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What attributes of recycled water make it fit for residential purposes? The Mawson Lakes experience

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Abstract

This paper considers an Australian community's perspective of the importance of various attributes of recycled water, including, colour, odour and salt, for various uses including, garden watering, toilet flushing and clothes washing. Results found that the importance of achieving aesthetic levels of these attributes increased as the applied use became increasingly personal. For example respondents rated the attributes of 'no colour' and 'no odour' of extreme importance for clothes washing, but they were not rated as important for toilet flushing or garden watering. Importance was placed on different attributes of recycled water quality and its delivery, depending on the specified use, with 'low salt' rated very important for garden watering in particular. This variation in attribute/use combinations suggests that the parameters of recycled water quality and delivery should be determined 'fit for purpose.' It is recommended that the parameters be established in consultation with the community involved, to determine the importance each community places on the various attributes of recycled water, for differing uses. Such an approach will ensure the quality of the recycled water will be to the community's satisfaction, providing a solid platform to successful implementation of recycled water use. Thus, the attributes of recycled water that make it fit for residential purposes vary depending on the use to which it is applied.

Keywords: Water recycling; Community; Salt; Odour; Colour

1. Introduction

Recycling of urban wastewater has been recognised as a necessary source and a key aspect of

sustainable water policy. This policy has evolved in many places in Australia and overseas. While a lot of research and development effort has been invested in the technical feasibility of producing alternate water sources, very little is understood

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about the social dimensions of such schemes — issues such as governance, management, regulation, ownership, and public acceptance of the different attributes of recycled water such as, saltiness, odour, and colour when used inside the house for toilet flushing and clothes washing, and outside for garden watering.

International research has identified significant community resistance to the use of recycled water in some instances, resulting in the abandonment of such projects. These instances include, Noosa, Australia [1], San Diego, USA [2], and Lichi Rijin, The Netherlands [3]. This resistance seems to relate to a number of institutional factors and in particular how well the community were prepared and consulted. Greater understanding of these social factors in a policy context will facilitate sound management of such schemes.

This paper brings the social aspects of water recycling mentioned above into broader context by exploring water recycling from the perspective of an urban Australian community located at Mawson Lakes in South Australia. The paper also discusses other Australian and international water recycling examples.

1.1. Australian recycled water use policy directives

Policy directives toward water recycling have been implemented in many countries and regions. In Australia, policy direction and impetus for water recycling was founded primarily in the Council of Australian Governments (COAG) Water Reform of 1994, which changed the governance structures of water authorities. More recently, in 2003 water recycling has come directly under the COAG Water Reform framework through the ‘National Water Initiative,’ an intergovernmental agreement which aims to encourage water conservation in cities through better use of stormwater and recycled water [4].

In addition to the COAG water reform initiatives, prolonged drought conditions in most of

Australia’s major cities during the past decade has led to serious national calls for less potable water to be used [5]. This has seen a strategic policy response from many State Governments, which has included bold targets for water recycling. Western Australia’s State Water Strategy set a target to recycle 20% of wastewater sources by 2012 [6], similarly Victoria’s now Department of Sustainability and Environment set a recycling target of 20% of Melbourne’s wastewater by 2010 [7].

Achieving such a change in the way water is consumed through these policies will require a major rethink of planning schemes and water policy in each state. Water recycling alternatives have important environmental, economic, social and public health impacts which must be considered in the establishment of such projects, failure to do so may lead to the projects being unfeasible or lead to community abandonment, as has occurred previously. For example: in Noosa where a small group in the community were concerned about the presence of ‘gender bending’ hormones [1]; San Diego where it was considered there was a lack of a timely and coordinated response to the questions of the community [2]; and Lichi Rijin where a cross connection between potable and grey water mains allegedly caused 200 people to be infected with gastro enteritis resulting in dual water supply systems to be outlawed in The Netherlands [3,8].

1.2. Current Australian water recycling initiatives

Current water recycling initiatives in Australia include the use of reclaimed wastewater and stormwater for urban, residential, industrial and agricultural purposes. Water efficient urban design, and dual supplies exist in a few residential subdivisions, notably the SOPA (Sydney Olympic Park Authority) development now known as Newington, and Rouse Hill in Sydney’s north west. Similar developments are planned throughout the country in response to water recycling policy directives. Aquifer Storage and Recovery

(ASR) is being investigated for the seasonal storage of recycled water in many places.

While there are many initiatives listed above, water recycling collectively represents only a very small proportion of Australia's water use, less than 1% of total water use across all sectors in 2000–01 [9]. Existing examples of water recycling are predominantly removed from direct human contact. It is not known how urban Australian communities will respond to new water policy directives especially those encouraging reuse with close human contact. Studies conducted in Australia and the US regarding community attitudes to using recycled water have shown support for using recycled water decreases as the use becomes increasingly personal [10–12]. In view of the uncertainty surrounding how communities may respond to water recycling initiatives, this paper suggests the most suitable approach to planning recycled water projects is to set the base line parameters toward defining water 'fit for purpose' through community consultation.

1.3. Understanding attitudes to recycled water attributes

This paper considers community preferences of various attributes of recycled water for differing uses including toilet flushing, garden watering and clothes washing. The attributes considered by respondents include saltiness, colour, odour and pressure. The community surveyed lives at Mawson Lakes South Australia, which is a Greenfields development where recycled water is delivered to properties for non-potable purposes in addition to potable water. The information gathered through this research can be used to better inform the delivery of a sound policy framework for recycled water. The above attributes (saltiness, colour, odour, low pressure) are potentially attributes of the recycled water delivered at Mawson Lakes and other similar schemes.

It is recognised that there are many factors that influence attitudes to use of recycled water

including perceived health risk and political issues, however there are many specific questions left unanswered about community attitudes to physical attributes of recycled water. These include: How will the community react to the recycled water if it has a slightly brown appearance in the toilet bowl? How will they respond if the recycled water has an odour at times? How will they respond if higher levels of salt damage the plants in their garden? Will they be concerned to wash their car with recycled water if it has a higher salt level than potable water? Will the lower pressure of the dual water supply system, a safety feature protecting against cross contamination affect their sprinkler systems (i.e. with a lower pressure, the irrigation spray will not cover the area originally designed for and may have to be reconfigured) and concern the residents?

Existing recycled water systems are known for possessing notable levels of attributes discussed above. An Australian study surveyed 20 residents of New Haven, a small Adelaide suburb where approximately 62 households use recycled water for garden irrigation and toilet flushing. Every respondent reported having occasional problems with recycled water use for toilet flushing including occasional odour, murky colour or sediment [13]. The attributes of recycled water do have potential influence on communities using recycled water systems. A study undertaken in Denmark investigating the use of rainwater and greywater for toilet flushing [14], found that in the instances of greywater use for toilet flushing, there were several complaints regarding bad smell, with one particular plant shut down because of the complaints. Such conditions have potential to have a major impact on the outcome and feasibility of such schemes.

The purpose of this research is to aid greater understanding of the social aspects of water recycling project considerations. The research also aims to understand the implications these considerations might have for policy direction and management of such schemes and the delivery of recycled water.

2. Case Study — Mawson Lakes, South Australia

Mawson Lakes is a greenfields development located 12 km north of the Adelaide central business district. The development is a joint venture between the South Australian government and private industry, and derives from a more extensive Commonwealth project called the Multi-function Polis. The population is expected to reach 10,000 residents by the year 2010. An encumbrance on all property titles requires each dwelling to have a dual water supply installed at the time of construction. The dual water supply delivers non-potable reclaimed water sourced from storm water and wastewater through a series of lilac pipes, conforming to the South Australian Reclaimed Water Guidelines [15]. Present South Australian water policy is largely risk averse, and highly cautious, allowing only restricted use of reclaimed water for domestic purposes. Permitted use includes: inside the house for toilet flushing, and outside the house for garden watering and car washing. The reclaimed water is also used for irrigation of public open spaces and top-up of the artificial lake within the development. The delivery of the reclaimed water commenced in March 2005. Until that time, potable water was delivered through the recycled water network.

3. Method

Surveys were conducted over the phone by professional interviewers during the months of August and September 2004 (prior to recycled water use commencing). Interviews were conducted at the household level, with households contacted at random. The interviews took an average of 30 min to complete. Information collected in the survey included: respondent's attitudes to different attributes of recycled water for different uses, responses to a series of attitude and perception statements, and demographic information about the individual respondents (including such variables as gender, income and responsibility for

household chores including gardening). This was the second survey of a panel/repeated cross sectional survey, assessing community attitudes to using recycled water. The first benchmark survey was completed in September 2002. Thus the first two surveys were completed prior to the commencement of recycled water use. It is planned to conduct a third survey some time after the recycled water use has been underway.

There were 3 major steps in designing the method for assessing consumer attitudes to different attributes of recycled water, which will each be discussed below:

- 1) Establish the attributes to be tested
- 2) Establish the uses to be tested
- 3) Establish a measurement scale

3.1. Establish the attributes

It was recognized that there would be many attributes of recycled water that would possibly impact an individual's consumption. The aim of the study was to establish the importance of a select number of attributes that would most likely impact the purpose for which recycled water could be used at Mawson Lakes. It was deemed beneficial if these attributes could possibly be controlled to some extent by the water retailer, i.e. having the potential to address any concerns that may arise through the outcome of the survey, and during the development of the scheme.

In order to reduce the number of attributes presented to the respondents, and in order to determine the most appropriate attributes to use, feedback from key stakeholders was sought (including residents), notes of a community meeting were reviewed, and literature regarding recycled water use was reviewed. The following attributes were chosen for analysis: odour, colour, salt, pressure, availability, and nutrients. 'Availability' referred to the fact that recycled water would be exempt from drinking water restrictions allowing the use of recycled water on the garden year round. 'Nutrients' referred to the fact that recycled water may contain more nutrients than

drinking water, and plants would possibly require less fertilizer when recycled water is used.

These attributes were chosen because they were thought to have key influence on the uptake and use of recycled water, and were capable of being modified by recycled water managers, not only at Mawson Lakes, but with future projects in Australia and potentially world wide.

3.2. Establish the uses to be tested

Having established the attributes of recycled water to be tested, uses for which to test them then had to be established. Garden watering, toilet flushing and clothes washing were chosen. Garden watering and toilet flushing were chosen because at the time of the survey they were uses for which the recycled water at Mawson Lakes was soon to commence. Clothes washing was chosen because of possible policy implications. South Australian reclaimed water guidelines [15], and other Australian guidelines for the use of recycled water presently do not allow its for clothes washing. 49% of respondents supported recycled water use for clothes washing in the 2002 benchmark survey at Mawson Lakes [11]. Further investigation of this support was of interest, because of the possible policy implications, and because of the potentially beneficial impact of increased recycled water use for this purpose. Studies have shown that the average Australian household uses between 10 and 15% of water for the purpose of clothes washing [16,17] so there is great potential to reduce de-

mand on potable water sources through increased use of recycled water for clothes washing.

Given the length and complexity of the total survey the authors were mindful not to present respondents with unnecessary or unrealistic attribute/choice combinations, which would not only add length to the survey but possibly encourage respondents to drop out of the survey prior to completing. This is why uses such as ‘car washing’ and ‘drinking’ were not included, and why the attribute of ‘availability’ was only tested for garden watering, as drinking water restrictions in Australia would rarely, if ever restrict water use for clothes washing or toilet flushing because of public health implications. The attributes and uses tested in the survey are shown in Table 1. A tick indicates those scenarios that were tested, and a cross those scenarios that were not tested.

3.3. Establish a measurement scale

An 11 point Juster [18] type scale was used to measure importance. Respondents were asked to rate each of the attribute/use combinations on a scale of 0 and 10 where 0 represents not at all important and 10 represents extremely important (other values include 3 — somewhat important, 5 — important, and 8 — very important). The Juster scale was considered the most appropriate scale for use over the phone. The scale was considered convenient for respondents to use and more conducive to accurate responses because of its ability to reduce mid-point biases and ‘yea-saying.’

Table 1
Attributes and uses of recycled water tested

Attribute	Garden watering	Toilet flushing	Clothes washing
No odour	✓	✓	✓
No discolouration	✓	✓	✓
Low salt content	✓	✓	✓
Availability — exempt from restrictions	✓	X	X
Good pressure	✓	X	✓
High nutrient levels — requiring less fertilizer	✓	X	X

3.4. Other considerations

Analysis of the results was conducted for the population as a whole, and for certain groups/segments of the population. The population was grouped according to gender (male and female), annual household income (<\$40,000; \$40,000–<\$80,000; >\$80,000), and whether the respondent was considered the ‘gardener of the house.’ One-way ANOVA was used to compare the means of each segment. The computer package SPSS was used to calculate these values, with F values and significance levels reported in the results section of the paper. Results of attitude and perception statements were considered.

4. Results and discussion

In total 300 households were phoned and invited to participate in the survey. Of these 300 households 136 agreed to participate, giving a response rate of 45%. This is a good response rate considering respondents were told at the outset that the interviews would take 30 min to complete, and no incentives were offered for participation. 136 households were interviewed, which is consistent with the previous benchmark survey conducted in September 2002.

At the beginning of the survey, respondents were asked what they think the recycled water will be like when it starts running through the pipes in a multiple response question, the results of which are displayed in Fig. 1 as a % of the total respondents. As can be seen, not very many

respondents anticipate the presence of the attributes the focus of this study. Many respondents answering ‘don’t know’ or ‘the same as drinking water.’

4.1. Factors influencing the uptake of recycled water for different uses

The mean (μ) and standard deviation (σ) of the importance ratings for each attribute/use combination tested, for all the respondents, is shown in Table 2. As can be seen from the mean scores, each of the attribute/use combinations was considered important overall, each receiving a rating over ‘5 = important’.

Fig. 2 shows graphically that as the use of recycled water becomes increasingly personal (moving from garden watering to toilet flushing and clothes washing), the importance of the attributes of ‘no odour’ and ‘no discolouration’ increased. The attribute of ‘low salt’ did not follow such a pattern. However, the attribute of ‘low salt’ was rated very important for garden watering, more important than ‘no colour’ and ‘no odour.’

4.2. Garden watering

For garden watering the most important attribute was found to be good pressure (34% of respondents rating this attribute as ‘10 = extremely important,’ with a low σ) followed closely by availability (exempt from restrictions) and low salt content. The issue of pressure was raised at a recent community meeting at Mawson Lakes.

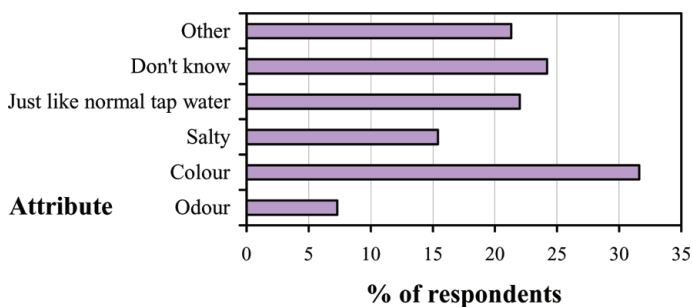


Fig. 1. Expected recycled water attributes.

Table 2
Results for mean and standard deviation analysis

Attribute	Garden watering (μ , σ)	Toilet flushing (μ , σ)	Clothes washing (μ , σ)
No odour	5.7, 3.2	7.1, 2.9	9.2, 1.7
No discolouration	3.9, 3.2	6.6, 2.8	9.3, 1.6
Low salt content	7.9, 2.6	5.2, 3.5	8.5, 2.2
Availability — exempt from restrictions	8.0, 2.2	—	—
Good pressure	8.4, 1.6	—	7.8, 2.3
High nutrient levels — requiring less fertilizer	7.0, 2.6	—	—

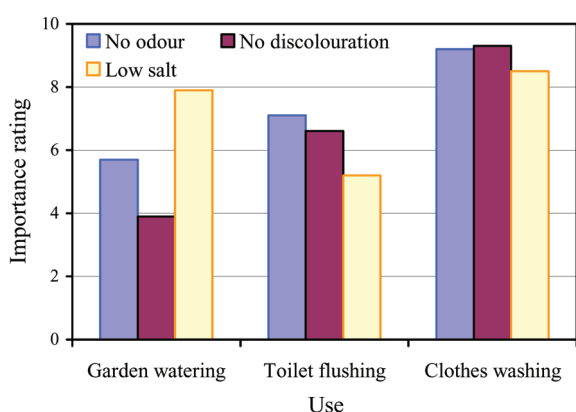


Fig. 2. Importance ratings for various attributes of recycled water.

Residents are concerned that when the recycled water commences delivery at a lower pressure they will have to adjust their sprinkler systems to compensate for the lower pressure (i.e. have the sprinkler nosels closer together), perhaps at some cost. It is thought 'availability' was rated with considerably high importance perhaps because Adelaide residents faced water use restrictions last year for the first time since 1967. These restrictions prohibited the use of potable water to irrigate lawns during certain hours. Recycled water would be exempt from such restrictions, a beneficial attribute for the residents at Mawson Lakes.

The attribute of 'low salt' was probably ranked very important due to many residents having knowledge of the impact slightly higher salt levels

would have on the plants in their garden. 'High nutrient levels, thus requiring less fertiliser use on the garden' was rated only moderately important. This moderate rating may be due to the fact that the residents were not familiar with this concept, they may also like to control the amount of nutrients they apply to their garden, or may make a negative association with high nutrient levels and perceived possible health impacts. The attributes of 'no odour' and 'no discolouration' were not considered very important, as was anticipated.

4.3. Toilet flushing

For toilet flushing the most important attribute was considered to be no odour (27% of respondents rating the attribute '10'), followed closely by no discolouration. These were considered overall to be 'quite important.' It was anticipated that these attributes would be rated very, if not extremely important considering the aesthetic impact these attributes may have inside the home, in the bathroom. Perhaps the importance rating would increase if recycled water were to be delivered with these attributes to households for the use of toilet flushing. In a separate section of the survey, respondents were asked what they would use recycled water for if it had a 'swampy smell at times'. Fig. 3 shows the results to this question. Only 40.4% of respondents said they would use recycled water with a swampy smell

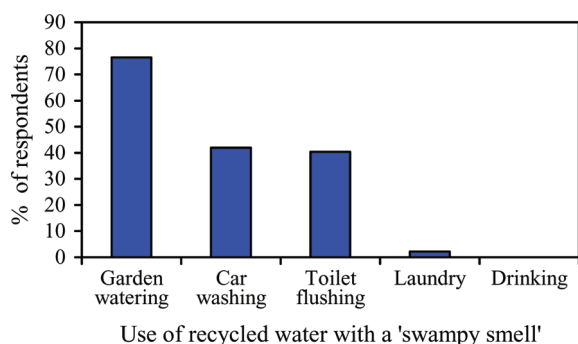


Fig. 3. Percentage of respondents who would use recycled water with a 'swampy smell' for various uses.

for toilet flushing. Fig. 3 showing the intended use of recycled water with a 'swampy smell' decreased as the stated use became increasingly personal. A 'low salt' content was not considered very important for toilet flushing, which was anticipated.

4.4. Clothes washing

For clothes washing, the attributes of 'no colour' and 'no odour' were considered 'extremely important' by most respondents (70% and 71% of respondents respectively rating the attributes '10', with a low σ). This may be due to the fact that the respondents were concerned about possible discolouration and odour of clothing laundered with recycled water having such attributes. The use of recycled water for clothes washing is more closely related to personal contact, which may also explain the high importance placed on these attributes.

A 'low salt content' was also considered very important for clothes washing (50% of respondents rating this attribute '10'), perhaps due to the association this may have with the feel of clothing after being washed. Having good pressure was also considered quite important (36% giving a rating 10) perhaps due to expected impact on the performance of the washing machine.

4.5. Segment differences

Segmentation of the respondents into gender and annual household income, revealed some significant differences. For gender, significant differences in responses are shown in Table 3. For all of the attribute use combinations, except two, females rated the combinations as more important than the males did. The two attribute/use combinations that the males rated as more important than the females were: Garden watering 'low salt content,' and garden watering 'exempt from restrictions,' but the differences were not significant, and only a matter of 0.1.

The difference could be due to the fact that 69% of male respondents claimed they are considered the 'gardener of the house' while only 56% of female respondents claimed they are considered the 'gardener of the house,' and thus they place more importance on those particular attributes of recycled water for use in the garden because they have greater involvement with the garden. However when the responses of those who considered themselves the gardener of the household were analysed against those that did not consider themselves the gardener of the house, although the gardeners rated the attribute/use combinations of more importance, again there was not a significant difference, with the difference in mean rankings again only 0.1. The gender difference could also be due to the fact that they are technical rather than aesthetic attributes, and there may be a gender difference attributed to those facts. This is only speculation, and is not conclusive.

In terms of income there was a trend for those in the lowest income bracket to rate most of the attribute/use combinations as more important, than the two other income groups did. There was also a trend for those in the highest income bracket to rate the majority of the attribute/use combinations of a lower importance when compared to each of the other income groups. The combinations with significant differences between income groups are shown in Table 4. This trend will have interesting

Table 3
Results for analysis of gender differences

Attribute	Male (μ) <i>N</i> = 71	Female (μ) <i>N</i> = 65	ANOVA (<i>F</i> , significance level)
Garden watering			
No odour	5.0	6.5	7.4, 0.008
No discolouration	3.2	4.6	6.9, 0.009
Toilet flushing			
No odour	6.48	7.74	6.7, 0.010
No discolouration	6.07	7.11	4.7, 0.031
Clothes washing			
No odour	9.2	9.3	0.18, 0.668
No discolouration	9.2	9.4	0.92, 0.338

Table 4
Results of analysis of income influence

Attribute	<\$40,000 pa <i>N</i> = 12	\$40,000–<\$80,000 pa <i>N</i> = 32	>\$80,000 pa <i>N</i> = 42	ANOVA (<i>F</i> , significance level)
Garden watering				
No discolouration	5.25	4.29	3.19	2.5, 0.090
Clothes washing				
Good pressure	9.4	7.9	8.7	4.8, 0.010

implications for ability and willingness to pay for an increase in recycled water quality — those with the lowest income seeming to place more importance on the aesthetic and delivery attributes of recycled water. 32 respondents chose not to respond, or did not know their household's annual income.

4.6. Recommendations, policy implications

Given the importance placed on various attributes of recycled water for different uses as discussed above, the following observations can be made. Depending on the proposed use of recycled water, the importance of particular attributes will vary. For garden watering a low salt content will be desired, with colour and odour of less im-

portance. For the use of clothes washing, an extremely high importance is placed on colour and odour, followed closely by salt. Given this variation in attribute importance depending on use, it is considered appropriate for the parameters of recycled water to be established 'fit for purpose.' Any policy changes, allowing new use of recycled water, would have to ensure that the community's expectations and desires of the delivered product for the particular use were capable of being met, otherwise the recycled water will potentially not be used for that particular application, leading to the failure of policy and projects, which are often expensive to establish.

There will be policy implications from the fact that a higher quality level desired for certain uses (i.e. laundry) over others (i.e. garden watering).

Higher quality recycled water, requires a higher level of treatment, which is accordingly more expensive and more energy intensive. An impact of this could be a stepped approach to the introduction of recycled water beginning with garden watering, and progressing to more personal uses as the community becomes increasingly familiar with the recycled water. It may be determined that certain uses of recycled water may not be appropriate in certain areas depending on the quality of incoming wastewater and attitudes of the communities involved. A sustainable approach to water cycle management will be important in order to weigh up the possible impacts of recycled water production and use, constraining application accordingly.

It is recommended that the parameters of reclaimed water use be established in direct consultation with the communities involved. This will ensure the outcomes of the human aspects are maximised for the benefit of each community, and that recycled water fit for purpose, and to the satisfaction of the community is delivered. This will lead to the adoption of appropriate policies and parameters contributing to the success rather than abandonment of water recycling projects. This approach would lead to more economically efficient supply of alternative water resources.

5. Conclusion

The results of this survey provide interesting information about the importance an Australian community places on various attributes of recycled water for various potential uses. If wishing to successfully implement recycled water policy objectives there are a number of key considerations water authorities must make from the community's perspective. These include: if introducing policy encouraging recycled water use for residential irrigation, it seems the main focus of the water authority should be to deliver recycled water at a suitable pressure with salt levels comparable to potable water. If wishing to increase

the use of recycled water through its use for clothes washing, a successful policy would have to ensure that the recycled water was of high aesthetic quality, importantly with no odour present, no discolouration (clear), with low salt levels and delivered with good pressure, as these attributes are of high importance to the community.

The generally high response rate (45%) for a survey of this length (30 min over the phone), and the considerations addressed make the results of this survey of particular interest to water retailers and water policy developers throughout Australia, with possible relevance to other countries. In answer to the question: "what attributes of recycled water make it fit for residential purposes?" The attributes will vary depending on the use for which it is applied.

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