GREYWATER REUSE IN A SEWERED AREA: DESIGN AND IMPLEMENTATION AT RESEARCH HOUSE

Ben Kele, Peter Wolfs, Ian Tomlinson, Barry Hood and David J. Midmore
Central Queensland University

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Abstract

In Queensland, the *Plumbing and Drainage Act* (2002) is being amended to allow greywater reuse in sewered areas. The greywater must be treated and applied in a safe manner for both public and environmental health. The Queensland State Government has built, in Rockhampton, a Research House as part of their 'Towards Healthy and Sustainable Housing Research Project'. Research House was built using water-efficient infrastructure and has two rainwater tanks (total capacity 7 kL). The Central Queensland University (CQU) was asked to design a greywater treatment and reuse system for the House. The proposed design incorporates a backflow prevention device on the water mains entry to the house. The harvested stormwater from the rainwater tanks will provide water for the hot-water system and laundry. This will reduce the amount of potable mains water required by the house and potentially provide softer water that should reduce the scaling in the hot-water system and require lower doses of detergents. The greywater from the laundry, shower, and vanity unit will be collected and primary treated in a deep vertical greasetrap. The primary treatment tank will have an overflow to the sewer. The primary treated greywater will be filtered and then used for sub-surface irrigation. Research House has an established monitoring program that will be adapted to record the volumes of harvested stormwater and greywater reuse. Water quality parameters will be examined on a monthly basis. The proposed stormwater reuse and greywater treatment and reuse plan is expected to reduce the amount of reticulated mains-supplied water used by Research House by approximately 45%.

Keywords

Backflow prevention, Plumbing and Drainage Act 2002, Queensland Greywater Reuse Legislation, stormwater reuse, rainwater tanks, water efficiency

1 Introduction

Research House was built as part of the Queensland Government Smart Housing initiative. It has been designed to be socially sustainable (safe and secure for people), environmentally sustainable (resource efficient in water, waste, and energy), and economically sustainable (cost-efficient over-time) (QG 2004). Research House has been constructed using water-efficient infrastructure. Currently, no wastewater reuse exists at the site due to legal restrictions. The aim of the project is to upgrade the existing stormwater system and design a greywater treatment and reuse technology for Research House. Research House is used by the Queensland Department of Housing as a rental public housing dwelling. In Australia, much of the legislation related to the recycling of water has been updated or is in the process of being revised. The increasing scarcity of water has reduced some of the old prohibitions on the recycling of wastewater, particularly greywater. National standards have been modernised and the corresponding state and local government legislation have been restructured to compliment these changes (Jackson 2004). The 2002 *Plumbing and Drainage Act* currently prohibits the reuse of wastewater in sewered areas (LGP 2002). In Queensland, the relevant legislation is currently being amended to allow treated greywater reuse (excluding kitchen) in sewered areas (LGP 2004). The kitchen greywater must be excluded due to fats, oils, and other associated solids. The Rockhampton City Council allows rainwater tanks, though they must comply with the 1996 Health Regulation, and be mosquito proof. Additional council by-laws state that rainwater tanks may not be directly connected to the mains water supply and a licensed plumber must make all connections to a household.

2 Rainwater tanks and stormwater reuse

There are two plastic rainwater tanks installed at Research House with a combined capacity of 7000 L (5000 L and 2000 L tanks). The stormwater harvested from the colour bond roof is currently used by the tenants for garden irrigation (QG 2004). No mechanism is presently installed that enables the determination of the total volume of rainwater collected and used each year. The present situation relies on the householder deciding to use the rainwater for irrigation. This may not result in the most efficient use of this water supply. An automatic system that uses stormwater for non-potable requirements within the dwelling may assist in maximising the utilisation of this resource. Sustainable building developments in Australia are using rainwater for many household tasks such as hot water production, toilet flushing, and laundry washing. To ensure continuity of supply, the rainwater tanks would need a low-level feed from the reticulated water supply. The low-water feed would require a backflow prevention device to comply with Rockhampton City Council by-laws. The harvested stormwater in the rainwater tanks at Research House has not been treated to reduce the presence of microorganisms. A series of tests was undertaken to establish the numbers of microorganisms in the rainwater tanks at Research House. A one-litre sample was taken from each rainwater tank. Prior to the sample being taken, ten litres of water was run through the tap to ensure that a representative sample of water within the tank was collected. Standard methods were used for the determination of heterotrophic organisms, thermotolerant coliforms, total coliforms, and faecal enterococci (see Table 1) (AS(a) 2000; AS(b) 2000; AS(c) 2000; AS(d) 2000). Tests to determine the electrical conductivity (EC), pH, dissolved oxygen (DO), and temperature were also conducted (see Table 2).

Table 1. Results from Microbiological Examination of the Rainwater from Research House

Test	5000 L Rainwater Tank	2000 L Rainwater Tank
Heterotrophic organisms / 1 mL	<80	<80
Thermotolerant coliforms / 100 mL	650	9300
Total coliforms / 100 mL	9200	9250
Faecal enterococci / 100 mL	300	2900

The results in Table 1 show that both rainwater tanks had substantial numbers of colony forming units of potentially pathogenic bacteria. It is important to note that these bacteria may not be pathogenic to humans but could have come from environmental sources such as birds, frogs, and small mammals. It is expected that the temperatures inside a hot water system would eliminate most of these bacteria. Alternatively an ultra-violet (UV) light could be installed in association with the tank, as a treatment system to reduce the numbers of bacteria, as done at the Healthy Home at the Gold Coast (Gardner *et al.* 2002).

Table 2. Results from Water Quality Examination of the Rainwater from Research House

Test	5000 L Rainwater Tank	2000 L Rainwater Tank
pH	4.15	4.55
Electrical Conductivity (EC) μS/cm	20.5	23.3
Temperature °C	18.4	18.2
Dissolved Oxygen (DO) mg/L	4.68	4.58

The harvested stormwater is acidic, and both tanks have similar temperatures and concentrations of DO. The EC of the two rainwater tanks is very low compared to the reticulated water supply of 460 μS/cm. The relatively low salinity of the harvested stormwater makes it ideal for sustainable soil application. The most efficient application of the harvested stormwater at Research House would involve reuse of the water at least twice. If the rainwater were used to flush toilets, it would be classed as blackwater and disposed of to sewer, only allowing it to be reused once on the property. Research House uses approximately 115 L of water per day in toilet flushing (QG 2004). If stormwater were used for toilet flushing, a maximum of 10% of the total reticulated mains water-usage would be saved (QG 2004). The main benefit of using the stormwater for toilet flushing instead of in the hot water system is the reduced risk of human consumption of the water. Some reports have stated that the stormwater used in hot water systems may harbour increased levels of heavy metals, in particular copper and lead at unsafe concentrations for drinking (Coombes *et al* 2000). Recent research has shown that hot water systems do have the ability to concentrate contaminants, such as heavy metals, through normal operating processes, and that this occurs regardless of the source of water (reticulated, stormwater, or groundwater) (Spinks *et al* 2003). Harvested stormwater stored in rainwater tanks does not appear to have any increased risk over other types of water for use in hot water systems in relation to heavy metals (Spinks *et al* 2003). Research House has used an average on 129 L per day or 47 085 L per year of hot water (QG 2004). The majority of the hot water is used in the shower, bath, and laundry. The wastewater generated from these processes is classified as greywater. The laundry used an average of 75 L per day or 27 375 L per year (combined hot and cold water). All wastewater produced is greywater and generated either from the laundry sink or washing machine. If rainwater tanks were used to supply the water requirements for the hot water systems and laundry use there would be the following benefits:

1. The system is automated and requires no input from the householder for the harvested stormwater to be used;
2. Approximately 75 000 L of mains supplied water saved if sufficient harvested stormwater is available;
3. Water can be used twice as the greywater produced can be treated and applied for garden irrigation;
4. Increased operating life for the hot water system as rainwater has smaller concentrations of calcium carbonates that may cause damage through scaling;
5. The heating process of the hot water system should inhibit and/or kill potential pathogens in the rainwater, thus reducing the public health risk;
6. Smaller amounts of laundry chemicals required due to the smaller concentrations of calcium carbonates. This produces a saving for the householder and a greywater with a reduced chemical pollutant load;

7. Chemical components of laundry cleaning chemicals should inhibit and/or kill potential pathogens in the rainwater, reducing the public health risk; and
8. Greywater produced with harvested stormwater as a major component, is preferred for irrigation as it has a lower concentration than mains supplied water of residual chlorine that adversely affects soil and plant health.

3 Greywater treatment

The aim of the project was to treat separate the greywater from the blackwater (and kitchen greywater) and to reuse the treated greywater for garden irrigation. Research House was built on a flat-slab foundation. The pipework for the house is contained within the flat-slab foundation; this is a common technique with many modern buildings. Unfortunately, the kitchen sink is connected to the main greywater plumbing line. The kitchen sink connection is difficult and costly to remove due to the construction technique used. The feasibility of installing a separate line for the kitchen sink is currently under examination. If it has to flow through the main plumbing line the amount of greywater available for reuse will be decreased by over 50%. In this situation it would save more reticulated water and be more cost-efficient if the harvested stormwater were used in the laundry and to flush toilets. This point is important as it shows that even many modern buildings may have difficulty in being retro-fitted to comply with the new greywater reuse laws. However, assuming all the greywater, bar the kitchen, were available for reuse it would be piped into a primary treatment tank. The type of primary treatment tank selected will also act as a vertical greasetrap (see Figure 1).

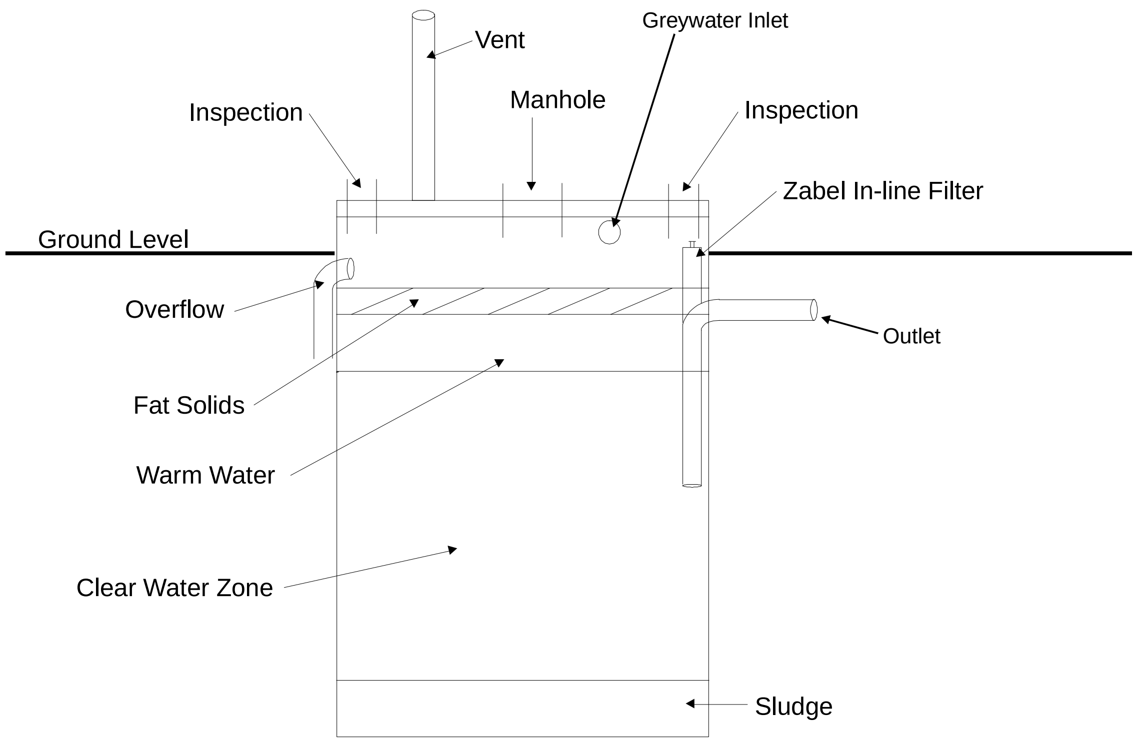

Figure 1. Greywater treatment tank

The aim of the primary treatment tank is to reduce solids and the numbers of potential microbiological pathogens, and to provide suitable conditions for nutrient transformations.

The primary treated greywater will enter the pump-well (see Figure 2). The greywater pump-well will have a working capacity of 40 L. The maximum volume of treated greywater during each pump cycle will be 40 L. The pump will require an electrical connection and the pump-well will require de-sludging. A venturi valve attached to the pump-line will aerate the greywater. Aeration improves the quality of the greywater and enables the irrigated plants greater resistance to potentially limiting factors, such as salinity (Bhattarai *et al.* 2005). If aerated water is delivered directly to the root systems, recent research has found that plants have an increased tolerance to the phytotoxic impacts of salinity (Bhattarai *et al.* 2005). The venturi valve will cost $75, requires no power connections, and will have an expected serviceable life of 15 years. The pump-well and components will cost about $800 to purchase and install.

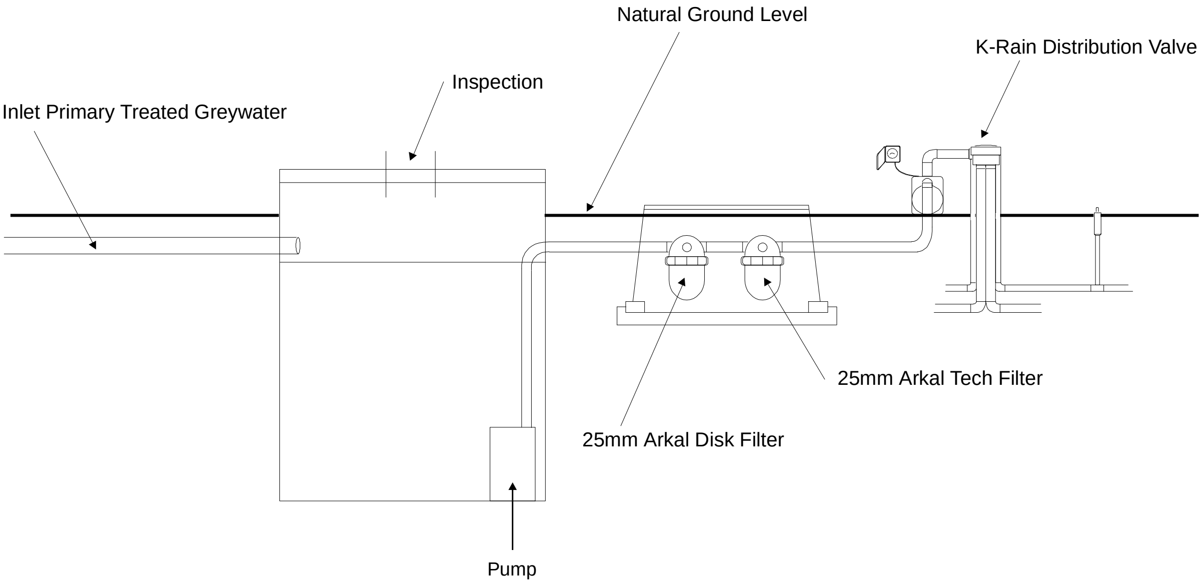

Figure 2. Greywater pumpwell, disc filters, and K-rain valve

Two Netafim filters will be installed, a 25 mm Arkal Disk Filter and 25 mm Arkal Tech Filter.

1. 25 mm Arkal Disc Filter
    - 120 mesh (130 micron) filter that removes suspended solids from the greywater
    - The filter is comprised of a red cartridge that can be removed and replaced
2. 25 mm Arkal Tech Filter
    - Releases a chemical called Triflurex that inhibits root growth
    - Prevents root intrusion from damaging the drippers in the sub-surface line
    - Requires the filter cartridge to be replaced every two years ($79)

The over-application of effluent to soils is a common mistake in water reuse projects (Beal *et al.* 2003; Bond 1998 Gardner *et al.* 1997). Soil infiltrates effluent in a more sustainable manner if the wastewater is applied intermittently (Bond 1998). The K-Rain valve is a sequencing device that will split the treated greywater into three distinct irrigation areas. Every time the pump is triggered the K-Rain valve moves to the next irrigation area in a clockwise sequence. Each area will be irrigated in turn and will receive a maximum of 40 L of recycled water per pump cycle. This should prevent any one section of the yard from being over-irrigated. The K-rain valve will cost $135 dollars plus installation labour.

4 Greywater reuse

The data collected show that the house uses, on average, approximately 420 kL of reticulated supplied water per year. Just over half of this water (between 51% and 55%) has been used to irrigate the yard (QG 2004). The householders who generated this data have changed dwellings and new tenants are expected in early 2005. New occupants will result in changed wastewater generation patterns and volumes. It is unknown whether the same number of people will be in Research House and what impact their lifestyle will have on wastewater generation.

Netafim sub-surface drip irrigation equipment is suitable for use with recycled water. Three dispersal irrigation zones are proposed for Research House. The irrigation pipes will be purple and uniform dispersal is maintained through a series of distribution valves. The soil at Research House is a clay loam and it is recommended that the dispersal rate is 35 mm/week, with an area of 0.285 m required per L/day. Drippers should have 250 mm spacing and drip lines placed 570 mm apart (WS/13/1 2000). The Netafim start up kit costs $680 and covers the filters and one of the designated irrigation areas. The irrigation line for the two additional irrigation areas will cost an additional $400. A small mechanical ditch-digger will be required. Installation labour is estimated at $800, equipment hire $200.

Greywater reuse provides a source of irrigation water for plants that is generally poor in nutrients when compared to the other types of domestic wastewater such as blackwater or all-waste (Zeeman *et al.* 2000). It is important to maintain a garden fertilizer application program, especially for trace elements, and not mistakenly believe that the wastewater reuse will provide all the plants nutrient needs.

5 Water efficiencies

All water use volumes are based on the wastewater generation patterns of the previous occupants of Research House. The proposed stormwater reuse, greywater treatment and reuse system will be operating with new tenants who may have different wastewater generation volumes and patterns. The water-use efficiency savings examined in this section will deal with approximate values and percentages rather than exact historical volumes due to the expected, but unquantifiable, upcoming changes. If the harvested stormwater were to supply the entire laundry and hot water requirements (approximately 200 L/day) of the Research House, this would reduce the total mains water used by around 16% (QG 2004). If we assume that roughly a third of water used from the rainwater tanks comes from the potable supply through the low-water feed then we can assume an approximate saving of 10% or 130 L/day or 47 450 L/year. It is important to note that all the water, harvested stormwater and low-water feed potable water, that is used in the laundry and hot water system will enter the greywater treatment tank and become available for reuse (excluding spillage). In addition to the greywater produced through the laundry and hot-water system, wastewater suitable for reuse will also be produced through the cold water taps in the shower, bath, and vanity hand-basins. On average 145 L/day or 52 925 L/year (12% of total potable water use) of greywater is generated via these sources (QG 2004). Research House has been producing approximately 100 000 L of greywater suitable for treatment and reuse per year (QG 2004). An assumption is made that 5% of this water becomes spillage, such as residue in wet laundry or transferred to towels, and does enter the liquid waste-stream. This leaves 95 000 L of greywater available for treatment. Hydraulic surges, extended wet weather impacts and maintenance issues may potentially cause 10% of the greywater that enters the primary treatment tank to exit via the overflow and be disposed of to sewer. This would leave roughly 85 000 L of greywater available for garden irrigation, reducing the volume of potable water used to irrigate the garden currently by approximately 36% and the total potable water use by about 20%. The sub-surface irrigation system is more water efficient than the current aboveground sprinkler irrigation (Oron *et al.* 1991). A conservative estimate is that sub-surface drip irrigation would save approximately 25% (160 L/day) of the water currently used for garden irrigation.

In summary:

1. Harvested stormwater saves approximately 10% of total reticulated water use;
2. Greywater reuse saves approximately 20% of total reticulated water use; and
3. Sub-surface drip irrigation saves approximately 15% of total reticulated water use

The combined stormwater and greywater reuse systems should be able to reduce the total water consumption by approximately 45% (190 000L/year using historical data).

6 Conclusion

The proposed system can save approximately 45% of the potable water currently used at Research House. It will cost about $6000 to install, excluding the retrofit on the existing plumbing pipework, and about $300 per year to maintain. The system, excluding electrical and consumable components, will have a minimum serviceable life of 15 years. During the serviceable life of the system a volume of water in the order of 2 850 kL of water may be saved. The system should prove to be a sustainable on-site water treatment and recycling technology. With the cost of water likely to increase and a possible decrease in the availability of water, due to climate change and growing populations, the system should be economically viable in the long-term, especially if the value of the irrigated landscape is added to worth of the dwelling.

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References

AS(a) (2000). Australian Standard 4276.3.1, Water microbiology - heterotrophic colony count methods - pour plate method using plate count agar.

AS(b) (2000). Australian Standard 4276.4 Water Microbiology - Coliforms.

AS(c) (2000). Australian Standard 4276.6 Water Microbiology - Thermotolerant Coliforms and *Escherichia coli*.

AS(d) (2000). Australian Standard 4276.8 Water Microbiology - Faecal *Streptococci*.

Beal, C., T. Gardner, A. Vieritz and N. Menzies (2003). Can We Predict Failure of Septic Tank Absorption Trenches? A Review of Their Hydrology and Biogeochemistry. On-Site '03, University of New England Armidale, Lanfax Laboratories.

Bhattarai, S. P., Su, Ninghu and Midmore, D.J. (2005). Oxygation unlocks yield potentials of crops in oxygen-limited soil environments. Advances in Agronomy 88: (In Press)

Bond, W. J. (1998). "Effluent Irrigation - an Environmental Challenge for Soil Science." *Australian*

Journal of Soil Research **36**: 543-555.

Coombes, P. J., G. Kuczera, J. D. Kalma and H. R. Dunstan (2000). Rainwater Quality from Roof, Tanks and Hot Water Systems at Figtree Place. International Hydrology and Water Resources Symposium, Perth, Institute of Engineers Australia.

Gardner, E. A., P. M. Geary and I. J. Gordon (1997). "Ecological Sustainability and On-Site Effluent Treatment Systems." *Australian Journal of Environmental Management* **4**(2): 144-146.

Gardner, T., R. Hyde, G. Millar and A. Vieritz (2002). The Healthy Home: A Step Towards Greening Paradise. 4th Queensland Environmental Engineering Conference, Brisbane, Environmental Engineering Society.

Jackson, G. (2004). Public Consultation Draft- Queensland Guidelines for the Safe Use of Recycled Water. Brisbane, Queensland Environmental Protection Agency**:** 1-127.

LGP (2002). Plumbing and Drainage Act 2002. Brisbane, Department of Local Government, Planning Sport and Recreation - Building Codes Queensland.

LGP (2004). Proposed changes to plumbing laws to allow greywater use in sewered areas. P. Beavers. Brisbane, Brisbane, Department of Local Government, Planning, Sport and Recreation - Building Codes Queensland.

Oron, G., Y. DeMalach, Z. Hoffman, Y. Keren, H. Hartman and N. Plazner (1991). "Wastewater Disposal by Sub-Surface Trickle Irrigation." *Water, Science and Technology* **23**(Kyoto): 2149-2158.

QG (2004). Annual Water Use Study Report December 2002-November 2003. Brisbane, Queensland Government; Queensland Department of Public Works and Queensland Department of Housing.

Spinks, A., P. J. Coombes, H. R. Dunstan and G. Kuczera (2003). Thermal Destruction Analyses of Water Related Bacteria in A Rainwater Medium at Domestic Hot Water System Temperatures. 28th International Hydrology and Water Resources Symposium, Wollongong.

WS/13/1, J. S. A. S. N. Z. T. C. (2000). Australia/New Zealand Standard On-site Domestic-Wastewater Management (AS/NZS 1547:2000). Australia/New Zealand, Joint Australian/New Zealand Standard**:** 1-170.

Zeeman, G., W. Sanders and G. Lettinga (2000). "Feasibility of the On-Site Treatment of Sewage and Swill in Large Buildings." *Water Science and Technology* **41**(1): 9-16.