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Article

Issues Affecting Community Attitudes and Intended Behaviours in Stormwater Reuse: A Case Study of Salisbury, South Australia

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Abstract: Stormwater has been recognised as one of the additional/alternative sources of water to augment freshwater supply and address the growing needs of humankind. South Australia has been a leader in the development of large-scale urban stormwater harvesting schemes in Australia for nearly 50 years and the Salisbury Local Government Area (LGA), in particular, is at the forefront of urban stormwater management and recycling, not only in the state of South Australia, but worldwide. This is mainly due to its pioneering achievements in stormwater capture and treatment through the managed aquifer recharge (MAR) process. However, there are many challenges in implementing water reuse strategies and past studies have identified public health concerns and public acceptance as major challenges. In line with this, our team conducted an internet survey to gauge the attitude and intentions of Salisbury LGA residents to use stormwater treated through the MAR process for non-potable uses. We found that respondents' emotions and perceptions of health risk, regarding the use of treated stormwater, were closely related to the proximity of the end use to human contact. In terms of quality indicators, colour, odour, and salt levels were all seen as being important. Quality preferences were also closely related to the proximity of the end use to human contact, and reflected the use of water for indoor/outdoor purposes.

Keywords: stormwater; recycled water; managed aquifer recharge; community attitudes; perception of health risk; trust in authorities

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1. Introduction

It has become evident that demand for water resources in many Australian urban centres is approaching supply capacity and in some instances, exceeding sustainable limits [1–4]. Achieving sustainable urban water systems and protecting the quality and quantity of freshwater resources are therefore identified as key components of ecologically sustainable development [5–7]. In this regard, there is considerable scope for a proportion of urban water currently consumed to be replaced by lower quality water [2,3]. It has been estimated that between 50%–80% of water used in urban areas does not require potable quality [8,9], which could be substituted with alternatives sources, such as recycled sewage/recycled rainwater and treated stormwater [1,2,10]. However, this study focuses on treated stormwater only.

Stormwater is defined as the runoff from pervious and impervious surfaces in predominantly urban environments where the impervious surfaces include roofs, driveways, pavements, footpaths, and roads [11]. Stormwater runoff from Australian capital cities has been found to be comparable to the total amount of potable water consumed [12]. The harvesting of this resource provides an alternative water supply, thus reducing pressure on existing water supply systems [11].

Urban stormwater management has undergone a transformation in recent years in Australia, from being considered as a problem requiring immediate and efficient drainage, to being considered as an alternative water supply approach for cities [1]. In a report released by the Australian Prime Minister's Science, Engineering and Innovation Council [13], the authors argued that Australia needs a diverse portfolio of water supply options, thus stormwater should be viewed as a potential resource rather than as a waste product.

Stormwater harvesting for mains water substitution is becoming increasingly common across Australia. While the majority of these projects operate on a small scale, there are several projects operating on a major, city-wide scale. Philp *et al.* [11] conducted a review on national stormwater harvesting practices and collected a series of case studies from across the country to reflect the different operations occurring in the various states of Australia. In the literature, no case studies were found about substituting treated stormwater for potable drinking water. The majority of the case studies reflected the current practice of using harvested stormwater as a substitute for irrigation water, as supported by the Australian practice review conducted by Hatt *et al.* [14].

Stormwater harvesting is frequently used in New South Wales, Queensland, South Australia and Victoria. No information was available for stormwater harvesting schemes operating in Tasmania or the Northern Territory. As a result, it is assumed that stormwater use is not common practice in these areas [11]. Stormwater is legislated to be used through indirect means in Western Australia, and a major investigation is currently underway looking at stormwater harvesting options for Canberra in the ACT. Among all Australian states, South Australia is the leader in the development of large stormwater harvesting and reuse schemes [15].

This paper is based on a recent study conducted as part of a larger research project sponsored by the National Centre for Groundwater Research and Training. The paper introduces the Salisbury stormwater harvesting project and reports on the perceptions of the residents in the Salisbury Local Government Area (LGA) with regards to using treated stormwater for non-potable purposes. The study does not consider rainwater harvesting from individual households, and focuses on centrally managed schemes for general stormwater runoff [9] that has entered drains or creeks.

2. Salisbury LGA

South Australia has been a leader in the development of large-scale stormwater harvesting schemes in Australia for nearly 50 years, and the Salisbury LGA is the leader in developing such schemes across the State of South Australia [15]. It is recognised around the world for its pioneering achievements in MAR technology, which is a process of injecting cleansed stormwater from wetlands into a suitable underground aquifer for storage and extraction for later use in drier periods [2].

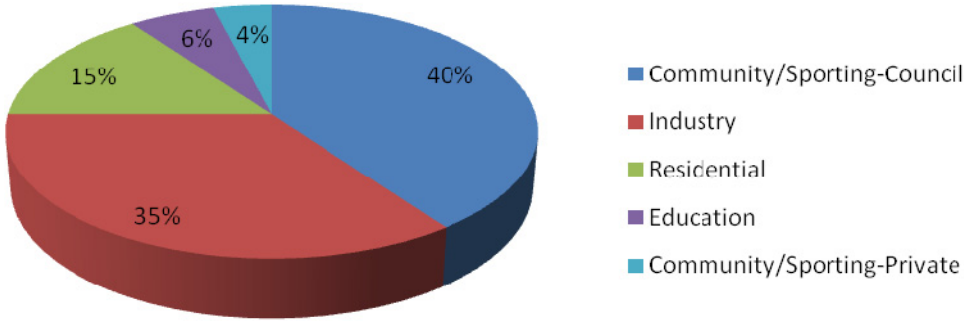
The Salisbury LGA covers an area of 161 km^2 and has developed 20 strategic stormwater harvesting sites and wetlands. Wetlands are used for storage in conjunction with aquifer storage and recovery technology, which allows water to be accessed during drier periods [11].

The Salisbury LGA is now taking stormwater harvesting and recycling to the next level—developing and expanding the distribution network to provide high quality recycled stormwater (Salisbury Water) throughout the Salisbury LGA and beyond [15]. Treated stormwater is distributed via the mains system, and sold to end users, including industrial, commercial and household facilities [11].

Salisbury's stormwater harvesting program is supported by the Federal Government. In June 2009, the Salisbury LGA secured $6.55 million worth of funding under the Federal Government's Water for the Future initiative [16]. Not only has the council been innovative in their approach towards the management of urban stormwater in the area, it has also developed a local market for recycled stormwater. Companies with high water dependency for their operations can access treated stormwater at cheaper rates than mains water [17].

Salisbury Council will be linking up about 16,000 homes in the council area with stormwater for using extensively for community facilities, and for irrigation of parks and ovals. The Salisbury stormwater harvesting scheme is the first project of its kind in Australia, and takes about 15 billion litres of stormwater a year to households and businesses, the equivalent of 18 percent of Adelaide's water supply [18]. During 2010/2011, the project distributed 1.389 gigalitres to its customers [18]. The distribution structure is shown in Figure 1.

Figure 1. Distribution chart of Salisbury Water Company—2010/2011.

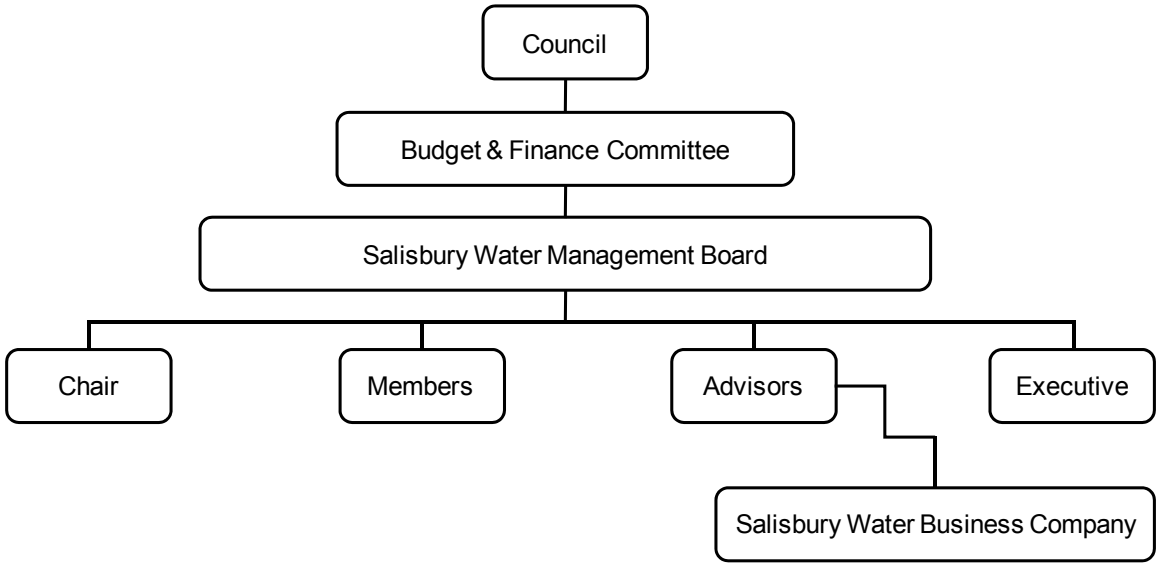


In addition to supplying customers with treated stormwater, a new governance structure was created to manage the stormwater recycling project. The Salisbury Water Management Board (and the Salisbury Water Company, a subsidiary company under the SA *Local Government Act*) was formed to deal with political interference by local governments [18]. This is unique, being the first of its kind across Australia. The Board is an independent body, and even though it reports to the Council, it can make policy decisions

on certain issues independently, such as pricing policies and deciding on applications for a connection. More importantly, significant policy decisions can be made without referring to local government [18].

The Salisbury Water Management Board has an advisory body to the CEO, and the CEO reports to, and is accountable to, Council. The Board has a maximum of 6 members (3 Salisbury Council Executive Managers and 3 external independent members). The Board Chair is also an independent member. The effectiveness of the Board is reviewed annually. The responsibilities of the Board are to consider and provide counsel to the CEO on matters brought forward for input, including: strategic direction; legal and regulatory environment and government policy; community issues; risk management; major capital expenditure; performance against targets and objectives; development and monitoring of relevant policies, including pricing; and reporting and accountability to Council. The governance structure of the Water Management Board is illustrated below in Figure 2 [18].

Figure 2. Governance Structure of Stormwater Project in Salisbury Local Government Area (LGA).



3. Community Acceptance of Stormwater Reuse

There are a range of challenges associated with the implementation of water reuse strategies, with public health concerns and public acceptance being the major ones. Therefore, this study has been designed to explore the perceptions of urban residents with regards to using, or rejecting, treated stormwater for various non-potables purposes.

Stormwater in Australia is being already used for a range of non-potable urban water uses, including: toilet flushing, garden watering, car washing, industrial uses, open space irrigation, ornamental water features, fire fighting, environmental flow provision, and groundwater recharge [14]. Given appropriate treatment, stormwater can provide a supplementary potable water supply, however the potable use of stormwater is not commonly practised in Australia or overseas [14]. Consequently, our research does not include drinking as a potential use of treated stormwater. However it does include options having close personal contact such as personal washing, washing of dogs and clothes, as well as other options

which do not have close personal contact, such as watering of fruit, vegetables and flowers, watering of lawns, gardens, and parks, flushing toilets, and washing cars.

Community acceptance is crucial to the success of water reuse schemes [9,19]. Although generally the community is supportive of water reuse, this support declines when the end use of recycled water involves closer personal contact [3,10,19,20]. Previous works on stormwater use indicated that there is no exception to this trend for stormwater use [21]. Meanwhile, attitudes to using recycled water is conditional on several factors, such as perceived health risk related to using the water, trust in authorities which provide information about the water, and the quality attributes of the water [10,19].

Community acceptance to recycled water was found to be related to the perceived risk of using the recycled water [10,19,22]. The perceived risk was found to be significantly related to a lack of trust in the local water authority and a perception of being poorly informed throughout the process [19]. There was a strong relationship between trust in the local water authority to manage risks associated with a recycled water project, and the communication of information, the perception of integrity, and a belief that the water authority had a vested interest in the project [19]. Consequently, community acceptance can be greatly enhanced by readily supplying accurate information in a fashion perceived to be transparent and fair to local residents [19].

Hurlimann and McKay [23] explored community perspectives about the importance of various attributes of recycled water, including colour, odour, and salt levels, for various non-potable uses such as garden watering, toilet flushing, and clothes washing. They found that the importance of achieving aesthetic levels of these attributes increased as the particular use became increasingly close to human contact [23]. The recycled water in Hurlimann and McKay's study [23] was a mix of reclaimed wastewater and stormwater. In our current study, we considered treated stormwater and its attributes of colour, odour and salt levels only. We aim to explore community perceptions of the importance of the attributes of treated stormwater for a greater scope of non-potable uses, including personal washing, washing of dogs, flushing toilets, washing clothes, watering fruit, vegetables and flowers, watering lawns, gardens and parks, and washing cars.

Hatt *et al.* [24] pointed out that a significant obstacle to widespread implementation of stormwater use is a lack of reliable and affordable treatment techniques. Where stormwater is being treated for use, public health and safety considerations impose a higher level of uniformity and certainty with respect to the quality of the treated water [10,20]. The level of treatment required is largely determined by both the catchment properties (which influence the type and level of pollutants) and the intended end use [25]. Studies on treatment techniques for reusing stormwater from scientists' aspects are often seen, but none from aspects of community, the end users. We, for the first time, explored the preferences of residents, the end users, to different treatment procedures of stormwater by which they are willing to use the treated stormwater for various non-potable uses.

4. Method

Data was collected through an internet survey using email addresses bought from a permission-based and research-only internet panel (this method has been employed and examined by Dolnicar and Grün [26]. The study was conducted in three Australian LGAs; Salisbury LGA and Charles Sturt LGA in South Australia, and Gold Coast LGA in Queensland [21]. This paper reports on the results from the Salisbury

LGA only. In total, we sent our survey to 2000 randomly selected email addresses in the Salisbury LGA, with 103 valid responses being received. We acknowledge that the response rate (5.15%) is low and thus the results are likely to be biased. We note this as one of the limitations of this study. Another issue is the potential sample-selection bias which is an obvious limitation of using online surveys because the people taking the survey may not be representative of the population in general [27]. The demographics of the sample are reported in [21]. Focus group discussion(s) will be conducted to further explore respondents' thoughts on a number of specific items in the questionnaire to supplement the results of this study.

5. Results and Discussion

We first explored the knowledge level of respondents about local water plans and local stormwater initiatives. More than 50% of respondents indicated that they had little knowledge about the water plans in the local region, while 32% of them had some knowledge about local water plans. There were 88 residents responded to this question. 40 out of the 88 respondents indicated that they had no or little knowledge about stormwater initiatives within the local area and 15 respondents had a sound knowledge about this. 12 out of the 15 residents were very proud of their local Salisbury Stormwater Harvesting Project, stating:

> Salisbury is a world leader in stormwater sustainability;
> Best in the world, leading technology, excellent in general;
> Salisbury is an innovator;
> Salisbury has one of the best systems for stormwater management;
> City of Salisbury is taking the lead on recycling stormwater via wetlands in SA.

Respondents were then provided with the definitions of "stormwater", "MAR (Managed Aquifer Recharge)", and "water treatment plant", as below, before they were asked questions relating to using treated stormwater through the MAR process for various non-potable uses. Detailed information about types of questions and response format that we have used are detailed in [21] and [28].

> **Stormwater:** Refers to the water resulting from rain draining into the stormwater system from roofs (rainwater), roads, footpaths and other ground surfaces.
> **MAR (Managed aquifer recharge):** MAR is the intentional recharge of water to aquifers for subsequent recovery or environmental benefit; the managed process assures adequate protection of human health and the environment. Aquifers may be recharged by diversion of water into wells or infiltration of water through natural processes.
> **Water Treatment Plant:** A facility that treats wastewater to remove pollutants.

The majority of respondents (>80%) recognized that stormwater is not "new" water, but a part of the overall surface water balance that needs to be accounted for. They also agreed that stormwater re-use is essential to help manage future water shortages and is a valuable resource that should be re-used. The majority of respondents (78%) also agreed that stormwater should be used as a fit-for-purpose supply given an appropriate quality being guaranteed. Nearly two-thirds of the respondents had ideas about how much they were willing to pay for using the treated stormwater. Generally, the higher the price was, the lesser number of people were willing to pay to use treated stormwater. No-one was willing to pay more than the current water price for the treated stormwater, while few respondents (10%) were willing to pay the same as the current water price.

The survey presented respondents with Likert-scale questions to understand their perception of whether using the treated stormwater for non-potable uses is good for managing water shortages, good for the environment, and/or good for the next generations. This was asked in relation to the potential uses of stormwater (see Table 1). The results revealed that respondents' perceptions were related to the quantity of water consumed through each purpose/use and how close that use is to human contact (Table 1). The uses having close human contact (personal washing, washing dogs, washing clothes, and watering fruit, vegetables and flowers) were also the uses that consume less water compared with uses such as washing cars, watering lawns, gardens and parks, and flushing toilets.

Table 1. Community perception of whether using the treated stormwater for non-potable uses is good for managing water shortages, good for the environment, and/or good for next generations.

Non-potable uses	Good for managing water shortages	Good for the environment	Good for the next generations
Personal washing	48.2%	56.1%	59%
Washing dogs	66.2%	63.4%	69.9%
Washing clothes	64.6%	69.5%	74.7%
Watering fruit, vegetables and flowers	65.9%	69.5%	70.7%
Watering lawns, gardens and parks	79%	79.3%	79.5%
Washing cars	77.8%	71.6%	78.1%
Flushing toilets	81.9%	81.7%	81.9%

Note: There are five-point Likert-scale questions: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree.

As mentioned earlier, public health concerns are also a major hurdle in implementing reuse schemes. In this case, 40% of respondents indicated that they trusted government authorities to ensure that the stormwater to which they had access was healthy and safe. The Health Department was indicated as the most trusted authority by respondents to oversee and manage the MAR schemes in the local area among the other parties (see Figure 3).

Similar to the findings of Leviston *et al.* [20], Hurlimann [19], and Nancarrow *et al.* [10], we found that community support for using treated stormwater declined when the end use involved close human contact. Consequently, kitchen use, cooking and drinking were the three options which respondents had the least preference for, while they felt reasonable happy with using the treated stormwater for flushing toilets, watering lawns, parks and gardens, and washing cars (see details in Table 2).

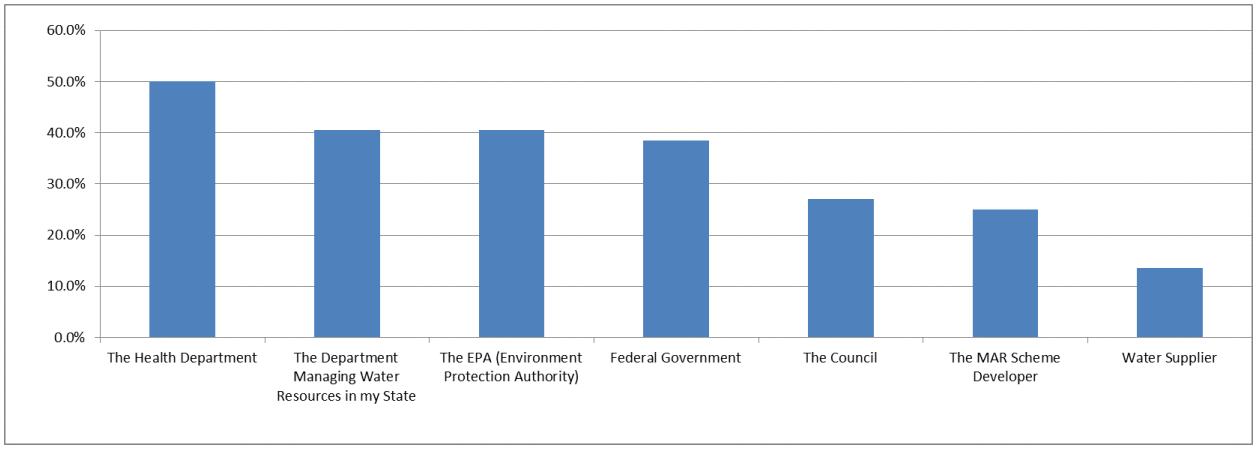
Community attitudes to using recycled water are conditional on several factors, as discussed earlier in this paper. Table 3 reports the frequencies only and the factors influencing Salisbury residents to uptake the stormwater treated through MAR process for different uses were explored and reported in our recent work [28]. The factors influencing Salisbury residents to take up the stormwater treated through the MAR process for different uses were explored and reported upon in Table 3.

More than half the respondents considered that using stormwater treated through the MAR process would not lead to health problems. Using the water for watering lawns, gardens, parks, flushing toilets, and

washing cars were perceived as being less risky than using the water for personal washing, washing dogs, washing clothes and watering fruit, vegetables and flowers. Respondents' emotions towards using the treated stormwater through the MAR process was again closely related to how near the use was to human contact. Personal washing was the use which respondents felt was the most undesirable, while flushing toilets, watering lawns, gardens and parks, and washing cars were the uses which respondents cared the least about emotionally.

About 80% of respondents indicated that they felt that there were no problems and that they would like to use the MAR water for flushing toilets, watering lawns, gardens and parks, and washing cars. These preferences were followed, in turn, by watering fruit, vegetables and flowers, washing dogs, washing clothes, and personal washing.

Figure 3. Frequencies of whom community trust to oversee and manage the managed aquifer recharge (MAR) schemes in the local area.



Note: This is a "tick as many as apply" question.

Table 2. What do you think the stormwater treated through the MAR process should be used for?

Potential uses	Frequencies
Flushing toilets	92.00%
Watering lawns, parks and gardens	87.50%
Washing cars	84.10%
Household cleaning	77.30%
Filling ornamental ponds (with no fish) and water features	76.10%
Washing pets or filling ponds that hold fish	63.60%
Washing clothes	60.20%
Watering fruit, vegetables and flowers	60.20%
Filling swimming pools and spas	47.70%
Personal washing, such as baths and showers	43.20%
Playing under sprinklers or other recreational purposes	43.20%
Kitchen use	42.00%
Cooking	29.50%
Drinking	22.70%
Nothing	4.50%

Note: This is a "tick as many as apply" question.

Table 3. Frequencies of influencing factors determining the uptake of stormwater for different potential uses.

Non-potable uses	Perceived no health risk	Emotion	Attitudes	Intention	Colour	Odour	Salt
Personal washing	47.6%	38.6%	40.7%	46.9%	81.7%	84.4%	63.9%
Washing dogs	59.7%	25.3%	61.7%	58.1%	56.1%	68.7%	54.2%
Washing clothes	58.6%	24.1%	56.8%	61.7%	72.8%	81.7%	61%
Watering fruit, vegetables and flowers	59.8%	23.4%	61.8%	65.4%	46.4%	54.2%	63.8%
Watering lawns, gardens and parks	68.3%	14.8%	80.2%	79%	28.8%	45.8%	54.2%
Washing cars	68.8%	13.4%	77.6%	77.8%	30.5%	41%	51.2%
Flushing toilets	74.4%	14.4%	81.5%	81.5%	29.6%	54.2%	31.4%

Note: These are five-point Likert-scale questions where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree.

Regarding the quality attributes of the MAR water, colour, odour, and salt levels were indicated as being of importance. Odour was marked as the most important attribute for those uses that have close human contact and which are indoor uses (personal washing, washing dogs and washing clothes), which was followed by colour and then salt levels. The salt level was indicated as the most important attribute for outdoor uses where the salt content of the water is perceived to have damaged the objects it was used on, for example, watering fruit, vegetables and flowers, watering lawns, gardens and parks, and washing cars. How important the attribute of the water is depended on the particular use. As the use of the water became increasingly personal, the importance of the attributes of colour, odour, and salt levels increased.

In order to gauge community attitudes towards various treatment options of stormwater that they would use for various purposes, we presented survey participants with three potential treatment options for stormwater for seven different non-potable uses (as indicated in Table 4). We asked respondents to rate their preference to using the treated stormwater for these uses by writing down the numbers 1, 2, 3, 4, 5, 6 or 7 against each use where the lowest 1 = least preferable and the highest 7 = most preferable. Ranking averages are reported in Table 4.

Table 4. Respondents' preferences to different treatment options of stormwater.

Treatment option	End uses						
	Toilet flushing	Watering lawns	Washing cars	Washing dogs	Washing clothes	Vegetable watering	Personal washing
Treatment option 1	Urban stormwater—Wetland—Groundwater—Non-potable uses						
Ranking average	4.59	4.58	4.55	4.04	3.89	3.74	3.06
Treatment option 2	Urban stormwater—Wetland—Groundwater—Water treatment plant—Non-potable uses						
Ranking average	4.57	4.60	4.26	4.16	4.23	4.00	3.53
Treatment option 3	Urban stormwater—Wetland—Non-potable uses						
Ranking average	4.64	4.63	4.35	3.40	3.12	3.62	2.78

Note: This is a ranking question. Ranking averages are reported.

The results again revealed that the respondents' preferences for using stormwater were more for uses that had limited human contact. Accordingly, personal washing was found to be the least preferred use,

irrespective of the treatment option. Even though the addition of a water treatment plant (Option 2) made no major difference in respondents' attitudes to using the stormwater, it was the preferred treatment option for using the water for uses that have close human contact. For example, the respondents indicated their preferences by stating:

> Option 2 is (the option which will do) good for health;
> Option 2 is the most feasible one to use—it may cost more but it is safe.

Option 3 was the least preferable option for uses close to human contact. There were no major differences amongst the three treatment options for using the water for uses that do not have close human contact, for example, flushing toilets, and watering lawns, parks and gardens.

Respondents were also invited to comment on the potential treatment options of stormwater and/or the potential uses of treated stormwater. The comments provided by respondents again informed us that as end users of the treated stormwater, they were cautious of using the water for purposes having close human contact. For example, respondents indicated that:

> We prefer not to use any of these options for personal washing if we have a choice;
> I rank personal washing, washing dogs and watering vegetables as the same. The others I would all be quite happy to use all three options;
> I would feel ok with all above 3 choices we only have to be careful for food and skin contact that the water is treated enough for these purposes.

6. Conclusions and Recommendations

Along with wastewater and desalinated water, stormwater has been recognised as an additional/alternative source of water to augment freshwater supply and to address the growing needs of humankind [29]. The Salisbury LGA Stormwater Harvesting Project is the first project of its kind in Australia and takes about 15 billion litres of stormwater a year to 16,000 households and businesses. Basically, this study provides an opportunity for planners and practitioners of stormwater management and use on the world stage, to look at the Salisbury LGA case. However we acknowledged the limitations of the response rate and thus the results are likely to be biased.

The survey results of this study suggest that the community has a positive attitude toward using the treated stormwater for non-potable uses, and they consider that using the stormwater treated through the MAR process as not being likely to lead to health risks, in particular for uses that do not have close human contact.

The preferences of the community towards using stormwater for a particular purpose, is closely related to the proximity of use to human contact. The closer the use is to human contact, the less preferred that particular use is. Depending on the particular use of the water, the importance of the quality attributes of the water varies. The attribute "no odour" was ranked as the most important for every proposed indoor use, including personal washing, washing dogs, washing clothes, and flushing toilets. For outdoor uses, such as watering fruit, vegetables and flowers, and watering lawns, gardens and parks, the attribute "low salt" was ranked as the most important. A higher quality (no colour, no odour and low salt) of water is desired for certain uses (*i.e.*, personal washing and clothes washing) more than others (*i.e.*, watering lawns, gardens and parks, and washing cars).

Based on the observations arising from this study, we recommend that policy initiatives aiming to promote stormwater use would need to consider that the community's expectations and acceptance of the delivered water for particular uses be met. The quality level of the water could vary because higher quality levels require a higher level of treatment at a considerably higher cost. Given the variation in the importance of the quality attributes, depending on indoor or outdoor use, it is considered appropriate to adopt dual pipes (alongside the mains) to deliver a higher quality level of stormwater for indoor uses, while delivering lower quality stormwater for outdoor uses. Ignoring this point may lead to failures of the policy and the projects which would be unfortunate, given that they are very expensive to establish.

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