pathogens may be present although detection of pathogens has been rare. Low levels of *Campylobacter* and *Salmonella* have been infrequently identified in some rainwater harvesting systems whilst other pathogens including *Shigella* have not been isolated. Birds are the source of *campylobacter* in rainwater storages and direct access by frogs and lizards to stored water may be a source of *Salmonella*.

Reports of illness resulting from consumption of roof collected rainwater are surprisingly infrequent given that indicator organisms are usually found in rainwater storages. Epidemiological studies by Heyworth (2001) did not establish a link between detection of fecal bacteria in rainwater supplies and human illness. These studies found that the risk of contracting gastrointestinal illness from drinking rainwater was similar to the risk posed by drinking mains water.

There has been small number of cases where the presence of *Salmonella* or *Campylobacter* in rainwater supplies used for drinking has led to illness. In each case, the rainwater harvesting system was observed to be in poor condition allowing direct access of birds and animals to the stored water. The only Australian case of gastrointestinal illness resulting from the presence of *Giardia* and *Cryptosporidium* in a rainwater harvesting system was linked to an underground rainwater storage that was contaminated by human sewage. The storage was not adequately sealed allowing inflow from a nearby septic tank.

The disparity between apparent frequent fecal contamination in rainwater supplies as implied by bacterial indicator organisms and the low prevalence of illness can be explained by the likely sources of contamination. For the majority of rainwater harvesting systems the sources of fecal contamination are limited to small animals and birds. The majority of enteric pathogens are host specific and microbes that are pathogenic to small animals and birds are less likely to be pathogenic to humans (Cunliffe, 2004). For example, human infections resulting from the protozoa *Cryptosporidium* are mostly related to genotypes of *C. parvum* sourced from humans and animals. The animal genotypes can be transmitted to other animals but human genotypes are specific to humans. Importantly, viruses are the most specific to the host of origin.

In addition, the concentrations of pathogens infrequently found in rainwater supplies may not be sufficient to constitute an infectious dose in humans. Research by Coombes et al. (2005) has also established that the use of bacterial indicator tests to determine the likelihood of fecal contamination of rainwater supplies are problematic with many environmental species of bacteria falsely presenting as Total Coliform, Fecal Coliform and *E. Coli* in tests.

Chemical and aesthetic issues

The sources of chemical and physical contamination can be described as on-site and off-site influences [Cunliffe, 2004; Spinks et al., 2003; Evans et al., 2005]. On-site sources of contamination arise from local influences on roof catchments and materials used in the construction of roofs, storages, gutters and household plumbing. These sources can be managed by the resident. Off-site sources of contamination are considered to be beyond the control of the resident, including emissions from traffic, industry and agriculture. The potential for contamination by lead from flashing used on some roofs, and emissions from industry and traffic is considered to be an issue worthy of consideration.

Contamination resulting from on-site and off-site sources can be mitigated by design choices that include exclusion of lead from roof materials (paints and flashing), careful selection and installation of storages and use of devices to filter rainwater supplies or inflows to storages.

A number of monitoring studies in urban areas have observed that roof collected rainwater supplies with concentrations of lead, nickel, manganese, zinc and hydrocarbons that were significantly below drinking water guidelines. However, there have been some localised cases where the quality of rainwater supplies has been affected by particular industries. For example, concentrations of lead that exceeded drinking water guidelines was observed in rainwater storages located near a lead smelter that resulted in advice that the rainwater should not be used for drinking and cooking purposes.

A wide range of roof materials are likely to be suitable for collection of rainwater including slate, fibreglass, cement and terracotta tiles, galvanised iron, Colorbond and Zinalume. Lead flashing, paints and solder used in roof construction may be source of lead in rainwater supplies. Bitumen or tar may leach hazardous materials and should not be used on roofs that capture rainwater for drinking purposes.

The aesthetic quality of rainwater supplies can be influenced by over hanging trees that contribute leaves and debris to the rainwater catchment. Rainwater storages should include leaf filters to exclude entry of leaves and debris to stored water. Installation of open storages (this is uncommon) that allow direct exposure of stored rainwater to sunlight can promote the growth of algae that may impact on the taste, odour and appearance of rainwater. Open rainwater storages should not be installed although screened access holes in the top of above ground storages are acceptable.

Soil and decaying vegetation in roof gutters that store rainwater between rain events may also impact on the aesthetic quality of rainwater. Roof gutters should be kept clear of debris.

Guidelines for use of rainwater harvesting systems

Rainwater harvesting systems and treatment trains can include a variety of elements that can be chosen to suit the desired domestic rainwater uses as shown in Figure 1:

- roof gutters
- first flush device or filter sock
- rainwater tank
- leaf diverters
- pump
- Inline filter or UV disinfection
- overflow to garden areas, infiltration trenches and street drainage system.

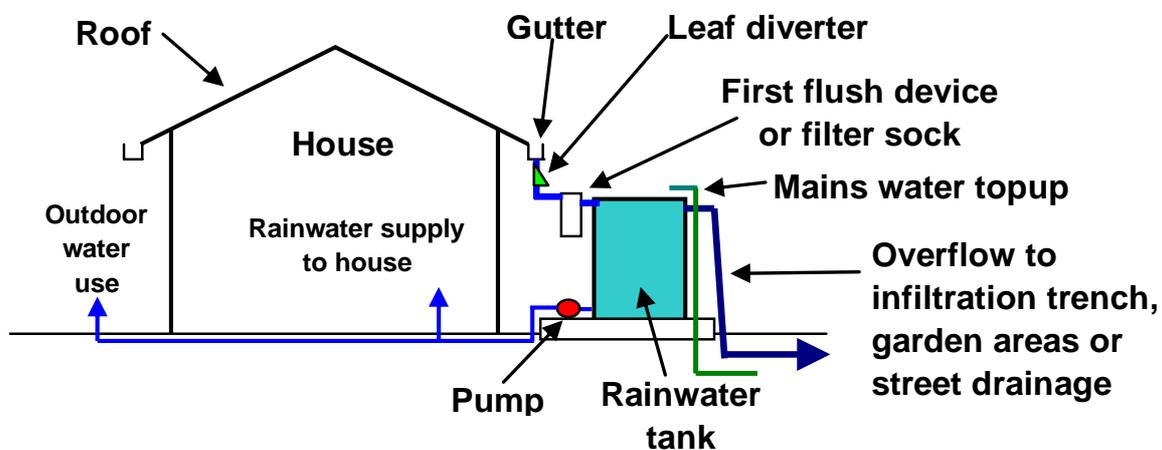


Figure 1: Elements of a domestic rainwater system (the rainwater treatment train)

The choice of the elements used in the rainwater treatment train is optional, and is dependent on user choice and the household use of the rainwater. For example the rainwater treatment train for supply to outdoor and toilet uses may only require leaf diverter (in areas with trees), a rainwater tank and a pump. Alternatively a rainwater tank system used to supply laundry, toilet, hot water and outdoor uses may only require a leaf diverter, a first flush device, a rainwater tank and a pump. Whilst a rainwater treatment train to supply all household water demands may also include a first flush device to remove sediments, an inline filter and UV disinfection on the drinking water supply line.

Depending on site conditions, user requirements and budget, rainwater tank systems can be installed using a variety of different configurations, including:

- installation of tanks above or below ground
- using gravity or pressure systems
- using dual water supply systems
- including a detention volume inside the tank for additional stormwater management.

Dual water supply systems

A dual water supply system utilises both rainwater and mains water. In this system, a rainwater tank can be topped up with mains water when the tank level is low (due to dry weather or high usage). This ensures a reliable water supply, whilst also providing significant mains water savings and stormwater management benefits. Required tank capacity will depend on the number of persons in the household, water use, rainfall and roof area. This is likely to be a small rainwater tank with capacity ranging from 1 kL to 5 kL. When designing the tank system, provision should be made for each of the following storage components (see Figure 2):

- minimum storage (or mains water top up zone) to ensure that water supply is always available
- rainwater storage zone
- air gap for additional stormwater management and backflow prevention
- anaerobic zone (water is drawn from above this zone to ensure that it is free of sediment).

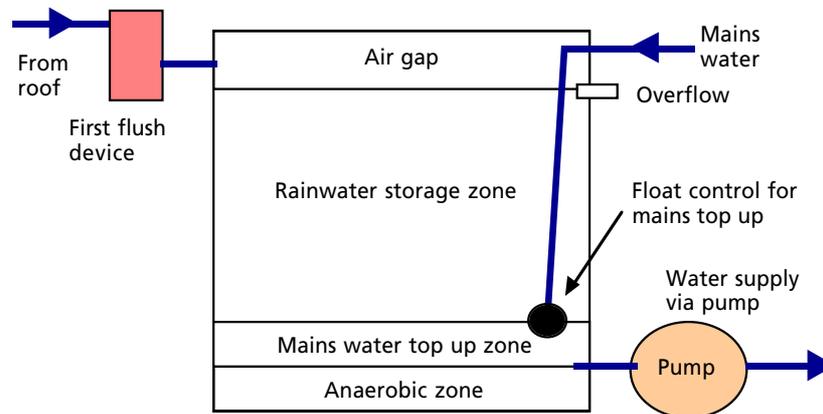


Figure 2: Storage components for a dual supply system

The minimum storage volume (mains water top up zone) is usually the maximum daily water use that is expected from the tank, less the potential daily top up volume of mains water (about 250 –750 litres). If the volume of stored water falls below the minimum storage volume, the shortfall can be overcome by topping up the tank with mains water to the required level. A simple float valve system can be installed to do this automatically.

The rainwater storage zone comprises the total volume available in the tank to store rainwater below the overflow pipe. The air gap between the overflow pipe and the top of the tank can be used to provide ‘stormwater detention’, thereby delaying the delivery of excess roof water to the drainage system. The rainwater storage zone and the overlying air gap provide both stormwater retention and detention. Note that the air gap provides the highest level of backflow prevention. The configuration of plumbing for rainwater tanks in a dual water supply scheme with mains water trickle top up is shown in Figure 3.

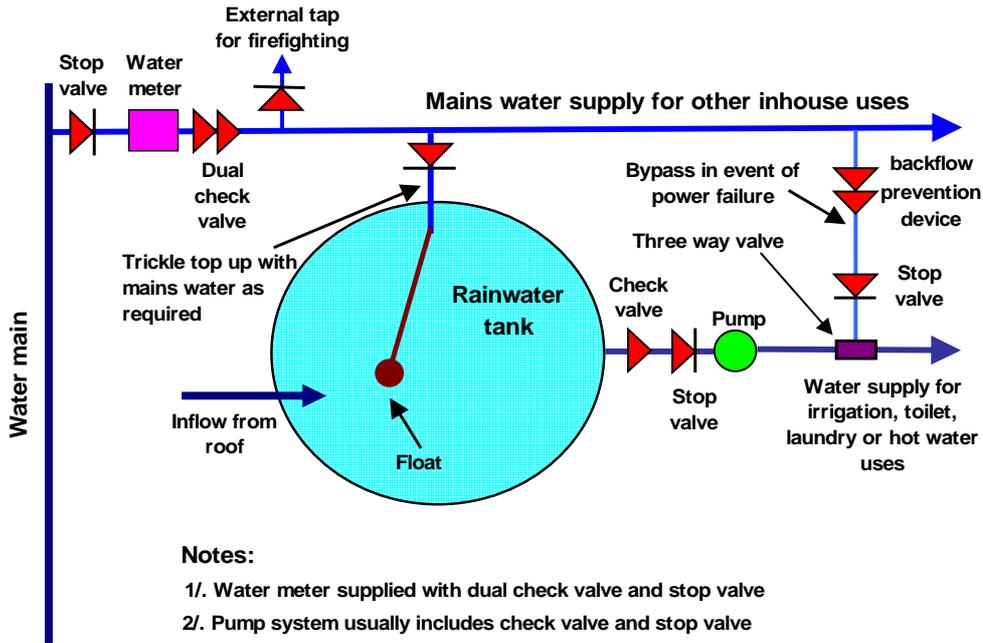


Figure 3: Configuration for a dual supply system with mains water trickle top up

Figure 3 shows a plumbing configuration for a dual water supply system that includes mains water trickle top up. Tank water is directed to indoor and/or outdoor fixtures via a small pump. When tank levels are low (such as during prolonged dry weather), the tank is topped up with mains water via a trickle system. This reduces peak demand on the mains water distribution network. The tank can be bypassed in the event of a pump or power failure. Australian Standards and national practice allows an internal top up arrangement for rainwater tanks.

A dual water supply system may also include a mains water bypass system rather than a mains water trickle top up arrangement. In this system a solenoid valve is used to switch between mains and rainwater supplies. When the rainwater storage is empty or in the event of a pump or power failure, the solenoid valve is open allowing all household water demand to be supplied with mains water. If rainwater is available in the tank the solenoid valve is close allowing the pump to deliver rainwater to the household (see Figure 4).

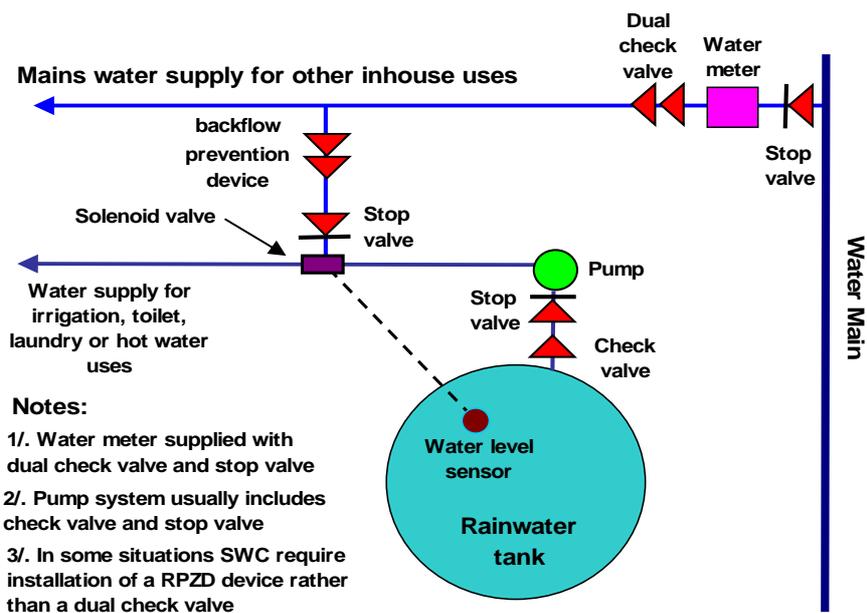


Figure 4: Configuration for a dual supply system with mains water bypass

Pressure systems

A pressure system involves using a pump to deliver rainwater to household or garden fixtures. Pressure systems are required where the tank cannot be installed at a sufficient height to provide acceptable pressure (see Figure 1), or if the tank is installed underground (see Figure 5).

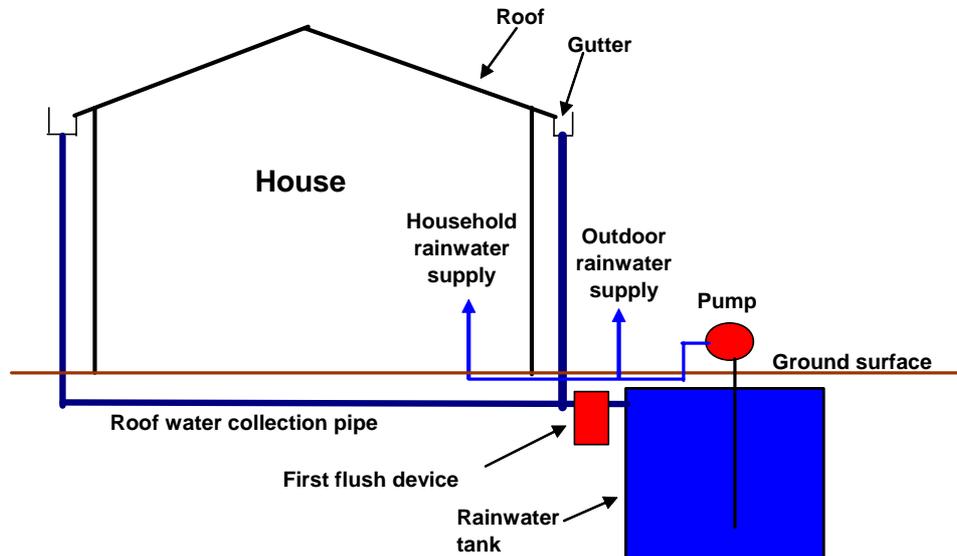


Figure 5: Configuration for a pressure system on an underground rainwater tank

Note that rainwater harvesting systems that include below ground rainwater tanks must ensure that the tank is adequately sealed to eliminate entry of stormwater and soil to stored rainwater.

Gravity systems

The installation of a rainwater tank system that relies on gravity to supply rainwater to the household and the garden will involve placing the rainwater tank on a stand or at a height greater than intended end uses as shown in Figure 6. The use of gravity to supply rainwater at low pressure to the household is common in rural areas and for the use of small rainwater tanks that supply outdoor and/or indoor water uses in urban areas.

In a gravity system, rainwater is collected from the roof and directed to the tank. All connections to outdoor and household fixtures depend on gravity alone. Water pressure at each fixture is governed by the difference in height between the tank and the fixture.

To achieve a water pressure similar to that of normal mains water, the tank needs to be positioned at least 20 metres vertically above fixtures. This is generally not practicable. However, many household water uses such as toilets, laundry tubs and garden hoses do not require such high water pressures. Gravity systems are often adequate for these purposes.

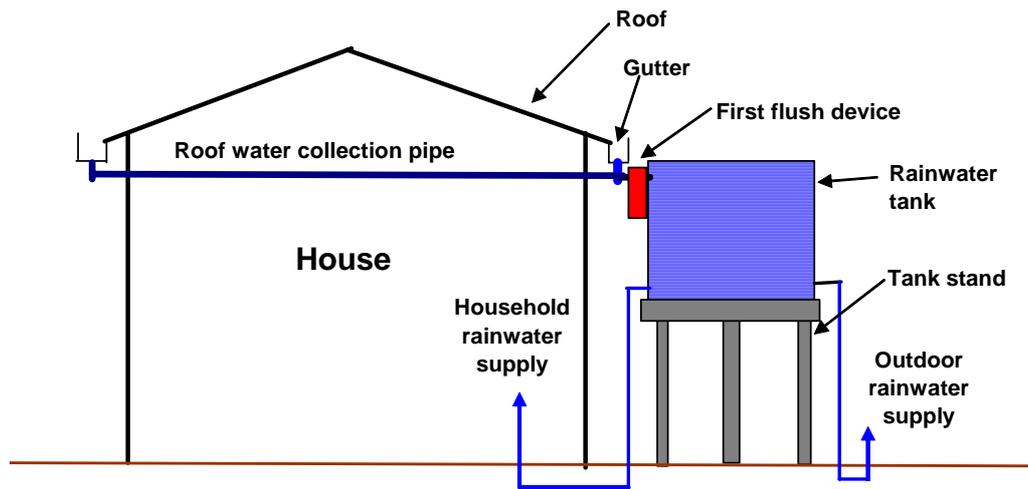


Figure 6: Configuration for a gravity system

First-flush devices

A first-flush device separates the first part of rainfall from entering the rainwater tank (see Figure 7). The use of a first flush device will prevent some of the sediment and debris from roofs or gutters from entering the rainwater tank. The device operates by filtering roof runoff through a mesh screen to capture leaves and debris. The first part of runoff is stored in the chamber to slowly trickle through a small hole whilst cleaner water at the top of the chamber passes into the rainwater tank.

The performance of first flush devices has often been misunderstood. Research from the University of Newcastle shows that first flush devices with capacities of up to 20 – 25 litres are successful at separating significant proportions of sediment and debris from rainwater. Larger first flush devices do not produce considerable additional improvement in rainwater quality. Indeed large first flush devices dramatically reduce the volume of rainwater that flows into a tank.

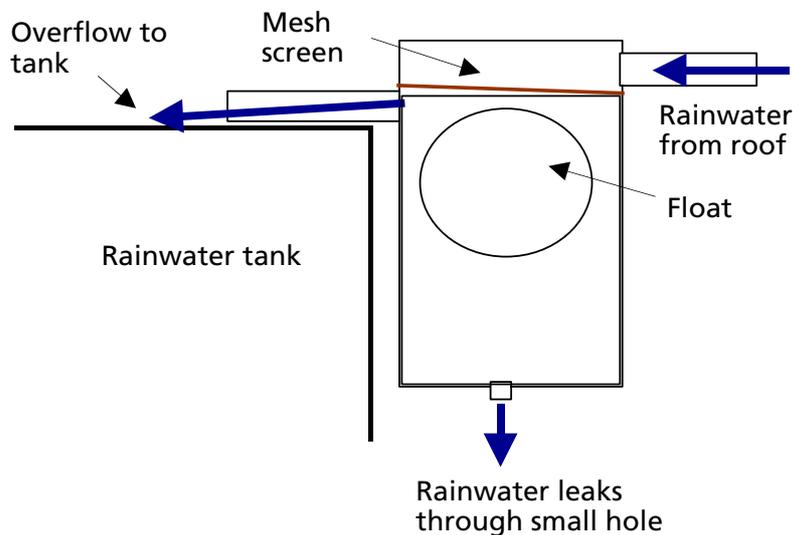


Figure 7: Basic design features of a first flush device

Note that a number of variations on the design shown in Figure 7 are available and alternative methods of removing sediment and debris (such as filter socks) from the rainwater discharging from roofs into rainwater tanks are also available.

Leaf diverters

A leaf diverter is placed in down pipes between the roof catchment and a rainwater tank (Figure 8). It

employs a mesh screen placed at an angle to rainwater flow in a down pipe to divert leaves and debris from entering the downstream down pipe and ultimately the rainwater tank.

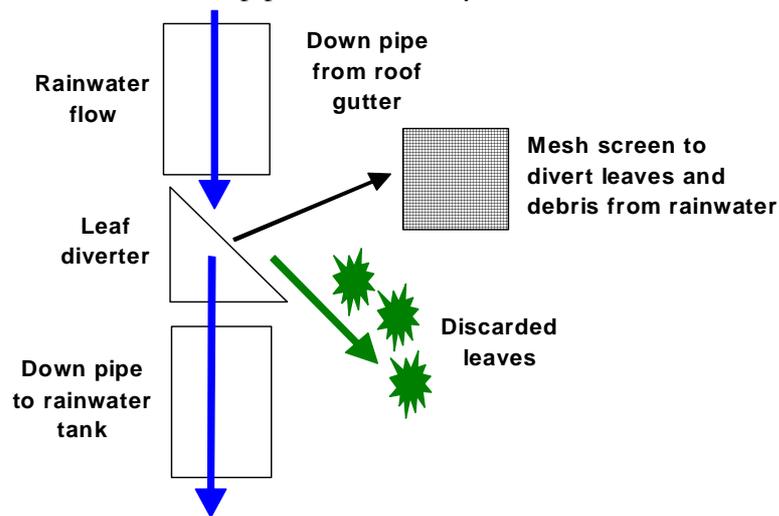


Figure 8: Basic design of a leaf diverter

Leaf diverters can be very effective at improving the performance of rainwater catchment systems and the quality of rainwater stored in tanks.

Roofs & gutters

Rainwater collected from roofs painted with lead-based or tar-based paints, or from asbestos roofs should not be used for drinking water supplies. Galvanised iron, Colorbond™, Zinalume™, slate or ceramic tiles provide acceptable water quality. Special roof guttering is not generally required. Normal guttering is sufficient provided that gutters are kept clear of leaves and debris.

Water quality

There is growing scientific evidence to confirm traditional knowledge and practice that water sourced from rainwater tanks is acceptable for most household uses. For example, research undertaken by the University of Newcastle has shown that domestic roof water stored in tanks is of acceptable quality for toilet, washing machine (laundry), hot water and outdoor uses. The processes improving rainwater quality in the rainwater treatment train include:

- Exposure to UV, heat, and desiccation on the roof top destroy bacteria
- First flush devices, leaf diverters or filter socks can limit to transfer of sediment and debris to rainwater storages
- Mesh screens on all inlets and outlets to rainwater tanks will exclude animals from entering tanks thereby minimising the possibility of harmful bacteria entering storages
- Most bacteria in rainwater tanks are trapped at the water surface
- Settlement processes remove sediments, metals and bacteria from rainwater
- Biofilms (slime) and sludge in the tanks remove organics, bacteria and metals from rainwater
- Hot water systems and pumps may also eliminate bacteria from rainwater supplies

This research also revealed that rainwater used in hot water systems was compliant with the *Australian Drinking Water Guidelines* provided that temperature settings greater than 50°C were maintained. Laboratory experiments also established that bacteria and pathogens were rapidly eliminated from water heated to 60°C. This result is consistent with the requirements of Australian Standard AS3500.2.4 that domestic hot water systems to be set at 60°C to eliminate bacteria from mains water systems, and hot water to be delivered to the house at a non-scalding temperature of 50°C. Pathogens are not commonly

found in rainwater tanks (Cunliffe, 2004).

It is not recommended that rainwater be used for drinking in high density urban areas unless it is passed through an approved filtration or disinfection system. This should be sufficient to remove possible residual contamination from accumulated soil and leaves in gutters, faecal material (deposited by birds, lizards, rodents and possums) and dead animals on roofs or in gutters that may not be removed from the rainwater treatment train. Acceptable water quality can be maintained by:

- installing mesh screens over all inlets and outlets to prevent leaves, debris and mosquitoes from entering the storages
- installing a first-flush device, leaf diverter or a filter sock to remove a proportion of sediment and debris from roof water
- regularly removing leaves and debris from roof gutters
- only cleaning the rainwater tanks when sediment levels become unacceptably deep
- drawing water from the tank above the anaerobic/sediment layer
- when rainwater is used in hot water systems ensure the hot water service is set at 60°C
- when rainwater is used for drinking or cooking employ an inline filter or UV light

Design standards

Cross connection between mains water supply and a domestic roof water tank as a low hazard connection. This requires a non-testable backflow prevention device (such as a dual check valve). If a higher level of backflow prevention is required for a greater hazard rating the following approaches can be used:

- no physical connection between the tank and the mains water system
- an air gap
- an approved backflow prevention device

An air gap refers to a physical separation between the mains water and rainwater supplies within or above the tank. This is a simple, reliable and maintenance-free solution. Testable backflow prevention devices such as RPZDs are mechanical devices that separate mains and other water supplies. Testable devices require regular servicing.

Materials & products

Concrete

Concrete storages can be purchased in a ready-made form or constructed on-site. They can be placed above or below ground. Concrete tanks can be subject to cracking although careful construction techniques will minimise the potential.

Fibreglass & Plastic

Fibreglass storages are constructed from similar materials as fibreglass boats and can be used in above-ground installations. Plastic or poly tanks are constructed using food-grade polyethylene that has been UV stabilised and impact modified. These storages are strong and durable. They can be used above or below ground depending on their design.

Metal

Galvanised iron storages are constructed from steel with a zinc coating, and can be used in above ground installations. These storages are strong and durable, but can be subject to corrosion if copper pipe for the household water service is directly connected to the tank. The first section of plumbing connected to the storage should be UPVC or other non-metallic material. ZincolumeTM tanks are constructed from steel with zinc and aluminium coating. They are similar to galvanised iron tanks.

Aquaplate™ storages are made from Colorbond™ lined with a food grade polymer. They can be used in above ground installations. These tanks are strong, durable and corrosion resistant. When cleaning the storage, it is important to avoid damaging the polymer lining.

Maintenance

A rainwater harvesting system requires very little maintenance provided that the storage is correctly installed. Regular maintenance tasks are:

- cleaning the first flush device every three to six months
- removing leaves and debris from the inlet mesh on the tank every three to six months
- removing leaves and debris from the gutters every three to six months
- checking the level of sediment in the storage every two years.

Rainwater storages require occasional cleaning. The frequency of cleaning will depend on the amount of sediment and debris that enters the tank. A first flush device and adequate mesh screens on all tank inlets and outlets will ensure that the majority of sediment and debris does not enter the tank. This will reduce the frequency of cleaning to every 10 years or so.

Testing for water quality

Guidelines and regulations for the installation of rainwater harvesting systems should not be dependent on testing for water quality. It is preferable to implement a multiply barrier approach to protecting human health that employs the knowledge provided above. In situations where water quality testing is prudent such as when a rainwater harvesting system is a small public water supply the following testing parameters shown in Table 1 is suggested.

Table 1: Suggested testing regime to indicate an acceptable rainwater supply

Test	Water use						
	Drinking	Cooking	Hot water	Bathroom	Laundry	Toilet	Outdoor
<i>E. Coli</i> (CFU/100 mL)	<10	<10	<10	<10	<100	<100	<100
HPC (CFU/mL)	<100	<100	<100	<100	<500	<500	<1000
Lead (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.2	<0.2	<0.2

The measurement of *E. Coli* indicates the potential for fecal contamination of rainwater, Heterotrophic Plate Counts (HPC) is an indication of general water quality and measurement of lead will provide an indication of the elemental quality of the rainwater. The required compliance level for each test is related to the expected use of the rainwater. The average water quality results from the rainwater harvesting system taken from 5 samples should comply with the above guidelines.

The multiple barrier approach should include the following considerations:

1. All rainwater storages used to supply domestic indoor uses should be adequately sealed including mesh screens on all inlets and outlets
2. Only rainwater sourced from roof catchments should be used to supply domestic indoor uses
3. When rainwater is to be used for domestic drinking and cooking purposes an appropriate treatment train should be installed including collection from roofs, use of leaf diverters or first flush devices, rainwater drawn from between 0.1 m and 0.4 m from the base of the storage and use of an inline filter or a UV light should be considered.
4. When rainwater that has been collected in an underground storage is used for domestic indoor uses compliance with the suggestions in point 3 should be confirmed by the testing proposed in Table 1.
5. If stormwater collected from other surfaces (such as pavements and grassed areas) is to be used for domestic indoor uses the treatment train proposed in point 3 should be combined with a regular testing program to ensure adequate water quality is delivered to the household

6. If the rainwater harvesting system is a public water supply system that supplies domestic indoor uses or drinking water the rainwater harvesting system should be subject to regular testing using the parameters in Table 1.

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