RAIN TANKS OR RETICULATED WATER SUPPLY?

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Abstract

Reticulated water supply systems, standard practice in urban areas, suffer from water losses due to leaks and pipe bursts, and for satisfactory service need a high level of investment and intervention. Due to growing concern over future water shortages in urban areas, localized measures such as rain tanks are being widely promoted as a more sustainable alternative: they can promote improved water management through behavioural changes, thereby reducing the overall consumption.

The two systems, however, vary widely in terms of scale, useful life, and level of service, and it is impossible to assess accurately the relative long-term sustainability performance without a detailed life-cycle analysis. Using the results of a life-cycle study of reticulated supply and rain tanks for urban houses in Auckland, New Zealand, which concentrates purely on the environmental performance, this paper argues that rain tanks may not be the most sustainable option in all situations – while rain tanks are better in some situations, reticulated supply is better in others.

Key words: rain tanks, residential water supply, life-cycle analysis, life-cycle energy, carbon emissions, life-cycle cost

1. INTRODUCTION:

Reticulated water supply systems, standard practice in urban areas, have attracted criticism for being inefficient. They suffer from water losses due to leaks and pipe bursts, and for satisfactory service need a high level of investment and intervention. It has been reported that leakage rates of over 10% are common in the water industry (Peters 2005). In Auckland, fire demand, losses due to pipe leaks and bursts, and the network maintenance purposes, etc., together consume 12% of the total water supply (Metrowater 2004: 4). The population of the Auckland region is expected to double in 50 years to reach 2 million (Waitakere City 2005). At current consumption levels the increased demand created by population growth of that magnitude would require major new investment in water infrastructure to avoid the potential for future water shortages in urban areas. As a result, localized systems such as rain tanks are being widely promoted as a more sustainable alternative (Choguill 1996; Maher and Lustig 2003). Some countries, such as Sri Lanka, are already taking action to make these initiatives mandatory, especially for urban residential developments (Ministry of Urban Development and Water Supply 2005).

Current rain tank research, however, tends to focus on water savings and stormwater control (Herrmann and Schmida 1999; Coombes et al. 2003; Villarreal and Dixon 2005) rather than on the wider environmental implications such as sustainable resource use, greenhouse gas emissions, etc. The two systems, mains supply and localised systems, vary widely in terms of scale, useful life, and level of service, and it is impossible to assess accurately the relative long-term sustainability performance without a detailed life-cycle analysis.

Life-cycle studies of large infrastructure systems such as water supply are limited (Peters 2005; Tarantini and Ferri 2001; Lundin et.al 2000; Nilsson and Bergström 1995) due to methodological difficulties and the need for large amounts of data, although some Swedish studies have considered entire water systems (Tillman et al. 1998). Peters (2005) considered three alternatives, extension of existing system, desalination of sea water and river water, to augment current mains water supply in South Australia. In a life-cycle environmental study of alternative water systems scenarios for residential premises in Bologna in Italy Tarantini and Ferri (2001) considered stand-alone mains supply and mains supply coupled with techniques for water use reduction, rain water harvesting, and grey water reuse. Major water infrastructure, buildings and equipment were not included in this study as these are common to both scenarios studied. This exclusion may not have affected the final conclusions, as Lundin et al. (2000), in their study of alternative waste water handling and treatment options for two settlements with vastly different population densities in Sweden, have already found that, as a consequence of the long life of the systems considered, the construction-related impacts are less important than the operational requirements. Tarantini and Ferri found that water treatment and pumping are the most energy intensive processes and the necessary electricity generation (mainly natural gas and oil based), the most environmentally detrimental with 93% of the greenhouse gas emissions (ibid.: 4). These results are similar to the findings of Nilsson and Bergström (1995), who concluded that use of precipitation chemicals for waste water treatment generates a high amount of waste as a consequence of the production process. Arpke and Hutzler (2006) also found the energy used for mains water supply to be significant.

1.1. Background:

This paper considers the life-cycle environmental implications of alternative water supply systems for residential use in Auckland, New Zealand. The typical suburban house plot (or section) in Auckland has decreased in size over the last 20 years, especially in city locations. While a stand-alone house with 3 bedrooms is still the most common housing type in the Auckland region (ARC 2003), current construction trends, especially in the inner city locations, signal a move towards higher density urban housing. Auckland Regional Council has estimated that to satisfy the demand generated by the population increase and the trend in declining household density 201,000 new dwellings are required in the Auckland region by the year 2021.

Eighty-nine percent of the 142,000 properties receiving water from the mains supply in Auckland are residential properties (Metrowater 2004: 4). They are estimated to use over 62% of the current supply of 49,000,000 m^3/annum (WSL 2005). Therefore the average volume of water attributable to a house connected to the reticulated network is 240 m^3/annum[1]. The total volume of rain water that may be collected by the current housing stock, if located in Auckland with an average annual rainfall of 1240 mm (NIWA 2007), is shown in Table 1. Roof eaves of New Zealand houses tend to vary from non-existent to over a half a metre. The volumes indicated were calculated based purely on the floor area with no allowance for roof eaves. Including eaves could add a further 3–14% to the roof area and hence to the volume of water collected. According to these calculations, the average volume of water currently consumed cannot be collected solely using rain harvesting systems in the existing houses.

The Parliamentary Commissioner for the Environment (PCE 2001: 37) suggests that technical measures such as dual-flush toilets, low-flow shower heads, front-loading washing machines and flow restrictors, can reduce household water use per person by 50%. This reduction, however, has been calculated for a 5-person household and represents only 7% of the houses in the Auckland region (ARC 2003: 9). Lucas et al. (2006) have shown that mains water savings increased with increasing occupancy and ranged from only 3% to 17% for a 150 m^2 house located in Auckland with 1–5 persons/house. However, their assumption on outdoor

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[1] The actual water use may be different from this and would depend on the number of occupants

water use was 32%, considerably higher than the average (20%) used in New Zealand houses. Tarantini and Ferri (2001) also reported that 50% reduction in mains water consumption volume was only possible with technical measures combined with rain water collection and grey water recycling in the Italian house with an average consumption of 180l/person/day. Average consumption in the Auckland house is 227l/person/day based on the volume of water supplied to residential properties although the water industry (WSL 2004: 8) estimates this to be about 300l/person/day.

Table 1: Capacity to collect rain water in the current housing stock in Auckland

Year of construction	**% of the total stock**	**Average floor area (m^2)**	**Volume of water that may be collected (m^3/house)**
BIAC[2]	-	94	105
1970s	18.7%	146	163
1980s	13%	149	166
1990s	13.2%	173	193
Since 2000	10.3%	194	217

(Based on: Centre for Housing Research, *Changes in the Structure of the New Zealand Housing Market*, 2004)

One could, however, argue that the current water demand in Auckland is not fixed and can be reduced through behavioural changes. Anecdotal evidence and personal experience of the second author living in an area of Auckland that has no mains water supply, and where a population of 8000 uses rainwater for all household needs, suggest rain tanks can promote improved water management through behavioural changes, thereby reducing the overall consumption to match supply. Darian and Darian (2006) argued that people are reluctant to change their behaviour to conserve resources because they believe that technology can overcome the problems of resource shortages. They found that a lack of knowledge of the specific actions required and the perceived difficulty in changing behaviour are hindering longer term water conservation. They argued that knowledge that a certain environmental problem is specific to a particular location is more likely to promote behavioural change than is general knowledge of environmental problems. According to Darian and Dairan’s survey, the most popular methods of reducing water use were turning the water off while brushing teeth, having larger loads of laundry, using less water when washing dishes, and repairing leaks (ibid.) Any measures to reduce the current consumption of potable water are important because of the energy and carbon emissions involved in treating and delivering water.

2. LCA OF ALTERNATIVE WATER SUPPLY SYSTEMS IN AUCKLAND, NEW ZEALAND

To assess the long-term performance of water supply alternatives to houses in Auckland based on wider environmental considerations such as resource use, energy use and carbon emissions, etc., three scenarios are considered:

- Use of mains supply only,
- Use of rain tanks only to supply all domestic water demand for new developments in greenfield sites lacking infrastructure, and
- Use of rain tanks to provide 65% of the domestic water demand[3] for residential developments in already established areas. Rain tanks would provide water for toilet

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[2] Building Industry Advisory Council

flushing, clothes washing, and garden watering, while reticulated supply would provide the balance.

2.1 Mains supply only scenario:

Mains water system to supply the total domestic water requirement.

2.2 Rain tanks only scenario:

The use of rain tanks alone to supply all domestic water requirements could not only eliminate the need to extend the mains supply network to greenfield sites but also encourage behavioural changes that would lead to lower water consumption. Furthermore, this use would eliminate water losses through pipe leaks, bursts and network maintenance purposes, thus reducing the actual water requirement to 211 m^3/house (from 240 m^3/house). With a conservative estimate of 15% reduction in the water use to account for technical measures, such as low-flow shower-heads, domestic water demand could be further reduced to 180 m^3/house. According to Table 1, 180 m^3 of water may be collected in larger houses with a floor area of over 150 m^2, while some behavioural changes would be necessary if rain tanks alone were to provide the total demand in smaller houses. The use of rain tanks alone in Auckland houses with varying floor areas and their impact on life-cycle performance have already been considered (Mithraratne and Vale; 2006a; 2007a; 2007c)

Water quality and fire demand would be the two main concerns with the rain tanks only scenario. Rain harvesting system components readily available in the market could be used to improve the water quality by screening and removing suspended matter from the water that enters the rain tank. On-site measures, such as in house water storage, could be used to meet the fire demand, although this could increase the cost to the individual home owners.

2.3. Rain tanks to supplement mains supply scenario:

The use of rain tanks to supplement the water needs of houses does not encourage water conserving behaviour as occupants are guaranteed supply from one source or the other. On the other hand, an earlier study of mains water supply to Auckland found that 61% of life cycle energy and 28% of life cycle carbon emissions are due to operation of the system (Mithraratne and Vale 2007b). Any reduction in potable water use could therefore reduce the environmental impacts. Nonetheless, unlike the rain tanks only scenario, this requires both a mains supply and a rain tank system for each house, leading to higher construction energy and resource use. The rain tank size commonly used to supply all domestic water needs in New Zealand is 25 m^3, which is impossible to accommodate in the smaller suburban house plots. The use of rain tanks to supplement the mains supply could reduce the tank size to 9 m^3 for New Zealand houses with a roof area of around 150 m^2 (North Shore City 2007).

If it is assumed that all houses have technical measures implemented for demand management (DM), water demand is reduced from its current 240 m^3/annum to 204 m^3/annum. When rain tanks supplement the mains supply, houses receive their potable water requirements (71 m^3/annum)[4] from the mains supply while a rain harvesting system with a 9-m^3 rain tank is used for the balance. The volume of rain water that could be collected is more than the 117

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[3] Domestic water use comprises 25% for toilet use, 20% for laundry, 20% for garden watering, 25% for bathroom use, and 10% for kitchen use (Waitakere City 2007)

[4] Network losses apply only to potable water

m^3/annum required for non-potable uses in all houses. Use of rain tanks to supplement potable water demand would therefore be feasible in all Auckland houses.

3. METHODOLOGY:

The life-cycle energy use by the water supply systems can be divided into the embodied energy of the system (construction and maintenance) and the operating energy (for pumping water from the rain tank or energy used for the reticulated system operation). Life cycle energy and carbon emissions of the reticulated system supplying water to Auckland have already been established (Mithraratne and Vale 2007b). Irrespective of the volume of water used, a house connected to the mains supply system is responsible for its share of the construction-related energy and emissions of the mains system.

Common materials used for rain tanks in New Zealand are plastic and concrete, with some use of galvanised steel in rural areas. This study is limited to the use of plastic and concrete rain tanks. For rain tank systems, the embodied resources would depend on tank materials, size, and the components used. Operating requirements would depend on the volume of water to be pumped from the rain tank (180 m^3 for the tank only scenario and 117 m^3 for the mains supplemented by tanks scenario) or used from the mains supply (204 m^3 or 71 m^3).

To investigate the relative performance of water supply systems and the impact of the system selection on the life-cycle performance, this study compares the following alterative supply systems.

- Mains supply with and without demand management,
- Rain tank only with demand management and 25 m^3 capacity concrete and plastic tanks, and
- Rain tanks to supplement mains supply with demand management and 9 m^3 capacity concrete and plastic tanks.

Life-cycle energy, CO_2 emissions and cost were established for the alternative water supply systems over useful house life, which is assumed at 100 years. Embodied energy and CO_2 emissions of various materials and systems are based on data published for New Zealand building materials (Alcorn 2003). Life-cycle cost was calculated in real cost terms (inflation excluded) using the current prices for water (Metrowater in Auckland), electricity (Mercury Energy in Auckland) and materials (rain tanks, rain harvesting systems, water pumps, etc.) at a discount rate of 5% and constant prices. Current electricity prices charged by Mercury Energy for residential customers are divided into 2 components – line charges and unit charges. Based on the standard all-inclusive price plan, unit charge is 15.73 cents/kWh and line charge is 80.86 cents/day (Mercury Energy 2007). Line charges, being common to all electricity uses in the house, have been disregarded. GST is also included for all costs. Life-cycle cost thus calculated represents the present value of the total amount required to be set aside today to maintain water supply to the average house in Auckland over the analysis period

4. RESULTS AND DISCUSSION:

Life-cycle energy use, carbon emissions, and the cost of alternative water supply systems (mains supply, concrete tank, plastic tank, mains supply with concrete tank and mains supply with plastic tank) were calculated over the useful life of the house. Life-cycle energy use comparison for the alternative systems is as shown in Figure 1.

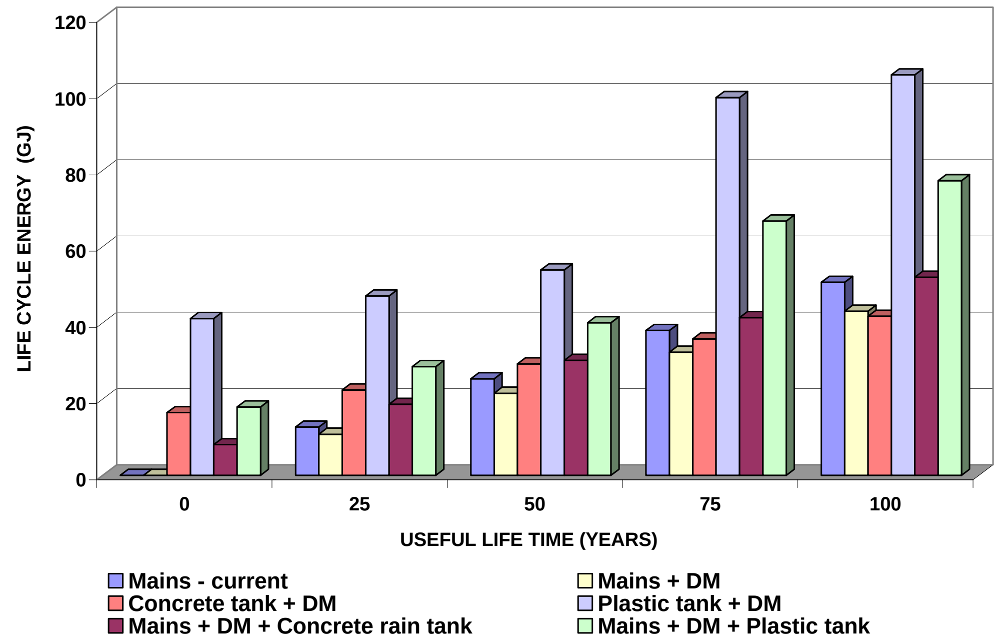

Fig. 1: Life cycle energy comparison for alternative water supply systems

In terms of the life-cycle energy contribution, the concrete tank system has the least life-cycle energy with 18% and 3% lower life cycle energy compared with mains supply with current water use and mains supply with demand management. However, mains supply with demand management is better than all the other alternatives considered. Due to the high energy content of plastic rain tanks, which require replacement during the life of the house, use of plastic rain tanks to supply total domestic water demand is inferior to the use of rain tanks supplemented by mains supply with both tank materials considered. Smaller tank size with lower embodied energy used in the rain tanks supplementing mains supply scenario leads to lower life-cycle energy.

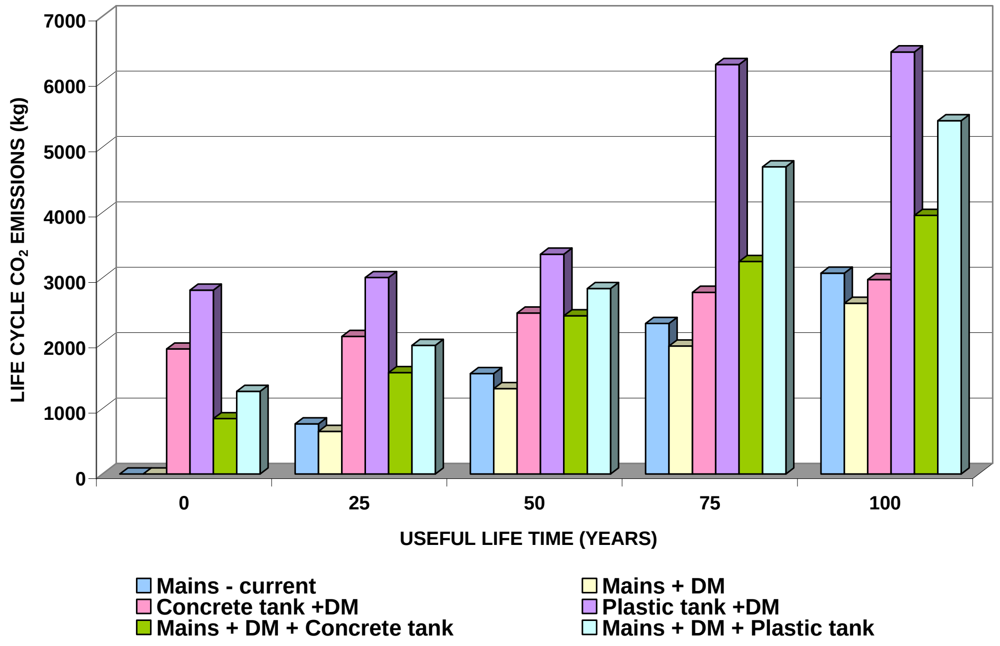

Fig. 2: Life cycle CO_2 emissions for alternative water supply systems

Figure 2 is a comparison of the life-cycle CO_2 emissions for the water supply alternatives over the useful life of the house. In terms of the life-cycle CO_2 emissions, the concrete tank system is marginally lower with 3% less emissions compared with mains supply with current water use, but 13% higher than the mains supply with demand management. The other alternatives follow a pattern similar to that for the life-cycle energy.

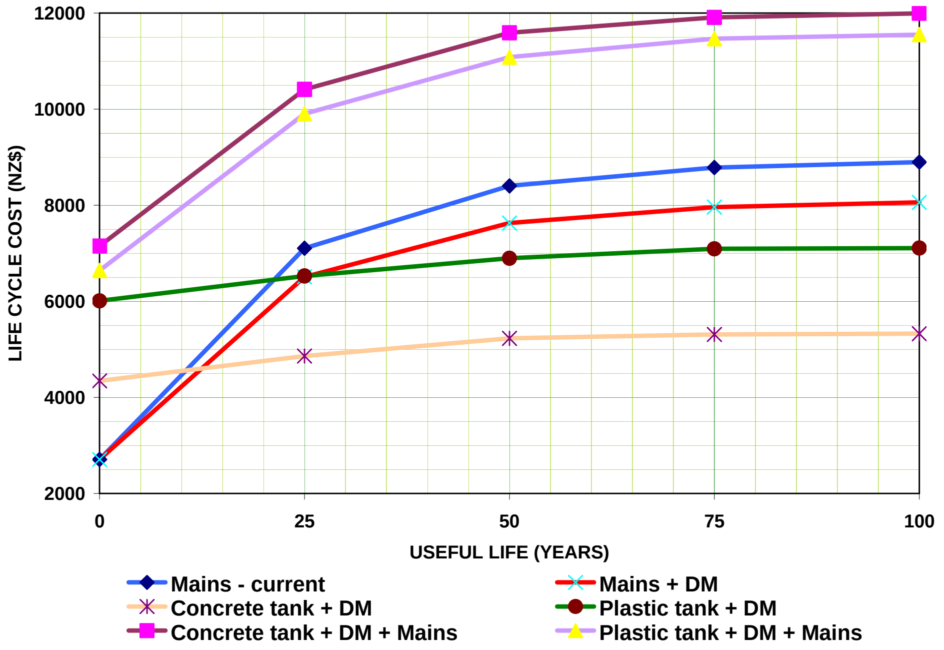

Fig. 3: Life cycle cost of alternative water supply systems

Initially, concrete and plastic rain tank only systems are 66% and 122% respectively more expensive compared with the mains supply system. However, concrete and plastic rain tank systems become cheaper than the mains supply with demand management after 12 and 20 years respectively. By the end of their useful life concrete and plastic rain tank systems are 34% and 12% respectively cheaper than being connected to the mains supply with demand management. Due to the need for both mains supply and rain tank systems, the use of rain tanks to supplement mains water supply is significantly more expensive than the mains supply throughout the useful life of the house.

5. CONCLUSIONS

- In Auckland, the current level of water consumption cannot be sustained with rain tanks alone. Reducing the consumption through employing technical and behavioural measures to reduce demand would be essential to supply all water demands with rain tanks. This could improve the life-cycle performance of residential water supply in New Zealand.
- The selection of the rain tank material is crucial in terms of life-cycle energy, carbon emissions and cost.
- The practice of supplementing the mains supply with rain tanks increases the life-cycle energy and carbon emissions attributable to the water supply system of a house.
- Rainwater harvesting systems, provided they use concrete rain tanks, could be proposed as a method to reduce the energy use and cost associated with water supply to residential buildings in Auckland. In these terms, the benefits to New Zealand could be significant.

This research, however, considered water supply system alternatives in isolation. The advantages of using rain water tanks extend beyond water supply, but this aspect was not included here. For a true evaluation of environmental performance of rain tank systems, the impacts on waste and stormwater management also need to be included.

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