HOW EFFEICIENT IS ON-SITE WATER REUSE AS A WATER MANGEMENT OPTION

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ABSTRACT

Sustainable management of freshwater resources has become a focus of the planning process to ensure future development in many urban areas is possible in New Zealand. Where water resources are in, or predicted to be in short supply, a holistic approach towards water management is required to provide efficient water management, rather than tackling water use and management options in a fragmented way. Several councils in New Zealand are already choosing water recycling and reuse in urban areas above water conservation measures with inadequate assessment of whether this is the most efficient water management option. This study compares the annual net present value (NPV) over a 20-year period for three water reuse systems which require different levels of treatment and therefore have different costs. It determines the level of water usage which would be needed to achieve a payback period in five years for the lowest cost treatment system and concludes that water conservation is important to effect a change in behaviour is required to effectively manage water.

KEYWORDS

water, reuse, greywater, conservation, domestic

1 INTRODUCTION

Sustainable management of freshwater resources is a focus of the planning process to ensure future development in many urban areas is possible in New Zealand. Where water resources are in, or predicted to be in short supply, a holistic approach towards water management is required to provide efficient water management, rather than tackling water use and management options in a fragmented way. Increased urban development and potential water shortages in areas predicted to become drier under climate change have increased the need to improve management of water.

In some urban areas, on-site reuse of greywater is one option which several councils are considering for water demand management. However, water recycling will only lead to greater sustainability when accompanied by effective water management (Sala & Serra 2004) such as resource efficiency. Water reuse without water efficiency is a waste of a resource (White & Turner, 2003). Water conservation strategies differ fundamentally to water reuse and recycling. Water reuse and recycling reduces demand on the water supply by partially replacing some of the demand by recycled water and/ or rainwater, it has no direct impact on the total water needed by the household. On the other hand, water conservation strategies decreases demand on the water supply by using less water to produce the same results and thereby reducing the total water need.

Proposed uses of greywater range from subsurface irrigation of gardens in dry weather to continuous reuse within houses for toilet flushing. Studies of greywater characteristics show that greywater quality ranges from being lightly- to highly- contaminated by microbial indicators, with some samples having microbial indicator concentrations similar to dilute sewage (Leonard & Kikkert, 2006, Leonard et al., 2008, Casanova et al., 2001). The presence of markers for human faecal contamination in previous greywater characterisation studies (Leonard et al., 2008) confirms the potential public health risk and therefore the need for treatment to a high level for reuse where human contact may occur. To protect public health, the Australian Greywater Guidelines (NRMMC, 2006) state that when greywater may come into contact with people e.g. toilet flushing, irrigation to open spaces or ornamental water bodies, a residual free available chlorine level of 1 mg/L is required which must be monitored daily, and a thermotolerant coliform concentration of < 1 cfu/100mL must be achieved. Determining the appropriate treatment system from greywater characterisation to achieve this microbial standard is difficult owing to the inherent variability of greywater. Even at a single site, microbial characterisations change from day-to-day and during the course of a day (Leonard et al. 2009). As there appears to be no obvious correlation between household activities and the quality of the greywater, there is no optimum time to sample greywater and design an appropriate treatment system. Therefore, as a precautionary approach, any treatment systems for reuse within the house need to provide a high level of disinfection to allow for variations in greywater quality. Providing a barrier to human contact e.g. subsurface irrigation is a precautionary approach. Lower cost reuse can be achieved by collecting rainwater and subsurface irrigation of greywater. However, all systems incur costs to the homeowner. It is therefore necessary to assess the capital and ongoing maintenance costs associated with water reuse options to determine whether water reuse is an efficient water management tool in reticulated urban areas.

2 METHODS

A range of treatment levels appropriate for the end uses were selected. These included: two water reuse options using greywater for subsurface garden irrigation (A - low cost), and a rainwater tank for garden irrigation and toilet flushing (B- medium cost); and a water recycling system consisting of greywater for irrigation of the garden and treatment to chlorinate greywater for toilet flushing (C- high cost). Continuous chlorination is required as chlorine tablets provide a variable dose and may not be replaced as required.

2.1 MODEL

The capital, operating and maintenance costs of the three options were obtained. A model was developed using a simple estimation of the total net present value (NPV) each year for 20 years, which is slightly longer than the minimum serviceable life of 15 years, which is required under the New Zealand Building Code. NPV is a standard method for estimating the opportunity cost of money over time and is often used to help compare the cost and benefits of projects. The process of converting the flows of costs and savings over time into its present value (PV), is called discounting. The discount rate is the rate of return that would be earned on the investment in the water reuse system, if an investment of similar risk had been made in the financial market.

The net present value (NPV) of a cash flow over a period of 20 years:

NPV= C(0)+ C(1)/(1+r) + C(2)/(1+r)2 + ….. + C(20)/(1+r)20

Where C(0) is the initial set up costs, which is not discounted because it occurs at the beginning of the project, C(n) is the cash flow for year n and r is the discount rate.

The cash flow for a particular year n is:

Cn = (operation costs + maintenance costs - savings)

and for any particular year:

operation costs = ∑ replacement parts + energy + chemicals for disinfection

maintenance costs = ∑ maintenance + inspection costs

savings = ∑ savings in water supply and sewage disposal (where applicable) costs

Rough orders of costs for capital costs and ongoing maintenance were obtained by phoning and emailing distributers throughout New Zealand. Councils were contacted for water and disposal charges. Rough costs for the water tank, rainwater collection fittings and toilet plumbing and fittings (including the pump) were obtained from the different suppliers and the Auckland City Council (ACC) Manual (ACC, 2008).

The annual NPV of the three systems have been compared where there are no charges and for Auckland which charges for both sewage disposal and water supply. The charges and volume of water used are manipulated to determine a payback period of five years.

2.2 ASSUMPTIONS

Several assumptions are detailed in this report to clearly outline the limitations of the data and their application. The assumptions/limitations are as follows:

- Costs are for individual, new, single occupancy dwellings with a household comprising 2.7 people (Heinrich, 2007). This is a conservative cost, as cost savings on site works, equipment supply and trades people are likely for a new dwelling. Costs for retrofitting depends on individual circumstances and are too complex to model in this study.
- No consideration has been given to any monetary benefit gained from a reduction in charges for water and wastewater other than to that of the householder through lower sewage disposal and water supply costs.
- All costs of fitting and running the wastewater system are borne by the householder who is building the house and lives there for up to 20 years.
- The discount rate (i.e. the opposite of an interest rate) used to calculate the net present value (NPV) has been set at 8% (Ministry of Health, pers. comm. 2008) which is within Treasury's range of 6–9.5% (Treasury, 2008).
- Although electricity and water charges will increase over time, they are assumed to have remained constant in this model. This is due to the difficulty in foreseeing future council increases and changes in future payment structures.
- End use water volumes were taken from a study of 55 houses in Auckland (Heinrich, 2009). The volume of water used outside the house in 'summer' was 29.8*l*/p/day. It was assumed that for half the year no water is required for irrigation and therefore there are no savings. Toilet flushing provides year round savings of 31.5*l*/p/day.
- Annual rainwater volumes are assumed to provide sufficient water for irrigation
- Electricity charges are proportionately calculated on 110 *l*/p/d used in the ACC Manual (ACC, 2008). Analysis shows that the NPV is not very sensitive to electricity prices (data not shown).
- No installation costs are included as they are assumed to be minimal additional costs during the construction of a house and will vary according to site layout.
- The size of the rainwater tank (system B) was that most commonly used for this purpose.
- Soil types are suitable for greywater irrigation. However, this may not be the case as clay soils, which are common in Auckland, are prone to dispersion owing to the high concentrations of sodium in household products.

3 RESULTS AND DISCUSSION

3.1 COSTS FOR WATER REUSE SYSTEMS

Costs were estimated directly from discussions with suppliers and then compared with data presented in the ACC manual (ACC, 2008). As the costs were similar, the ACC manual data were used for electricity and component parts, where not other data were available. All costs include GST and are given in Table 1.

Table 1: Capital and maintenance costs for a greywater or rainwater system

Type of expense	System	Components	Timing of expense	Cost $
Capital	A	Small tank, filter, pump, 50m irrigation line, emitters	Initial	2,000-3,500
	B	Raintank 13,500*l*	Initial	2,875
	B	Pump	Initial	700
	B	Irrigation line and emitters	Initial	175
	B	Backflow preventer, mains connection, float shut off*	Initial	450
	B	Rainwater collection system with first flush diverter	Initial	650
	C	Small tank (providing 30 minutes chlorine contact time), filter, pump, 50m irrigation line, emitters	Initial	3,500
	C	Redox meter	Initial	5,138
Maintenance	A	Pump	10 years	285
	B	Pump	10 years	600
	C	Pumps(2)	10 years	570
	A-C	Irrigation line	10 years	175

	C	Redox probe	3 years	558
Operation	C	Chlorine	Monthly	50
	C	Inspection	2 years	250
	A	Electricity charges based on 21.78m^3/yr	Annual	9.05#
	B, C	Electricity charges for pumping 21.78m^3/yr	Annual	22.71#

* installed # \$0.415/m^3 (ACC, 2008) guide only as actual price will depend on specific pump

The overall cost for the low-cost greywater system is within the range reported in another New Zealand study Brown (2007). However, that study did not include an irrigation system, essential for greywater disposal, or replacement costs. The overall costs for a rainwater tank (medium cost) are similar to those estimated by Kapiti District Council at NZ$6,200 (Kapiti District council, 2007) and for retrofitting rain tanks in Auckland (ACC, 2008). Pumps have been found to be important for effective irrigation (Coombes, 2002) and therefore have been included in the costs. The continuous chlorination system in the high cost system is a requirement of the Auckland Regional Council (ARC) (ARC, 2004) and requires regular maintenance by the supplier. Manufacturers of the other systems propose home owner maintenance.

3.2 ANALYSIS OF ANNUAL NPV

3.2.1 ANNUAL NPV - ABSENCE OF DIRECT WATER CHARGES

Many urban areas in New Zealand, e.g. Christchurch, Kapiti Coast do not charge for water use. Figure 1 presents the annual NPV over 20 years for the three options where there is no direct charge for water use. Replacement of pumps and irrigation equipment at year 10 (Table 1) introduces a new, one-off cost which is seen in the graph as the slight decrease in NPV.

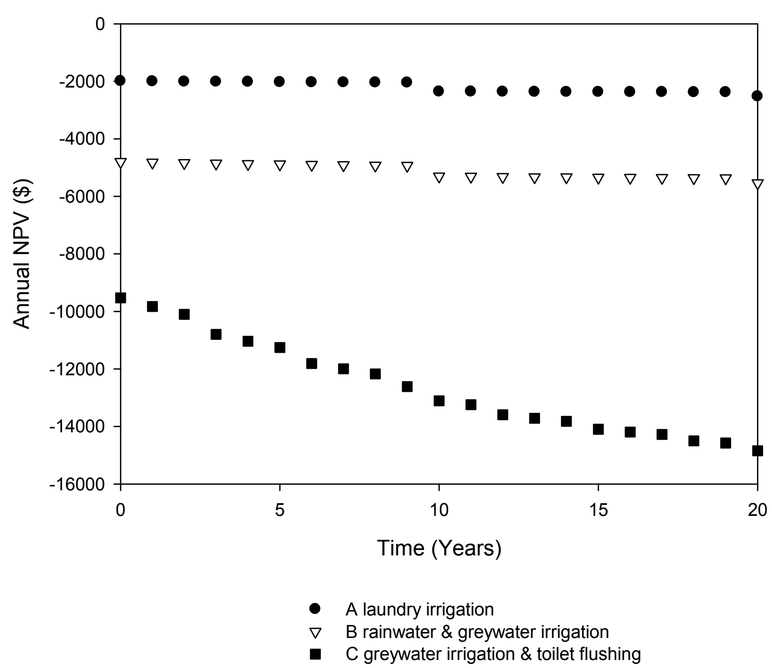

Figure 1 Annual NPV for three water reuse options in the absence of direct water charges

In water short areas such as Christchurch or Kapiti Coast, the cost of water is not linked to usage, so there are no potential savings and consequently no direct financial benefit to the home owner to install water reuse or recycling devices. Over 20 years home owners never recover their investment. The high cost system has the greatest reduction in NPV over time due to the high capital cost of redox monitor which automatically disinfects and high level of maintenance involved with disinfection for reuse in the home. Based on the NPV analysis of these systems there is an ongoing financial cost to the home owner to reuse water.

3.2.2 ANNUAL NPV – OFFSET BY WATER AND SEWAGE CHARGES

The model was applied where there are charges for water and wastewater, using Auckland as the example. The costs of water and wastewater disposal in Auckland were $1.41 for mains water supply and $3.36 for sewage disposal. The water and wastewater savings achieved by the water reuse systems are presented in Table 2.

Table 2 Total annual household savings with the different treatment levels

	Volume water saved (m^3)	Water cost ($)	Sewage disposal cost ($)	Total savings ($)
Greywater to garden	19.8	27.87	66.64	94.51
Rainwater to garden and toilet	51.87	72.87	112.22	185.10
Greywater to toilet and irrigation	51.87	72.87	112.22	185.10

For a household the annual water usage was calculated as 174 m^3/household as average water consumption from 51 Auckland households was measured at 175 *l*/p/d in winter and 179 *l*/p/d in summer (Heinrich, 2009), and the average household is 2.7 people (Heinrich, 2007). The actual volume of greywater irrigated in the garden will be greater than that used in the calculations in Table 2, but a limit of 29.8*l*/p/d for six months of the year has been set, as this is volume which is recorded as being used in 'summer' for irrigation (Heinrich, 2009).

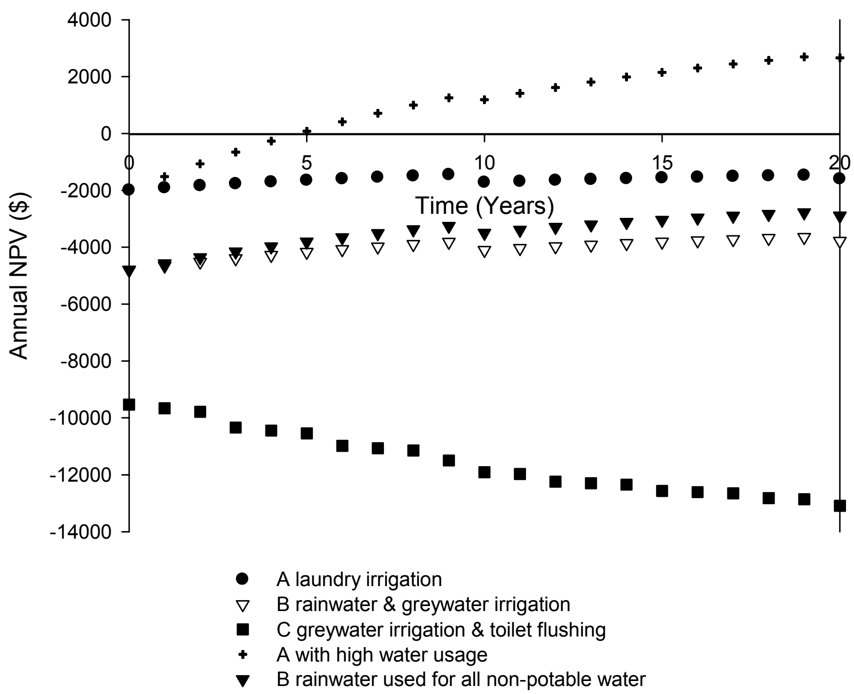

Figure 2 Annual NPV for three different water reuse treatment systems for average and high water usage

The annual NPVs for the three treatment options over 20 years are in Figure 2. The high cost system has a rapidly declining NPV owing to high maintenance costs, due to the continuous chlorination system. The high initial costs mean that there is no financial benefit to the home owner, even after 20 years under average conditions. A similar conclusion was reached in the analysis of greywater systems in Australia (Brennan, 2004).

The time period for a return on investment reported here is different to that previously reported for a New Zealand system (Brown, 2007), which indicated a return on investment in approximately 15 years, for a two-person household and seven years for a four-person household. These differences in financial benefit arise from the estimation in the volume of water which can be saved.

Coombes (2002) reported that rainwater used for all household activities, except potable water, was cost-effective for a house in Newcastle, Australia. However, in our analysis even substituting rainwater for all water use except potable water remains non-cost effective (Figure 2). Rainwater has another major drawback in that while average water consumption may be reduced, it is ineffective in reducing peak demand in summer when there is the highest demand for water (SKM, 2008). In areas with low summer rainfall such as Christchurch, where rainfall between October and March is only 60% of that in Auckland, it would be impractical and expensive to the householder.

The length of the payback period depends on the volume of water used. If all the greywater could be collected and reused (140 *l*/p/day), then for a household of 4.3 people the low cost system would payback in five years if the household was paying for 600 *l*/day to water the garden. Such water usage could be considered profligate.

3.3 WATER CONSERVATION

Reuse of greywater is inefficient if it is not combined with water conservation (White & Turner, 2003). Water conservation strategies differ fundamentally to water reuse and recycling. Water reuse and recycling reduces demand on the water supply by partially replacing some of the demand by recycled water and or rain water, it has no direct impact on the total water needed by the household. On the other hand, water conservation strategies decrease demand on the water supply by using less water to produce the same results and thereby reducing the total water need. Water conservation offers greater benefits through water reduction, at less expense to the homeowner, than water reuse or recycling and behavioural changes. The actual cost-benefits of water conservation versus reuse or recycling would need to be calculated based on local prices, wider community benefit, and more accurate data on water end use (especially irrigation).

In established residential areas in Sydney water demand management saved 27m^3/ household by indoor auditing, retrofitting appliances, price increases, outdoor water use restrictions, shower head rebate and leakage control (White & Fane, 2002). Showers account for 25-30% of indoor water use in Auckland, even though most houses have low water pressure systems. The laundry also uses large volumes of water (23-24% of indoor water usage). In New Zealand, 96% of washing machines are top loaders. Use of a front-loading washing machine instead of a top-loading machine was estimated to save up to 8.5m^3/p/yr – 12% of water use for an average household (Heinrich, 2007). By combining use of a front-loading washing machine with a low flow shower head, it was estimated that total water use could be reduced by up to 33% for high water users (Heinrich, 2007).

Solutions such as greywater reuse and water efficient appliances fall into the category of the technical fixes (Heberlein, 1974). Imposing technical fixes may lead to perverse incentives. For example in the case of water recycling it is possible people may use more water within a household during dryer times to maintain garden irrigation. Water recycling allows the same amount of water to be used and does not change behaviours. In addition to technical fixes, behavioural changes offer the potential to deliver significant long-term demand reductions. Water conservation can be achieved through both technical fixes and behaviour changes.

Price has often been used to provide signals to conserve water, but price responsiveness varies by income group. Although assumed to be inelastic i.e. the same amount of water is required by everyone for personal hygiene and the functioning of a household, it has been shown that there is a certain amount of elasticity, related to income. The less the proportion of income spent on water, the less responsive people are to price (Domene & Sauri, 2006), particularly when considering outdoor use (large gardens, swimming pools etc). Socio-demographics also play a role with household size and type being a factor (Domene & Sauri, 2006). The attitude of people in the house to environmental issues is another important aspect (Corral-Verdugo & Frias-Armenta, 2006). Changing behaviour is therefore important to achieve water conservation.

With potentially very high water use from leaks in the home (Heinrich, 2007), municipal leakage (Porter & McCormack, 2008) and outside water use, targeting these activities offers opportunities for water conservation, before assessing reuse and recycling options (Stone, 1996). Water conservation should be the starting point for water management as it has the potential to save costs and energy (White & Turner, 2003).

4 CONCLUSION

Under the present pricing systems there is no direct monetary benefit to an average sized household over 20 years from installing rainwater tanks or greywater reuse systems. However, pricing becomes elastic in higher socio-economic groups. Installation of water saving fixtures in a house can provide immediate benefit to the home owner and save significant amounts of water without the expense of water reuse and recycling. As attitude and personal beliefs are major factors in water conservation overseas, research should not ignore the barriers and drivers which change behaviours. Recycling does not reduce water use. It is not therefore the most cost effective means of managing water. Understanding water end use and controlling excessive use of water should be the first step in water management, before water reuse or recycling.

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