32nd WEDC International Conference, Colombo, Sri Lanka, 2006

SUSTAINABLE DEVELOPMENT OF WATER RESOURCES, WATER SUPPLY AND ENVIRONMENTAL SANITATION

Water Quality Of Rainwater Tanks in Urban Environments

Asoka Jayaratne, Australia

The opportunities and problems pertaining to harvesting and using rainwater is a critically important issue to the community and to the water industry. Nearly 17 percent of Australian households, particularly in rural and remote areas, use rainwater tanks. Rainwater is also becoming a supplementary source of household water in many urban areas. Research into the potential use of rainwater in high-density developments is an important area of inquiry for water utilities around the world as they consider alternative servicing strategies that promote water conservation and environmental sustainability. This paper discusses quality issues associated with the use of untreated rainwater as a source of hot water for household use, and reviews issues pertaining to ongoing maintenance of water quality. The discussion and review are derived from findings of a pilot rainwater quality-monitoring and testing program undertaken in Melbourne, Australia.

Background

The opportunities and problems pertaining to harvesting and using rainwater is a critically important issue to the community, particularly households in rural and remote areas around the world who use rainwater tanks. Rainwater is becoming a supplementary source of household water in many urban areas because of additional demands being placed on existing water due to growth, climate change, prolonged drought conditions and the introduction of water restrictions by water authorities as a means of managing water shortages. The use of rainwater in the garden, for toilet flushing and hot water can reduce the demand for drinking water in homes. Rainwater tanks combined with other demand management practices including water sensitive urban design can significantly reduce the demand for treated drinking water.

VicUrban, the urban development authority in the State of Victoria, Australia, is developing an 8,500 lot residential development (*Aurora* Project) within Yarra Valley Water's service area Melbourne. Yarra Valley Water is the largest Victorian State Government owned retail Water Company in Melbourne, Australia. It provides water and sewerage services to 1.6 million people in the northern and eastern suburbs of Melbourne. This development aims to showcase new sustainable development concepts. The project incorporates water conservation initiatives such as demand management and a recycled water system. The use of rainwater tanks to supply hot water systems is being considered for this development. Yarra Valley Water will be responsible for providing water, sewerage and recycled water services to this new development. Research into the potential use of rainwater is an important area of inquiry for water utilities around the world in considering alternative servicing strategies that promote water conservation and environmental sustainability.

During the planning stage of the *Aurora* Project, it became evident that there were few intensive studies that could offer baseline data for water quality in rainwater tanks within urban context. Whilst some historical data on the microbiological quality of rainwater was available from previous studies, limited information was available on the physical and chemical quality of rainwater. Past studies had not investigated in any great detail the potential of rainwater sources being contaminated by industrial emissions, traffic emissions, and plant debris on roofs. Yarra Valley Water, VicUrban and Coomes Consulting Group designed and installed a rainwater harvesting system at the Centre for Education and Research in Environmental Strategies (CERES), a community environment park, situated in the Melbourne suburb of Brunswick. Yarra Valley Water, VicUrban with consultation from the Cooperative Research Centres for Water Quality and Treatment (CRCWQT) undertook a pilot program at CERES.

Objectives

This paper discusses and reviews findings of the pilot rainwater quality-monitoring and testing program at CERES. The paper (a) discusses quality issues pertaining to the use of untreated rainwater as a source for household uses (in kitchens, laundries and bathrooms), and (b) reviews issues pertaining to ongoing maintenance of hot water systems in residential developments.

Whilst the results of this investigation are more specific to the study area, the findings provide guidance to rainwater uses in general.

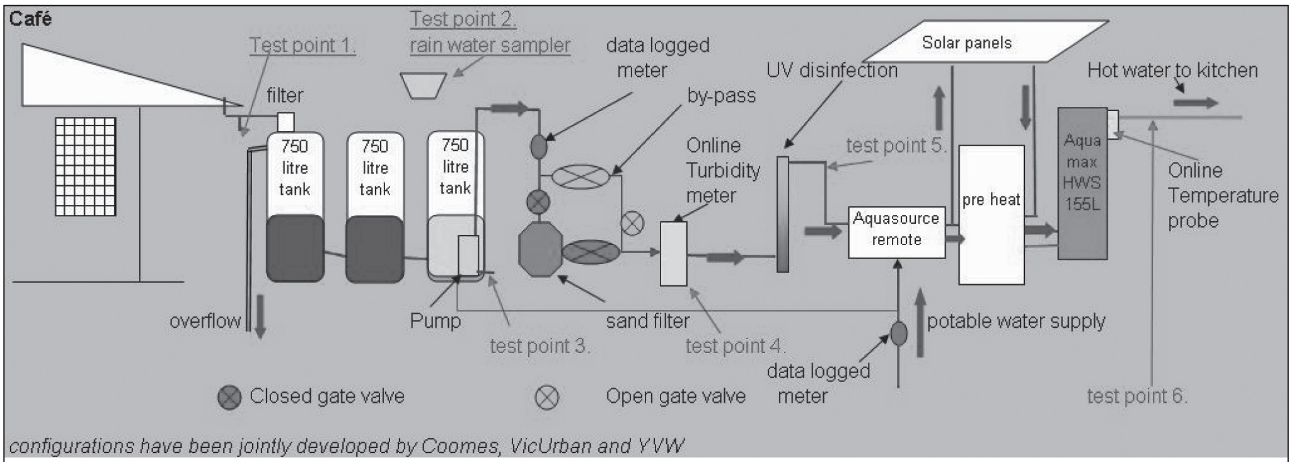

Figure 1. Trial Rainwater Harvesting

Methodology

Reasons for Choice of Site

The CERES site was selected for the trial because it simulated the conditions in a high density urban environment. The rooftop of buildings at the site had large amounts of overhanging branches from trees that enabled easy access to small animals, high levels of leaf debris, and increased the chances of bird droppings falling into the harvested rainwater. The site was also potentially subject to levels of industrial and traffic emissions within a high-density urban setting. Consequently, the site appeared to represent a worse case environment for contamination.

Duration of the Trial

A 12-month trial to assess the water quality was undertaken at this site. Based on available literature on rainwater quality (CRCWQT, 2005) it was decided that the monitoring would be conducted for microbiological indicator organisms, specific bacterial pathogens, and health and non-health related aesthetic and physiological parameters.

Experimentation Techniques

The system configuration was designed to capture and test the water supplied to the Ceres Café. The system used three sequentially positioned 750-litre rainwater tanks with a pump, a sand filter and an ultraviolet (UV) disinfection unit located downstream to the tank (Figure 1). To ensure continuous water supply, the system was plumbed to mains drinking water supply. The backup supply was triggered through an automatic supply selector (*Aquasource Remote*) that monitored the water levels in the rainwater tank. The flow meter at the rainwater tank outlet provided information that ensured samples were collected only when the rainwater harvesting system was online. A rainwater sampler to capture rainfall events greater than 5mm (test point 2, Figure 1) was also installed outside the Café.

To protect the mains water supply from cross contamination, a backflow prevention device was fitted to the *Aquasource Remote*. A preheat tank circulated and heated water through the solar heating panels placed on the roof. Preheated water passed through a 155-litre gas hot water unit that supplied hot water to the Café.

The UV unit was turned off during the latter part of the trial for two months in order to assess the effectiveness of UV disinfection in removing microbiological hazards.

Monitoring Regime

More than 30 parameters were tested during the trial. Samples were collected and tested from across the harvesting system, from the roof catchment to the kitchen tap (test point 1 to test point 6).

The water samples were tested for *E.coli*, total coliforms, heterotrophic colony count (on a weekly basis); pH (weekly); temperature (continuously at the hot water outlet and on a weekly basis at others); copper, hardness, turbidity, electrical conductivity, lead, polycyclic aromatic hydrocarbons (PAH), plasticisers, total organic carbon (TOC), nitrate and sulphate (all on a fortnightly basis); true colour, iron, manganese, (all on a quarterly basis). The following parameters were also tested at the rainwater tank after a rain event: lead, nitrate, sulphate, PAH, benzene-toluene-xylene (BTX) *Campylobacter, Salmonella, Legionella, and Enterococci*.

Microbiological Monitoring

Data available from earlier studies and the potential water quality risks associated with the trial site were the basis by which the microbiological monitoring program for CERES was developed. Salmonella and Campylobacter are infectious to humans and may be carried by birds and mammals. Bacteria such as Legionella may grow in rainwater where organic matter are present and at temperatures between 30o and 45o Celsius. Hot water systems operated below 60OC may favour growth of Legionella (Australian Drinking Water Guidelines (ADWG), 2004).

Physical and Chemical Monitoring

In contrast to the studies conducted on microbiological water quality from rainwater tanks, very limited data is available on the chemical water quality. To address these gaps in data, a comprehensive chemical and physical water quality-monitoring program was developed. Number of metal contaminants, combustion products such as PAH and products from vehicle emissions such as BTX were included in the monitoring program.

Findings and discussion

Rainwater quality data from 11 rain events were captured during the trial. It was necessary to modify the planned sampling frequencies as rainwater tank supply was adequate to meet the demand in the Café only up to a two-week period after each rain event.

Microbiological Test Results

As shown in Table 1, *E.coli*, total coliforms, *enterococci* and plate counts were detected but *Salmonella, Campylobacter* and *Legionella* were not detected at the rainwater tank (test point 3). These parameters were not detected in four of five samples tested after UV disinfection (test point 5). In one sample, 10 *E.coli* /100mL and 34 total coliforms /100mL were detected. It is well established in the scientific literature that these bacteria are inactivated by UV irradiation. The transmissivity of the UV unit at CERES was not monitored and the detection of these parameters could be attributed to improper operation of the UV unit or ineffective treatment. *E.coli, enterococci* and total coliforms were not detected after hot water treatment in all samples at the kitchen tap (test point 6).

Physical and chemical test results

The physical and chemical test results (Table 2) indicate the following: (a) High lead levels in excess of the ADWG limit of 0.01 mg/L were detected in eight of the 10 samples tested from the first flush (test point 1) due to the lead flashing; (b) Elevated lead levels were also detected in the kitchen (test point 6) in one of the eight samples and in the tank (test point 3); (c) True colour in all samples were above ADWG value of 15Pt/Co units. The high colour may be associated with the decomposition of organic matter from the leaves and particles from the roof catchment; (d) Of 49 samples tested, 32% recorded pH levels between 5.5 and 6.5 pH units. This may lead to corrosion of internal plumbing and hot water systems; (e) Turbidity levels were below the ADWG level of 5NTU in all seven samples tested in the kitchen tap; (f) Copper, iron, hardness, electrical conductivity, total organic carbon, nitrate and sulphate levels are low and below the ADWG limits; (g) PAH, BTX and plasticiser levels were below detection limits. Low PAH and BTX levels indicate that the effect of combustion products and vehicle emission are not evident despite CERES being located in a high density urban environment.

Conclusions

The findings of this study are consistent with that of previous studies cited in the paper. The results confirm that microbiological contamination can occur in rainwater tanks. As evidenced by the non-detection of bacteria such as *E-Coli, Enterococci*, total coliforms *and* plate count after hot water treatment indicate that if water temperature is maintained above 60^o Celsius, this could inactivate microbial contamination in rainwater tanks. However, inactivation of pathogens such as Salmonella and Campylobacter and Legionella could not be confirmed, as these organisms were not detected in the sample prior to treatment.

The study indicated that UV treatment may not be necessary if the hot water system maintains the temperature above 60^o Celsius. However, this could not be confirmed from the data as the effectiveness of the UV irradiation was not monitored at CERES.

In addition, the study identified potential physical and chemical hazards that need to be considered in installing

Table 1. Microbiological Test Results

Parameter	Unit	Tank (test point 3)	After UV (test point 5)	Kitchen tap (test point 6)
E.Coli	Orgs /100mL	1-2400 (2-160)	0-10 (3-110)	0 (0)
Total Coliforms	Orgs /100mL	3-2400 (240-460)	0-34 (190-250)	0 (0)
HPC	Orgs /mL	1-100,000 (1-810)	0-320 (550-1300)	0-260 (30-560)
Salmonella	orgs/L	Not Detected		Not Detected
Campylobacter	orgs/L	Not Detected		Not Detected
Legionella	Orgs /mL	Not Detected		Not Detected

Note –Results in parenthesis show data when the UV unit was turned off

Table 2. Physical and Chemical Test Results

Parameter	ADWG Guideline	Unit	Rain (2)	1st Flush (1)	Tank (3)	After UV (5)	Kitchen tap (6)
Turbidity	5	NTU			1.5-6.7	2.1-8.5	<4.2
True Colour	15	Pt/Co			40-60	30-70	25-60
Hardness	200	mg/L			<9.4		<16
pH	6.5-8.5	units			6.1-7.7	5.8-7.7	6.5-7.6
Lead	0.01	mg/L	<0.002	0.05-0.9	0.001-0.022		0.002-0.013
Copper	1	mg/L			<0.01	<0.3	<0.2
Iron	0.3	mg/L					<0.18
EC	1000	μS/cm			<68		<72
TOC		mg/L			7.4 -10		<7.5
Manganese	0.1	mg/L			0.003-0.019		0.002-0.016
Nitrate		mg/L	0.02-0.69	0.009	0.11-0.36		0.24-0.37
Sulphate	250	mg/L	0.3-3.5	10	0.9-3.9		2.9, 6.3
BTX		mg/L	<0.001				<0.001
Plasticisers		mg/L			<0.001		<0.001
PAH		mg/L	<0.0001		<0.0001		<0.0001

rainwater tanks. For example: (a) high lead levels in the first flush indicate leaching of lead from the lead flashings. It is important to prevent use of lead flashings and other roof materials which contain lead in order to minimise the risks; (b) High colour caused by particles or dissolved organic matter can stain washings and create quality issues pertaining to the aesthetics of the water. This is a site-specific problem and may be overcome through installing a filter to remove the colour; and (c) Low levels of pH in the water can corrode hot water units, copper pipes and fittings used in hot water systems.

This trial has identified a number of water quality and maintenance issues associated with the use of rainwater and provide guidance to such uses in an urban environment. However, potential water quality risks associated with such systems will be site specific and require more intensive studies to determine the appropriate use of rainwater.

References

Australian Bureau of Statistics (2004): *Environmental Issues: People's Views And Practices 4602.0.*

National Health and Medical Research Council (2004): *Australian Drinking Water Guidelines 6.*

The Cooperative Research Centre for Water Quality and Treatment (2005): *Public Health Aspects of Rainwater Tanks In Urban Australia, Occasional Paper No. 10*, CRC for Water Quality and Treatment, Salisbury, Australia

Jayaratne, A., Snadden D. and Sukumaran N.: (2006): *Proceedings of Enviro 06 Conference*, Melbourne, Australia.

Contact address

Asoka Jayaratne
Senior Water Quality Planning Engineer
Yarra Valley Water, Private Bag 1, Mitcham, VIC 3132, Australia.