Feasibility assessment of recycled water use for washing machines in Australia through SWOT analysis.

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Abstract

Sustainable urban water consumption has become a critical issue in Australia due to increasing urbanization, the country's dry climate and its increasingly variable rainfall. Water recycling is considered vital to alleviate the demand on limited water supplies. The demands on water utilities to develop water recycling capacity and supplies are therefore expected to intensify in Australia. Dual reticulation systems have already been introduced in many cities in Australia and this is likely to expand to many other cities in the future. Developed and proposed dual reticulation schemes in Australia demand the substantial replacement of tap water with recycled water to ensure system optimisation and the sustainability of water supplies. This study successfully applies Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis as a research tool to assess the feasibility of use of recycled water in washing machine applications. Through the identification of the reuse schemes' strengths (elements to leverage and build on) and weaknesses (areas to seek assistance and support) in addition to community opportunities (areas to leverage for program advantages) and threats (elements that could hinder the scheme), the positive aspects for the use of recycled water in

25 washing machines is observed. Further study to address the specific concerns of the general
26 public and the development of guidelines for this new end use is however essential to guide
27 the implementation of recycled water schemes.

28 **Author keywords:** Water recycling; Washing machine; End use; SWOT analysis.

29 1. Introduction

30 Australia is in the midst of a water crisis and at present almost all Australian capital cities,
31 with the exception of Darwin and Hobart, are experiencing water supply problems. The
32 International Water Management Institute has declared that Australia is one of the high water
33 stress regions of the world (IWMI, 2006). Pressure on the availability of Australian
34 freshwater resources is significantly increasing due to emerging climate change and
35 population growth factors (Dismitriadis, 2005). Most of the eastern part of the Australian
36 continent has experienced almost five years of continued lower-than-average rainfall. As the
37 consequence, many cities and towns continue to face drought conditions with some water
38 supply reservoirs at their lowest recorded levels (Willis et al., 2010). The Australian National
39 Climate Centre showed the decreasing trend of annual rainfall by up to 50 mm per year over
40 the southern half of the continent (CSIRO, 2007). With the limited water supplies in the
41 urban cities coupled with increasing urban population, providing safe, reliable and
42 sustainable water services for Australian cities is a major challenge for the 21st century.
43 Sustainable urban water consumption has thus become a critical issue for Australia.

44 From a worldwide perspective, urban water management has many challenges and water
45 recycling is considered vital to alleviate the demand on existing but limited water supplies
46 and is gaining impetus throughout the world. Demands on water utilities to develop water
47 recycling capacity and supplies are therefore in the future expected to intensify in many
48 countries of the world. The impetus on use of recycling water in Australia is increasing with

the time however; suitable clients of the recycled water product are difficult to come by. Household water use is the second largest user of water in Australia. A study by Birrell et al. (2005) on the impact of demographic change and urban consolidation on domestic water use in Australian cities revealed that, during 2001–2031, water demand in major cities of Australia will increase by an average of 37%. Householders in highly urbanized cities like Sydney (Sydney Water, 2010) and cities of Western Australia (Water Corporation, 2006) use 70% of the total supplied drinking quality water. Almost 66% of the total supplied water to the Gold Coast was for residential water consumption monitored in the year 2007-2008 (Willis et al., 2010). It is therefore of great importance to reduce the potable water consumption of the residential sector.

Water sensitive urban development (WSUD) which aims to optimise the substitution of non-potable water for potable water has been already introduced in Australia. Dual water supply systems are a major component of WSUD and have been activated in many cities of developed world. In Sydney, recycled water is currently provided for residential use in several suburbs including Rouse Hill, Sydney Olympic Park and Newington, and will be used in the future in Hoxton Park and Rope Crossing. In addition, as part of the Metropolitan Water Plan, the NSW Government will provide recycled water to 160,000 homes that are expected to be built in new suburbs in Sydney's North West and South West (Metropolitan water plan, 2006). In the period 2004-05 compared with 2001-02, Australian households experienced a ten-fold increase in the use of reused water (ABS, 2004/05). In the future, there is a high probability that the supply of recycled water in many Australian communities with dual water supply systems will be increased because of the increasing water shortage and rapidly spreading urbanization. Housing developments at Newhaven and Mawson Lakes in Adelaide, South Australia also featured dual pipe systems. The Aurora Estate in Melbourne and Pimpama Coomera in the Gold Coast have also commenced construction of dual water

systems (Radcliffe, 2004; Tjandraatmadja et al., 2009). Developed and proposed dual reticulation schemes in Australia demand more replacement of tap water with recycled water in Australian households for system optimisation and sustainability in water supply. However, the existing end uses of such schemes are very limited.

Currently, garden irrigation, toilet/urinal flushing and car washing are the most popular end uses of the recycled water from dual reticulation systems. The United Nations Economic and Social Council released a policy in 1958 stating that, "No higher quality water, unless there is a surplus of it, should be used for a purpose that can tolerate a lower grade". However, in many countries including Australia, potable quality water is typically used for laundry activities. The laundry use of recycled water has not been sufficiently investigated and researched in the past. Water efficiency in terms of washing machines has been the focus of many regulations and some significant improvements have been already achieved, including water rating of machines and subsidizing the cost of the more water efficient machines that are available to the general public (Water Corporation, 2006). The impetus for replacing the top loading style of washing machine by front loading options (as they are more water efficient) is one strategy implemented to fulfil this aim. In addition, the current persisting and increasing water stress impels us to learn from overseas experiences and to improve this efficiency even further. Recycled water for washing machines is believed to be more sustainable option and this study attempts to make use of SWOT analysis to assess the feasibility of this new end use of recycled water

2. Methods

This study applies a SWOT analysis, which is a research tool that is widely used in business management applications. There have been several examples of the successful application of SWOT analyses in the fields of regional energy planning (Terrados et al., 2007) and municipal solid waste management (Srivastava et al., 2005).

This analysis tool was used to identify the strengths and weaknesses of the new end use (use of recycled water for laundry) followed by the associated external opportunities and threats. With the aid of this tool, the strengths of any project or scheme are identified so as to improve efficiency and also identify weaknesses so that they can be minimised.

Every programme, project, development and management plan has its strengths and weaknesses, opportunities and threats. SWOT analysis identifies the project's strengths (elements to leverage and build on) and weaknesses (areas to seek assistance and support) plus community opportunities (areas to leverage for program advantages) and threats (elements that could hinder the program). Hence SWOT analysis can provide an insight to the ways and means of converting the threats into opportunities, and off-setting the weaknesses against the strengths. This analysis could be undertaken for any idea, organization, person, product, programme or project (Johnson et al., 1989). The technique is credited to Albert Humphrey from Stanford University (Arslan and Er, 2008). SWOT analysis is designed to be used in the preliminary stages of decision-making on one hand, and as a precursor to strategic management planning on the other (Arslan and Er, 2008).

When used properly, SWOT can provide a good basis for strategy formulation (Hill and Westbrook, 1997; Yüksel and Dagdeviren, 2007). However, SWOT analysis does not provide an analytical means to determine the relative importance of the factors, or the ability to assess the appropriateness of decision alternatives based on these factors (Kajanus et al., 2004). But it does pinpoint the factors in the analysis and allows analysts to categorize factors as being internal (Strengths, Weaknesses) or external (Opportunities, Threats) in relation to a given decision, and thus enables them to compare opportunities and threats with strengths and weaknesses (Shrestha et al., 2004).

123 ## 3. Results

124 ### *3.1. Strengths and Opportunities analysis*

125 Recycled water has proven to be effective and successful as a new and reliable water supply.
126 Non-potable reuse is a widely accepted practice and its use is likely to continue to grow in the
127 future. Households are the second largest water consumer of water in Australia (ABS,
128 2004/05). Almost all households (97%) have washing machines (ABS, 2008) and water is the
129 single most important resource in laundering operations. Large amounts of water are
130 routinely used in laundering facilities that involve washing and rinsing cycles. Prolonged
131 drought conditions in most of Australia's major cities during the past decade have led to
132 many calls from the community for less consumption of potable water (Hurlimann and
133 McKay, 2006). The uses of recycled water are likely to be increased in the future to meet the
134 needs of the environment and to satisfy escalating water demands. Even if Australia were to
135 cut its per capita water use by 7% and if one-quarter of new suburbs were to use recycled
136 water for outdoor activities and toilet flushing, Australia would still face a shortfall in supply
137 of 800 GL by 2030 (Howe, 2005). Current recycled water initiatives in Australia include the
138 use of reclaimed wastewater and stormwater for urban, residential, industrial and agricultural
139 purposes, but not for washing clothes. According to statistics in the NSW State of the
140 Environment Report on typical water usage in Sydney metropolitan households, laundry use
141 consumes up to 20% of total water demand (Ngo et al., 2009). A significant reduction in
142 household drinking water demand could therefore be achieved if the drinking quality water
143 for clothes washing was replaced with recycled water. Dual reticulation schemes, for
144 example, the Rouse Hill Development Area (RHDA) and Sydney Olympic Park Authority
145 (SOPA) traditionally provide recycled water for outdoor garden use and toilet flushing at a
146 total saving of approximately 35% of potable water use. It is estimated that the addition of
147 recycled water in washing machines would increase this saving of potable water to 45% (Ngo

et al., 2009). The introduction of this new end use of recycled water would therefore increase the saving of potable water use by 10%. Pakula and Stamminger (2010), advocate that the volume of water used for laundry washing significantly influences the total water consumption of households in most of other countries in the world. The influence of laundry water consumption is significant on household water consumption of different states of Australia as shown in Fig. 1 (ABS, 2004).

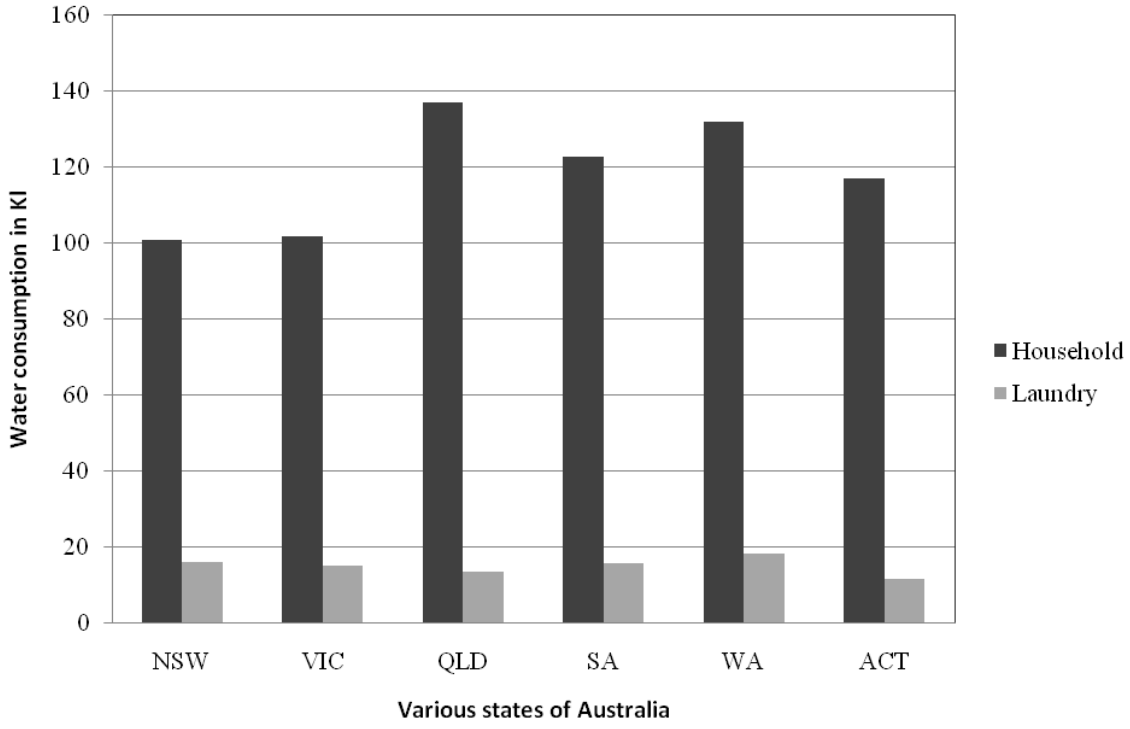


Fig. 1. Annual per capita water consumption by location of use in 2001 (Kl)

Note: NSW: New South Wale; VIC: Victoria; QLD: Queensland; SA: South Australia; WA: Western Australia and ACT: Australia Capital Territory

Kl: kiloliter

The significant laundry water consumption in households can be observed in major cities such as Sydney, Melbourne and Perth, as shown in Fig. 2, reproduced from Wilkenfeld et al. (2004).

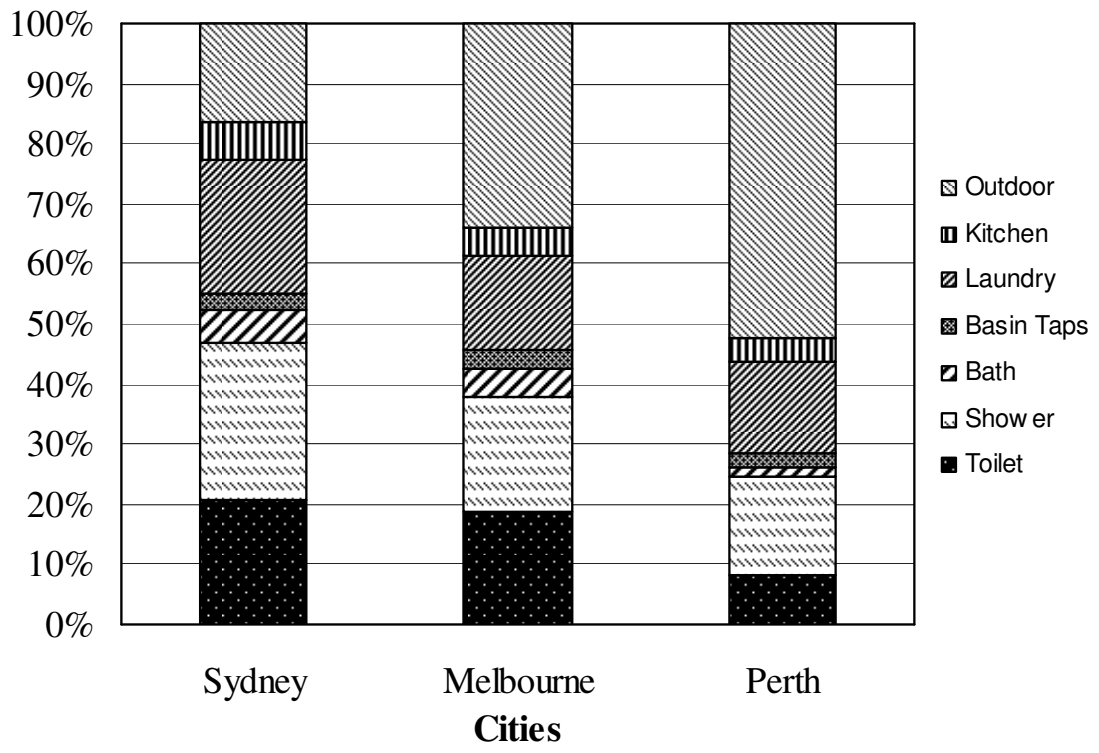


Fig. 2. Estimated use of water by households in Sydney, Melbourne and Perth

In Australian dual reticulation schemes, there is higher demand for recycled water during hotter (and generally drier) summer months due to increased outdoor watering than in cooler months. In line to this, washing machine (washing clothes is a year round activity) as a new end use will have almost constant demand throughout the year and hence would provide a means to even out the demand. In addition to that, residential use of recycled water for laundry use involves no extra cost for the dual reticulation system but increase the saving of potable water in the same costing. Therefore this would bring down the cost of residential dual water reticulation systems. Anderson (2006) also believes that amendment of the NSW

guidelines for urban and residential use of recycled water to allow laundry use would bring down the cost of residential water recycling systems.

For the successful implementation of any recycled water schemes, detailed consideration of community concerns are vital. From a review of eight studies (Fig. 3) undertaken in different parts of Australia regarding the attitudes of community towards the use of recycled water in washing machines, the authors reveal that the average percentage of respondents (irrespective of the number of the participants and the locations) opposed to the use of recycled water in washing machine is 25%, as shown in Fig. 3 i.e. 75 % of respondents support the use of recycled water in washing machines.

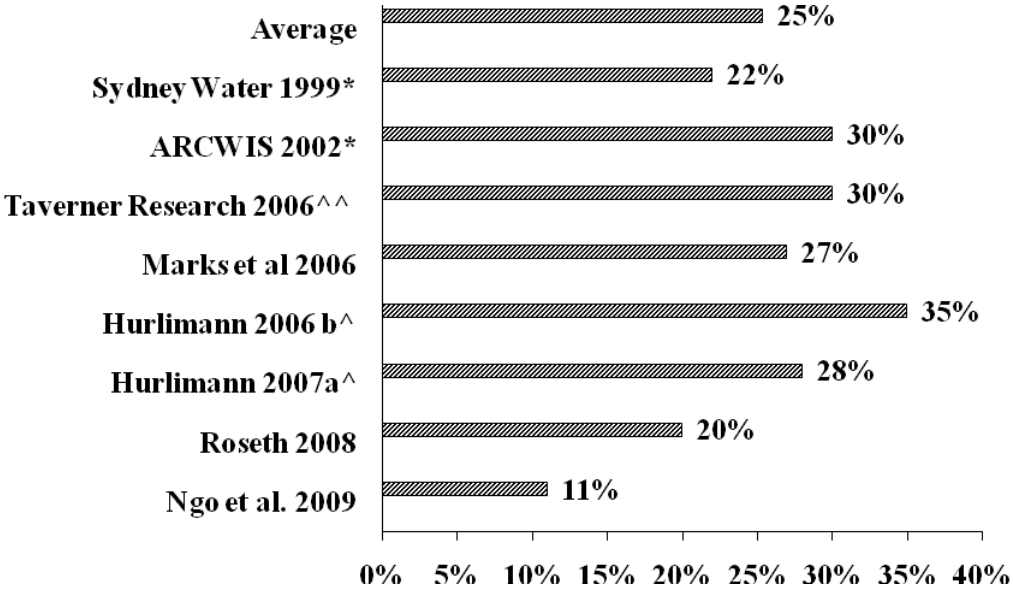
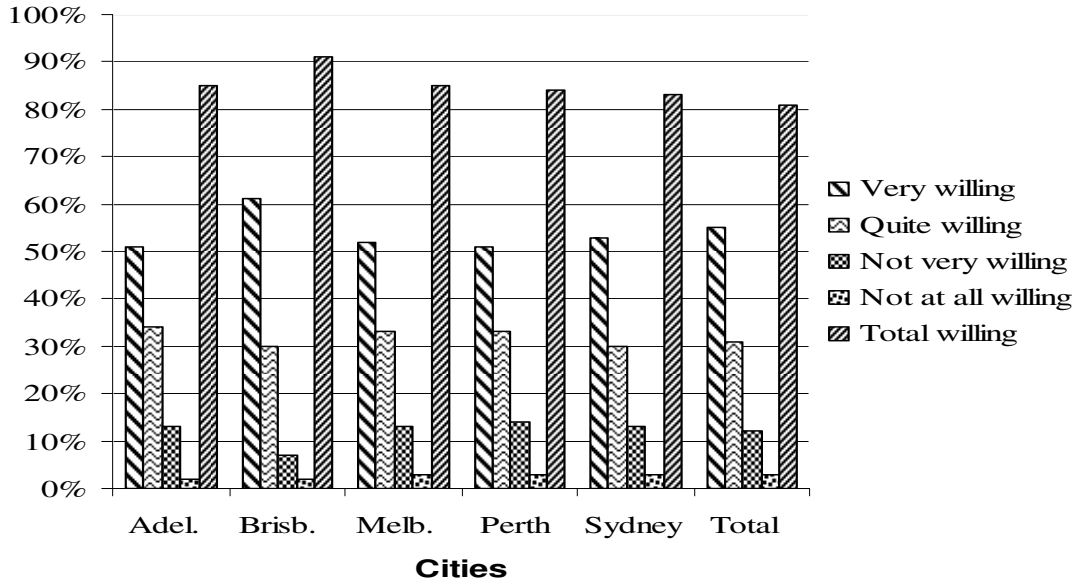


Fig. 3. Respondents (%) opposed to use of recycled water in washing machines in Australia.

*Note: * Cited in Radcliffe* (2004), ^^ *Cited in Storey* (2009) ^ *Cited in Hurlimann* (2008), *ARCWIS= Australian Research Centre for Water in Society*

Dolnicar and Saunders (2006) from their study suggest that the average support for using recycled water for laundry purposes is 80%. Roseth (2008) carried out a survey in Australia to investigate the willingness of the people to adopt certain forms of usage of recycled water.

209 On average more than 80% of respondents from different cities of Australia are willing to use
210 recycled water for washing clothes as shown in Fig. 4.



211

212 **Fig. 4**. Willingness to use recycled water for washing clothes

213 *Note: Adel. - Adelaide, Brisb. - Brisbane, Melb. – Melbourne.*

214 The Department of Epidemiology and Preventive Medicine at Monash University suggested
215 that class A recycled water, as used in the Rouse Hill scheme, for washing machine use will
216 not lead to the transmission of micro-organisms at concentrations likely to cause enteric
217 diseases (Storey, 2009). O'Toole et al. (2008) investigated the microbiological safety of using
218 recycled water in washing machines and concluded that highly treated recycled water used
219 for machine washing will not lead to the transmission and consequent exposure of users to
220 micro-organisms likely to cause enteric diseases. Storey (2009) concludes from his study that
221 recycled water is not considered to have a negative effect on washing efficacy or staining.

222 The proposed laundry as a new end use of recycled water has a high potential. The ownership
223 rate of washing machines, in Australia is 97% whereas in most of the developed countries it

is approximately 90%. In a survey of 780 million households in 38 countries of the world that involved approximately 2.3 billion people (one third of the world population), 590 million houses are using washing machines (Pakula and Stamminger, 2010). Therefore, there is a significant opportunity of using this new end use of recycled water to most countries of the world whether they be developed or developing where laundry use is vital. The use of cold water in washing machines has been steadily increasing in Australian households, rising from 61% in 1994, to 74% in 2008 (ABS, 2008) and this is a good trend for using recycled water for washing machines as the recycled water supply in the existing and proposed dual reticulation systems are in cold supply form.

Weaknesses and Threats analysis

The use of recycled water for washing clothes, in the physical sense, is closely related to their close physical contact and interaction with the recycled water. The results from various surveys (Bruvold, 1984; Denlay and Dowsett, 1994; Jeffrey and Jefferson, 2003) have confirmed this sentiment through the unfavourable responses from users towards the perceived detrimental impacts of human contact with the reclaimed water and a sense of residual germ transfer. Prior to introducing any new use of recycled water, it is very important to ensure that community's expectations and desires of the delivered product for the particular use are acceptable and understood. Customer research commissioned by Sydney Water, involving a residents strategy survey in Australia and other related studies show general support for the concept of using recycled water in washing machines. However, significant concerns were raised by participants that include the effects of recycled water on; public health; aesthetics and discolouration of laundry and washing efficacy; as well as; machine durability (Storey, 2006; Ngo et al., 2009). From aesthetic reasons and public health concerns, higher quality water is required to be used in washing machines (Ngo et al., 2009; Pham et al., 2011). The study of Hurlimann and McKay (2006) concerning the importance of

various attributes of recycled water also concludes that the general public demands for higher quality water for washing clothes in comparison with garden watering and toilet flushing applications. Higher quality recycled water, requires a higher level of treatment which is more expensive and more energy intensive.

Through the survey phase, people demonstrated their willingness to accept the use of recycling water in washing machines, but the scenario is less supported when the practical implementation is more fully considered. There has been no recognition of this new end use of recycled water in the Australian guidelines for the use of recycled water (Hurlimann and McKay, 2006) and even if recognized as in draft guidelines for the use of recycled water in Western Australia (Department of Health, Government of Western Australia, 2009) has been considered as high risk end use. There is a noticeable lack of social research in understanding the general public perceptions of this application. Only a few studies (Hurlimann and McKay, 2006; Roseth, 2008; Ngo et al., 2009) have been undertaken. Detailed research to address all the major concerns of the general public is urgently needed. Most state health authorities in Australia currently do not endorse the use of recycled water for laundry and machine washing because of a lack of safety data (Roseth, 2008). There is a noticeable lack of research in defining or establishing the appropriate criteria and parameters of recycled water fit for the intended new end use. Very few researchers (O'Toole et al., 2008; Storey, 2009) claim that highly treated recycled water used for machine washing will not lead to the transmission and consequent exposure of users to numbers of micro-organisms likely to cause enteric diseases. However, it is a common belief that laundry after wash should be free from bacteria. The bacteria removal efficiency of tap water is high in wash cycle of high temperature. The bacteria removal efficiency of the recycled water which will be in the form of cold supply has not yet been given due consideration. Hence, the weakness and threat analysis indicates that

the community and scientific perception has a significant impact on decision making and understanding associated with this new end use.

3.2. SWOT profile of the new end use

The strengths and weaknesses of the new end use (recycled water for washing clothes) followed by the associated external opportunities and threats correspondingly are identified and the SWOT profile of the new end use is summarized in Fig. 5.

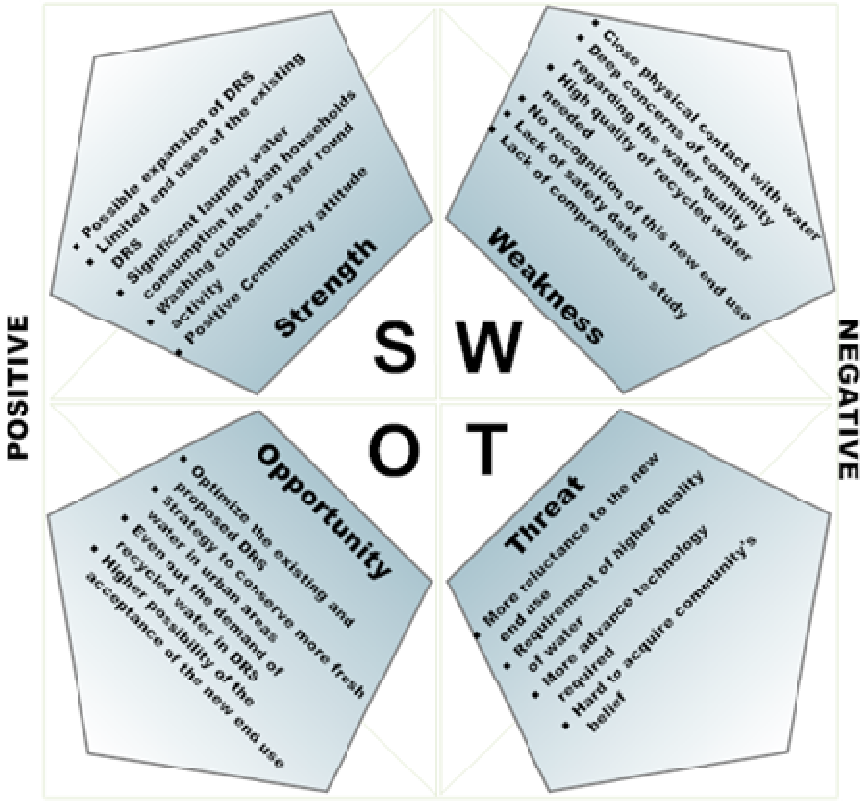


Fig. 5. SWOT profile of the new end use

Note: DRS- Dual reticulation systems.

4. Conclusions

From this study, the SWOT analysis has been successfully applied as a tool to identify the feasibility of using recycled water in washing machines. The positive trend for using the

286 recycled water in washing machines is observed. The necessity for a further comprehensive
287 study on the feasibility of use of recycled water in washing machine is confirmed. The focus
288 should be on field trials investigating customer acceptance, their specific concerns towards
289 this new end use and implementation issues as well as washing machine durability and
290 longevity. The required recycled water quality for washing machine use without
291 compromising the health of the people and the aesthetics of clothes as well as assuring the
292 machine durability can be experimentally verified. The formulation of an appropriate criteria
293 and parameters for recycled water use in washing machines together with the identification of
294 the community perceptions and all specific concerns can be studied. An assessment model for
295 the new recycled water application can be developed. An overall risk assessment can be
296 undertaken to determine the value of this new end use.
297

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403 **Figures Listed**

404 **Fig. 1.** Annual per capita water consumption by location of use in 2001 (Kl)

405 **Fig. 2.** Estimated use of water by households in Sydney, Melbourne and Perth

406 **Fig. 3.** Respondents (%) opposed to use of recycled water in washing machines in Australia.

407 **Fig. 4.** Willingness to use recycled water for washing clothes

408 **Fig. 5.** SWOT profile of the new end use