

## Research Paper

# Investigation into untreated greywater reuse practices by suburban households under the threat of intermittent water supply

N. Nel and H. E. Jacobs 

## ABSTRACT

Untreated greywater reuse at the household level is an accessible water source to supplement non-potable water requirements in times of emergency water curtailments but poses various risks to the consumer, the wider community, infrastructure and the environment. Little information is known about unregulated, untreated greywater reuse practices under emergency conditions in suburban communities where consumers have become accustomed to reliable potable water supplied via a pressurised, piped distribution system. There is a lack of knowledge regarding the sources of greywater used, collection methods, storage and distribution of greywater, the application points, the level of treatment (if any) and the perceived risks associated with the greywater reuse. The City of Cape Town was selected as a case study site for research into greywater reuse under the threat of 'Day Zero' and stringent water restrictions, implemented during the 2017/2018 summer season. A consumer survey and analysis of relevant online forums was conducted in order to obtain the necessary information. Greywater reuse practices from a sample group of 351 consumers were identified and classified. Untreated greywater reuse was found to be common, mainly for garden irrigation and toilet flushing. The results point to high-risk activities in the study group.

**Key words** | greywater, risk, water restrictions

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## INTRODUCTION

### Background

Various on-site supplementary household water sources are available to residential consumers (Nel *et al.* 2017). In serviced areas with a reliable supply of potable water via the water distribution system (WDS), such sources may never be required – and thus may never need to be installed. A more proactive, sustainable outlook or desire to preserve water as a precious resource may, however, trigger the use of supplementary water sources. Further prompts to use supplementary sources may be out of necessity due to ongoing intermittent water supply or in an emergency situation such

as a drought. Recent stringent water restrictions and news of possible water supply system failure in various municipalities in South Africa have led to increased uptake of supplementary household water sources, even in relatively affluent and well-serviced suburbs. Alternative water sources, such as rainwater (Mukheibir *et al.* 2014), groundwater (Wright & Jacobs 2016) and greywater (Carden *et al.* 2018), are commonly used in some South African cities and towns, although the penetration ratio has not yet been researched. Greywater is the least expensive and most accessible supplementary water source but poses various risks, especially when used without treatment.

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Untreated greywater use at the household level is the focus of this study.

## Rationale

Nel *et al.* (2017) noted that the interaction between non-potable consumer supply, such as greywater reuse, and potable municipal supply is poorly understood. There is a critical gap when it comes to an understanding of the practices regarding the relatively high-risk use of untreated greywater in serviced urban areas by residential consumers. This is an investigation into untreated greywater reuse in serviced suburban areas of the Cape Town Metropolitan area under the threat of 'Day Zero'. It sheds light on the opportunities and challenges presented by household greywater as a consumer-driven solution to potential water supply system failure.

## Case study site

The metropolitan area of Cape Town is located in the South Western region of South Africa, with a population of 3.7 million people (StatsSA 2011). The city is characterised by a warm Mediterranean climate with winter rainfall and hot, dry summers. Household water consumption typically peaks in the summer months creating a demand–supply imbalance which is compounded by a heavy reliance on surface water – making up 98% of all available water sources. With dropping dam levels and relatively low rainfall, water demand was poised to outstrip supply early in 2018, but 'Day Zero' was ultimately avoided and water restrictions were eased in October 2018.

## CONTEXT

The focus of this study is on suburban households, where consumers are accustomed to continuous pressurised drinking water supply, with water quality in line with acceptable potable standards. Prior to the 2017/2018 drought in the study area, suburban residential consumers would generally have had no pressing need to reuse greywater, but had to consider alternative options, including untreated greywater use, when faced with the urgent and sudden dilemma of having water supply to the entire city potentially fail.

Carden *et al.* (2018) conducted a thorough legal review of greywater reuse in South Africa and greywater reuse guidelines for households were published (City of Cape Town 2017b) during the drought. These greywater guidelines, however, encourage greywater reuse in the interest of water saving with less emphasis on the associated risks. They are sometimes in contradiction with information in peer-reviewed journals and legislation such as the National Building Regulations and Building Standards Act (Act No. 103 of 1977), which requires that wastewater be disposed of in the sewer.

## Cape Town water restrictions 2016–2018

In a desperate effort to avert a major crisis with Cape Town's deepening drought, various supply augmentation and demand reduction strategies were employed; and as the drought intensified, additional behaviour changing strategies were introduced which included stringent water restrictions and increased tariffs.

Figure 1(a) and 1(b) present an overview of the water restriction levels in Cape Town and the related timelines, respectively. In June 2017, all outdoor water use in the City of Cape Town metropolitan area was banned (City of Cape Town 2017a), and the tariffs became relatively expensive with additional fines imposed on consumers for exceeding certain levels of monthly water consumption. Level 6b water restrictions were implemented in February 2018, with exorbitant tariffs and severe fines imposed on households exceeding 10 kL/month.

Despite these emergency water restrictions, Cape Town was at risk of running out of water. In January 2018, the projected date for 'Day Zero' was announced daily in the media, and it was defined as a day when all surface water resources combined would reach a level of 13.5% of full supply level. It was envisaged that, on 'Day Zero', the water supply to consumers would be closed off, with only 200 distribution points available for the physical collection of 25 L per person per day. A result of this shock tactic – and other emergency demand management measures – was that total consumption by the City of Cape Town dropped notably from 1,200 ML/day in February 2015 to 515 ML/day in March 2018 (Gosling 2018). The implementation of alternative water sources by consumers in the

(a)

Water Restriction Level	Pools and Water Features				Tariffs and Fines							General Outdoor Use					
	Pool cover mandatory	No portable pools	No water features	No topping up pool	Increased tariff <sup>B</sup>	Notable tariff increase <sup>C</sup>	Fines for exceeding consumption limit	Fines for outdoor use	Increased fines	WDM Device (high water usage homes)	Per capita use limited	Limited garden watering <sup>D</sup>	No hosing hard surfaces	No hoses or sprayers	Washing vehicles only with buckets	No washing of vehicles	No watering or irrigation
1-2 <sup>A</sup>	●				●							●	●				
3-3b	●				●							●	●	●	●		
4-6b	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●

## Notes

- A) Conservation measures are considered integral to modern urban life under an unrestricted scenario.  
 B) Consumption-based block tariffs increase relative to the previous step, but within "normal margins".  
 C) Notably increased water bill (at least by double, thus >200% increase), unless consumption is reduced.  
 D) Garden watering limited by day of week or time of day, but not completely banned.

(b)

DETAILS	CITY OF CAPE TOWN WATER RESTRICTIONS											
	2016											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Level	2						3					
Date	1-Jan						1-Nov					
	2017											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Level	3					4	4B	5	5B			
Date	1-Nov					1-Jun	1-Jul	3-Sep	1-Oct			
	2018											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Level	6	6B							5		3	
Date	1-Jan	1-Feb							1-Oct		1-Dec	

Figure 1 | (a) and (b) City of Cape Town water restrictions levels and timelines (2016–2018).

study area would have contributed to the notable demand reduction.

While the reduction in the potable demand is indeed a beneficial result of the 'Day Zero' threat, little is understood of the extent and repercussions of the uptake of these alternative water sources (including greywater).

### Greywater reuse

For the purpose of this study, the term greywater is defined as all household wastewater, except toilet waste (adapted from Ludwig 1997). Greywater is inherently variable in quality, and the negative impacts on health (Christova Boal *et al.*

1996), the environment (Al-Hamaiedeh & Bino 2010) and water services (Penn *et al.* 2012) are well documented. This further highlights the need to better understand untreated greywater reuse practices during water shortages.

## RESEARCH FOCUS AND OBJECTIVES

Past greywater studies in South Africa have focused on dense informal settlements (e.g. Carden *et al.* 2007) where greywater use is common due to the relatively large distances that consumers have to physically convey water from a standpipe. The informal use of greywater in unserved areas was considered beyond the scope of this study. The focus is instead on greywater use by middle- to high-income households in fully serviced homes, during temporary yet severe water shortages.

The following were the project objectives:

- Identify a study group of greywater users.
- Design a suitable consumer questionnaire for distribution to individual consumers in the study group.
- Assess the greywater reuse practices and identify sources and end uses.
- Classify methods of collection, storage and distribution of greywater.
- Identify perceptions in terms of general risks associated with untreated greywater reuse at individual homes.

## DATA COLLECTION

### Overview

Data collection for the consumer survey occurred between 1 October 2017 and 30 August 2018, while additional analysis of online forums and social media platforms was undertaken between November 2016 and April 2017 to further determine greywater practices under the threat of 'Day Zero'. The *Water Shedding Western Cape* Facebook Group provided a particularly rich source of water-saving initiatives and greywater reuse data. The group was started in January 2016 with the onset of stringent water restrictions in the Western Cape in order to share water-saving ideas online.

At the time of this study, the group had 47,578 members from the greater Cape Town region.

### Consumer survey

An online survey was used due to the relatively low cost per survey and the speed with which to retrieve results, and *Survey Monkey* was utilised as user-friendly survey software. A link to the survey was posted with permission on institutional Facebook Pages, and further channels were utilised for the distribution of the survey. The questions were devised in line with the research objectives and the development tools as listed by Glasow (2005) so as to avoid many of the biases and disadvantages inherent in written surveys and to ensure ease of analysis. The survey included 20 questions, mostly in multiple choice format.

As the purpose of the study was to gain a general sense of greywater reuse, small sample size was deemed sufficient to gain a reasonable degree of precision (Glasow 2005). The distribution of the survey was, however, sufficient to allow for non-responses and incomplete responses (Glasow 2005).

### Ethical considerations

Ethics considerations relating to confidentiality, protection of information and the informed consent process were addressed during the course of this study, and an application for ethics approval and institutional permission was accepted by Stellenbosch University in September 2017 before the distribution of the survey.

### Online greywater forum review

A further review of the online forum *Water Shedding Western Cape* was conducted to gain greater insight into the extent of greywater use. A search was conducted using keywords such as: 'greywater', 'grey water', 'graywater', 'reuse', 'recycling' and 'wastewater' in order to hone in on relevant posts. The text strings were extracted, analysed and logically organised.

## SURVEY RESULTS

### Summary of study groups and responses

The results of the survey are presented below. Respondents in the online consumer survey are referred to as Group A with forum members from *Water Shedding Western Cape* referred to as Group B.

The investigative online survey for Group A was completed by 175 respondents. Data were organised using Microsoft Excel, and all responses were valid and were included in the subsequent analysis. In addition, the Group B sample included another 176 forum members' posts with a total of 206 greywater-related forum posts. Ultimately, 7 different greywater generation points were identified, 12 different end uses and 3 different methods for collecting and distributing the greywater.

All respondents in Group A were located in the greater Cape Town area and were over the age of 25. Of the group, 78% resided in a suburban house serviced with potable water through a WDS. While it was not possible to determine the type of residence in which Group B members resided, it was inferred by the content of the posts including details of their appliances and plumbing systems that the majority lived in serviced homes.

### Extent of greywater reuse and barriers to entry

The extent of greywater use in the survey sample should not be extrapolated to the larger population, because the online nature of the survey targeted respondents that have access to

the internet and could create a bias towards greywater users with interest in the field.

Approximately 161 of the 175 of respondents in Group A used greywater in addition to potable water (and sometimes in addition to other alternative sources such as rainwater and groundwater) at the time of the survey.

### Sources and end uses

Word clouds compiled based on words extracted from the Group A survey responses are portrayed in [Figure 2](#) and specifically relate to sources and end uses of greywater. The main subject of these survey responses (excluding pronouns, conjunctions, adjectives, etc.) was used for the generation of the word clouds. Repeated answers were excluded, and no weighting was given. The investigation indicates that the shower was the most common source of greywater, with 87% of group A respondents utilising it at the time of the survey. The bath was utilised by 51%, while 49% utilised the washing machine, and 45% utilised the kitchen sink. Bathroom hand basins, laundry troughs and the dishwasher were utilised by a minority. The most common greywater sources in Group B included the shower (27%), washing machine (29%) and bath (20%). Less commonly used greywater sources included water from freezer defrosting, water from food preparation, geyser overflow, duck pond water replacement, and hot tub and pool backwash water.

In Group A, these greywater sources were mostly used for flushing toilets (74%) and irrigating the garden (57%). Other end uses included washing of driveways and



**Figure 2** | Cape Town Case Study: greywater sources and end uses word clouds.

paved surfaces, and washing of vehicles (11.5%) and bicycles (<6%).

Of Group A respondents who reused greywater for garden irrigation, the majority irrigated container plants or small sections of the garden (59%); with some watering their lawns (34%), root vegetables (4%), leafy vegetables (7%), and fruit and nut trees (11%). The results from Group B mostly included greywater reuse for garden irrigation including vegetable garden (67%) and toilet flushing (16%), and a smaller number indicated its reuse for pool filling (6%).

### Methods of collection, storage and distribution

In Group A, 81% of the respondents distributed the greywater by carrying it in buckets to various end uses, with a further 18% indicating that piping was used for greywater distribution. The remainder utilised a dual plumbing system or a commercial product. Of the Group A respondents reusing greywater for toilet flushing, 79% were transferred directly into the cistern or toilet bowl via buckets. Analysis of the Group B forum posts indicated a fairly even distribution between makeshift, non-commercial piped systems (pumped or gravity fed) installed by the homeowner and bucketing, with a relatively minor number of group members utilising commercial greywater systems with varying levels of treatment.

Of Group A respondents, 76% reported that greywater was used without storage or was stored for less than 24 h. Storage vessels, noted in the various responses, included buckets, plastic bottles, wheelie bins etc. Of the respondents who reused greywater, 75% did not treat the greywater at all. Only 26 of the 175 respondents from Group A reported any form of treatment or disinfection, generally in the form of basic filtration and by adding bleach or other products. No respondents indicated that they used biological, chemical or other commercial systems. The use of 'environmentally friendly' or natural hygiene products at source was also prevalent in both Groups A and B.

### Risks

A concern was identified during this study with regard to the risk of greywater use and related consumer perception of the risk. Of Group A, 71% of respondents did not perceive there

to be any risk to personal health, and 57% indicated that there is no environmental risk when reusing untreated greywater.

## DISCUSSION

This study probed the greywater use practices of consumers during serious water restrictions. The results paint a slim picture of actual practices standing in contrast with knowledge from published research, especially in terms of health risks inherent in untreated greywater reuse. Table 1 provides a comparison between significant Group A and B survey results and published literature:

The survey results indicate a lack of awareness of the risks of raw greywater reuse with some practices, in contradiction to the literature. Under emergency conditions, consumers are faced with a trade-off between the risks associated with reusing greywater and those associated with not using greywater (e.g. dying garden and no potable supply). Greywater reuse guideline documents highlighting the risks associated with untreated greywater use, published in the wake of 'Day Zero' (e.g. City of Cape Town 2017b), were ineffective in communicating the potential risks to consumers in the study sample.

## CONCLUSIONS

Under the threat of 'Day Zero' and severe water restrictions, this small-scale survey in Cape Town, South Africa has given valuable insights into direct, raw greywater reuse practices.

The study highlights a lack of awareness of the significant risk to public health and the environment. It serves as a lesson to the global community facing water challenges of the complexities of conserving the potable supply, the unintended consequences and that risk laden initiatives in the interest of water-saving may prevail. The study provides insights into how individuals may respond to emergency water restrictions when given responsibility for global issues. It is a lesson in drought planning and public engagement in an increasing water stressed world.

This study has also shed light on the need for several areas of further research regarding greywater to better

**Table 1** | Survey results versus literature

Survey response	Literature
<b>Sources and end uses</b>	
The shower was the most common greywater source followed by the bath, washing machine and the kitchen (Group A). <i>'I place a bucket in the bath for the water which I reuse for my plants. I do the same in the kitchen sink ...'</i> Anonymous, January 2017 (Group B)	While greywater composition from a specific source in one household may vary through time depending on a range of variables, certain sources are generally classed in the literature as riskier than others. Kitchen water, for instance, is highly contaminated with the disease-causing pathogens from food particles, high organic loads, grease and detergents which may further impact on the environment and on public health. Maimon <i>et al.</i> (2010) and Carden <i>et al.</i> (2018) suggest that it should not be reused at all.
The majority of greywater users did not treat greywater (Group A).	Maimon <i>et al.</i> (2010) and Memon & Ward (2019) explicitly advocate for the treatment of greywater to mitigate the risks.
Respondents reusing raw greywater for toilet flushing were transferred directly into the cistern via buckets (Group A).	Undesirable materials potentially present in raw greywater may cause clogging of the toilet-operating components (Christova-Boal <i>et al.</i> 1996), thus resulting in leaks and negating the intended water savings.
4% were watering root vegetables, 7% were watering leafy vegetables, and 11% were watering fruit and nut trees with untreated greywater (Group A). <i>'My 'grey water' tomatoes! Proud. Homegrown. Sweet.'</i> Anonymous, March 2017 (Group B)	Research suggests that microbial contamination of crops can occur from greywater irrigation, providing sufficient scientific grounds to render the practice unsafe. Carden <i>et al.</i> (2018), in fact, suggest that fruit and vegetables should only be irrigated with greywater in a time of dire food shortage when the risk of disease becomes less than the risk associated with diminished food supplies. Irrigation by means of greywater is especially risky for crops that are eaten raw or lightly cooked.
<b>Harvesting</b>	
The most popular form of greywater harvesting in the survey sample was bucketing (82% of Group A).	When bucketing raw greywater, there is a higher chance of direct exposure to harmful pathogens which can be transmitted to the mouth via contaminated hands (Carden <i>et al.</i> 2018) or aerosols.
Encouragingly, most consumers did not store their greywater or reused it within 24 h, but there were exceptions (Group A). <i>'Why can grey water NOT be stored for more than 24 hours? Been using mine after 2 days sometimes.'</i> Anonymous, February 2017 (Group B)	Prolonged storage of greywater, including in toilet cisterns, can result in anaerobic conditions and therefore offensive odours, a breeding ground for mosquitoes and the proliferation of microorganisms (Carden <i>et al.</i> 2018).
The use of 'environmentally/ecofriendly'/'biodegradable' or 'natural' hygiene products at source was prevalent (Groups A and B).	There is no indication that so-called eco-friendly products are more suitable for greywater irrigation than conventional products (Carden <i>et al.</i> 2018).
<b>Risk</b>	
71% did not perceive there to be any risk to personal health, and 57% indicated that there is no environmental risk when reusing untreated greywater (Group A).	Greywater reuse and the risks to public health, the environment and water services are well documented in the literature (e.g. Christova Boal <i>et al.</i> 1996; Al-Hamaiedeh & Bino 2010; Maimon <i>et al.</i> 2010; Penn <i>et al.</i> 2012).

understand the scale of the consequential issues. This would include the effect of country wide, small-scale household greywater reuse and reduced water consumption on wastewater flows and wastewater quality in serviced areas. The legal implications of greywater mismanagement for both homeowners and water service providers are poorly

understood. An examination into waterborne illnesses in the countdown to 'Day Zero' will also provide a better understanding of the extent of the impact greywater reuse on public health. A thorough risk assessment through the analysis and evaluation of greywater events in Cape Town or similar case studies is a further knowledge gap. It will

provide a window into the vulnerability of consumers, the environment and infrastructure during drought conditions and the trade-off between risk and water-saving.

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