GREYWATER RECYCLING – RISKS, BENEFITS, COSTS AND POLICY

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ABSTRACT

There has been much research into the risks, benefits and cost of greywater recycling in New Zealand, Australia and worldwide. On the whole policy has been disjointed and uptake of greywater systems low, but in the current climate this may be about to change. This paper summarises the research and policy decisions to date and offers some commentary on them. It also offers a wider perspective than is usually found by considering some of the risks of *not* recycling greywater, including the risk of running short of water and the climate change influence of the greenhouse gas emissions generated by reticulated water and wastewater supply networks. The concepts of Water Miles and Peak Water are introduced. There is an analysis of the estimated costs and savings to the owners of a greywater system under different types of regulation, in terms of the Payback Time, Net Present Value and Internal Rate of Return. Recommendations are made for appropriate policy.

KEYWORDS

Greywater recycling, cost-benefit analysis, water miles, peak water, health, policy, net present value

1 INTRODUCTION

There is risk involved in any water or wastewater system. There are also costs and benefits. Quantifying these is difficult and it is thus not surprising that policies for greywater recycling have varied considerably both within (Brennan and Patterson, 2004) and between countries (Pidou, 2006, pp. 7-8), given that it is a relatively new area. Additionally, there has been variation in the degree of urgency in considering the topic. In Australia there are now lots of research dollars available for research into water recycling, whereas in New Zealand there are not. In part this is because water is now understood to be a critical resource in Australia, but in New Zealand the belief persists that we have an abundance, with authorities citing high rainfall as a reason that recycling is not required (Auckland Regional Public Health Service, 2007 - personal communication by letter of Ministry of Health policy). In fact, India has a higher rainfall than New Zealand and experiences serious drought illustrating the fact that rainfall is only one factor in meeting water demands.

The decision to construct a new water treatment plant and 38km pipeline to abstract water from the Waikato River was based in large part on the need to reduce the Auckland region's dependency on rainfall (Schaffler, 2002), following the water shortage of 1994. It was also a response to the predicted rapid growth of the region's population from 1.2 million in 2004 to 2 million by 2050 (Waitakere City Council, 2004). However, this water supply is of a lower quality by an order of magnitude than previously existing supplies, due to pollution from Hamilton's sewage outfall (indicated by the presence of 3157 MPN faecal coliforms per 100ml, compared to the next worst supply which has 95 MPN/100ml; Watercare Services, 2002). This requires greater treatment to remove pathogens and there are also concerns about chemical contamination (Cayford, 1999; Fitzsimons, 2002) that may not be filtered from the supply, or even monitored.

If Hamilton were to recycle its wastewater, it could maintain a higher flow through the river and return less waste, as illustrated in Anderson (2003, p. 7). In that paper there is a hypothetical example comparing two cities, which demonstrates the benefits of water recycling. Namely that the COD of the river water downstream of the city is a factor of nearly seven times lower for the city which recycles, plus there is more water available for use. It is highly likely that demand in Auckland could be met by reducing water use and by recycling wastewater or greywater locally, rather than by using a source contaminated with wastewater from Hamilton. Greywater recycling is a low risk activity when performed under certain conditions (Nolan, 2005). Indeed from a risk management perspective it is more risky to sit in a bath than it is to reuse the water for flushing the toilet or watering the garden (Dixon *et al.* 1999). Risk increases as more sources of greywater are included, due to an increased number of potential pathogens entering the system. Risk also increases as the number of people served by the system increases, due to more people potentially being exposed to any pathogens. It also increases if a full wastewater stream is used instead of greywater. As a result, the level of treatment needs to be higher to bring the risk back down to an equivalent level of a single dwelling system.

The water downstream of Hamilton's sewage treatment plant was found to be the most contaminated with pathogens of any site in the Ministry of Health's research into recreational water quality (McBride *et al.* 2002). The probability of a treatment failure at the Waikato pipeline treatment plant is very low, but the health threat that it would pose should it happen is very high, due to the large numbers of people consuming the water. It is possible for mistakes to be made or accidents to happen. A disease outbreak affecting an estimated 403,000 people occurred in Milwaukee (Wisconsin) due to drinking water contaminated with cryptosporidium, and there have been other failures (Ford & Mac Kenzie, 2000). Large-scale recycled water distribution systems (using dual pipelines) are also at risk from cross connection. For example there was an outbreak of gastroenteritis in the Netherlands, which now bans community level water recycling. In this case, partially treated surface water (which they call 'grey water') was able to mix with the potable water supply after it was deliberately connected to it for maintenance work but was not subsequently disconnected due to an oversight. Accidental high pressure in the 'grey water' system resulted in 'grey water' circulating in the drinking water pipes (Fernandes *et al.* 2007). Note that use of alternate water supplies *within an individual dwelling* was allowed to continue (although it is under review; *ibid* 2007).

In contrast to this example, a failure of a greywater treatment system in an individual household would likely have no impact since there would only be pathogens in the system if there was already sickness in the household. Even then, transmission by exposure to toilet water or irrigation water is very unlikely – and extremely unlikely in large doses – as will be discussed later. (This is in contrast to drinking water from the tap, which could lead to large doses if contaminated with pathogens). Cross-connection risks are minimized in individual systems, and all greywater recycling systems need a building consent, which will check that cross-connection cannot occur.

This paper addresses concerns that have been expressed about the safety and expense of greywater recycling (eg by Leonard & Kikkert, 2006). It demonstrates that it is a low risk activity when conducted within an individual household and investigates whether it can be considered an economical activity when conducted at this level. If well-intentioned but exaggerated concerns about its safety (based on poor science) lead to legislation or bureaucratic obstruction – making it unlawful or uneconomic – then the consequences are the loss of a valuable resource, with consequent negative environmental and social/financial outcomes.

1.1 COSTS AND BENEFITS

It has been stated above that the risks of recycling water increase with the scale of the operation, but does the additional cost of treatment to mitigate the increased risk outweigh the supposed cost reduction of reticulating on a larger scale? This question assumes of course that it is possible to account for risk adequately to make such a decision rationally and that there *is* a reduction in cost of reticulated networks. A precautionary approach to risk would favour on-site treatment as the consequences of a bad assumption or miscalculation are less important. Irrespective of the accuracy of risk assessment, Fane *et al.* (2002) noted that: "smaller systems were found to pose a lower risk of waterborne infection, all other things being equal. Pathogen risks were then included within an economic analysis of system scale. It was concluded that with the inclusion of pathogen risks as a costed externality, taking a decentralised approach to urban water reuse would be economically advantageous in most cases." In other words, reticulation is less economically viable than decentralized recycling when the risks are costed.

Research that has found a benefit for reticulation over on-site systems often does not take account of the levelised cost of the projects. Levelised cost (as opposed to annualised cost) takes account of the fact that the new capacity will not be fully utilized immediately; rather it will incrementally be used as demand rises, so much of it will be unproductive. Localised water recycling investment can be installed progressively, spreading the capital investment over years, which all else being equal will save money (Fane *et al.* 2003). An example of such an approach can be found in Coombes *et al.* (2000), in relation to the economic advantages of rainwater tanks over new supply infrastructure such as dams. For an application of this type of analysis to the Waikato river water source see Cayford (1999), who estimated that the cost of water from the pipeline would be $3.00 per cubic metre for the first few years.

Other cost-benefit analyses have assumed that greywater needs to be treated to a very high standard (essentially to a drinking water standard in terms of microbial indicators) even in a single dwelling, which of course leads to high costs. It would be more reasonable to demand treatment to bathing water standards, since the exposure is less than that tolerated with bathing water. Opponents of greywater recycling standards based on bathing water might reasonably be expected to argue for legislation to prevent swimming in rivers, lakes and the ocean, since the risk is higher (McBride *et al.* 2002; McBride *et al.* 1998). This standard can be achieved at much less cost per system and is important as it has been shown that the per-connection costs of treatment within water and wastewater networks reduce with scale, but that the per-connection costs of transport do not (Fane *et al.* 2002). If unnecessarily high treatment costs for greywater recycling are avoided, then the levelised costs can be lower than those associated with increasing the capacity of the reticulated water and wastewater networks.

This study assesses the costs of greywater recycling within an individual household in Auckland City and relates them to the cost of regulation. It is difficult to estimate the costs of the reticulated network for comparative purposes, but the costs charged for water and wastewater in Auckland City are used as a surrogate measure. Auckland City Council does not believe that current pricing fully recovers costs and states that ratepayers subsidise Metrowater customers (Auckland City Council, 2007, sec. 5.5, p. 4). Certainly more of the costs are recovered in Auckland City than in Waitakere City, where water is one of the most significant council costs, with 35% of the rates being spent on water and wastewater services. In total, $48m is spent on the three waters annually, including stormwater (Waitakere City Council, 2007) out of a total rates budget of around $100m. There would be significant benefits to the public if just 10% of that expenditure could be saved by the introduction of greywater recycling and spent on alternative services. Two concepts are now introduced to further explain the need for (and benefits of) localized water recycling, irrespective of the financial costs (which will be examined in due course).

1.2 WATER MILES

The energy that is required to treat and pump the water from the Waikato River up to Auckland is significant and contributes to emissions which in turn are responsible for climate change (IPCC, 2007) which the World Health Organisation (WHO) believes is responsible for 150,000 deaths and around 5 million ‘disability adjusted life years’ (DALYs) around the world each year (Patz *et al.* 2005). Clearly, the emissions from the Waikato pipeline are only a tiny part of that. However, the issue is one of the two largest facing humankind (water supply is the other) and there is no single solution. Carbon emissions must be considered when assessing projects and yet there was no assessment of the carbon emissions from the construction or operation of the Waikato pipeline in the Assessment of Environmental Effects for that project (Watercare Services, 1996).

The WHO suggests that public health bodies need to reevaluate their policies in the light of global warming, including promoting safe re-use of greywater (Campbell-Lendrum *et al.* 2007). The WHO’s guidelines list some of the benefits of using greywater in agriculture, which include reducing the demand for freshwater supply, mitigating the stress on water resources and nutrient supply, helping poor families meet their nutritional needs due to improved household food security, saving money on fertilizers, etc. (World Health Organization, 2006).

The energy issues involved in water and wastewater service provision can be considered under the concept of ‘Water Miles’. Food Miles as a concept is now widely accepted as not referring strictly to the number of miles that a product has travelled, but the overall environmental impact of its production and transport, including production costs such as feed/fertiliser; pesticides; distribution method and distance (including the consumer's journey); and so on, usually expressed as a carbon emission. It could also include an assessment of other environmental impacts (such as eutrophication of lakes). ‘Water Miles’ would be a similarly useful concept, relating to the energy expended or carbon emitted in the sourcing (dams, pipelines, pumping); treatment (chemical and physical processes); and distribution (pipelines, pumping) of water. This concept should extend to wastewater, which has to be collected (pipelines, pumping); treated (chemical and physical processes, truck movements); and disposed of (pipelines, pumping). It could also include an assessment of other environmental impacts (un- or poorly-treated effluent entering the harbours, the embodied energy of concrete pipes, plants and dams, etc.).

In addition, people reusing greywater can utilize some of the otherwise problematic nutrients to grow their own food crops, provided certain precautions are taken, which in turn represents a further reduction in carbon emissions, compared to goods which are grown with petroleum-based fertilizers, then packaged in petroleum-derived plastics and transported both to supermarkets and then home in petroleum-powered vehicles. It also represents further water saving if water would have been used for agricultural irrigation to grow the crops.

Rodney District Council (in the Auckland Region) expends 39% of its total energy consumption on water and wastewater treatment and pumping (Rodney District Council, 2006), Waitakere City Council 35% (Waitakere City Council, 2005) and the New Zealand average is 24% (Communities for Climate Protection – New Zealand, 2006). Other Auckland Councils have not released their figures. Although the reason for the higher figures for Auckland Councils is not known by the author, they might be evidence of the 'Peak Water' concept described in Section 1.3. The absolute figures are expected to increase in a 'do nothing' scenario; eg Rodney District Council expects a 58.72% overall increase in greenhouse gas emissions by 2010, with a disproportionately high percentage to be in the Water and Sewage sector (Rodney District Council, 2006).

1.3 PEAK WATER & 'CAPABILITY'

'Peak Water' relates to the Peak Oil concept in that the assumption is that as the easier sources of water supply are used up, less pure and more geographically removed supplies are required, at considerably more cost, so prices will go up to pay for the considerable capital and operating costs of these projects. It also assumes that water supply is not endless and that there is a point where capacity cannot be increased (although it may still be possible to increase capability). There are similarities too in that there are increasing environmental impacts associated with pursuing these less attractive sources, once the 'low apples' have been plucked from the tree.

Rather than use the term 'capacity', which is the volumetric limit to supply, the term 'capability' is used here to mean the capacity minus the savings made by conservation and recycling. It is instructive to consider the cost of adding more capacity as opposed to the cost of achieving a usage reduction or re-usage, each of which increase capability and can be used to respond to increasing demand.

Costs of water supplies increase as additional capacity is added, since the easier sources of potable water (those most reliable, closest to the point of distribution, least polluted, etc.) will already be in use so only less attractive sources remain. For example, the Auckland Region now sources some of its water from the Waikato River. It is the most expensive water supplied into the network, adding up to 150 million litres a day to the supply (with 50 million litres supplied now and the remainder to follow) (Watercare Services, nd). Watercare are alleged to have stated that the cost of the Waikato river supply is three times that of the Hunua Dams (Cayford, 2002) which supply 60% of Auckland's water (Watercare Services, nd[b]).

1.4 PRICING

Water conservation is not encouraged by the current pricing policy of water. Water and wastewater account for a significant portion of a council's budget, but the price charged to consumers is heavily subsidized by the general rates both in New Zealand (Waitakere City Council, 2007) and Australia (PriceWaterhouseCoopers, 2000). There are social justice and political motivations for doing this, but it does lead to consumers failing to conserve water as much as they would if the pricing were higher. Individual household water saving technologies are not subsidized by an equivalent amount. If they are to be encouraged then the subsidy on reticulated water would need to be removed, or at least an equal subsidy would need to be offered for the installation of such systems. Rainwater tanks are eligible for subsidies in some areas, whereas greywater recycling systems are not (except in some parts of Australia). Indeed, there are additional costs associated with building consents and even resource consents, which are barriers to uptake. Domestic solar hot water systems have recently become a fee-free building consent in New Zealand to encourage their installation. The impact of consent fees on the affordability of greywater recycling systems is considered in Section 3.3.

1.5 RISKS

A number of studies have concluded that greywater recycling is a high risk activity due to high numbers of indicator organisms found during tests (Leonard & Kikkert, 2006; Jeppesen & Solley, 1994) and by interpretation of those data by application of the knowledge base that exists for reticulated wastewater and water supplies. However these studies have not looked for real pathogens and if they had would have been unlikely to find any. It is now known that the numbers of indicator organisms multiply in greywater – even as any pathogens which did exist would most likely be declining in number (Ottoson, 2003; Ottoson & Stenström, 2003). Pathogens, in stark contrast to indicator organisms, are likely to die outside their hosts in most cases, especially when subjected to greywater, which is not a particularly benign environment for them (World Health Organization, 2006). The rate of decline is even faster in the soil, and faster still on crops (*ibid*, 2006). For irrigation of crops with greywater the WHO recommends $<10^5$ *E. coli*. This appears high for those familiar with wastewater reuse, but it is in recognition of the fact that 'In relation to guideline values, it is essential to consider the phenomenon of overestimating the health risks due to regrowth of indicators. Elevated indicator values should therefore always be assessed in relation to potential faecal inputs' (*ibid*, 2006). The same caution should be applied to F-RNA phage as an indicator organism as it replicates when *E. coli* (its host) is replicating, particularly in the presence of *Enterococcus faecalis*. and has been found in higher quantities in wastewater than in faeces (Woody & Cliver, 1997). In contrast, viral pathogens cannot replicate outside their hosts.

It has been suggested that these hypothetical pathogens can infect householders by aerosol ingestion from toilet flushing. In reality, aerosol ingestion generated by toilet flushing forms a very rare route for pathogen transmission. When it does occur, it is from stools (especially diarrhoea) being subjected to the flush of water (Barker & Jones, 2005), or from pathogens originating from these stools (such as salmonella) which have been found to be living under the rim of the toilet where conditions are good for their survival (Barker & Bloomfield, 2000), rather than from greywater which has a tiny fraction of the pathogens present in the stools themselves. Studies have shown that a chlorine residual is an effective way to reduce this pathway of disease transmission (Bloomfield & Scott, 1997), so utilising greywater that has been treated to have a chlorine residual is likely to reduce rather than increase the incidence of disease, when compared to using fresh water, although either way the effect is likely to be tiny and does not appear to have been a major public health concern previously.

Finally, the risk of disease transmission through greywater is of course also prefaced on the entry of pathogens into the system, which will almost always only occur in any significant numbers if members of the household are already infected. In this case there are many more likely methods of transmission than through the greywater for the reasons stated. Indeed, taking a bath might be more risky (Dixon *et al.* 1999), not to mention using a spa or swimming pool (Lumb *et al.* 2004). Arguments for legislation based on an inability to control householders' behaviour (eg Auckland Regional Public Health Service, 2007 **-** personal communication by letter of Ministry of Health policy) might equally be applied to spas and swimming pools (or indeed the sale of fresh chicken or cars, etc.). In each case there is some individual responsibility to behave in a manner that minimizes risk, by following the manufacturer's instructions.

1.6 POLICY / REGULATION IN NEW ZEALAND

There are no specific water quality requirements for greywater recycling in New Zealand, however there are several pieces of legislation which apply to greywater recycling, as detailed below (Taranaki Regional Council, 2006):

- **The Local Government Act 2002**, requiring district councils to provide water and sanitary services and the efficient and effective management of all types of waste within their districts.

- **The Building Act 2004**, where district councils ensure that building consent applications make proper provision for the disposal of wastewater.

- **The Resource Management Act 1991**, where district councils control the effects of land subdivision and development on the environment through district plan rules and associated standards relating to wastewater treatment and site drainage.

- **The Health Act 1956**, where district councils are responsible for public health within their district. Environmental health officers inspect and take action on situations where conditions are likely to be injurious to health.

There is some flexibility for councils to interpret this legislation, although it is reasonably certain that a building consent is required for installation of a greywater recycling system, which will include an inspection to ensure that cross-connection with potable water is not possible. Most councils do not require a resource consent for greywater irrigation provided it meets some criteria (such as not ponding or running off the property, being a minimum separation distance from a watercourse and being below a certain volume). The Auckland Regional Council (ARC) does however require a consent, with an accompanying deposit of $2000 and a form that is technically complex (and which advises that a 'Consulting Engineer, experienced in wastewater disposal' should complete it). The full cost is unknown at this stage (even by the ARC), but this study has assumed it will be in the region of $1000. It is likely that any consent would be accompanied by a requirement to monitor Free Available Chlorine levels in the treated greywater (personal communication with ARC officers).

Local authorities are influenced by the Ministry of Health to varying degrees in their policy making, with different Regional Public Health Services expressing varying levels of concern (Easton *et al.* 2006) in response to consultation with these authorities (the consultation itself happening in an unstructured and inconsistent way). For example, the Auckland City Council had a policy of actively promoting greywater recycling (Paterson, 2006) but later retracted it after consultation with the Ministry of Health (Paterson & Menzies, 2007).

The Ministry of Health opposes greywater recycling on the grounds that:

- system performance and public health risk is dependent on the level of maintenance of the treatment system
- when the owner is less vigilant or ownership changes the risks multiply
- the risks are not justified by the need
- there is a risk of cross connection with potable supplies

Much of the Ministry's policy is informed by a report by Leonard & Kikkert (2006), which the present author believes suffers from methodological errors and contains logical flaws, including conclusions drawn from the results which are not warranted from the stated premises and scope of the study. The researchers utilized an opportunity sample of an assortment of greywater recycling systems, many of which featured no treatment or were home-made, which is a little like looking at the performance of long-drop toilets to form policy on septic tanks. The authors did not define what a greywater system meant to them in the context of their study and some of the systems included kitchen wastewater, which many people would not consider to form part of a greywater stream due to its higher levels of contamination. Additionally, indicator organisms were used as a surrogate for pathogens, with some systems having concentrations of *e. coli* and F-RNA phage 'similar to those in raw sewage'. This finding is an example of the ability of indicators to multiply as discussed above and is presented in a misleading way, given that the authors appear to be aware of the work of Ottoson & Stenström (2003), which is referenced in their paper.

The study states that 'toilet flushing presents particular health risks' (although it doesn't state what they are), but to put it in perspective, one popular resource for greywater recycling has calculated that greywater has five thousands of one percent of the fecal matter that toilet water has normally (Oasis Design, 2005, p. 19). This document has a wealth of information and commentary, such as a discussion of relative risk (*ibid*, 2005, pp. 62-63). It also shows that policy in the United States is not as homogenous as it is represented in Leonard & Kikkert (2006). Overall, there is a sufficient research base internationally to form policy on greywater recycling. The present author finds much to recommend in the approach of Nolan (2005) and little to recommend in the approach of Leonard & Kikkert (2006).

1.7 COMMENTARY

The present author believes that greywater recycling has been subjected to a degree of caution that is scientifically unwarranted and which does not bear up to comparison with equivalent activities. Over-regulation resulting from this would lead to greywater recycling becoming significantly more expensive, as is the case in Australia which has some of the most restrictive regulation in the world. There is still to date no evidence of any disease having resulted from single-dwelling greywater recycling, whereas there have been disease outbreaks resulting from reticulated supplies of wastewater, low-grade water and potable water. Greywater recycling can reduce the likelihood of these events as it can reduce wastewater volumes and support the use of higher quality water supplies. It can also contribute towards reducing climate change, which is also responsible for death and illness. Regulators must consider the full picture of risks, benefits and costs before taking what they may believe to be a precautionary approach to policy. Many of these factors are difficult to quantify and this study does not attempt to do so. However it is possible to estimate the cost implications of the different regulations in New Zealand and Australia by estimating the cost of a system that can meet the regulations and comparing it to the savings that can be obtained, based on water supply cost.

2 METHOD

A spreadsheet was created to evaluate two different greywater recycling systems, according to the following three calculations:

1) The Net Present Value after 20 years

2) The Payback Period

3) The Internal Rate of Return after 20 years

The Net Present Value (NPV) is the estimated value of an investment based on the money spent on that investment subtracted from the money or savings received from that investment over time, based on the current value of that money. The money received is based on water bill reductions, whilst the money spent is based on the initial outlay for the system, installation and consents, as well as the ongoing operating costs. Numerous assumptions have to be made and these are detailed in Section 2.1. A major assumption is which year to calculate the NPV (which was chosen to be year twenty in this study).

The Payback Period is the amount of time required for the investment to show a positive return and it corresponds with the year that the NPV becomes zero. It is the time after which the investment has paid back the initial and ongoing costs and is thereafter returning a profit.

The Internal Rate of Return is the return on the investment over the chosen timeframe, expressed as a yield. It enables comparison between investments, such as putting the money into a savings account, purchasing a solar hot water heater or even investing in a new water supply pipeline or dam. Therefore it can be used to compare the value of the investment for the homeowner and also compare its value with that of a major infrastructure project, to see if it makes better financial sense to recycle water within a household or supply more water (and treat more wastewater) on a municipal scale.

The New Zealand system referred to is an actual greywater recycling system that has been sold in New Zealand for over a decade, whilst the Australian system is a theoretical system based on the minimum price of an aerated wastewater treatment system in Australia that could meet the regulations there for recycling water back into a dwelling (according to Brennan and Patterson, 2004). This price does correspond to current reality so far as the present author has been able to discern, insofar as the prices for Australian greywater recycling systems (irrespective of the technology that they actually use) appear to start at that level, and some are considerably more expensive.

2.1 ASSUMPTIONS

Figures were chosen to apply to installing and operating a system in Auckland City, using data obtained from Metrowater (the Auckland City water company), the councils, plumbers and the manufacturer. The cost of a building consent from Auckland City Council was included. Money to purchase the system was assumed to be borrowed at a constant interest rate of 8%. This is the average interest rate which is estimated to apply across the time period under consideration, as available to homeowners in the form of a home loan. At the time of writing the rate is higher, indeed the highest since 1998, but this is predicted to be at a peak and to fall in around a year (Tuffley, 2007) and the rate averaged about 8% over the last decade (as estimated from graphs in Tuffley, 2007), so choosing this rate would have made for a reasonably accurate calculation over that time. Although the difference in rate can have a significant effect on the results, it should not influence the ability to compare the systems with each other as they were all subject to the same discount rate.

Water prices are assumed to double over the next decade due to a projected increase in the prices charged by WaterCare (the Auckland Region's bulk water supplier) (personal communication from the services delivery manager of EcoWater, the Waitakere City water company, 2007). A recent article in the NZ Herald suggested that the price increase may in fact be higher for Auckland City (Orsman, 2007).

A useful life of 20 years was used for the calculations, with the assumption that the system had no value at the end of this period. This may be too long or too short, but is a reasonable estimate based on the fact that the New Zealand system has been running successfully in a number of homes for over a decade without significant or expensive failures of any components and is made from durable materials. There is no allowance for replacement parts for either system in the calculations due to this reliability, although the Australian system is more likely to require replacement parts because of its treatment method (aeration), which means that the results are more likely to be biased in favour of the Australian system (appearing more affordable than it is).

There were assumed to be approximately 0.9 Australian Dollars for every New Zealand Dollar (based on recent historical rates), so the AU$8000 system was priced at NZ$8888. The installation cost was estimated to be $250 for a new installation, but would be more expensive (say $1000) for a retrofit situation. The new installation cost was used for the calculations.

2.2 VARIABLES

A spreadsheet was created which was able to take a number of inputs, as illustrated in Table 1. The values for each input, for each system, are shown in the table.

Input to spreadsheet	New Zealand system	New Zealand system *(Alternative values)*	Australian system
The purchase cost of a system	$2500	$2500	$8888 ($8000 AUD)
The cost of building and resource consents	$250 Building consent	$250 Building consent *($1000 Resource consent)*	$250 Building consent
The cost of installation	$250	$250	$250
The current water charges (and wastewater charges)	$1.405/m3 water $3.36/m3 wastewater	$1.405/m3 water $3.36/m3 wastewater	$1.405/m3 water $3.36/m3 wastewater
The number of occupants	4	*(2 and 6)*	4
The volume of water used per occupant per year	70 m3	70m3	70m3

Table 1: Spreadsheet inputs by system type

All prices are expressed in New Zealand Dollars. The resource consent fee is not known as the Auckland Regional Council (ARC) have been unable to give a specific price. They hope to be able to do so in the future and improve the simplicity of the consent process, but at present it is sufficiently complicated that it requires a $2000 deposit and would be beyond the ability of most laypeople, requiring an engineer to complete the application (and therefore more cost). In Auckland, resource consent is not required for toilet flushing but is required for garden irrigation. It is hoped that this may change, or that a simple consent might be obtained in place of the complex one currently in place (personal communication with ARC). Other regional councils outside Auckland do not require a consent for this (invoking the legal principle of *de minimus*). It was decided for the purposes of this study (in the absence of specific information) that the most likely costs for obtaining a resource consent would total $1000. The comparison between New Zealand and Australian systems was based on the $0 (fee-free) resource consent as a cost of $0 is more reflective of practice outside the region, so lends itself to wider application of the figures (so this was also calculated). The building consent in Auckland City is $250 with no plans to reduce it. In Waitakere City it is $395 but there are plans to make it fee free (personal communication with the Mayor). Eventually it is hoped that this will apply across the country (as has recently become the case for solar hot water systems).

The annual operating cost was calculated based on the electricity costs, assuming three and a half minutes of pump operation per person per day (in the region of a couple of dollars over the course of the year due to the use of a 12v pump), and a standby cost for the transformer of $12 per annum. Note: it is possible to run the system from a 12v battery and solar panel, which would remove these operating costs but add to the capital cost. The Australian system was assumed to have a similar power usage for the purposes of comparison, although in reality it is likely to be much higher due to the nature of the process. The cost of the calcium hypochlorite treatment tablets was assumed to be $50 per annum.

It was assumed that greywater recycling would account for a water saving of 50%, the combined average total of savings for toilet (30%) and garden uses (20%) of a typical household, according to Metrowater (2005). The total possible could be higher for an individual household, such as 70%, if all greywater available from the bath/shower and washing machine was effectively reused (eg in a household that previously had a garden irrigation system supplied by fresh water), or even higher if the washing machine was fed by greywater.

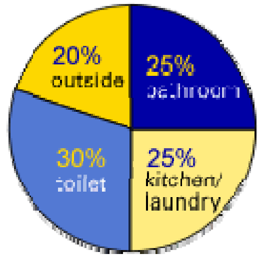

Figure 1: Representation of typical water use (from Metrowater, 2005)

It was assumed that there would be no ongoing repair costs to any of the systems tested. This was due to the fact that the New Zealand system had next to no costs for replacement of any of the parts for any of the systems sold over the last ten years. It is difficult to know what the maintenance costs might be for the Australian system, but given the nature of the process one might assume them to be greater than zero. However, that is what they were assumed to be for this study. Any bias created by this omission would favour the Australian system. The cost for the calcium hypochlorite tablets was applied to both systems in the absence of any data as to treatment chemical costs from the Australian system. Again the bias is likely to be firmly in favour of the Australian system since material or maintenance costs could be expected to be higher due to the greater complexity and regulatory demands (ie scheduled maintenance and testing).

3 RESULTS

The Net Present Value (NPV), Payback Time and Internal Rate of Return (IRR) for each system are shown in Tables 2 and 3, for the New Zealand and Australian systems respectively.

	Four occupants	**Two occupants**	**Six occupants**	**Four occupants $1000 resource consent**
NPV	$5,838.18	$1,114.73	$10,561.63	$4,838.18
Payback	<7 years	<15 years	<5 years	<9 years
IRR	22.85	11.44	32.56	17.96

Table 2: Results for New Zealand system

	Four occupants	**Two occupants**	**Six occupants**	**Four occupants $1000 resource consent**
NPV	-$549.82	-$5,273.27	$4,173.63	-$1,549.82
Payback	<22 years	>25 years	<14 years	<24 years
IRR	7.38	0.66	12.16	6.37

Table 3: Results for Australian system

3.1 THE EFFECT OF AUSTRALIAN VS NEW ZEALAND REGULATIONS ON FINANCIAL PERFORMANCE

The Australian system had a NPV of -$549.82, with a payback period of between 21 and 22 years; longer than the assumed life of the system. For a typical four person household in Auckland City it would not be worth installing such a system on purely financial grounds, compared to simply using the money to pay off a mortgage, having an IRR of only 7.38 percent.

The New Zealand system which had the same assumptions as the Australian system had a NPV of $5,838.18. It would take between 6 and 7 years to payback the investment. With an IRR of 22.85 percent it represents an excellent investment for a typical four person household in Auckland City. The NPVs for both systems are shown in Figure 2.

The payback time was 15 years faster for the New Zealand system than for the Australian system.

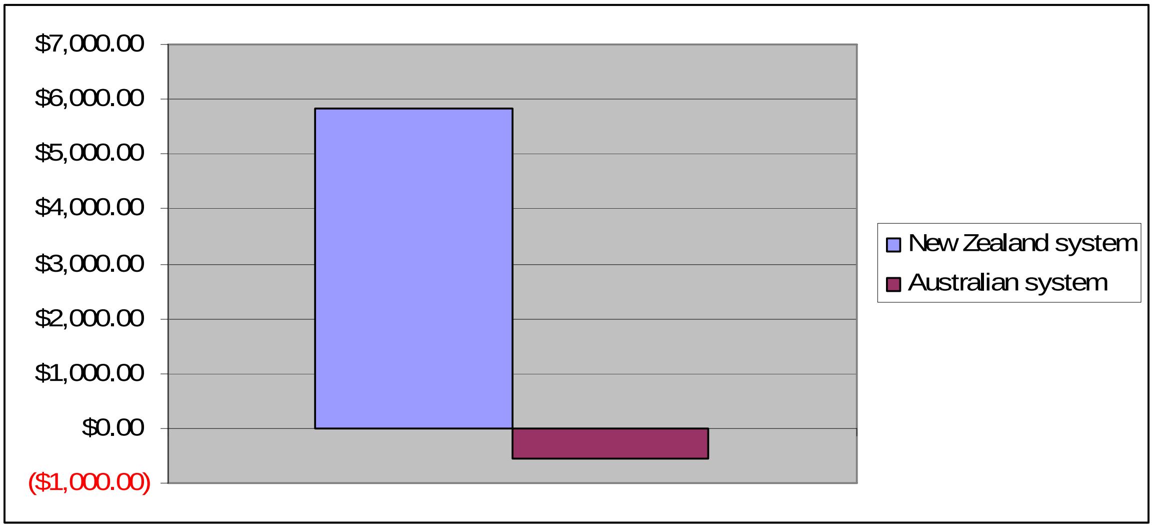

Figure 2: Net Present Values of New Zealand vs Australian systems (four occupants)

3.2 THE EFFECT OF DIFFERENT NUMBERS OF OCCUPANTS ON FINANCIAL PERFORMANCE

For a six person household the New Zealand greywater recycling system represents an even better investment, paying back in less than 5 years, with an IRR of 32.56 percent. Even a two person household should purchase a greywater system if judged on purely financial grounds, with a payback period of less than 15 years and an IRR of 11.44. The NPVs for the New Zealand system with two, four and six occupants are shown in Figure 3.

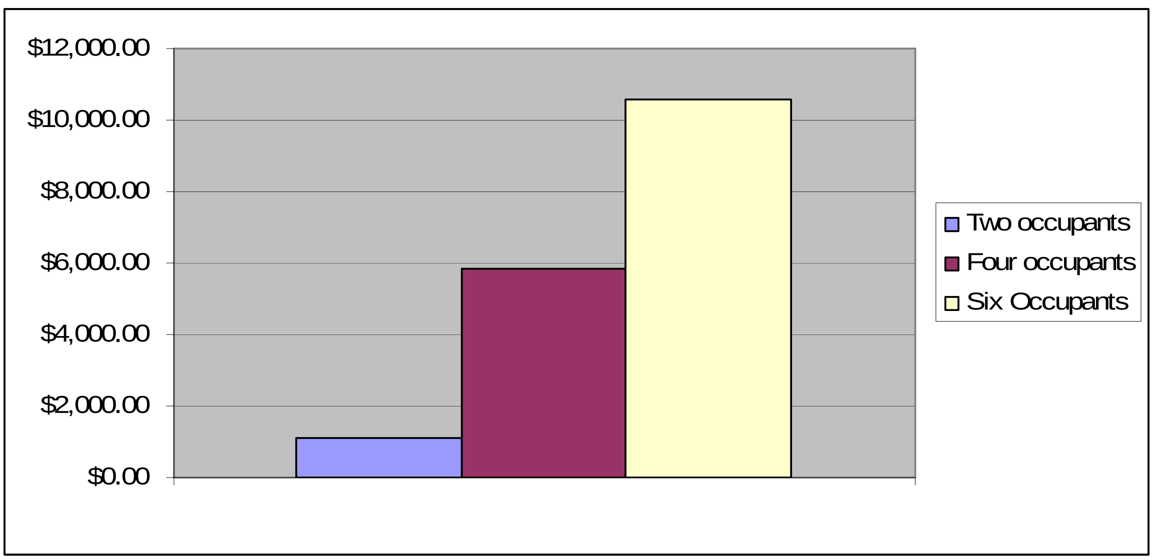

Figure 3: Net Present Values of 2, 4 and 6 person New Zealand systems

Installing the Australian system in a two person household would represent a very poor investment, with a NPV of -$5273.27, but for a six person household the investment is a good one, with a NPV of $4,173.62 and a payback period of under 14 years and IRR of 12.16%. This is not as good as the New Zealand system, of course and is subject to the assumption of the same low operating costs as well as longevity and reliability of that system, which is doubtful given the nature of the process used. The NPVs for the Australian system with two, four and six occupants are shown in Figure 4.

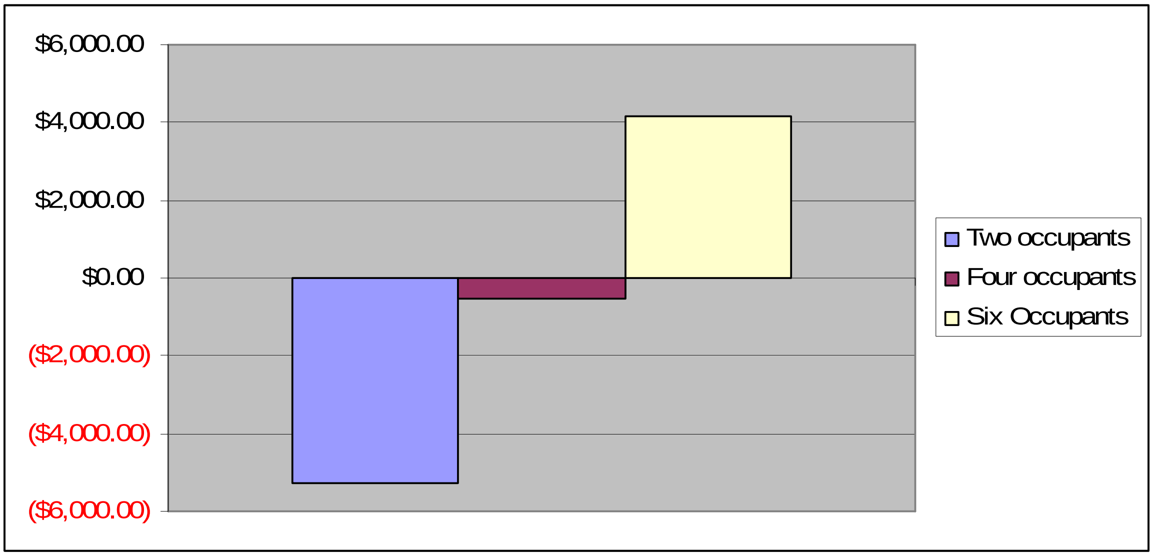

Figure 4: Net Present Values of 2, 4 and 6 person Australian systems

3.3 THE EFFECT OF RESOURCE CONSENT FEES ON FINANCIAL PERFORMANCE

A $1000 resource consent fee being charged resulted in a payback time of about two years longer than if such a fee had not been charged for the New Zealand system and an IRR that was nearly five percentage points lower. The NPVs of the system with and without resource consent fees of $1000 are shown in Figure 5.

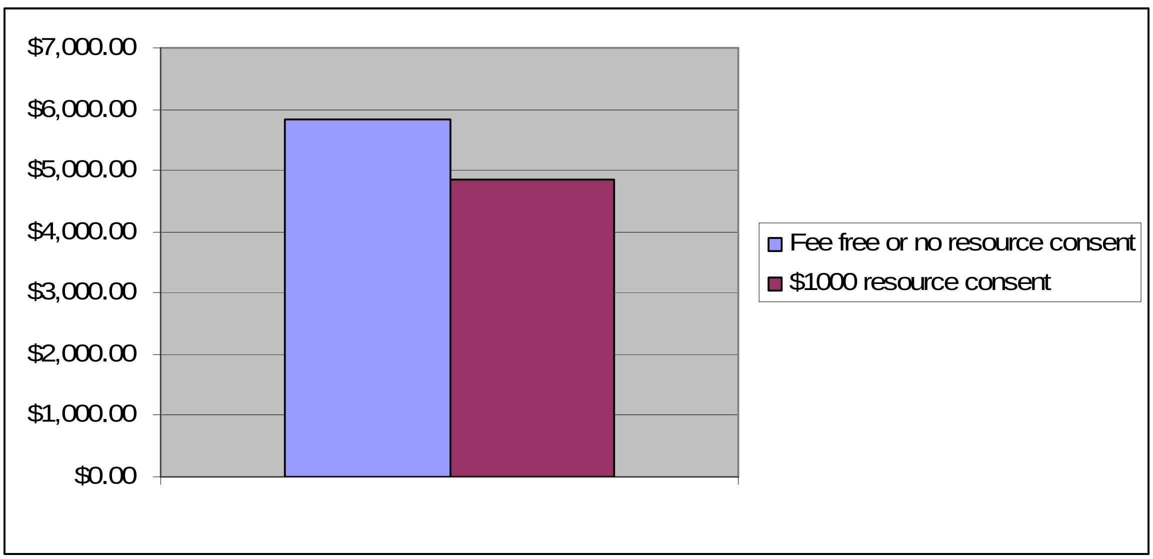

Figure 5: Net Present Values of New Zealand system with and without resource consent fees of $1000

The same resource consent fee also added about two years to the Australian system and reduced the IRR by a fraction over one percentage point. The NPVs of the system with and without resource consent fees of $1000 are shown in Figure 6.

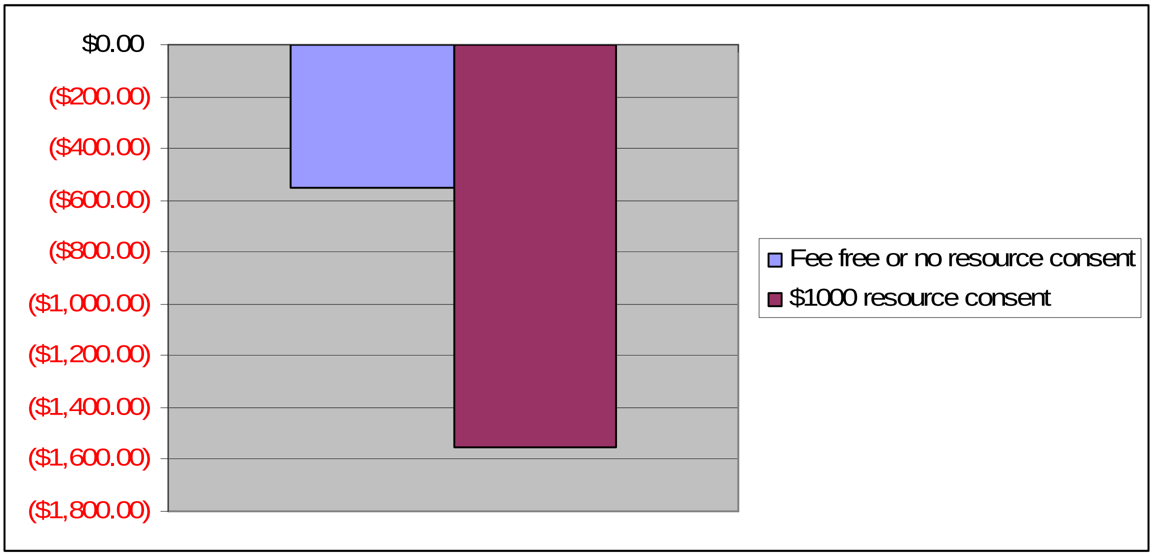

Figure 6: Net Present Values of Australian system with and without resource consent fees of $1000

4 DISCUSSION

It is clearly the case that the Australian regulations make greywater recycling at the household level uneconomic. It would only be worthwhile installing such a system if the household had a larger than average number of occupants, for environmental reasons or to solve a particular problem (such as garden irrigation in the event of a water ban or an overloaded on-site wastewater treatment system). This is perhaps why many Australian states offer a grant towards the cost of installing a system. Of course, the affordability would change significantly if the cost of water increased to the level of AU$2.50 per cubic metre that the PriceWaterhouseCoopers (2000) study suggested reflected a full user-pays approach. At present however it is unlikely that many people would be inclined to subsidise other water users and tax payers by purchasing a system to recycle water which would cost them more to own than it would save them.

On the other hand, the New Zealand system offered significant savings and a short payback period. It is presently an economically attractive proposition to even a small household in Auckland City, with a very high rate of return. Although the resource consent fee has a significant negative impact on affordability, it is still a very attractive investment. A rational consumer would be advised to purchase such a system, all things being equal.

However, uptake has been low. There are numerous possible reasons for this, but the perception of a quite different cost-benefit relationship and negative comments from council officers are amongst this author's favourite theories for the inertia. It appears that the Ministry of Health's position is quite influential, but this author believes that this comes at an environmental, financial (and thus social) and even public health cost.

If the arguments made in this paper regarding the relative risks and benefits are accepted, it is beholden upon regulators and officials to do more to promote greywater recycling, rather than passively permit, or actively discourage it, as presently happens. The author calls upon the Ministry of Health to re-evaluate its position and to communicate that to the local and regional councils.

Clearly, there are some risks from greywater recycling, although they are very small as discussed due to the relatively closed nature of an individual dwelling system and the inability of pathogens to successfully multiply in greywater. Those small risks can be further mitigated by ensuring that the greywater is dosed with chlorine (or an equivalent method used) and that the uses of the greywater are restricted to sub-surface irrigation and toilet flushing. These are the findings of a study of the risks on behalf of the Victorian council by Hyder consulting (Nolan, 2005) and are adhered to by the manufacturers of the New Zealand system discussed in this paper.

5 CONCLUSIONS

1) The Australian regulations result in a higher system cost, but for little practical effect; no further savings are made to water as a result, wastewater volumes are not reduced and health risks are not significantly increased.

2) Individual household greywater recycling can be more cost effective than reticulated services, but only if regulation is not overbearing.

3) Regulation is important to reduce risk, but it should focus on *permitting* low-risk uses and *controlling* higher-risk uses.

4) Adopting overly restrictive regulations would be unscientific and would lead to poorer public and environmental health outcomes as well as poorer social/financial outcomes.

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