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Investigation of pump and pump switch failures in rainwater harvesting systems

Magnus Moglia [a,*], Kein Gan [a,b], Nathan Delbridge [a], Ashok K. Sharma [c], Grace Tjandraatmadja [d]

[a] CSIRO Land and Water, Ian Wark Building (B203), Clayton South, VIC 3169, Australia
[b] Melbourne Water, 990 Latrobe Street, Docklands, VIC 3008, Australia
[c] Victoria University, Ballarat Rd, Footscray, VIC 3011, Australia
[d] Engineers Without Borders Australia/Habitat for Humanity, Ho Chi Minh City, Viet Nam

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SUMMARY

Rainwater harvesting is an important technology in cities that can contribute to a number of functions, such as sustainable water management in the face of demand growth and drought as well as the detention of rainwater to increase flood protection and reduce damage to waterways. The objective of this article is to investigate the integrity of residential rainwater harvesting systems, drawing on the results of the field inspection of 417 rainwater systems across Melbourne that was combined with a survey of householders' situation, maintenance behaviour and attitudes. Specifically, the study moves beyond the assumption that rainwater systems are always operational and functional and draws on the collected data to explore the various reasons and rates of failure associated with pumps and pump switches, leaving for later further exploration of the failure in other components such as the collection area, gutters, tank, and overflows. To the best of the authors' knowledge, there is no data like this in academic literature or in the water sector. Straightforward Bayesian Network models were constructed in order to analyse the factors contributing to various types of failures, including system age, type of use, the reason for installation, installer, and maintenance behaviour. Results show that a number of issues commonly exist, such as failure of pumps (5% of systems), automatic pump switches that mediate between the tank and reticulated water (9% of systems), and systems with inadequate setups (i.e. no pump) limiting their use. In conclusion, there appears to be a lack of enforcement or quality controls in both installation practices by sometimes unskilled contractors and lack of ongoing maintenance checks. Mechanisms for quality control and asset management are required, but difficult to promote or enforce. Further work is needed into how privately owned assets that have public benefits could be better managed.

1. Introduction

Residential rainwater harvesting is the collection, storage, and distribution of rainwater from the roof to meet water demand inside and/or outside the home. Rainwater harvesting can provide an option for many people who do not have access to centralised piped water (Cook et al., 2013) and it can also help reduce excessive run-off (Burns et al., 2015) which in turn helps protect environmental values and reduce the risk of urban flooding (Walsh et al., 2012). It has also been argued that rainwater harvesting is a particularly useful and reliable complementary approach at times warmer and dryer conditions (Coombes and Barry, 2008; Rahman et al., 2012). Underlying such arguments are estimates of yield contributions from urban rainwater harvesting, which have progressed over the years (Fewkes, 1999; Imteaz et al., 2011; Neumann et al., 2011; Cook et al., 2013) and the more recently developed system available online http://gettanked.org/ (Peterson, 2016). In light of these considerations, rainwater harvesting is considered an important technology option to support sustainable urban water management (Marlow et al., 2013).

Rainwater harvesting systems are also considered an important option for urban water management in developing countries as they can help mitigate some of the health impacts of degraded piped systems (Moglia et al., 2008; Neumann et al., 2014). Nonetheless, it is important to remember that poorly designed rainwater harvesting systems may cause public health issues related to mosquito breeding and associated water borne diseases and these issues are perhaps particularly pertinent in locations with tropical climates and/or poor sanitation and hygiene (Neumann et al., 2014; Hammond et al., 2007).

* Corresponding author. Tel.: +61 3 9545 2376.
E-mail address: magnus.moglia@csiro.au (M. Moglia).

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In recognition of the benefits of rainwater harvesting systems, there has been a dramatic adoption rate of residential rainwater harvesting systems in Australian cities over the last decade. Fig. 1 shows that by 2013, 31% of households in Melbourne had a rainwater harvesting system (Australian Bureau of Statistics, 2013). Similar rates of adoption are also reported in Adelaide, Sydney, and Brisbane.

In Melbourne, the installation of residential rainwater harvesting systems was encouraged by government rebates (Gato-Trinidad and Gan, 2014) and the five-star home regulation for new constructions that was introduced by the Victorian government in 2005. This regulation requires that in addition to a range of water and energy efficiency measures, all new homes must be provided with either a solar hot water heater or a rainwater harvesting systems of at least 2 kL connected to a toilet (Moglia et al., 2015a, 2015b). Water planners have supported rainwater harvesting systems to a large extent on the basis of theoretical estimates of yield but it is now recognised that there is a discrepancy between theoretical and practical performance. As such there is a need for evaluation of yield performance in practice (Cook et al., 2014).

There is a growing body of evidence to suggest that many tanks are not fully functional and that maintenance efforts are often lacking (Moglia et al., 2011, 2012, 2013, 2015a, 2015b). This is complimented by a growing body of research into understanding householders' often limited willingness to maintain their rainwater harvesting systems (Mankad et al., 2013; Mankad and Greenhill, 2014; Tapsuwan et al., 2015).

Rainwater harvesting systems may fail due to the malfunctioning of the components of the system (Moglia et al., 2014). The components include but are not limited to: the catchment (i.e. roof, gutters, downpipes and auxiliary devices such as strainers and first flush devices), the tank itself, and the tank foundation to safely hold up a significant amount of weight, the tank overflow system, the pump, and the pump switches. There is, however, a notable knowledge and data gap in relation to how often different types of failures occur and what their consequences are.

To address the above mentioned data gap, this paper reports on a rainwater harvesting system inspection survey and householder questionnaire which provides data on the condition of rainwater harvesting systems and householders' self-reported situation, behaviour, and attitudes. This data is analysed using a statistical approach in order to understand underlying factors and influences and should provide general insights into appropriate measures to improve the management of rainwater tanks, applicable widely around the world.

2. Methodology for data collection

A total of 417 sites were inspected between February 2013 and August 2014. The inspection covered residential rainwater harvesting systems, including connected roof area, pumps, pump switching devices, filters, and other appurtenances. In addition, owners of rainwater harvesting system were surveyed in regard to their attitudes and behaviours towards maintenance of their systems.

A number of methods to recruit participants were adopted. Recruitment included offering participants a free rainwater harvesting system inspection and condition report, and a modest financial incentive of $20. Recruitment methods included:

- Door knocking in selected suburbs. This was a time-consuming method with a low recruitment rate as many residents were either not at home or they did not have a harvesting system.
- Pamphlets distributed in target suburbs. This was also a time consuming method with a low recruitment rate of around 3% and 5% of the number of pamphlets distributed. Pamphlets were dropped in all homes as it was not known which properties had tanks. Assuming one third of the addresses in the area had a rainwater harvesting system, this translates to a participation rate of around 10–15% of tank owners.
- Advertisements were placed in various newsletters including those published by local councils and community groups. Whilst a relatively successful method in terms of numbers, a recruitment rate could not be determined.
- Water retailers provided the email addresses of people who had claimed a Government rebate for a rainwater harvesting system. This method had a variable recruitment rate of between 20% and 40% of households emailed in the different email batches.
- Word of mouth. Those who had participated in the survey were encouraged to let others know of the call for survey participants.

Once the participants had been recruited, each site was visited by a trained CSIRO researcher. During site inspections, participant's engagement was undertaken in a respectful and ethical manner in line with the protocols approved by the CSIRO ethics board. The following data collection activities were undertaken during site inspection:

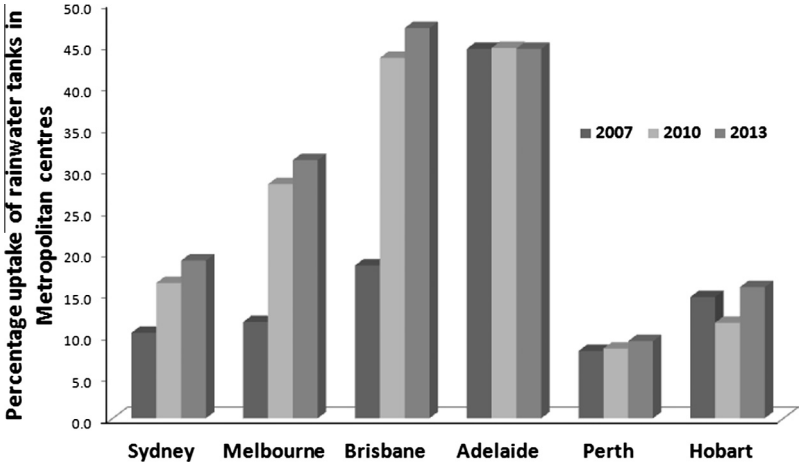

Fig. 1. Uptake of rainwater harvesting systems in Australian cities 2007–2013. Data from Australian Bureau of Statistics (2013).