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Water scarcity and alternative water sources in South Africa: can information provision shift perceptions?

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ABSTRACT

Consumer perceptions are key to the success of strategies to address water scarcity. A decision pathway survey was used to investigate attitudes amongst South Africans ($N = 668$) in urban areas towards four alternative water sources. Results showed that storm and rainwater harvesting was the most (49.7%), and reclaimed wastewater the least acceptable options (15.7%). Direct potable reuse was the most supported alternative (26.6%), followed by indirect potable reuse (22.2%), reuse with additional piping (18.3%), direct non-potable reuse (8.3%), and indirect non-potable reuse (6.8%). Importantly, information provision led to a >66% increase in reclaimed wastewater acceptance amongst those initially opposed to it. In contrast, support for desalinated water and water restrictions decreased. Information provision also led to greater acceptance for direct relative to indirect reuse in situations of severe water scarcity. Together, the data suggest a role for information in influencing attitudes towards alternative water sources amongst consumers.

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Recycled water; water reclamation; water reuse; day-zero; sustainability

1. Introduction

Urban water demand is predicted to exceed supply by 2030, making the supply of clean water one of the most significant challenges for cities in the coming decades. In South Africa, a 17% (2.7 billion m^3) demand gap by 2030 is projected, and this increases to 3.8 billion m^3 when climate change impacts were factored in (Water Resources Group 2009). South Africa already receives less than 50% of the global rainfall average, and climate predictions are that the region will receive decreased precipitation over the coming decades. Total wet day precipitation is projected to decrease by 15–45% with some areas around the west coast having decreases of up to 30% (Serdeczny et al. 2017).

Urban water demand accounts for 3.5 billion m^3 of the overall water demand within South Africa. This is second only to agricultural demand (8.4 billion m^3) and greater than industrial demand (1.5 million m^3) (Water Resources Group 2009). Yet, the reservoirs that provide water to the three largest cities: Johannesburg, Durban, and Cape Town, are expected to face severe shortages as demand increases. By 2030, the Upper Vaal and Olifants water management areas which supply Johannesburg will face supply-demand gaps of up to 31% and 39%, respectively. Similarly, the Western Cape Water Supply System (including the Berg water management area) which supplies Cape Town, will face up to a 28% demand gap (Water Resources Group 2009).

The 2018 Cape Town drought that culminated in frantic efforts to stave off 'Day Zero' intensified calls to improve the country's water security and motivated other cities to find ways to avoid a similar situation (Muller 2018). While desalinated water may be an option for cities along the coastline, such as Cape Town and Durban, long distances from the coast make this a very costly option for cities like Johannesburg. Indeed, the high energy requirements of desalination plants and the country's already strained energy situation (Ting and Byrne 2020) mean that desalination would require very careful consideration in any city. Wastewater reclamation may seem more feasible because it requires comparatively less energy, but public acceptance of this option can sometimes present significant challenges, as evident from studies in Australia and South America (Thorley 2006; Hurlimann and Dolnicar 2010; Fragkou and McEvoy 2016; Fielding, Dolnicar, and Schultz 2018). Harvested rain and stormwater, and demand management have also been proposed as options for increasing supplies but these also have their challenges (Mankad and Tapsuwan 2011; Mannel, Prozesky, and Cloete 2014; Fielding et al. 2015; Leonard, Mankad, and Alexander 2015; Leonard, Walton, and Farbotko 2015).

1.1 Past research

Admittedly, a considerable part of the current understanding of public acceptance of alternative water sources is from studies on reclaimed and desalinated water in Australia, Namibia, the United States, and South Africa (Thorley 2006; Dolnicar, Hurlimann, and Duc Nghiem 2010; Hurlimann and Dolnicar 2010; Gibson and Burton 2014; Leong 2016; Wester et al. 2016; Etale et al. 2020). These studies show that people are less accepting of reclaimed water for drinking and close to body uses such as washing, but much more accepting of it for purposes such as outdoor irrigation and toilet flushing (Marks,

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Martin, and Zadoroznyj 2008; Dolnicar, Hurlimann, and Grün 2014). Desalinated water is also more acceptable compared to reclaimed wastewater. A study with Australian respondents showed that perceptions of fitness for drinking were highest for desalinated water (76%), followed by rainwater (69%), and then reclaimed wastewater was least acceptable (54%) (Dolnicar, Hurlimann, and Grün 2014). Similar findings were reported by Marks, Martin, and Zadoroznyj (2008), who found rainwater to be the most acceptable alternative water for drinking (76%) and that just about half of the respondents (51%) were willing to drink desalinated water without hesitation.

Few studies, however, have examined perceptions of desalinated and reclaimed wastewater alongside rainwater and stormwater. Nevertheless, where this has been done, the data show that rainwater and reclaimed wastewater are the most and least preferred options, respectively, for drinking. Stormwater and desalinated water lie in between these two (Marks, Martin, and Zadoroznyj 2008; Fielding et al. 2015). The data also show that stormwater reuse support is greater if it is developed for non-potable rather than potable use, whether the reuse is direct or indirect (Leonard, Mankad, and Alexander 2015).

1.2 Determinants of alternative water acceptance

Much of our understanding of factors that underlie the acceptance of alternative water sources is also from studies on reclaimed wastewater and desalinated water in (Po, Kaercher, and Nancarrow 2003; Dolnicar, Hurlimann, and Grün 2011; Hurlimann and Dolnicar 2016; Fielding, Dolnicar, and Schultz 2018; Etale et al. 2020). These studies show that a variety of factors, including, concerns about health risks, water quality, costs, and environmental friendliness, trust in authorities responsible for water treatment and maintenance of supply networks, trust in the treatment technologies and scientific information provided, and perceived knowledge also influence acceptance. Demographic factors: age, gender and education levels are also significant predictors in some cases, with older individuals, males, and those with higher levels of education being more accepting of desalinated and reclaimed water (Po, Kaercher, and Nancarrow 2003; Dolnicar, Hurlimann, and Grün 2011; Hurlimann and Dolnicar 2016; Fielding, Dolnicar, and Schultz 2018; Etale et al. 2020).

Studies on stormwater contributed additional predictors of acceptance. People seem more supportive of stormwater reuse projects if the project was judged to be sustainable in the long term and that the rest of their community was also in support of it (Leonard, Walton, and Farbotko 2015). Fairness, cost of the scheme, and its perceived effectiveness at addressing water scarcity were key issues for public acceptance. Nevertheless, as with other alternatives, trust in the technology and scientific information provided and in authorities responsible for the safety and quality of the water were key factors (Leonard, Mankad, and Alexander 2015).

1.3 The effect of information on decision making

Despite criticism by some scholars of the 'knowledge deficit' approach in characterising public attitudes (Sturgis and Allum 2004), there is evidence to suggest that information provision can shift attitudes and increase acceptance of alternative water sources. Dolnicar, Hurlimann, and Duc Nghiem (2010) found that people were more willing to use recycled and desalinated water after receiving brief information about the production process. Fielding and Roiko (2014) also found that participants who received brief information about the production process for recycled potable water had more positive emotions and lower risk perceptions relative to a control group. Further, when given the opportunity to drink water that contained purified recycled water, these participants consumed a larger amount of the water than participants with higher risk perceptions in a controlled study. They were also twice as likely to support a recycled water scheme. In South Africa, Slabbert and Green (2020) found a positive correlation between recycled water acceptance and knowledge about water reuse. This observation is in line with the findings of a study on residents of Beaufort West, where reclaimed water was introduced to address long-standing deficiencies to supply (von Dürckheim and Marais 2011). Despite initial negative perceptions in the von Dürckheim and Marais (2011) study, awareness campaigns resulted in increased acceptance of reclaimed water by the community. Similarly, Visser et al. (2021) have found that behavioural nudges such as information on comparative water consumption, real-time feedback on water consumption, warning letters, and the provision of water-saving tips were effective in reducing water consumption during the Cape Town water crisis of 2018.

Other studies on the role of information have examined what particular aspects of information are useful for shifting perceptions. Tameika and Fielding (2020) showed that positive affective framing increased acceptance of reclaimed water by lessening risk perceptions. Together, these studies suggest that information provision can shift attitudes and acceptance of water provision alternatives.

Some limitations of previous studies are worth noting. Firstly, most studies have examined alternatives in isolation, a situation that can be argued to be unrealistic since, in a situation of water scarcity, people would likely have to choose from a suite of options, trading off one or two options against others. Second, most studies did not include water restrictions as an option for addressing water scarcity. It is known that in some cases, those opposed to considering alternative water sources have proposed demand management instead (Muller 2018).

1.4 The present study and hypotheses

The present study, therefore, builds upon past research in two ways. First, by presenting respondents with various options, including water restrictions, desalinated water, reclaimed water, stormwater and rainwater, it allows for the exploration of attitude towards alternative water for potable and non-potable reuse and choice-making in a more realistic scenario. Second, no assumptions are made regarding the level of awareness about the water sources. As such, information that allows for consideration of the pros and cons of the alternatives is presented, equipping participants for the trade-offs that would have to be made in realistic scenarios. Finally, examining perceptions using a decision pathway survey allows gathering insights on values underlying perceptions and rationales for acceptance or rejection, and information generated can be especially valuable for the design of effective public communication (Gregory et al. 1997).

Traditionally, questionnaires and surveys have been used to gather information from participants through a set of questions and answers. Surveys have, therefore, acted as a type of standardised interviewing platform with little opportunity by researchers to probe or clarify respondents' responses. It could be argued that in some cases, such surveys collect uninformed opinions (Gregory et al. 1997). In contrast, decision pathway surveys allow the researcher to glean underlying reasons for respondents' choices (Gregory and Wellman 2001; Gregory, Satterfield, and Hasell 2016; Robinson et al., 2019).

A decision pathway survey was developed to collect information and insights into South Africans' decision-making processes when considering ways to address future water scarcity. Using four options determined by preliminary surveys (i.e. harvested rain and stormwater, desalinated water, reclaimed water and water restrictions), this study examined the following research questions:

(1) Research Question 1: What is the most preferred approach to water provision in water scarce urban South Africa, and the reasons underlying these preferences?
(2) Research Question 2: Can information provision about the different options change initial preferences for approaches to addressing water scarcity?

2. Methods

2.1 Sample

Ethics clearance was obtained from the University's Human Research Ethics committee (Protocol numbers H20/02/13 and MAORG/20/04) before data collection. Survey respondents (N = 668) were drawn from urban regions of all nine provinces within South Africa and consisted of individuals from different ethnic groups and religious beliefs (Table 1). Most individuals were from Gauteng (n = 252), followed by individuals from Western Cape (n = 111), KwaZulu-Natal (n = 102), Eastern Cape (n = 54), Free State (n = 37), Limpopo (n = 33), North West Province (n = 33), Mpumalanga (n = 31), and Northern Cape (n = 15). This sample was broadly representative of the national population. The programmed survey was distributed to respondents provided by a commercial survey company (Kantar BV). Thus, nonprobability voluntary response sampling was used to reach a quota sample size. There were 386 females and 280 males; two individuals did not disclose their gender. The average age of the respondents was 37.23 years (SD = 13.02) and ranged from 18 to 79 years. Less than two-thirds of respondents (n = 195) had a secondary school education or higher or a combined monthly household income of R25 601 – R51 200 ($1 600.1 – $3 200) ($n$ = 166). Most respondents (72%, n = 483) reported their main source of drinking water to be from pipes within their dwellings, and of the 42% (n = 281) who stayed in a detached house, 233 reported the dwelling as being fully paid off.

2.2 Survey design

The decision pathway survey was developed based on themes drawn from three focus groups (two with laypeople (n = 19) and one with experts (n = 6)). Themes included (dis)trust in government, concerns about infrastructure maintenance, technology, the need for an environmental buffer, health concerns, public awareness of water reclamation, costs and incentives, and the role of the media and advertising. Gaps in information identified during these focus group discussions were then used to design tutorials in the decision pathway survey.

The decision pathway survey comprised 33 questions (Supplementary information 1). The longest path comprised twelve questions and the shortest seven questions. Questions examined value positions or trade-offs that participants were willing to make in addressing water provision using alternative waters. Each pathway also contained several information tutorials to aid in decision-making (Figure 1). Information was also collected on respondents' understanding of terminologies, including wastewater, greywater, and blackwater.

The initial question gauged levels of concern for South Africa's water security on a scale of 1 to 4. Following this rating, a tutorial on the country's water situation and three alternative water sources that could be used to address scarcity was presented to respondents (Tutorial 1) (Supplementary information 2). They were then asked to indicate support (or not) for the exploration of alternative water sources. Respondents in favour of exploring alternatives then followed paths seven to 11, and those not in favour followed paths one to six to the end of the survey.

2.2.1 The 'No' pathway

Respondents who indicated that alternative water sources should not be explored were provided with a tutorial with definitions of some of the alternative sources of water available before being allowed a second chance to respond to the question on the exploration of alternative water sources. After the tutorial, those maintaining opposition to alternatives were asked to indicate reasons for this from eight provided reasons. Each choice then led to questions that allowed for a better understanding of underlying reasons/concerns and the specific information these individuals deemed essential for decision-making about alternative water sources.

2.2.2 The 'Yes' pathway

Respondents who supported alternative water sources were provided with specific definitions and asked to rank the alternatives in their order of preference. A follow-up question then asked about the reasons for their most preferred alternative from a suite that included (i) a belief that it was the cheapest option, (ii) that it provided the cleanest water, (iii) their choice had been because of media influence, (iv) the choice was environmentally friendly, (v) it would reduce water wastage, (vi) that was the option they had most knowledge on, or (vii) they trusted the government's management of the system (in the case of water reclamation). After this, respondents were shown a tutorial on wastewater reclamation and related terminology (i.e. tutorial three)

Table 1. Frequency distributions and description of the consumer sample.

Demographic	Frequency (*n*)	Percentage
Total Number of Completed Responses (*N*)	**668**	
Age		
Mean	37.23 (*SD* = 13.02)	
Range	61	
Minimum	18	
Maximum	79	
Sex		
Female	386	57.78
Male	280	41.92
Prefer not to say	2	0.30
Population Group		
Black African	330	49.40
White	208	31.14
Coloured	79	11.83
Indian or Asian	39	5.84
Prefer not to say	8	1.20
Mixed Race	4	0.60
Province		
Gauteng	252	37.72
Western Cape	111	16.62
KwaZulu-Natal	102	15.27
Eastern Cape	54	8.08
Free State	37	5.54
Limpopo	33	4.94
North West	33	4.94
Mpumalanga	31	4.64
Northern Cape	15	2.25
Religion		
Christian	497	74.40
No religious affiliation or belief	41	6.14
Traditional African Religion	37	5.54
Prefer not to say	26	3.89
Islamic	19	2.84
Atheist	16	2.40
Hindu	12	1.80
Agnostic	11	1.65
Other (Jewish, Bahaism, Buddhist, Judaic Buddhist)	9	1.35
Education		
High School completed – Matric/Grade 12	195	29.19
Vocational or FET College – Diploma or Certificate	177	26.50
Bachelor's degree	167	25
Honours Degree	54	8.08
Master's degree	30	4.49
Some High School	29	4.34
Doctoral Degree	9	1.35
Primary School completed	7	1.05
Combined Monthly Household Income ($1=R16)		
R25 601 – R51 200 ($1 600.1 – $3 200)	166	24.85
R12 801 – R25 600 ($800.1 – $1 600)	154	23.05
R6 401 – R12800 ($400.1 – $800)	125	18.71
R51 201 – R102 400 ($3 200.1 – $6 400)	64	9.58
R3 201 – R6 400 ($200.1 – $400)	39	5.84
R1 601 – R3 200 ($100.1 – $200)	35	5.24
Prefer not to say	32	4.79
R1 – R1 600 ($0.1 – $100)	16	2.40
R102 401 – R204 800 ($6 400.1 – $12 800)	14	2.10
No income	12	1.80
R204 801 or more (> $12 800.1)	11	1.65
Source of Drinking Water		
Piped (tap) water inside the house from a municipality	483	72.31
Bottled water only	66	9.88
Piped (tap) water inside the yard from a municipality	65	9.73
Borehole	27	4.04
Public or communal tap	6	0.90
Watercarrier or tanker	6	0.90
Spring	5	0.75
Other (Flowing water, stream, or river; Well)	4	0.60
Neighbour's tap	3	0.45
Rain-water tank	3	0.45

before being asked to indicate whether they agreed that implementing direct wastewater reclamation could help to ensure sustainability for South Africa's future water supply.

Respondents who agreed or disagreed with the statement: 'direct wastewater reclamation is a viable option' received further information on reclaimed water before being directed to choose between pathways seven to 11. A fourth tutorial provided the meaning of direct and indirect reclamation for potable and non-potable reuse. The paths following this tutorial aimed to provide insights on how comfortable respondents were with the idea of using these types of water for both potable and non-potable use. In the end, each respondent, by answering yes/no to a series of questions, followed a particular pathway resulting in a constructed representation of their point of view.

2.3 Survey validation and pilot testing

Before being administered, the survey was validated by 12 South African experts (five male and seven female) in July and August 2020 to assess the accuracy and viability of the pathways and tutorials. Experts had extensive knowledge of, or an interest in, water management, sustainability, survey design, consumer behaviour, or reclaimed water and waste management.

A pilot test was run during September 2020 using 51 respondents selected by convenience sampling and snowball sampling. The respondents were male and female, 21 to 73 years of age, and largely urban dwellers living in Johannesburg. They comprised university students, staff and were Black African, Coloured, Indian or Asian, Mixed Race, or within the White population group. The pilot test was used to test the functionality of the online survey, to determine the dropout rate per question and the completion time. Responses were also monitored for potential errors in the programming. All completed responses were included in the full analysis.

2.4 Data analyses

The quantitative nature of the study required descriptive statistics to be run, which included obtaining means, frequencies, and standard deviations. The one group pre-test post-test design allowed for a chi-squared test to be used. Change in acceptance of alternative water sources was calculated using Equation 1, where $\Delta accept$ is the change in acceptance of alternative water sources, and opp_{t1} and opp_{t2} represent opposition to alternative water sources at the beginning and end of the survey, respectively.

$$\Lambda_{accept} = \left(\frac{opp_{t1} - opp_{t2}}{opp_{t1}} \right) \quad (1)$$

Changes in acceptance of the individual alternative water sources were also assessed using Chi-squared tests. A post hoc comparison, using the Bonferroni adjusted alpha level, $a_{Bon} = .00313$ per test (.05/16) with a corresponding critical value of $N(0,1)_{1\text{-}aBon/2} = 2.96$, was performed due to a large number of cells.

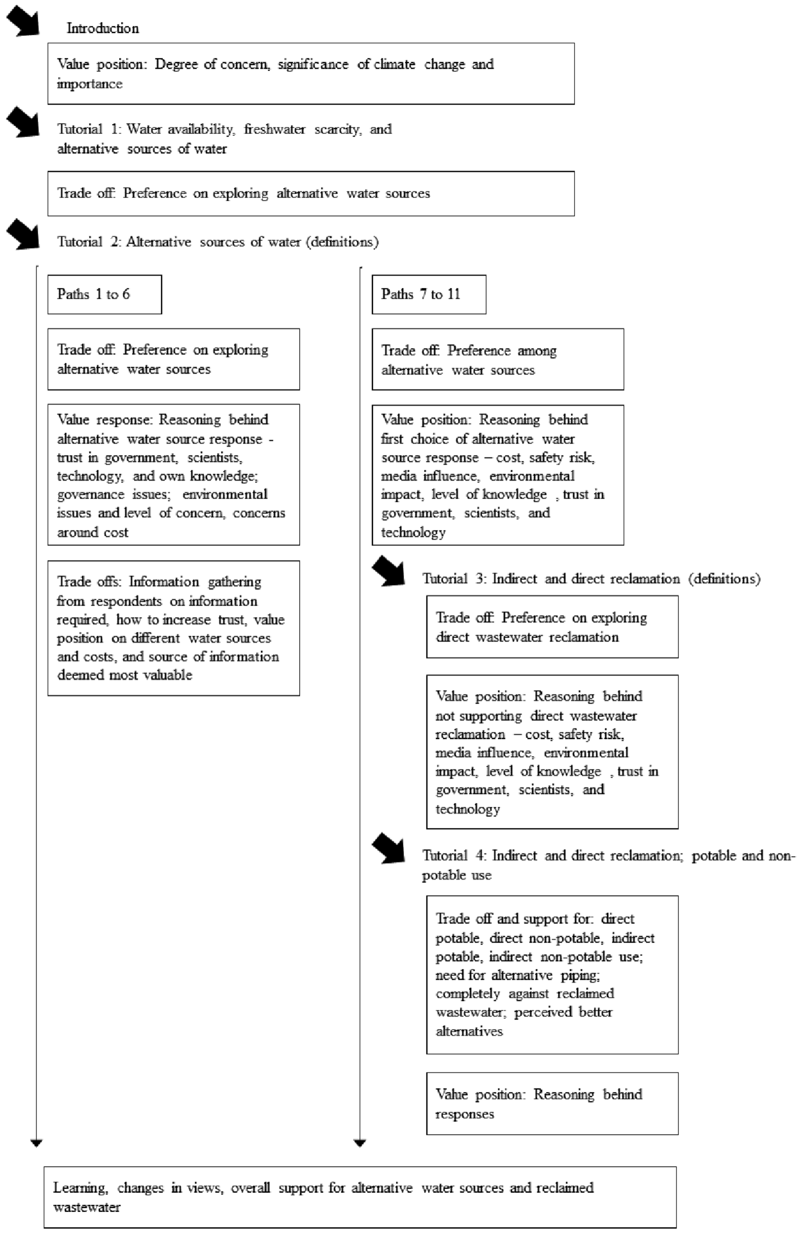

Figure 1. Decision pathway design sequence.

3. Results

General knowledge on water terms was tested before respondents embarked on the decision pathway survey to provide an idea of levels of understanding among the respondents. The results are summarised in Table 2. It shows that while most respondents were familiar with 'greywater' and 'blackwater', familiarity with the other terms was lower. Additionally, from the total sample (M = 3.84, SD = 2.03), roughly 40% of the respondents had a correct understanding of at least four of the seven terms. A very low faction (7.5%) had none of the terms correct.

Results of the decision pathway showed that at the start of the survey, 647 of the 668 surveyed respondents thought it prudent for South Africa to explore alternative water sources to secure its future water supply. Thus, only 21 respondents (3.1%) were against the idea initially. Nevertheless, 14 of these 21 respondents changed to support exploring alternative water sources in South Africa after information provision. Harvested stormwater and rainwater were the most preferred options (n = 332), followed by desalinated water (n = 116), water restrictions (n = 108), and finally, the use of reclaimed wastewater (n = 105) (Table 3).

Most of those who selected harvested rain and stormwater as the most preferred option at the beginning of the survey believed it to be the option that would provide the cleanest and safest water and that it would be the cheapest option. Desalinated water was perceived as a more environmentally friendly option than reclaimed water, and that it would result in water that was cleaner and safer.

Table 2. Responses to water terminology.

Question/ Terminology	Options	n	%
The term 'wastewater' means	a) Water that is safe to drink	47	7.04
	b) **Used water from homes, businesses, or industrial activities ***	423	63.32
	c) Water that is of potable standard	48	7.19
	d) Water in municipal reservoirs	71	10.63
	e) I do not know	79	11.83
The term 'greywater' means	a) Water that is clean	33	4.94
	b) **Water from baths, showers, sinks, washing machines, and other kitchen appliances ***	453	67.81
	c) Water from toilets that contain a mixture of urine, faeces, and flush water	55	8.23
	d) I do not know	127	19.01
The term 'blackwater' means	a) Water that is clean	15	2.25
	b) Water from baths, showers, sinks, washing machines, and other kitchen appliances	54	8.08
	c) **Water from toilets that contain a mixture of urine, faeces, and flush water ***	448	67.07
	d) I do not know	151	22.60
The term 'potable water' means	a) Water that is NOT safe to drink or is NOT safe for cooking	61	9.13
	b) **Water that is safe to drink and can be used for cooking ***	312	46.70
	c) Water directly from lakes, rivers, or the ocean	117	17.51
	d) I do not know	178	26.64
The term 'non-potable' means	a) **Water that is NOT safe to drink or is NOT safe for cooking ***	362	54.19
	b) Water that is safe to drink and can be used for cooking	40	5.98
	c) Wastewater that is treated to drinkable quality	49	7.33
	d) I do not know	217	32.48
The term 'reclaimed water' means	a) Untreated wastewater	48	7.18
	b) **Treated wastewater (black & greywater) ***	322	48.20
	c) Treated greywater	101	15.11
	d) Treated blackwater	14	2.09
	e) I do not know	183	27.39
The term 'alternative water sources' means	a) Water from desalination plants	40	5.98
	b) Harvested rainwater	122	18.26
	c) Reclaimed wastewater	30	4.49
	d) **All of the above ***	246	36.82
	e) Only options a and b	130	19.46
	f) I do not know	100	14.97

Note. * The correct answer to each question is in bold.

3.1 Decision pathways: opposition to alternative water sources

There were 11 possible pathways available to respondents in the study, six of which could be followed by respondents against the exploration of alternative water sources to address water scarcity in South Africa (Figure 2).

After their initial opposition, these respondents were provided with information on alternative water sources proposed by the study and allowed to change their initial choice. Fourteen respondents changed their opinions after reading the information in Tutorial 2, but seven (1%) did not. These followed Paths one to six of the survey, which comprised questions designed to explore reasons for this opposition. The data show that those who followed:

Path 1 (n = 1) believed the government or municipalities did not know enough about technologies required to safely implement alternative water use or manage complex environmental issues. They also did not believe that the government and scientists had the public's best interest at heart.

Path 2 (n = 1) indicated that they did not know enough about alternative water sources to make an informed choice. This respondent also indicated that they would find information on the quality of the water and any associated health risks most valuable and that children should be taught about alternative water sources at school.

Path 3: (n = 2) indicated that they did not trust the government or municipality to manage the processes required to implement the use of alternative water sources. One respondent believed that the government and municipalities should allow citizens to vote on the available options before implementation to increase the public's trust. The other respondent indicated that they believed the retraining of employees was required, suggesting a lack of confidence in their current competence.

Path 4: (n = 1) indicated that water is abundant globally, and municipalities should continue to do things as they have always been done.

Path 5: (n = 1) indicated that they were more worried about other environmental issues such as deforestation or pollution because it was reported more in the news or spoken about more by celebrities.

Path 6: (n = 1) indicated that the exploration of alternative water sources would be too expensive.

3.2 Decision pathways: support for alternative water sources

Respondents who agreed that South Africa should explore alternative water sources (n = 647) and those who changed their answer from *'No'* to *'Yes'* after the first tutorial (n = 14) followed pathways 7–11. They received a tutorial on the differences between indirect and direct reuse, and potable and non-potable reuse. Their support for these options is summarised in Figure 3. The results show that support for direct reuse was generally higher than for indirect reuse (n = 231 and 192, respectively) and that, in both cases, potable reuse had greater support than non-potable reuse.

Most respondents in favour of direct reuse thought it was cost-effective (n = 105), believed that the government, municipalities, and scientists had sufficient knowledge to successfully implement it (n = 52), or that it was an environmentally friendly option (n = 31). Notwithstanding, 48% (n = 111) of respondents in this group were concerned that the success of this alternative could be hampered if poor water quality resulted in waterborne diseases or public acceptance of it was low (n = 42). Nevertheless, a small number (n = 30) believed there would be no problem implementing direct reuse.

For the respondents in favour of indirect reuse, health risks were also a major concern (n = 112), as were cost (n = 43), and public acceptance (n = 29). Respondents who believed that only non-potable reuse should be implemented gave the following reasons:

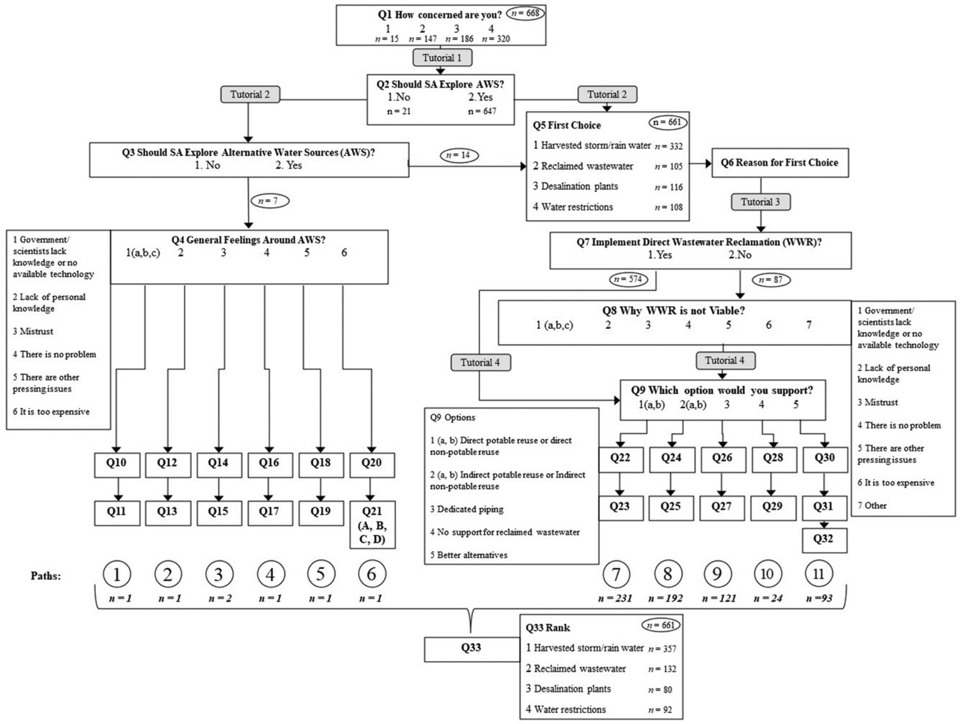

Figure 2. Decision pathway map and frequencies. *Note*. Question numbers refer to questions provided in the supplementary information.

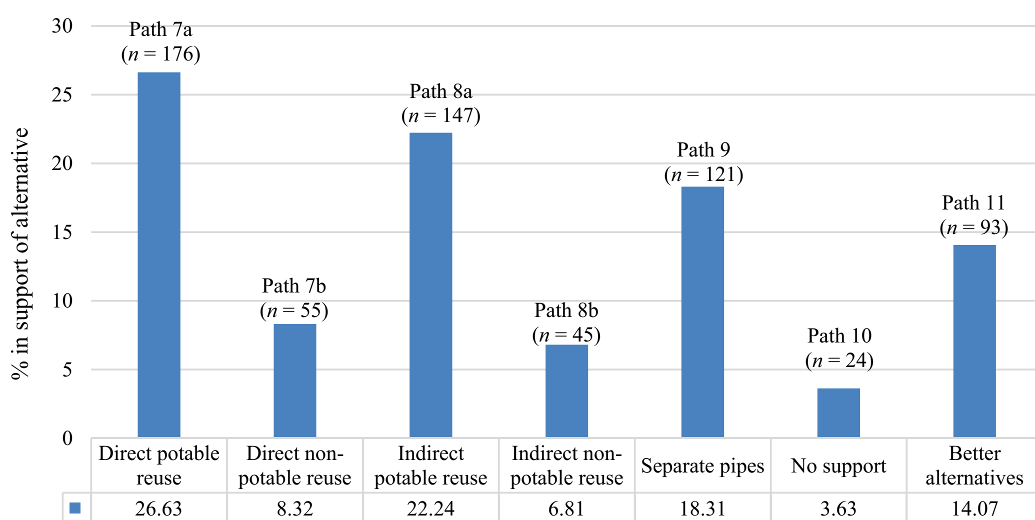

Figure 3. Levels of support for approaches to addressing water scarcity.

Table 3. Cross-tabulation of respondent's first choice by reason.

	Water would be cleanest & safest		Most knowledge of option		I trust government		Environ-mentally friendly		Often mentioned in media		Would reduce wastage		Option would be cheapest	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Harvested storm & rainwater	135	20.4	8	1.2	8	1.2	59	8.9	7	1.1	36	5.4	79	12
Desalinated water	57	8.6	4	0.6	7	1.1	23	3.5	11	1.7	8	1.2	6	0.9
Water restrictions	27	4.1	4	0.6	1	0.2	17	2.6	3	0.5	37	5.6	19	2.9
Reclaimed wastewater	35	5.3	3	0.5	7	1.1	19	2.9	6	0.9	13	2.0	22	3.3
Total	**254**		**19**		**23**		**118**		**27**		**94**		**126**	

(1) The government or municipalities could not maintain the infrastructure (n= 63).
(2) They did not trust the government or municipalities to maintain the water quality (n = 53).
(3) Drinking reclaimed water could have health risks (n = 39).
(4) The cost of treating water to drinking water standards would be too high (n = 11).
(5) Drinking reclaimed water would be disgusting (n = 7).
(6) It was against their religion to drink reclaimed wastewater (n = 4). Three of these respondents identified as Christian, one as an atheist.

Some respondents (n = 121, 18.3%) in the '*Yes*' pathway indicated that additional piping should be run to homes, specifically for reclaimed wastewater, so that consumers could decide which water they wanted to use. Most respondents on this pathway (n = 50) indicated that they did not trust the government or municipalities to maintain a high level of water quality and believed that separate pipes would ensure drinking water was not contaminated. Others (n = 36) were concerned about health risks, while others (n = 26) did not trust the government or municipalities to maintain the infrastructure. Disgust at the thought of using reclaimed water (n = 6) and trust in the scientists to maintain the water quality (n = 3) were not major reasons for non-support.

Finally, a small minority (n = 24, 3.6%) indicated that if reclaimed wastewater were the only viable option for South Africa's water crisis, they would still not support its use. Their reasons included:

(1) Feeling not well informed about wastewater reclamation (n = 7).
(2) Little trust in the government or the municipalities' ability to manage the infrastructure or water quality (n = 6).
(3) A belief that the government/municipalities did not know enough about the technology required to safely implement wastewater reclamation (n = 5).
(4) Disgust (n = 2).
(5) Doubting scientists' knowledge on the reclamation technologies (n = 1) and the possible cost implications (n = 1).
(6) None of the respondents indicated that using wastewater was against their religion.

Respondents who followed Path 11 believed that there were better alternatives to address South Africa's water crisis than wastewater reclamation (n = 93, 14.1%). Their preferred alternatives included: storm or rainwater harvesting (n = 48), water restrictions (n = 24), and desalination plants (n = 21). The most common reason for support amongst this group was a belief that this water was purer (n = 26), or cheaper (n = 24) than reclaimed water. Respondents in this group thought that opposition to reclaimed water by consumers was likely to stem from perceived health risks (n = 40), disgust emotions (n = 13), or cost concerns (n = 12).

3.3 Information provision and changes in preference

At the beginning of the survey, 21 respondents indicated that they were against exploring alternative water sources in South Africa. However, after receiving more information on the alternatives, 14 respondents changed their responses, representing a 66.7% increase in favour of exploring alternative water sources.

For respondents on the 'Yes' pathway from the beginning, opportunities were presented at the beginning and end of the survey to state their most preferred alternative water source. An examination of preferred alternatives shows that as respondents went through the survey and engaged with the information provided, support for storm and rainwater harvesting increased from 50.2% at the beginning of the survey to 54.0% at the end. Support for reclaimed wastewater also increased from 15.9% to 20.0%. In contrast, the number of people favouring desalinated water and water restrictions as options for addressing scarcity decreased from 17.5% to 12.1% and 16.3% to 13.9%, respectively. Nevertheless, Chi-square tests suggested significant associations between respondents' preferred water alternative at the start and end of the survey, χ^2 (9, n = 661) = 145.17, $p < .001$.

The results (Table 4) show that most individuals in favour of storm and rainwater harvesting or desalinated water, or water restrictions at the beginning of the survey, were still in favour of these options at the end. Significantly fewer respondents than expected who were in favour of stormwater and rainwater harvesting at the beginning changed to support desalinated water or water restrictions at the end of the survey. Also, significantly fewer respondents than expected who were in favour of desalinated water at the start of the survey changed to support stormwater and rainwater harvesting. Together these data suggest that amongst those in favour of exploring alternative waters, choices of which alternatives to pursue were stable between the two time points. This result can be explained in one of two ways which we explore in the Discussion.

In sum, the results showed, in the case of RQ1, that the most preferred alternative water source to address water scarcity was harvested storm and rainwater, while the least preferred option was reclaimed water. Desalinated water and water restrictions were the second and third most preferred options, respectively. The data also show that these preferences were strongly influenced by perceptions of water safety, purity, and low cost in the case of storm and rainwater harvesting, and environmental friendliness, purity, and safety in the case of desalinated water. For RQ2, the data suggest that information provision can indeed influence perceptions, both increasing and diminishing acceptance. For instance, while acceptance of recycled water and harvested storm and rainwater increased, support for desalinated water and water restrictions, decreased. Information provision also led to greater acceptance for direct instead of indirect water reuse i.e. 35% versus 29% in situations of severe water scarcity.

4. Discussion

In the present study, a decision pathway approach was used to investigate preferred alternative water sources. Within the decision pathway survey, respondents received information on

Table 4. Cross-tabulation of preferred alternative at the start of survey by preferred alternative at the end of survey.

Preferred Alternative at Start of Survey		Preferred Alternative at End of Survey				
		Harvested storm- and rainwater	Reclaimed wastewater	Desalinated water	Water restrictions	Total
Harvested storm – and rainwater	Count	228	56	21	27	**332**
	Expected Count	179.3	66.3	40.2	46.2	
	% within First choice at Start	68.67%	16.87%	6.33%	8.13%	
	Adjusted Residual	7.59981*	−2.00419	−4.57494*	−4.31709*	
	Bonferonni Correction (*p* of 0.05/ 16 = 0.00313	0.00000*	0.04550	0.00000*	0.00002*	
Reclaimed wastewater	Count	48	32	6	19	**105**
	Expected Count	56.7	21	12.7	14.6	
	% within First choice at Start	45.71%	30.48%	5.71%	18.10%	
	Adjusted Residual	−1.85949	2.93630	−2.18842	1.34824	
	Bonferonni Correction (*p* of 0.05/ 16 = 0.00313	0.05743	0.00373	0.02781	0.19360	
Desalinated water	Count	35	26	43	12	**116**
	Expected Count	62.7	23.2	14.0	16.1	
	% within First Choice at Start	30.17%	22.41%	37.07%	10.34%	
	Adjusted Residual	−5.67293*	0.72515	9.07926*	−1.22454	
	Bonferonni Correction (*p* of 0.05/ 16 = 0.00313	0.00000*	0.483930	0.00000*	0.23014	
Water restrictions	Count	46	18	10	34	**108**
	Expected Count	58.3	21.6	13.1	15	
	% within First Choice at Start	42.59%	16.67%	9.26%	31.48%	
	Adjusted Residual	−2.60263	−0.93876	−0.99058	5.76507*	
	Bonferonni Correction (*p* of 0.05/ 16 = 0.00313	0.00932	0.36812	0.31731	0.00000*	
Total		**357**	**132**	**80**	**92**	**661**

Note. Significant values are indicate with an asterisk (*) at *a* = 0.00313 and z-critical value = −2.95517 (two-tailed).

alternative water sources, allowing them to make more informed decisions as a slower and more deliberative decision-making process was activated (Gregory et al. 1997). Furthermore, when respondents choose one pathway and avoid others, insights into their underlying values are gained (Gregory et al. 1997). Information produced from such a survey can provide valuable insights to policymakers for implementation and engagement strategies in selecting alternatives during water scarcity.

The results showed that most respondents supported the exploration of alternative water sources, and very few respondents (1.1%) were completely against it, suggesting an understanding of current or future water insecurity. Support for direct and indirect potable reuse in this study was similar to that reported by Slabbert and Green (2020). Up to 48.5% of urban and rural South Africans supported treating wastewater to drinking water quality during a drought situation in South Africa. Although their study included other actions, e.g. water restrictions, drilling for groundwater, the traditional survey format of the study did not necessarily allow for uncovering reasons behind people's choices, opposition or support.

An interesting finding of our study was the less prominent place of disgust as a factor in reclaimed water acceptance. In this study, the reasons most cited for not supporting either alternative water sources in general, or direct water reclamation, in particular, were low trust in the government, and low confidence in municipalities' ability to manage the processes. Some respondents also felt that they did not have sufficient information for decision-making. While mistrust in the local authorities or the national government might be due to perceptions that these institutions are corrupt and incapable of maintaining water supply infrastructure (Goldin 2010; Muller 2018; Wall 2018), low levels of knowledge may be down to the level of media engagement with water scarcity and alternative water sources (compared to discussions around energy shortages and alternatives). Support for indirect reuse for potable or non-potable use was also strongly influenced by beliefs around potential health risks, a finding supported by previous studies (Doria, 2010; Rozin et al., 2015; Etale et al. 2020).

Support for direct reuse was associated with perceptions of its cost-effectiveness and environment friendliness. Those who supported this option also had greater levels of confidence in the capabilities of responsible institutions to successfully drive the process. Overall, it is essential to note that most respondents would support direct reuse in severe drought, including for potable reuse. This is encouraging because it suggests that most respondents are willing to consider this option if it had to be implemented. Nevertheless, even in this case, we presume that trust would still be a significant determinant of willingness to consume. One way to increase the public's trust would be communication and continuous public engagement for information provision by authorities as evidenced by the success of the Beaufort West reclamation project (von Dürckheim and Marais 2011).

The finding on acceptance of direct reuse is different from what has been reported in other studies (e.g. Thorley 2006; Dolnicar and Hurlimann 2009; Fielding et al. 2015). It may demonstrate the effects not only of information provision, but also of having to make trade-offs. Previous studies did not involve the use of trade-offs, which we think represent a more realistic scenario of what would happen in cases of scarcity. It is therefore plausible, as this study shows, that acceptance of reclaimed water and direct reuse, in scenarios of actual scarcity may be different from choices made when shortages are not a reality or cannot be envisaged.

Regarding those against alternative water, concerns seem to have been around the effectiveness of the proposed solutions at addressing water scarcity considering the high energy requirements of some of the options suggested, and the current energy crisis in the country. It is, however, important to note that the country's high rainfall variability would make storm and rainwater harvesting an unreliable option for South Africa. Nevertheless, this remained the preferred option for some respondents before and after information provision, suggesting a lack of understanding of severe drought or knowledge of the hydrological cycle. Unfamiliarity with the terminology used to describe alternative water sources has been shown to be a barrier to consumers' support of more sustainable water sources (Dolnicar and Hurlimann 2009; Slabbert and Green 2020).

Alternatively, heuristics may have influenced preferences, leading respondents to prefer rainwater due to perceptions of it as natural, and therefore, safer than anything acted upon by humans (Rozin 2006; Etale and Siegrist 2018). Furthermore, the provision of rainwater is cheap (aside from the cost of investing in containers and piping), so it is likely perceived as a low-cost option. Nevertheless, as the dominant reason for choosing any alternatives was a belief that the water would be the cleanest and safest to drink, it is important that authorities maintain high standards as incidences of water-borne illness could destroy trust and lead to rejection of alternative waters.

Regarding information provision, we found that information provision resulted in a change of opinion for some respondents, suggesting that making the challenge salient and providing information on potential solutions, focused the decision making for these individuals. Nevertheless, some maintained their non-support, stating an unwillingness to consider some options such as reclaimed water even under a scenario of severe water scarcity. Perhaps, for these individuals, the information provided was not sufficient to convince them of the water's purity or low risks or alternative approaches e.g. based on affective frames (Etale et al. 2020; Tameika and Fielding 2020).

Although respondents' preference for harvested stormwater and rainwater at the start and end of the survey were comparable, the second most preferred alternative changed from desalinated water to reclaimed wastewater after information provision. However, an important observation concerns the fact that most respondents in the 'Yes' pathway scarcely altered their preferences after interacting with the information provided in the survey. It may seem that perceptions were mostly stable amongst the people who were pro-alternatives. Those who had already acknowledged that water availability was a problem had probably already engaged with information on potential solutions and made up their minds on what the best options to address the challenge were. The information provided in the tutorials did not present any information they had not already engaged with. A key takeaway from this study is that information provision can impact decisions on support for alternative water sources, including reclaimed water. Besides making salient the issue of water scarcity in general, information on the treatment involved in the various options may help to avoid the use of heuristics in decision-making. The format in which the information is presented may also be important. It is plausible that providing this information for multiple water sources in a manner that allows for comparisons of the various aspects e.g. treatment processes and aims, to be made, can aid decision-making. The use of local examples that respondents can relate to e.g. the recent Cape Town water crisis, may also influence perceptions and acceptance of alternatives.

Some limitations of the study are worth acknowledging. First, although terms were explained to respondents, the use of the English language in the survey may have limited some respondents' understanding of some concepts and terms. Second, sampling was conducted at the height of the COVID-19 pandemic, and some individuals may have had a more negative perception of reclaimed water and associated perceived health risks of water reuse. High rainfall during the study period could have inflated respondents' confidence in the potential of rainwater or stormwater harvesting to address water scarcity.

5. Conclusion

We set out to investigate attitudes towards alternative water sources amongst consumers in urban and suburban regions of South Africa. At the beginning of the survey, storm and rainwater were the most preferred options, and reclaimed water was the least preferred. However, during the decision pathway survey, the information provided to respondents shifted preferences. Support for reclaimed and harvested storm and rainwater water increased while support for desalinated water and water restrictions decreased. Information provision also led to greater acceptance for direct instead of indirect water reuse in situations of severe water scarcity. Together, these data suggest that information provision can influence consumers' decision-making on alternative water sources. The decision pathway approach also enabled a better understanding of trade-offs people would be willing to make when alternative water sources are required to augment conventional supplies. The data suggest that in situations of severe water scarcity, water reclamation, and more specifically, direct water reclamation, could be supported. Using this approach thus provided opportunities to (i) supply respondents with information to aid decision-making during the survey, (ii) glean insights on factors influencing decisions, and (iii) examine decision-making around alternative water sources in a more realistic scenario i.e. involving trade-offs. These data can be useful both for improving public engagement and for policy formulation.

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