Title: Alternative Water Management in Pretoria, South Africa: An Investigation into Public Perceptions of Water Recycling

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Alternative Water Management in Pretoria, South Africa: An Investigation into Public Perceptions of Water Recycling

ALISON STOAKLEY

Abstract: Growing water resource challenges posed by urbanization, population growth and climate change necessitate alternative solutions beyond the traditional 'once-through' centralized water management system. These pressures, combined with the need to address aging infrastructure, have catalyzed interest in water recycling and reuse, around the world. The city of Pretoria, South Africa offers a rare chance to directly investigate these perceptions and associated implementation opportunities due to the existing water situation and current government responses. While South Africa is facing severe water scarcity and equity issues, the country is equipped with well-articulated, globally recognized water policy frameworks, as well as stated government desire to pursue prospects for water recycling. This study utilized an online survey to collect responses from South African university students regarding the acceptability of recycled water for various tasks and under different variables. The results showed a high degree of acceptability, especially for watering gardens and toilet flushing, which increased with the assurance that the system would benefit the environment, or the individual would personally experience a water shortage without it. It is suggested that university campuses provide a valuable opportunity to demonstrate the implementation of water recycling and reuse among a supportive audience. Each future project offers immense benefit through building familiarity and engagement with water reuse which could be extended and locally tailored to communities throughout South Africa.

Keywords: Water reuse, water recycling, South Africa, public engagement

1. Introduction

Water is at the forefront of the international conversation around sustainability due to the increasing pressures of urbanization, population growth, and climate change challenging communities all around the world. Countries around the world, including South Africa, have recognized the opportunity to address these urgent water challenges through the investigation and implementation of various forms of water reuse.

As will be shown in a review of the literature, water reuse and specifically water recycling, offers the opportunity to supplement existing stressed water supplies and capitalize on the benefits of decentralized systems, thereby generating diverse ecological and financial benefits. However, past water reuse projects from around the world have demonstrated that the level of community acceptance of recycled water and perceptions around elements such as cost, risk, and necessity are vital indicators of a planned project's eventual success or failure. This documented implementation experience, supported by the literature on community engagement, illustrates the benefits of proactively investigating the attributes of communities involved in water reuse projects and the necessity of providing opportunities for public participation in the development process.

This research is an investigation into the common perceptions of water recycling and reuse among university students in South Africa. South Africa provides a rare window to look directly into the opportunities and barriers of implementation of water recycling projects, for while the country is facing severe water scarcity and equity issues (DWAF 2012b), it is also equipped with a well-articulated, and globally recognized, water policy framework (van Koppen *et al*. 2011). It also has a long-stated desire (government) to pursue prospects for water recycling (DWAF 2012b, Philip van der Walt, P. E., 2013, pers. comm., 5 April). The following review of the literature will clarify the role of water recycling in a sustainable world and the importance of public engagement in the planning process, leading into a more specific elaboration on water management and possibilities for water recycling in Pretoria. The results of the student survey will then be discussed in the context of similar studies completed in other locations and the impact of this knowledge on policymaking and project planning. The outcomes of the research are available to inform the future implementation of water infrastructure with regards to important considerations and opportunities for planning new water recycling projects.

2. Role of water reuse in a sustainable world

2.1 Clarifying terms

Prior to elaborating on the literature surrounding water recycling and reuse, it is necessary to clarify what processes are implied by these terms. For the purposes of this review, water reuse is defined as the 'utilization of treated or untreated wastewater for a purpose other than the one that generated it' (Jiménez and Asano 2008) and refers to various sources such as treated wastewater, greywater (eg. from showers, sinks, laundry, etc.), storm water, and rainwater harvesting (Po *et al*. 2004). The survey used in this research mainly employed the term 'recycled water', which Po (*et al*. 2004) notes usually indicates the treatment and beneficial reuse of wastewater from municipal, industrial or agricultural sources. Although the survey used in the research did not distinguish between scales of implementation, water reuse systems can operate on individual, district, wide urban and/or agricultural, or industrial levels (Ilemobade *et al*. 2009) and involve various degrees of technological sophistication.

2.2 Potential for water recycling and reuse to augment supply

Interest in water recycling and reuse is growing around the world in a diverse array of countries and along a spectrum of scales and uses. In a review of urban water recycling for non-potable uses, Lazarova (*et al*. 2003) notes that the emphasis on water reuse is prevalent in both water-scarce, and more water-affluent but highly populated countries due to the shared challenge of meeting a growing demand with finite available water. Water reuse can begin to address this supply challenge by augmenting an existing water supply with treated wastewater, greywater, storm water or rainwater. As illustrated in *Figure 1*, water reuse schemes allow for a 'closed loop' system where the water wastes of a traditional system are instead viewed as resources and recycled through the catchment (Stenekes *et al.* 2004 cited in Chanan *et al.* 2009). Finding beneficial uses for previously unutilized resources such as storm water runoff or recycled water, known as 'source substitution', can reduce the need for inflow or imported water (Chanan *et al.* 2013, White and Turner 2003). Additional benefits can result from capturing the underutilized supply of valuable nutrients such as nitrate and phosphorus that are prevalent in wastewater (Angelakis *et al.* 2003). With some level of treatment, effluent can be a beneficial source of water for irrigation and also reduce the demand for fertilizers.

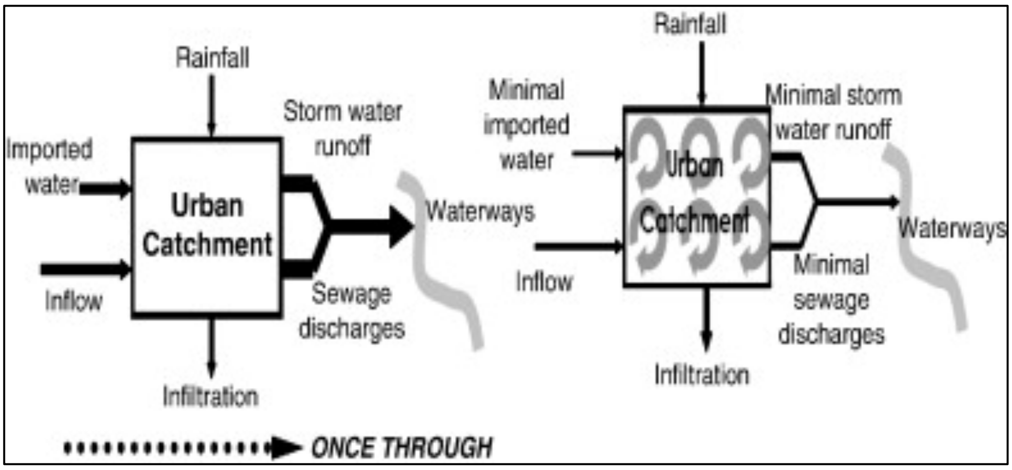


Figure 1: The traditional view of water management (left)
in contrast with a sustainable system (right)
Source: Stenekes (*et al.* 2004) citied in Chanan (*et al*. 2009)

In addition to increasing the overall supply of water, water reuse also introduces the idea of fit-for-purpose application, in which water scheduled for reuse is matched to a purpose and then only treated to the quality necessary for this task, if it has to be treated at all (Chanan *et al.* 2009). Using fit-for-purpose water for specific tasks reduces the demand on potable water supplies by, for example, ensuring that water treated to drinking standards is not used for washing cars. Based on the quality, recycled water can be harnessed for various potable and non-potable uses such as agricultural or landscape irrigation, toilet flushing, or domestic requirements. Linking the quality of a wastewater source to an appropriate subsequent use is known as the water quality cascade and allows all available water to be put to its most beneficial use even as the quality decreases each time it is reused (Chanan *et al*. 2003, Fane 2005, White and Turner 2003). Examples of matching a wastewater source with an appropriate end use are shown in *Figure 2*. Based on the typical water needs of commercial office building, implementing the principles of the water quality cascade can reduce the potable water demands by 50 per cent (Chanan *et al.* 2003), freeing up high quality water for more appropriate uses and reducing the energy costs associated with treatment.

Increasing perception of risk

Source	End Use
Scheme water OR Treated and disinfected rainwater	Drinking Kitchen Showers Basins
Treated and disinfected greywater	Cleaning Cooling tower make up Toilet flushing
Treated and disinfected cooling tower blowdown	Cleaning Toilet flushing
Treated and disinfected blackwater and blackwater blowdown	Roof garden irrigation

Increasing quality requirement

Figure 2: The water quality cascade matches the wastewater source with an appropriate end use
Source: Chanan (*et al*. 2003, p. 2)

Lastly, it is important to note that in addition to supplementing human needs for water, reusing wastewater can also produce positive results for the environment by reducing pollution from the inappropriate disposal of effluent, recharging groundwater, and repairing river flows within a catchment (Angelakis *et al*. 2003, Jiménez and Asano 2008).

2.3 Water recycling and reuse as decentralized systems

Water reuse concepts such as a closed-loop management system, fit-for-purpose application, and the water quality cascade all involve the local planning and management inherent in decentralized systems. From the compatibility of water reuse and decentralized systems emerges two more attributes of water reuse of note to this research: the availability of water 'near the point of use' and a visible system that can create a sense of community ownership and responsibility for water use.

A significant benefit of water reuse and recycling systems is the capacity to produce fit-for-purpose water in proximity to the task (Hermanowicz and Asano 1999, Lazarova *et al*. 2006). By minimizing the distant water must be transported, decentralized systems reduce the need for large, complex pipe infrastructure and avoid massive maintenance costs and environmental impacts (Fane and Mitchell 2006). While centralized water infrastructure consisting of large, complex pipe networks creates significant costs when these systems either reach the end-of-life or require extension (Fane and Mitchell 2006), localized water reuse systems avoid the extensive resource use associated with conveyance and can be easy to upgrade (Chanan *et al*. 2009).

Additionally, by producing water near the location of beneficial use, decentralized infrastructure can create a visible system with which the community can interact and build a relationship. As Mitchell and Campbell (2004) argue,

> 'the current well-intentioned form of "mediation" of people's interaction with resources via largely invisible infrastructure dis-empowers us, reducing both our understanding of the relationship between our actions and resource consumption; and our ability to reduce resource use should we choose to' (Mitchell and Campbell 2004, p. 5).

Water reuse and recycling practiced on a local level can increase the visibility of water in daily activities and create a sense of ownership that manifests as responsibility over resource use. As Chanan (*et al*. 2013) also notes, decentralized water systems can raise community awareness through increased opportunities at direct or indirect management of the resource.

A discussion of the transport, treatment and responsible use of water merits, note of the inherent interconnection between energy and water known as the energy-water nexus. The energy-water nexus recognizes the cause-effect relationship between water and energy, meaning that water is used to produce energy and energy is used to transport and treat water (Kenway *et al*. 2011). Minimizing the transport and treatment costs of water through the decentralized use of fit-for-purpose water can result in significant energy savings. More specifically, replacing potable water with appropriate, fit-for-purpose non-potable water can avoid massive energy costs associated with treatment and distribution. Likewise, the planning of recycled water schemes must consider the energy required to treat wastewater to the quality necessary for the specified end use. Knowledge of this balance increases the visibility of the connection between energy and water, and can increase efficiencies in both resources (Lofman *et al*. 2002).

2.4 Water reuse and public acceptance over time

Early successful examples of water reuse projects did not involve any significant attempt at public engagement or consultation (Marks 2006, Po *et al*. 2004). However, subsequent controversial projects have both instigated research into the acceptability of various aspects of water reuse and highlighted the importance of including the community in decision-making processes (Marks 2006, Po *et al*. 2004).

In one of the earliest studies on public perceptions of recycled water usage, Bruvold and Ward (1972) identified ‘psychological repugnance’ as the main reason for a stated opposition to purified water sourced from community or municipal wastewater. While the concept of disgust, labelled the ‘yuck’ factor in most literature, is still present in surveys completed today, Po (*et al*. 2004) have distinguished numerous additional factors that appear to influence the acceptability and overall successful usage of recycled water within a community:

- Disgust or ‘Yuck’ factor;
- Perceptions of risk associated with using recycled water;
- The specific uses of recycled water;
- The sources of water to be recycled;
- The issue of choice;
- Trust and knowledge;
- Attitudes toward the environment;
- Environmental justice issues;
- The cost of recycled water; and
- Socio-demographic factors

More recent studies demonstrate that while the issue of disgust is occasionally still present, communities often have other concerns such as the risks of recycled water (Hurlimann 2007), trust in the quality of treated water (Brown and Davies 2007, Wilson and Pfaff 2008), or no issues with recycled water apart from the cost of installation (Troy 2008).

Despite a shift in concerns, a consistent finding across studies from different decades and countries is that the acceptability of recycled water use decreases in direct relationship to the extent of personal contact with the water (Brown and Davies 2007, Bruvold and Ward 1972, Ilemobade *et al*. 2009, Po *et al*. 2004). For example, a survey of residents in the Ku-ring-gai local government area in Sydney, Australia found that 95 per cent approved of using treated recycled greywater for watering gardens, however only 31 per cent would use the water for washing clothes and 13 per cent would use it for showering (Brown and Davies 2007).

Consultation processes that investigate the needs and perceptions of the future users are a necessity when proposing alternative methods of water management. Analysis of water reuse projects in the United States and Australia demonstrates that each of the unsuccessful proposals suffered from inadequate community engagement and a lack of inclusive decision-making in early project planning (Marks 2006). For example, all eight projects investigated by Marks (2006) in which potable use was proposed and subsequently rejected, no alternative sources or end uses for reclaimed water were put to stakeholders for discussion. Instead of embracing opportunities for public involvement, the focus was placed on selling the planned project (Marks 2006). Consequently, the research summarized in this paper emphasizes the value of an approach that begins with an initial survey of perceptions to water reuse followed by future deliberative consultation with the community based on the opportunities and concerns revealed in the survey.

3. The South African Context

South Africa provides a unique context in which to investigate the public perceptions that create opportunities or barriers to the implementation of water reuse and recycling projects. The country is facing complex water management challenges stemming from a water-stressed geography, which will be exacerbated by climate change, and significant socioeconomic inequalities as a lasting result of the former apartheid government (Kahinda *et al*. 2010, van Koppen *et al*. 2011). Additionally, as part of the drastic governance reforms that came with the end of apartheid, South Africa has developed some of the most comprehensive and admired water policies in the world (Schreiner and Hassan 2011), which includes requirements for water reuse and public engagement (DWAF 2012). Lastly, however, though this legislation provides a solid foundation, it can be argued that on-the-ground implementation has been slow to catch up (Eales 2011). The combination of significant water management challenges, a basis in policy, and apparent impediments to implementation create an interesting layered framework within which is very appropriate to consider the role of water recycling and reuse.

3.1 The Water Situation

South Africa experiences low, variable rainfall and high rates of evaporation creating water-stressed conditions throughout the country (DWAF 2013, van Rooyen *et al*. 2011). While physical and hydrological characteristics dictate different water availabilities in different parts of the country (wetter in the east, drier in the west), water balance calculations completed by the Department of Water and Forestry (DWAF) for the first edition of the National Water Resource Strategy showed more than half of the catchments were in a deficit (DWAF 2004), implying the majority of catchments were already facing water scarcity. The city of Pretoria, the focus of the survey shown in *Figure 3*, was originally built around abundant dolomitic fountains (Haarhoff *et al*. 2012) but is also now transferring water from the distant Lesotho Highlands Water Project to meet demand (DWAF 2004). The city of Pretoria, also referred to as Tshwane, is shown relative to the rest of South Africa in *Figure 3*.

Figure 3: Pretoria, South Africa.
Source: CIA World Factbook.
Available from: https://www.cia.gov/library/publications/the–world-factbook/graphics/ref_maps/political/pdf/africa.pdf

Though the magnitude of the impact from a changing climate on water resources is uncertain, models agree that South Africa will experience an increase in average temperature as well as the distribution of rainfall (wetter in the east, much drier in the west) (Mukheibir 2008). These direct impacts also have the associated effects of increased rates of evapotranspiration, more variable runoff, and reduced recharge of groundwater and surface flows. The northeast of South Africa, in which Pretoria is located, is predicted to experience increased evapotranspiration rates, increased stress and more frequent floods as carbon dioxide (CO_2) levels increase (van Jaarsveld and Chown 2001). As Kahinda (*et al*. 2010, p. 742) note, climate change is a 'supplementary hazard' inflicted on a country whose water requirements are already quickly outpacing the available supply.

In addition to environmental constraints, the South African water situation is also heavily influenced by allocation inequities from the time of apartheid. Water resource provision has been historically focused on the white population to the extent that, at the time of the first democratic, multi-racial elections in 1994, the new government estimated that approximately 12,000 to 15,000 communities did not have 'adequate water or sanitation services' (RSA 1994). Upon the end of apartheid, the government embarked on a massive effort to extend basic service provision under the policy 'of access to sufficient water for all in South Africa' outlined in the Bill of Rights of the new Constitution (van Koppen *et al*. 2011). Government reports show these attempts have been relatively successful so far, with water supply backlogs dropping from 41 per cent to five percent from 1994 to 2012 (DWAF 2103), however issues with reliability and rural services still exist (Eales 2011). These efforts at historical redress show that the legacy of apartheid continues to influence water management.

As du Plessis (*et al*. 2003) point out, the traditional consumption patterns of higher income areas as well as the extension of basic services and quality of life improvements for historically marginalized areas are the two main drivers behind water scarcity concerns.

These points all suggest that the Director for the National Water Resource Strategy, Fred van Zyl, was justified in his recent warning that 'if something was not done to improve the management of water, South Africa could face serious water shortages as early as 2020' (Water Wheel 2013).

3.2 The case for reuse and recycling

The challenges of water security and equity, as well as additional issues not unique to South Africa regarding water quality, environmental concerns and financial constraints, create a massive management and allocation issue addressed through numerous recent governance reforms.

The potentially beneficial role of water reuse is highlighted specifically in the most recent draft of the National Water Resource Strategy, 2nd Edition (NWRS2) (DWAF 2012b). 'Water reuse' is defined as Technical Strategy #7 and the document goes on to describe actions such as targeted investments in the reuse of water and implementation of water re-use infrastructure in water scarce and urban areas (DWAF 2012b). Additionally, DWAF is in the process of developing guidelines for the planning, implementation, engagement, financing and other aspects of water reuse projects with the goal of optimizing the use of existing water resources (DWAF 2013). As the massive governance reforms after apartheid have placed a strong emphasis on local control and participatory decision-making (see RSA 1994), these guidelines are expected to contain a strong emphasis on the process of community engagement.

Importantly, the NWRS2 highlights negative public perceptions of water reuse due to the current 'poor operation, maintenance, and performance of municipal wastewater treatment plants' as a specific barrier to implementation (DWAF 2012b, p.162). Any effort at water recycling and reuse will have to take into account potential community distrust in municipal systems created by this history of poor performance.

4. Methods

A short online survey was generated to gain insight into the current attitudes towards water recycling amongst South African university students and government officials. While government officials currently hold the power to implement projects, university students represent the future generation of educated decision-makers, therefore the perceptions of both groups are considered valuable insight into the potential for water management in Pretoria. Additionally, university students are considered representative of the young, educated population, and, therefore, expected to be relatively receptive to proposals for alternative water management. It was estimated that the survey would take approximately 10 minutes to complete and individuals who completed the survey were invited to enter a draw for 800 Rand. Response data was imported into Microsoft Excel and analyzed through the program's statistical applications.

The survey was distributed in conjunction with two similar University of Melbourne research surveys to students from the University of Pretoria and the University of Cape Town. Students were targeted through announcements on the student web, student society listserves, and social media. While it is recognized that sending out three surveys at once may have reduced the overall response rate for each survey, this approach offered the benefit of each survey reaching the widest target group possible and offered the opportunity for each survey to receive equal attention. This survey received 71 responses from university students. The response rate is considered adequate to develop initial information regarding the common attitudes of university students in South Africa and infer potential opportunities or barriers for water reuse projects. However, a survey should be viewed as simply the precursor to a more thorough engagement process.

Responses to only this survey were independently sought from government employees through email and distribution from the listed employees on the Tshwane City Council website. Only two government employees completed the survey and only one responded to requests for further information. Due to the low response from this target group and the value provided by adopting a more thorough interview process, a survey of government officials was discontinued and several subsequent interviews were conducted with Philip van der Walt, Professional Engineer and Consulting Engineer for the City of Tshwane instead. The local professional insights of Philip van der Walt, PE are included in the results and discussion. The reported survey results reflect only the responses from university students.

The survey was broken down into sections, with focus on demographics, opinions on the water situation in Pretoria, familiarity with water recycling, acceptability of recycled water for different uses and changes to that acceptability as a result of various factors. Questions were developed using examples compiled during the literature review. Previous studies on water recycling in South Africa by Ilemobade (*et al*. 2009) and Wilson and Pfaff (2008) as well as the South African Water Quality Guidelines (1996) for domestic water use were specifically consulted to ensure the appropriate water uses in South Africa were considered in the survey. The specific technical definitions of water reuse and water recycling were intentionally not included in the beginning of the survey in order to capture preconceived notions among university students. However, it is noted that it would be valuable in future studies to see if the results of the survey are affected when more context or background is provided.

Brief surveys comprised of simple questions to provide useful information regarding community perceptions of water recycling (Lachmilane and Babcock 2013), however, it is important to add that this research is not a substitute for thorough community engagement. While the survey provides a valuable exploratory snapshot into the current social opportunities and barriers to water recycling, it is noted that in future project development this consultation process must be iterative and involve multiple opportunities for the community to discuss, question and form opinions regarding the proposed system (Russell and Lux 2009).

5. Results

Given South Africa's water scarce geography and need to continue the extension of services, it is not surprising that survey respondents showed concern regarding the future water supply for Pretoria. As shown in *Figure 4*, 79 per cent of university students showed concern about the potential for water scarcity in Pretoria. Perhaps even more importantly, 68 per cent of these students urged the prioritization of actions to address water security.

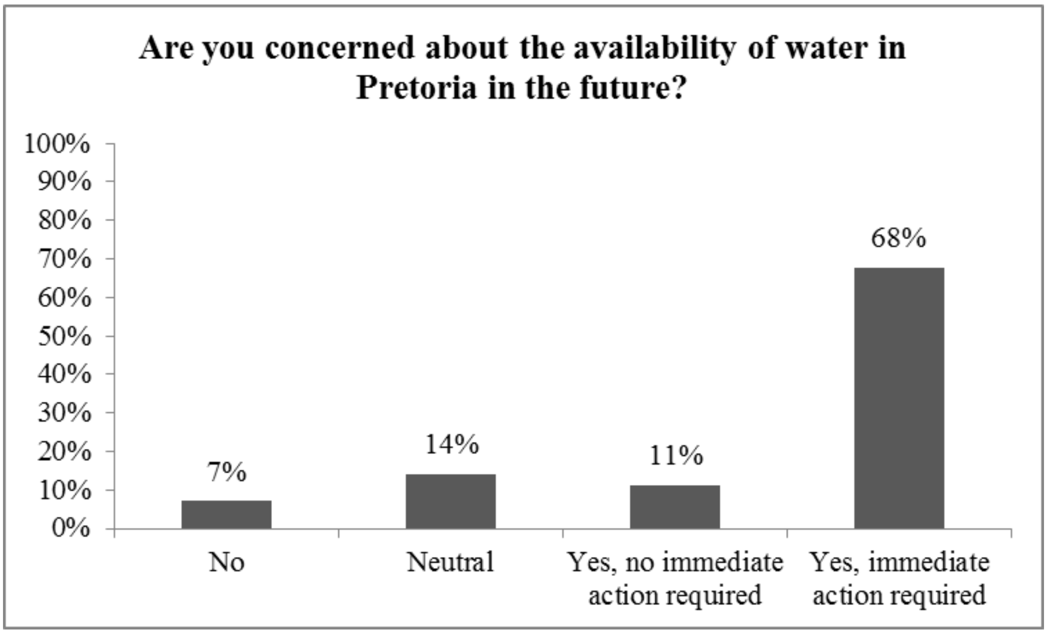


Figure 4: Importance of actions to ensure future water security in Pretoria

Similar to other surveys in the literature (Brown and Davies 2007, Bruvold and Ward 1972, Hurlimann 2007, Ilemobade *et al*. 2009, Po *et al*. 2004), this survey found that the acceptability of different uses for recycled water is strongly related to the proximity of human contact. The use of recycled water for tasks such as toilet flushing or watering gardens was acceptable to approximately 97 per cent of respondents; however, as shown in *Figure 5*, this acceptability drops significantly as the use became more personal.

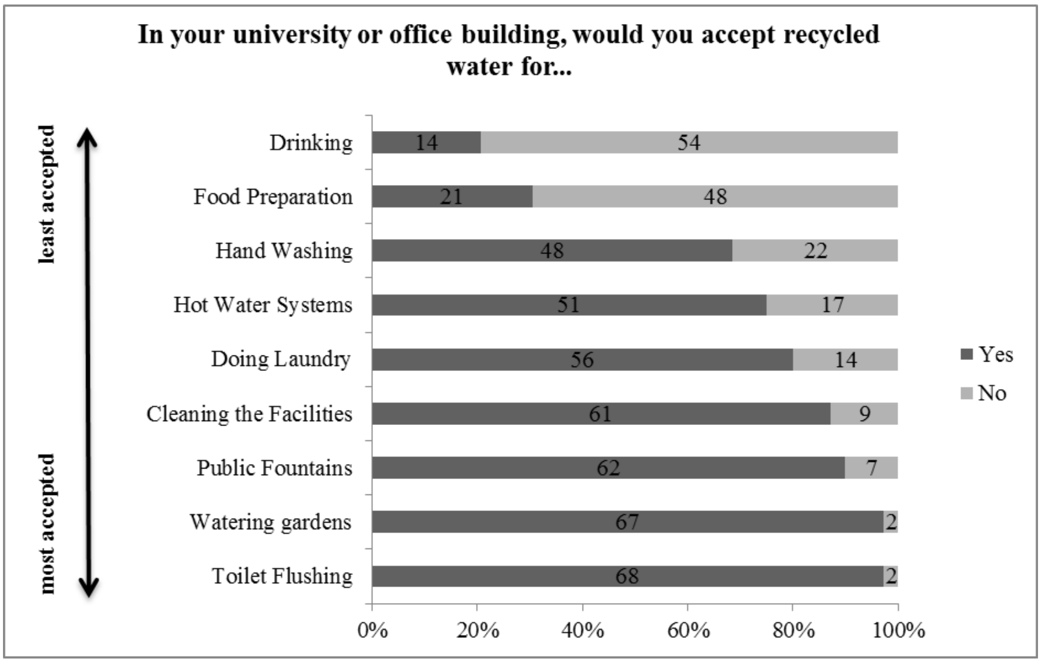
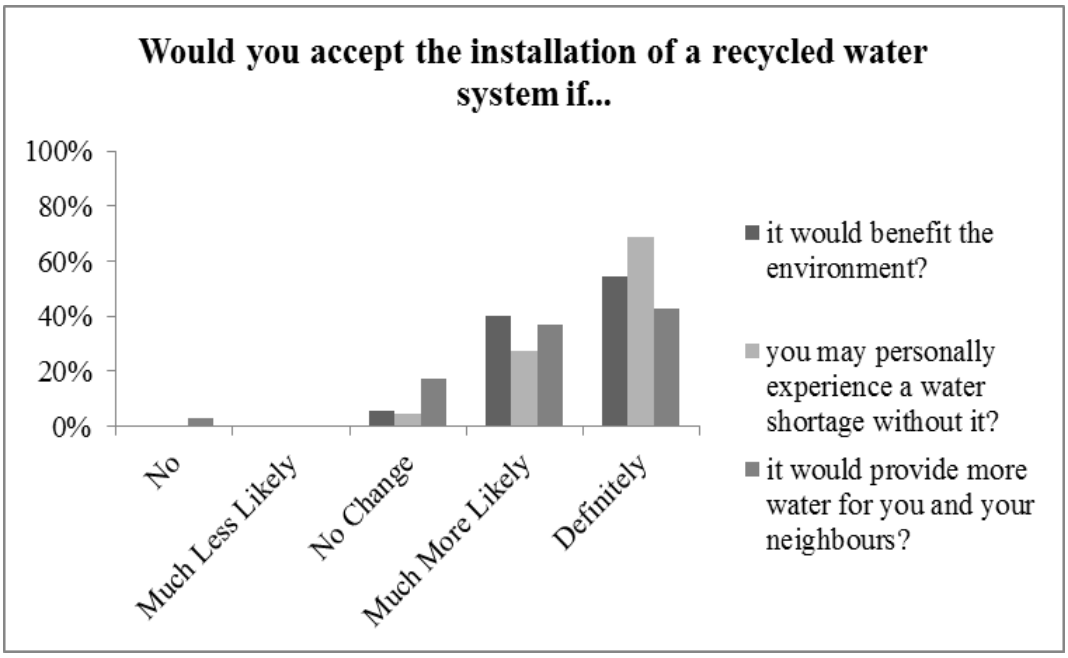


Figure 5: Acceptability of recycled water for various tasks

Additional survey questions focused on the effect of different installation or operating conditions on an individual's acceptance of a recycled water system. Specific significant trends, shown in *Figure 6*, related to knowledge of environmental benefits, personal water scarcity, and system installation charges.



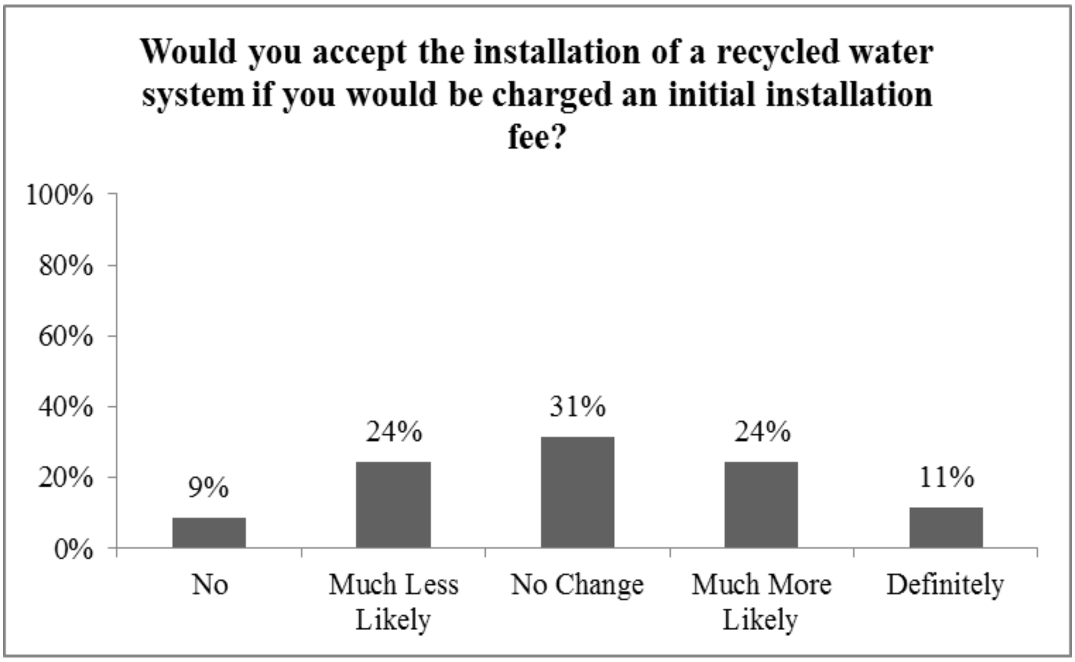


Figure 6: Changes in willingness to accept recycled water systems given certain knowledge

Similar studies regarding attitudes toward water reuse in South Africa support the strong environmental values found in this survey amongst both consumers (Ilemobade *et al*. 2009, Wilson and Pfaff 2008) and decision-makers (Ilemobade *et al*. 2009). As Wilson and Pfaff (2008) note, users tend to approve of the use of recycled water given the knowledge that the system will benefit the environment. This provides an opportunity to emphasize sustainability during community engagement and project planning. Additionally, the Ilemobade (*et al*. 2009, p. 222) survey of domestic water users in Emahlaleni, South Africa found that 94 per cent of respondents would 'consider water reuse … if a period of water shortage were to be experienced', supporting the finding that personal water scarcity increases acceptance of water recycling and reuse. A later interview with Philip van der Walt, P.E., Consulting Engineer, elicited a similar opinion: 'the best incentive for accepting recycled water is a decent drought' (Philip van der Walt, P.E., 2013, pers. comm., 15 May). Interestingly, the threat of water scarcity was found to be a more powerful motivator for the implementation of recycled water than simply the knowledge that the system would augment the current water supply. As shown in the top of *Figure 6*, 80 per cent of students surveyed responded 'much more likely' or 'definitely' to accepting the use of recycled water given the knowledge that the system would provide additional water for the community. In contrast, this acceptance jumped to 96 per cent with only four per cent responding 'no change' given the threat of personal water scarcity in the future.

The only variable considered in the survey that was detrimental to the perception of recycled water was the prospect of an installation fee for the system. As shown in *Figure 6*, if a cost were applied to the system, 33 percent of respondents would either be much less likely or would definitely not accept the use of recycled water. However, even with an installation fee, 35 per cent of those surveyed would be either very likely or completely willing to accept a recycled water system. In contrast, Ilemobade (*et al*. 2009) found a much more dramatic decrease in willingness to use recycled water when an additional cost is involved. The acceptability of recycled water among users dropped from 71 per cent to 15 per cent given the knowledge that recycled water would be more expensive than the current supply (Ilemobade *et al*. 2009).

As shown in *Figure 7*, the majority of respondents expressed concern regarding the expense and health risks of recycled water. Given that the literature does not show uniform reasons for opposing water reuse across different populations, the issues revealed in this survey may be unique to South African university students. For example, while Friedler (*et al*. 2006) found that a majority of users were anxious about the perceived health risks of recycled water, only four per cent of respondents in Troy (2008) highlighted health effects as a reason for discouraging water recycling. The issue of trust causes similarly varied responses. Trust in the service provider's capacity to deliver water of an appropriate quality had no effect on support for recycled water in Friedler (*et al*. 2006), but was found to be considered a significant obstacle by Illemobade (*et al*. 2009) as well and Wilson and Pfaff (2008). The extent of concern regarding cost, health risks and trust shown in *Figure 7* means that any implementation project will have to address each issue, however the most prominent concerns may vary based on the context of the project. Though 44 per cent of university students cited trust in the treatment process as a reason for opposing the use of recycled water, a later interview with Philip van der Walt P.E., Consulting Engineer, highlighted the point that, unlike many countries in the world, 'in South Africa everybody drinks water from a tap' thereby 'expressing confidence in the treatment processes' (Philip van der Walt, P.E., 2013, pers. comm., 15 May).

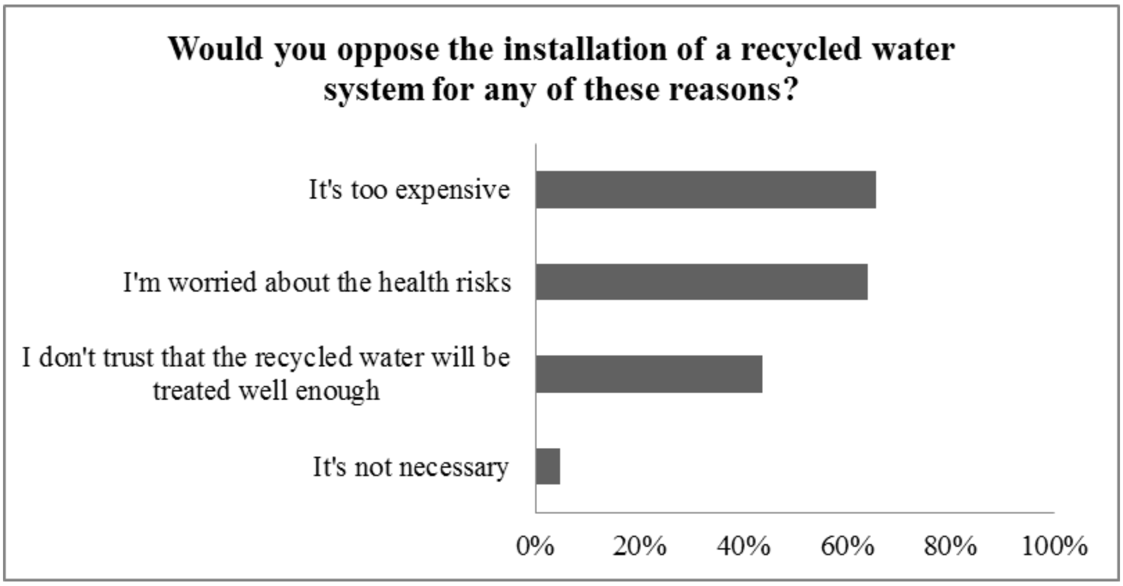


Figure 7: Reasons for opposing the installation of a recycled water system; multiple answers allowed

An analysis of the correlation between familiarity with recycled water and reasons for opposing the installation, shown in *Figure 8*, reveals similar concerns regarding recycled water across the spectrum of knowledge. This result suggests that future engagement will have to address all concerns equally regardless of the audience. It is noted, however, that few of the respondents claimed to be familiar with recycled water so this finding may change with a larger sample size. The number of respondents in each category of familiarity is shown in brackets in *Figure 8*. Due to the much higher response rates from individuals with a low level of familiarity with water recycling, the confidence in the concerns of this population is much higher.

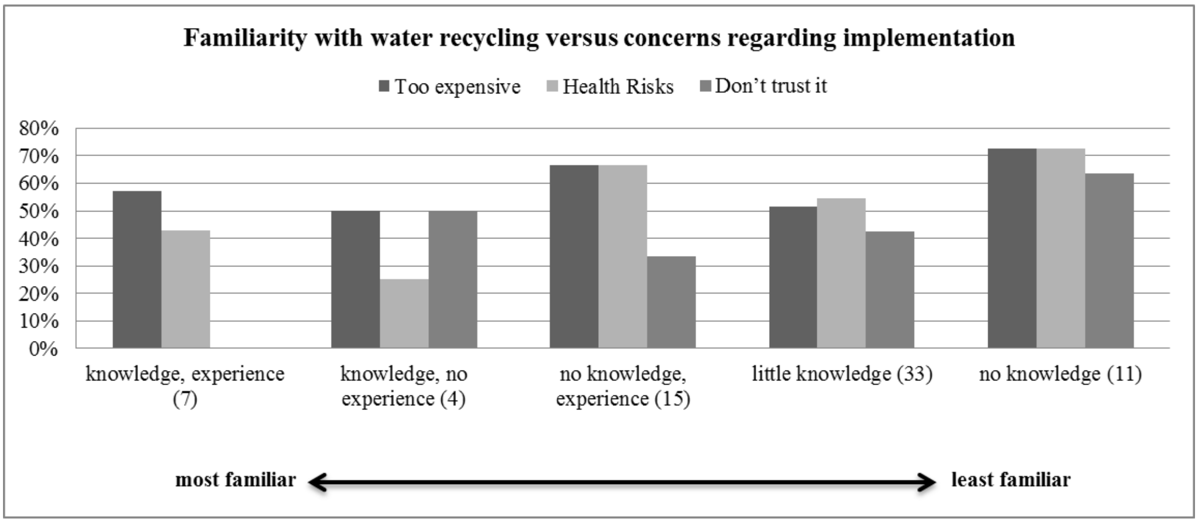


Figure 8: Relationship between familiarity and concerns regarding recycled water systems

The results shown in *Figure 8* suggest a similar 'overall unfamiliarity with the topic' of water recycling and reuse found in the Wilson and Pfaff (2008, p. 6) study in Durban, South Africa. The individuals surveyed by Wilson and Pfaff (2008, p. 6) had yet to 'formulate comprehensive opinions or developed entrenched positions', which was subsequently found to be a significant characteristic of the population when entering into the process of public engagement. As shown in the columns of *Figure 8*, 84 per cent of respondents in this study claim little or no knowledge regarding recycled water systems.

Despite the low levels of familiarity shown in this survey, further discussions with a Consulting Engineer for the City of Tshwane, Philip van der Walt, highlighted the fact that indirect reuse is very common in South Africa and many Pretorians are likely already consuming water that has already been reused in some form. Planned indirect reuse is the process of discharging treated water into a river system for extraction downstream (Chanan *et al*. 2013, Philip van der Walt, P.E., 2013, pers. comm., 15 May) which is inherently more distant from human awareness and contact than a direct reuse system. The current practice of indirectly reusing treated sewage effluent has been in use for decades and is viewed as a necessary strategy to continue and expand water services in Tshwane (Philip van der Walt, P.E., 2013, pers. comm., 5 April).

This lack of familiarity and desire for more information surrounding water recycling and reuse appeared again frequently in the final comment section of the survey. Numerous respondents expressed opinions such as ‘being informed about recycled water would be really beneficial for everyone’, ‘more information about recycled water must be published’, and ‘I wish the concept and installation of recycled water would be greater publicized’. There were no comments, however, as to how and where this information would be best distributed. Public support for the dissemination of knowledge regarding water recycling is prevalent in the findings from other surveys in the literature. For example, though respondents in Lamichhane and Babcock (2013) were supportive and even willing to pay for urine-diverting toilets, users still cited ‘not much information’ as the most common reason for discouraging the installation of such a system. All comments in this survey were supportive of water recycling and reuse.

6. Discussion

The high willingness among university students to accept recycled water systems for non-potable tasks reveals an opportunity to substitute water sources with community endorsement. University students appear to be very supportive of using recycled water for non-potable purposes which, as discussed previously, would reduce costs and energy use through only treating water to a level appropriate for the subsequent use. The opportunity for source substitution is particularly significant with regards to water use for toilet flushing given that the survey showed 97 per cent of university students would approve of using recycled water for this purpose. Approximately 63 per cent of the water used in public environments or offices is for flushing toilets (Shouler *et al*. 1998 cited in Lazarova *et al*. 2003), so replacing the current potable water stream with reused water would significantly reduce the demand for potable water on the university campus.

In addition to the immediate benefit of reducing potable water requirements, source substitution for acceptable tasks such as toilet flushing or watering gardens provides an opportunity to build familiarity with the process of water reuse. The eager endorsement of non-potable water reuse in a community creates a ‘window of opportunity’ to build knowledge, awareness and trust around water reuse systems (Marks 2006). Marks (2006) emphasizes that building the degree of understanding around water reuse is valuable for proceeding from non-potable into potable reuse projects. However, in South Africa the experience of each project could also simply be used to spread familiarity with non-potable water reuse into other communities that may not initially accept of any form of water reuse. Statements in the NWRS2 demonstrated concern regarding the public acceptance of water reuse given public awareness of the recent poor performance of municipal systems. Water reuse projects in supportive communities can provide the opportunity DWAF is looking for, to 'show results on a consistent basis' (NWRS2, p. 162) and build the trust required to implement water reuse in areas where current public perceptions are a barrier.

A major benefit of implementing non-potable water reuse projects in accepting communities lies in this idea of each project as a stepping stone into either new communities or different forms of reuse. However, it is also important to note that experience with water reuse projects often catalyzes creative thinking and new, innovative processes can emerge (Hermanowicz and Asano 1999). Implementing water reuse on university campuses can stimulate not only awareness of the current practices, but learning around more appropriate or efficient solutions as well. South Africa has already shown through recent legislation such as the National Water Act that the country is willing to demonstrate leadership and innovation in the water sector. It is possible that alternative water reuse operations or management systems emerge as the implementation and management experience in South Africa grows.

Though respondents were, in general, very supportive of water recycling and reuse, uniform concern existed around the issues of trust, health risks, and cost. Any future water reuse project will have to clearly address these concerns.

A lack of trust in the level of service delivery appears in surveys of communities throughout South Africa. Studies on water reuse in South Africa have found similar doubt expressed among users regarding the capacity of each municipality to deliver water of an appropriate quality. Wilson and Pfaff (2008, p. 5) specifically refer to the 'erosion of trust' that has occurred among residents in Durban due to recent power outages and inadequately maintained infrastructure. Concern regarding the sufficient treatment of water suggests the need for a transparent, credible and easily understood system for water reuse. For example, Ilemobade (*et al.* 2009) found that residents in Emahlaleni were significantly more accepting of a non-potable water system in which the pipes were simply colour-coded and clearly labelled. Efforts to ensure that a water reuse system and the associated management process communicate clear, credible information may contribute to building trust in the level of water treatment.

Existing examples of building trust in the service delivery process are the South African Blue Drop and Green Drop programmes for drinking water and wastewater quality management. Currently in their fifth year, the Department of Water Affairs and Forestry (DWAF) programmes were 'prompted by the desire to be transparent and ensure that credible information is communicated' regarding tap water and wastewater quality management (DWAF 2012a, foreword). In addition to assessing compliance with water quality standards, the Blue Drop and Green Drop report cards also evaluate aspects of water and wastewater service provision in the areas of water safety planning, DWQ process management and control, management, accountability and local regulation, and asset management (DWAF 2012a). Significant improvements in the management and quality of drinking water and wastewater have resulted from this incentive—and risk-based regulation (DWAF 2011, DWAF 2012a) recognized internationally in 2011 with the Environmental Engineering Excellence Award from the American Academy for Environmental Engineering (DWAF 2012a). The success of the Blue Drop and Green Drop programmes demonstrates that a municipality can build trust through auditing and incentivizing service providers and communicating clear information to users. Notably, the recent NWRS2 mentions the consideration of a 'purple drop' system to recognize 'safe and successful water reuse projects and operations' (DWAF 2012b, p. 153). Adapting proven regulations to water reuse systems could provide a valuable means of building trust in the level of treatment among both community members and decision-makers.

Building both familiarity with non-potable reuse and trust in the capacity of service providers to deliver appropriate quality can reduce the perceptions of health risk associated with recycled water (Marks 2006). Additionally, a risk management process could assist with distinguishing between the real and perceived contaminants in wastewater (Toze 2006). The source of the effluent, the potential for faecal contamination, and the proximity of the task to humans or animals are necessary considerations for completing a risk assessment and determining the necessary level of treatment (Toze 2006). Any risk assessment of water reuse must also consider that the probability and magnitude of risks are inherently different for centralized and decentralized systems (Fane and Mitchell 2006). While experience with decentralized water reuse is lower than traditional centralized processes, and therefore the probability of failure may be higher, the magnitude of risk is significantly smaller (Fane and Mitchell 2006). Additionally, it is foreseeable that the probability of decentralized system failure can be reduced through proper monitoring and management, however, the large magnitude of a centralized system failure is a stubborn characteristic of the system (Fane and Mitchell 2006). A transparent risk management process that considers the characteristics of the decentralized system could contribute to addressing perceptions of health risks from recycled water.

In addition to public perceptions regarding the quality of water and service delivery, it is clear that financial constraints are a significant consideration when planning water reuse projects. The city of Pretoria is currently under significant pressure to balance the extension of services with the maintenance of existing infrastructure and has previously stated that the budget is simply not large enough to do both (City of Tshwane 2012). The introduction of water recycling and reuse offers the opportunity to harness potential cost savings associated with both water reuse and decentralized systems.

The literature review has discussed the potential cost and energy savings associating with utilizing fit-for-purpose water. On a larger scale, decentralized systems also allow for the relationships between infrastructures to be reimagined in order to capitalize on synergies. The majority of respondents in this survey were concerned about the expense associated with water recycling. As Fane and Mitchell (2006, p. 2) agree, 'there is a danger that sustainability will be seen as something of a luxury' should water infrastructure continue to operate independently and ignore the opportunity to accumulate savings. However, water recycling and reuse that is integrated with the surrounding infrastructure can enable implementation of the water quality cascade, closed-loop systems, and other processes that use the relationships between activities to save treatment costs, energy, transport, time, etc. For example, Mitchell and White (2003) describe greenfield development in Melbourne, Australia that has harnessed 'water cycle thinking' to create a 70 per cent reduction in demand from the centralized water system.

Lastly, a system for water recycling and reuse that operates in a decentralized fashion must consider financial characteristics that are fundamentality different from traditional, centralized projects. As Fane and Mitchell (2006, p. 1) summaries, decentralized systems offer the opportunity for:

- Location specific solutions
- Targeting costly operations and augmentations to existing systems
- A variety of business models
- Qualitatively different technical, health and environmental risk profiles
- Meeting demand incrementally as it occurs
- Avoiding the large financial risks inherent in big projects

Planning for the expansion or maintenance of water systems must consider these characteristics when analyzing infrastructure options. The full value of considering these characteristics will be achieved through adopting a long-term view for management. For example, least cost planning is one potential technique for analyzing infrastructure alternatives that focuses on the service provided by water rather than a specific amount that must be delivered (Mitchell and Campbell 2004). Least cost planning allows for a balanced consideration alternatives but requires a vision of a desirable future rather than just short-term goals.

Conclusion

Through a review of water reuse, an investigation of the South African water context, and a survey of university students, this research has demonstrated that university campuses offer a potentially valuable opportunity to demonstrate the implementation of water recycling and reuse among a supportive audience. Water resource challenges are continuing to grow around the world due to pressures posed by increasing urbanization, population growth and climate change. However, the urgent need to address water management should be viewed as an opportunity to rethink the traditional, 'once-through' centralized system. South Africa has already shown global leadership in the water sector through the past decade of legislation and now has the opportunity to translate these policies into practice. While this research shows that university campuses are favourable locations to begin public engagement with water reuse, the most significant value likely lies in the vision of university campuses as stepping stones into the wider community. Each future project offers immense benefit through building familiarity and engagement with water reuse which could subsequently be extended and locally tailored to communities throughout South Africa.

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