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Article

Feasibility of Recycling Grey-water in Multi-Storey Buildings in Melbourne

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Abstract: The Australian government has been promoting water conservation and recycling through active campaigns and through offering incentives/grants for water saving ideas/innovations. One of several water conserving techniques is on-site grey-water recycling for non-drinking purposes. However, there is a general reluctance to adopt on-site grey-water recycling measures. One of the reasons behind this reluctance is lack of awareness of the shortness of payback period for initial investment through potable water savings. In this study, the feasibility of grey-water recycling in multi-storey buildings in Melbourne was analysed and discussed. The study confirmed the significant potential for reducing the water demand and the benefits that the Melbourne population and water authorities can gain through adopting simple water conservation practices and greywater recycling in multi-story buildings. In such buildings, the available grey-water can significantly exceed the demand, which suggests that grey-water collection from some floors would be enough to meet the demand of all the floors in a building. The discussion was extended to proposing unique greywater recycling schemes for Melbourne, involving partial grey-water recycling from the higher floors of multi-storey buildings, and locating greywater treatment systems on the roofs of buildings. Finally, the effect of the number of floors on cost recovery periods was investigated, and the effect of using water conserving devices in combination with greywater recycling on cost recovery periods was assessed.

Keywords: Potable water, water conservation; on-site greywater recycling; multi-story buildings and cost recovery period

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1. Introduction

With increasing population and changing climate regime, water supply systems in many cities of the world are under stress. In Australia, water demand is increasing day by day but resources of fresh water are limited. At times, water shortage in Australia become crucial due to lack of rainfall and high evaporation, and the situation got worse by climate change effects and changes in the El Nino-Southern Oscillation pattern (Jefferson et al., 1999). To tackle this problem, water authorities are adopting several measures including demand management and identifying alternative water sources such as stormwater harvesting, greywater and wastewater reuse and desalination. Among all the alternative water sources, stormwater harvesting perhaps has received the most attention. In Australia, federal, state and local government authorities have been promoting stormwater harvesting through campaigns, as well as offering financial incentives and grants to promote water saving ideas and innovations (Imteaz et al., 2011). However, to date the option of greywater recycling has not got much attention, mainly due to initial cost, users' acceptance due to safety concern and lack of knowledge regarding actual payback period. To enhance the sustainability features of modern buildings, current construction practices aim to minimize the use of natural resources (i.e. water), energy, as well as minimum emissions of wastewater and greenhouse gases.

Melbourne is the second largest city of Australia, having a population of 4.1 million with latest annual population growth rate of 1.6% (DPCE, 2012). On the other hand, during 2005-06 Melbourne's residents were consuming potable water at a rate of 330 l/c/d (WSAA, 2007), which places Melbournians as one of the highest water users worldwide. Melbourne's water supply is mainly based on surface storages (reservoirs) feed from rainfalls from contributing catchments. According to Melbourne Water, even with a medium impact of climate change, average annual inflow into Melbourne's storages is expected to reduce by 7% and 18% by the year 2020 and 2050 respectively (Howe et al., 2005). To avoid an acute water stress and to reduce potable water consumption, the Victorian Government has set a target of 20 percent water recycling by 2020. The City of Melbourne plans to reduce water consumption in the municipality by 12 percent (compared to usage in 1999) by 2020, although during this time the residential population will increase by 41 percent. The authorities have been promoting different types of water recycling options. For a single house, implementation of greywater recycling may not be feasible, due to high initial cost and low uses of greywater. However, due to increasing population and subsequent housing demand, most of the cities in the world adopting construction of multi-storey buildings for housing purpose. For the multi-storey buildings, as the greywater generation will be higher, a centralized treatment system may be feasible in many cases. To avoid high treatment costs, many studies suggest using greywater for non-potable purposes (i.e. toilet flushing and garden irrigation). Also, as the composition of greywater is different to domestic wastewater in terms of organics, nutrients and microbiological contamination; the required level of treatment to use it for toilet flushing and garden irrigation is not high (Eriksson et al., 2002).

Categories of water usage in multi-storey buildings comprise drinking water (including kitchen use); fire sprinkler testing; toilet flushing; showering; garden watering; and cooling. This suggests that water consumption in this type of building has the potential to be reduced by 90 to 95 percent, if mains water was only supplied for use in its kitchens. Many studies have demonstrated the technical, economic and environmental benefits of reducing water demand through greywater recycling for flushing toilets and irrigation in residential dwellings (Friedler and Hadari, 2006; Wong and Mui, 2007; Cheng, 2003; Nolde, 2000; Surendran and Wheatley, 1998). Most multi-storey residential buildings in Australia typically have no green areas that require watering. Therefore, only a fraction of available greywater requires recycling for flushing toilets. Also, installations of different water conserving devices will reduce residential water consumption. Shanableh et al. (2012) developed a primary framework for installing water conserving devices, as well as using greywater recycling for the purpose of toilet flushing in multi-storey buildings in UAE. Such a framework is yet to be developed in Australia. This paper presents a feasibility study of installing water conserving devices and using greywater recycling in multi-storey residential buildings in Melbourne, which can form a preliminary framework for such usage in Australia.

2. Methodology and Data

2.1. Methodology

Water demand and usage data was collected from Melbourne Water. Costs of different types of water conserving devices were collected from local suppliers. Amounts of expected water savings from each of those devices were assessed and converted to expected costs savings in yearly basis. For greywater recycling, as only a fraction of available greywater requires recycling for flushing toilets, first of all evaluation was performed to determine number of floors requires for greywater collection to serve the reuse needs of whole building. A membrane biological reactor (MBR) system was considered for the treatment of greywater before recycling. Initial and maintenance costs of such system were collected from local supplier. Costs of domestic water supply and sewerage disposals were also collected from local water authorities. Eventually, payback periods were calculated for varying number of floors considering three options: i) using water conserving devices only, ii) using greywater recycling only, and iii) using both water conserving devices and greywater recycling.

The payback period for the water conserving devices was calculated using following equation:

$$PP_{WC} = \frac{TAC}{AS} \tag{1}$$

where, PP_{WC} is the payback period for water conserving devices, TAC is the total additional initial cost for having water efficient devices (difference between cost of water efficient devices and cost of traditional devices) and AS is the annual saving.

$$PP_{GR} = \frac{TC}{AS - AC} \tag{2}$$

where, PP_{GR} is the payback period for greywater treatment system, TC is the total initial cost, AS is the annual saving and AC is the annual maintenance/operational costs. All the costs and savings are in Australian dollars. To keep it simple, net present values of the future costs were not considered. This simplification is expected to be compensated through future increases of water and sewerage charges, which were not either considered in this study. In all the calculations it was considered that each floor will have six units and in each unit there are four occupants.

2.2. Data

Table 1 shows the breakdown of Melbourne's residential water usage collected from Melbourne Water (2012). The table also shows the amount of consumption per unit considering an average consumption of 277 liters/capita/day for Melbourne (Melbourne Water, 2012). As garden irrigation using greywater was not considered in this study, this item is not considered in the calculation. Based on approximate 2012 rates of water in Melbourne, a water charge of A$2.0 per kL and sewerage disposal charge of A$1.60 per kL was considered.

Table 1. Breakdown of Melbourne's residential water usage

Item	Minimum quality required	Wastewater generated	Water use (%)	Water use per unit (L/day)
Toilet	Grey	Black	19	210.5
Bathroom Basin	Fresh	Grey	30	332.4
Kitchen	Fresh	Black	10	110.8
Dishwasher	Fresh	Black	5	55.4
Laundry	Fresh	Grey	16	177.3
Garden	Grey	None	20	221.6

Using water conserving devices is a logical and quite feasible option for reducing residential water demand. Water conservation is easily achievable; however the level of awareness as well as the cost and convenience of conservation determine the level of community participation. Example water conservation measures that can practically be implemented in Melbourne homes are listed in Table 2 (EnviroWise, 2011). Table 2 also shows the costs of different items (normal item and efficient item) and their water savings potentials.

It is found that the daily greywater generation per unit is approximately 510 L, whereas daily greywater needs for toilet flushing is 210.5 L. As such, less than half of the generated greywater is required to be recycled. To reduce system's installation and maintenance cost, i.e. to achieve an optimum design of grey-water treatment system, number of floors required for the collection of greywater system to fulfill the intended demand was determined. Figure 1 shows the relationship between total number of floors in the building and number of floors require to supply expected greywater demand.

Table 2. Costs and water savings potentials of different items

Water use sector	Efficient item	Normal item cost ($)	Efficient item cost ($)	Water savings (%)	Water savings per unit (L/day)
Toilet	Dual flash	200	400	50	105
Bathroom	Flow restrictor	20	50	40	133
Kitchen	Flow restrictor	20	50	40	44
Dishwasher	Efficient dishwasher	500	800	30	17
Laundry	Efficient washing machine	400	800	50	89

Figure 1. Relationship between total no. of floors and no. of floors require to supply greywater demand

3. Analysis and Results

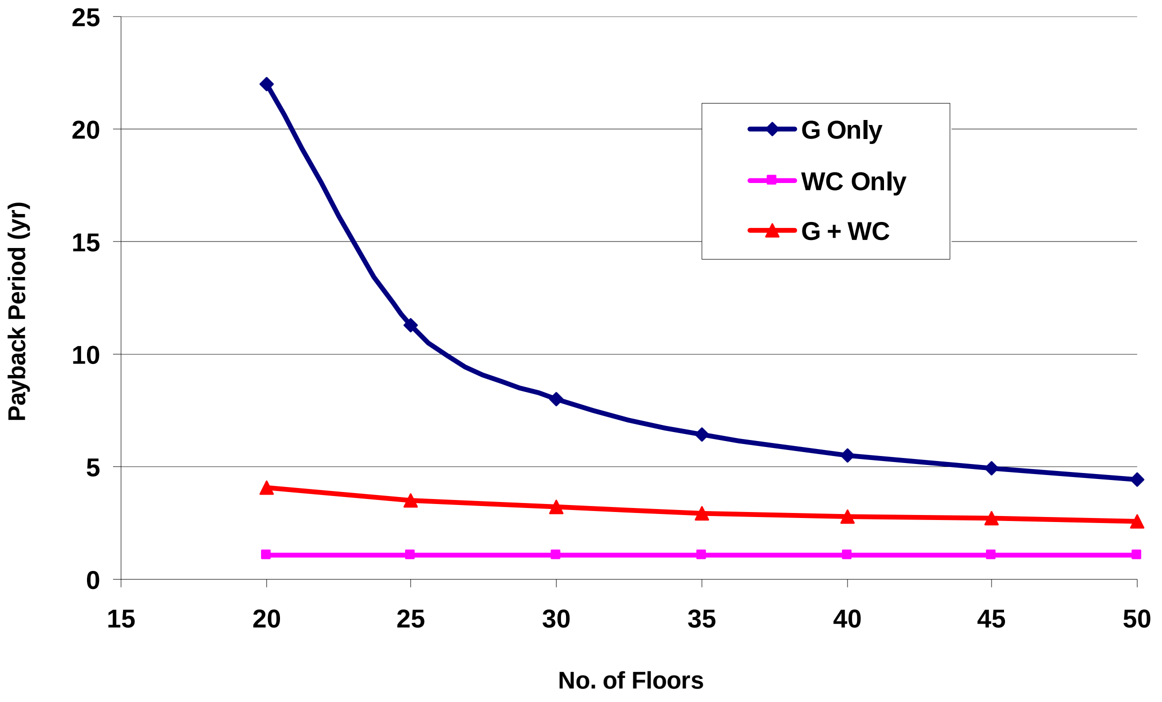
3.1. Water Conservation Only

Considering only installations of water conserving devices, using data presented in Table 2, analysis was performed to calculate payback period for the water conserving devices. It is to be noted that for the calculation of costs in this case, not the actual costs of water efficient devices were considered. Rather additional costs of these devices were considered, as without these devices traditional items will be used anyway. Such additional total cost per floor for the listed water efficient devices was calculated. Total amount of water saving per floor and the cost of that saving in a year was calculated. Then payback period was calculated using Equation 1. It is found that payback period for the water efficient devices would be only 1.9 years. This payback period will not vary with the variations of number of floors in the building.

3.2. Greywater Recycling Only

For the greywater recycling scheme, a primary treatment of greywater is required before it should be recycled. Membrane Biological Reactor (MBR) treatment system is widely used treatment facility for this purpose. Details of MBR system's capital, maintenance and operational costs were collected from Hai and Yamamoto (2011). For a building with 20 floors, a total installation costs is $163,000 and maintenance cost per year is $4,300. Considering all the capital and operational costs as well as expected water savings, payback periods were calculated using Equation 2 for different number of floors. It was found that due to high initial cost of the system, greywater recycling system would not be feasible for buildings less than 18 floors. For a 20 storey building, the payback period is 22 years and decreases sharply with the increase of number of floors. However, for very high number of floors (> 40), an increase in number of floors does not provide a significant decrease in payback period. Also, it is found that for a floor number of 30, a significantly low payback period of 8 years is achievable. Figure 2 shows the relationship of return periods with number of floors for greywater recycling scheme as well as other schemes.

Figure 2. Relationships between total no. of floors and payback periods for different options



3.3. Both Water Conservation and Greywater Recycling

Finally the option of having both the greywater recycling and water conservation was investigated. For this option, all the previous data and assumptions remained same. Total costs of greywater treatment installation & maintenance and water conservation were calculated. Then total cost per floor was evaluated. Total water savings per floor from the combined systems were also calculated. Then payback period was calculated using Equation 1. It is found that the combined implementation of greywater recycling and water conserving devices is very feasible for multi-storey buildings. For a 20 storey building, a payback period of only 4.1 years is achievable and for higher number of floors it drops down to 2.8 years.

4. Conclusions

With increasing population water demand is increasing day by day, but resources of fresh water are limited. In addition, with the impacts of climate change, water supply systems in many cities of the world are under stress. Among several possible water conservation and recycle schemes, implementation of greywater recycling is scarce. The main reasons behind this are treatment requirement, people’s perception, high initial cost and ignorance about payback period. This study presented feasibility and payback period analysis of greywater recycling for multi-storey buildings in Melbourne.

It is found that payback period for implementing water efficient devices would be only 1.9 years, which is very significant in terms of feasibility. This payback period will not vary with the variations of number of floors in the building. For only greywater recycling system, it was found that due to high initial cost of the system, it would not be feasible for buildings less than 18 floors. For a 20 storey building, the payback period for implementing greywater recycling is 22 years and decreases sharply with the increase of number of floors. However, for very high number of floors (> 40), an increase in number of floors does not provide a significant decrease in payback period. Also, it is found that for a floor number of 30, a significantly low payback period of 8 years is achievable. Also, it is found that the combined implementation of greywater recycling and water conserving devices is very feasible for multi-storey buildings. For a 20 storey building, a payback period of only 4.1 years is achievable and for higher number of floors it drops down to 2.8 years.

The above-mentioned results will vary among the cities/countries depending on the costs of water, power, water-efficient appliances/fixtures and treatment system as well as maintenance costs. However, this study provides a general insight of looking greywater recycling in a positive way. Moreover, the benefits of water conservation and greywater recycling extend beyond the consumers to the concerned water authorities and the environment.

In this study, partial greywater recycling is proposed to reduce the costs of pumping and installation as the demand for greywater is usually less than the potentially available greywater. In multi-storey buildings, partial recycling can be achieved by collecting greywater from the higher floors to serve the needs of the whole building. Furthermore, it is proposed that greywater treatment systems be located on the roofs of multi-storey buildings to reduce the need for indoor space and the need for extra odor control systems.

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