Greywater reuse in Saudi Arabia: current situation and future potential

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Abstract

Water conservation and reclaimed wastewater use are currently being considered as strategic solutions to water supply limitations in Saudi Arabia and other arid and semi-arid countries. Greywater is non-industrial wastewater generated from domestic sources other than toilet wastewater (blackwater). Sources of greywater include landscaping drainage, showers, baths, sinks and washing machines. Greywater represents a substantial fraction of total domestic wastewater and, because it contains lower levels of contaminants, is much easier to treat than blackwater. Public acceptance of treated greywater use is an important prerequisite for expanding its implementation and realising even greater freshwater savings. Public reluctance to reuse greywater is most likely based on two important factors: cost and quality. Greywater reuse incurs both initial and continuing costs. In countries like Saudi Arabia, the cost of greywater reclamation and reuse is lower than the actual cost of fresh water; however, this fact may not be appreciated by most of the public because freshwater is currently subsidised by the government. The goal of this study is to assess the degree of public acceptance of greywater reuse. Data from 721 household owners were collected, analysed, and evaluated in the context of additional available information. The results are presented and suitable recommendations are discussed.
Keywords: greywater, blackwater, water reuse, water conservation, public acceptance.

1 Introduction

Water shortages in arid and semiarid countries like the Gulf Cooperation Council (GCC) States and especially Saudi Arabia have driven these countries to find

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water sources other than conventional options (groundwater and desalinated water). Saudi Arabia is distinguished by low precipitation levels, which range from 50 to 300 mm yearly and average 100 mm (Alshaikh [1]). A recent study concluded that Saudi Arabia is facing a severe water shortage and fulfils demand with nonrenewable groundwater. Therefore, water should be considered similarly to other valuable, strategic resources.

One of the goals of the seventh development plan for the Kingdom of Saudi Arabia is to reduce the growth in nonrenewable groundwater consumption and stabilise groundwater and surface water consumption at present rates while increasing the utilisation of other, non-conventional (i.e., other than desalinated) water sources (Al-Abdulkader and Al-Jaloud [2]). Domestic and agricultural wastewater can be treated and reused for agricultural irrigation and other purposes, and this process is one of the strategic solutions intended to augment unconventional water resource utilisation. In addition, treated wastewater is considered the second unconventional water source in Saudi Arabia (Alshaikh [1]) because the total volume of wastewater treated in 2000 was about 140 million m^3 (Ministry of Planning [3]). Domestic use represents the second greatest demand for water consumption; the total quantity of drinking water consumed in 2002 was about 2 billion m^3 (Al-Tokhis [4]). Average daily water consumption was estimated to be 230 litters per person daily (Alshaikh [1]). A substantial part of drinking water in Saudi Arabia is desalinated water, which is highly expensive. In 2001, the actual quantity of desalinated water was 857 million m^3 [5].

There are two types of domestic wastewater [6–8]: the first is blackwater, which is water generated from toilets, and the second is greywater, which is wastewater generated from showers, baths, hand-washing sinks, washing machines [6, 10, 11] and kitchens [9, 11] and does not include toilet water. The pollutants found in greywater are less than those found in blackwater, and consequently its treatment is simpler and less costly. Table 1 shows the characteristics of greywater from a household occupied by two adults in the United States (Casanova *et al*. [11]).

Table 1: Characteristics of greywater from a household occupied by two adults in the United States.

Parameter	Units	Value
Faecal coliform	colonies/100 ml	5.63×10^5
Total coliform	colonies/100 ml	8.03×10^7
pH		7.47
Turbidity	NTU	43
Biochemical Oxygen Demand (BOD_5)	mg/L	64.85
Total Suspended Solids (TSS)	mg/L	35.09
Electric conductivity (EC)	ms/cm	0.43

Recently, the reuse of greywater has gained greater attention from individuals and scientific studies. Separating greywater from blackwater by an in-house dual pipe system and onsite treatment is required to reuse the water for other purposes other than drinking, such as toilet flushing [12–14], watering lawns and gardens [10, 12], and washing courtyards. Reuse of greywater reduces water consumption and satisfies the requirements of the seventh of Saudi Arabia's Five-Year Development Plans.

This study aimed to assess the degree of public acceptance of greywater reuse. The specific objectives are: 1) assessing the awareness of the public regarding the problem of water shortages and the importance of conservation, the real cost of water, and their desire to reduce its consumption, 2) assessing the awareness of the public regarding the advantages of greywater reuse, their opinion about its quality, and determining the current situation concerning the reuse of greywater, and 3) determining the potential for greywater reuse in the future and factors that can improve its reuse.

2 Methodology

Riyadh city was selected to represent the Kingdom of Saudi Arabia. Data from 721 household owners were collected through verbal surveys. Three different types of questions, including multiple choice, numeric open end and text open end, were planned based on the goals of this research. These personal interviews were performed in different areas of Riyadh city. The number of interviewees was proportional to the population of each area. The data collected were analysed and presented in various forms showing important results.

3 Results and discussions

The results of this research are categorised into three groups as follows:

3.1 Awareness of public of the problem of water shortages and the importance of its conservation, the real cost of water, and their desire to reduce its consumption

Figure (1) shows that 41.6% of consumers realise that there is water shortage, 42.4% believe that the problem is not serious, and 16% feel that the problem does not exist. These percentages are almost identical for consumers between 18 and 50 years old. Of older people, 25.4% feel that there is no water shortage problem. This means that the awareness of water shortage problem will increase in the near future as the current generation replaces the former one. More intensive awareness campaigns and water conservation programs for the public will result in greater percentages of awareness.

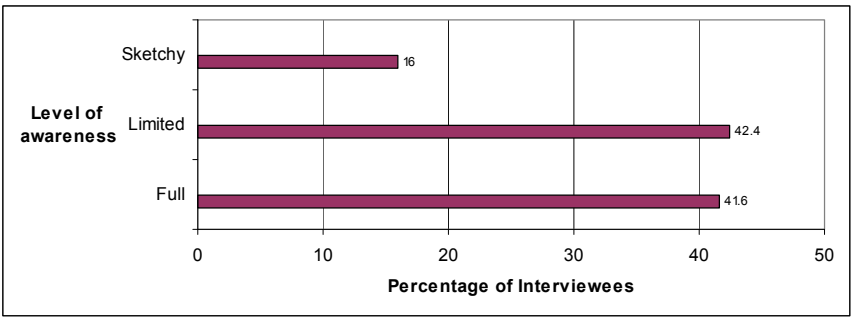

Figure 1: Interviewees level of awareness of the problem of water shortages.

With respect to the relationship between education level and the awareness of the problem, the results showed that (Figure 2) 62.5% of uneducated (do not hold any degree) interviewees realise the problem and, unexpectedly, this percentage decreased to 40%, on average, for educated consumers. The results also showed that 25% of uneducated interviewees believe that there is a water shortage problem, but that it is not serious; this percentage was higher (37.5% to 48.8%, based on level of education) for educated people. Only a few of the few interviewees (12.5%–25%) did not recognise the problem. According to the results, we can state that education did not significantly affect consumers' recognition of the water shortage problem.

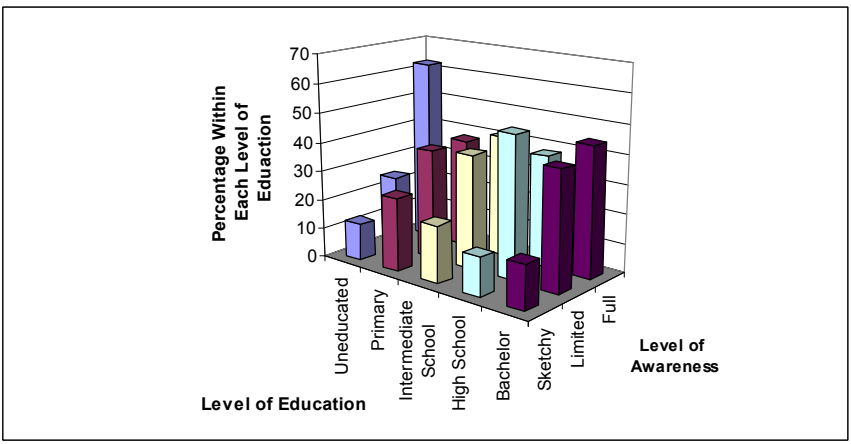

Figure 2: Relationship of level of education to the degree of understanding about the problem of water scarcity.

We found that 8.6% of the interviewees believe that the price of water was expensive, whereas 37.5% understand that water has a cost, but that it was not too expensive, and 53.3% believe that water is inexpensive. This was expected as

the cost of water is subsidised by the government, which results in causing most consumers to remain oblivious to the actual high cost of water. As per the results of this study, about half (48.5%) of the interviewees know that the actual cost of water is much higher than what they are paying, whereas 18% are not aware of this. About one third (33.5%) of the interviewees think that that they are paying the actual cost (Figure 3). For the first 50 m^3/month, consumers pay 10 Hallals or 2.67 US Cents per m^3 and 15 Hallals per m^3 for the next 50 m^3 per month. The actual cost of water was determined to be 4 Saudi Riyals or US$ 1.07 per m^3 (including the cost of production and transportation) [15, 16].

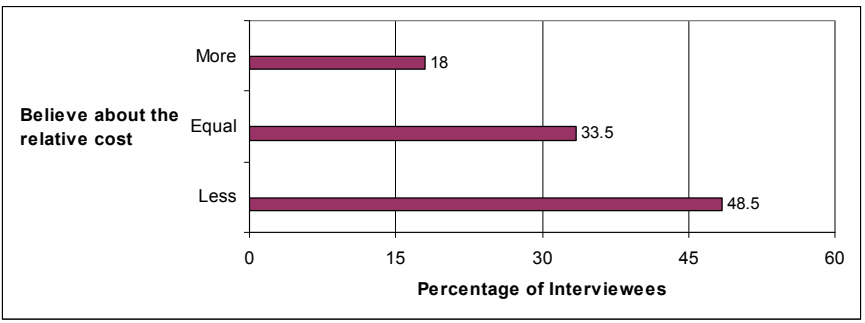

Figure 3: Interviewees believe about the cost of distributed water relative to the actual cost.

The level of concern of consumers regarding water preservation was encouraging (Figure 4), as we found that 85.3% of the interviewees care about water conservation, 11.8% of them care but to a less extent, whereas only 2.9% do not care at all. We found a positive relationship between the awareness of water shortage and caring about its preservation; therefore, it is important to invest in more awareness campaigns and water conservation programmes. The relationship between awareness about the preservation and the cost of water was unexpectedly negative. We found that the percentage of those who care about

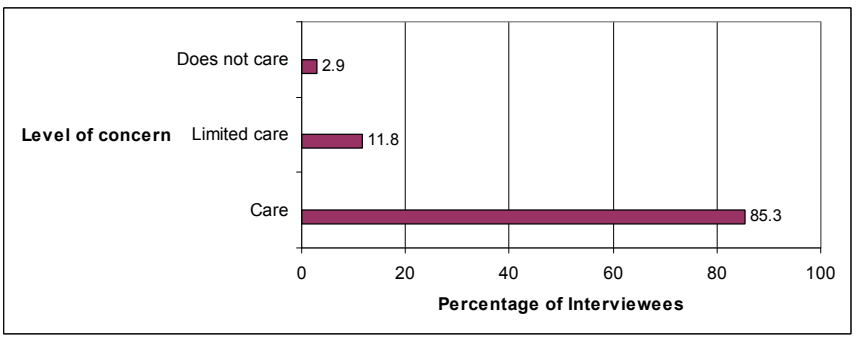

Figure 4: Interviewees level of concern regarding water preservation.

preservation was higher within those groups that believe that the sale price of water is inexpensive, whereas this percentage decreased among those who believe that water is expensive. Therefore, the knowledge of the price of water does not cause the consumer to care more about water conservation, especially for those who consume less than 100 m^3/month.

3.2 Awareness of the public regarding the advantages of greywater reuse, their opinion about the quality of treated greywater, and determining the current situation concerning the reuse of greywater

The study revealed that 53.9% of water consumers have some knowledge, regardless of the level, about greywater reuse in houses, whereas 46.1% had none. About 50.8% of the interviewees recognise that greywater can be reused in houses, whereas 18% do not realise that it can be reused. The remaining (31.2%) interviewees are not sure about the possibility of greywater reuse in houses.

This study showed that 67.5% of those who know about greywater reuse understand that it is possible to reuse this type of water, whereas 9.7% believed the opposite. The remainder (22.8%) are not sure. We found that 66% of those who understand that it is possible to reuse greywater believe that its quality is suitable for houses, 15.6% of them expect that its quality is insufficient for houses, whereas the remainder (18.4%) do not believe it is suitable for any use. Of those who understand that it is possible to reuse greywater in houses, the results revealed that 32.8% know that its quality is suitable for some uses in houses, and 23.9% assume that its quality is not suitable for household use, whereas the remaining 43.3% have doubts about its quality. In general, the study found that 48.9% of the interviewees know that treated greywater is suitable for some household uses, such as toilet flushing, watering lawns and gardens, and washing courtyards. About 26% of them think that it is not suitable for such uses, and the remainder (25.3%) are not sure. Therefore, it can be said that awareness campaigns and water conservation programmes regarding greywater reuse are not sufficient to convince consumers that treated greywater is suitable for some uses in houses.

The survey did not locate anyone who reused greywater in his house, and we are aware that there are relatively very few homes that do so. Therefore, we believe that the current situation of greywater reuse in houses is very limited in Saudi Arabia in general and specifically in Riyadh. This situation is not acceptable for a country that faces a drastic water shortage. Therefore, more awareness campaigns and water conservation programmes are required to improve the knowledge of consumers about water shortages and greywater reuse.

3.3 Potential for greywater reuse in the future, and factors that could improve its reuse

At the beginning of the third part of the verbal survey, each interviewee was assured that greywater that is treated to an appropriate level instead of drinking water is safe and suitable for in-house uses such as toilet flushing, watering lawns and gardens, and washing courtyards. The results (Figure 5) showed that

35.7% of the consumers would reuse greywater if they build a new house in the future, 20.5% would not do so, and 43.8% are unsure. Most of those who were sure about reusing greywater in the future would use this water for toilet flushing and watering their lawns and gardens, whereas only few of them would use it to wash their cars and courtyards and to feed desert coolers (evaporative coolers).

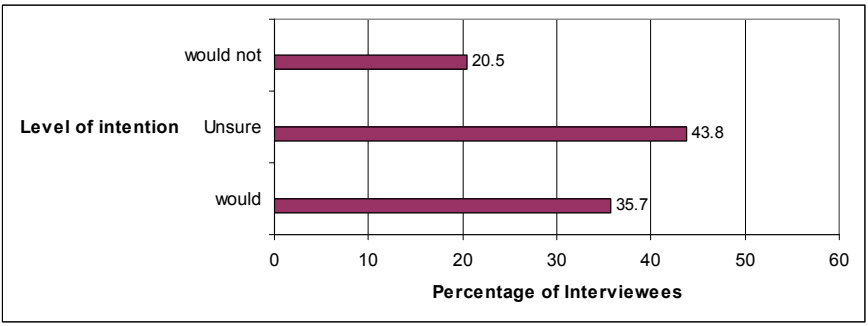

Figure 5: Interviewees level of intention for greywater reuse if they build new house.

The low cost of a reuse system was effective in directing consumers to greywater reuse in the future. A maximum of 10,000 Saudi Riyals (US$ 2670) was the limit for 68.7% of the interviewees, and SR 20,000 or US$ 5340 was the limit for 18.3%. Only 7% of the consumers would build a reuse system if the cost reached SR 30,000 or US$ 8000, only 2.8% would if the cost reached SR 40,000 or US$ 10670, and only 3.2% would if the cost reached SR 50,000 or US$ 13,330. According to the results of this study (Figure 6), 44.6% of the interviewees support the idea of a full governmental subsidy for constructing such systems, 48.3% of them support the concept of a partial subsidy, while 7.1% belief that there is no need for any kind of subsidisation and that the house owner should bear the entire cost. Of those who were open to the reuse of

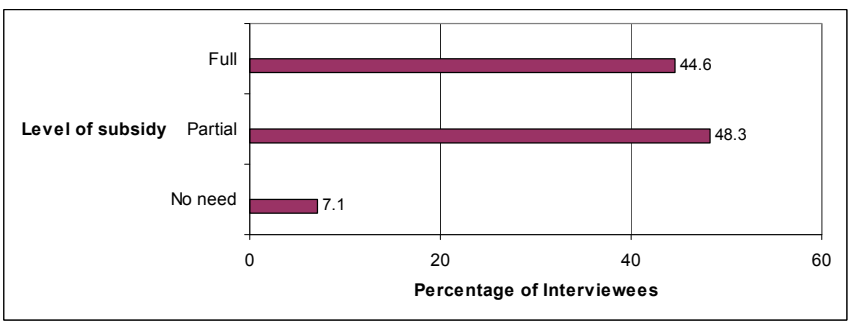

Figure 6: The level of governmental subsidy required for constructing individual greywater reuse systems.

greywater in the future, 41.7% of them wanted a full subsidy, 52.1% asked for a partial subsidy, and 6.2% believed that there is no need for any kind of subsidisation.

The cost of a simple system for an individual household with a capacity of 3 m^3/d and consisting of a greywater collection system, a treatment system, and a treated greywater in-house distribution system is approximately SR 10,200 (US$ 2720). The treatment system consists mainly of a storage tank, a carbon-sand filtration unit, a chlorination system, and a treated effluent storage tank. The total operational cost is approximately SR 900 (US$ 240) yearly. Assuming a design life of 15 years, 3 m^3/day of greywater, and an interest rate of 2.5%, the cost of each cubic meter of treated greywater is SR 3.18 (US$ 0.848). This is much less expensive than the sale price of fresh water, which ranged from SR 2 (or US$ 0.53) to SR 6 (US$ 1.6) per m^3 when consumption was greater than 100 m^3/month. Table 2 depicts the treatment cost per cubic meter of greywater and the sale price of freshwater.

Table 2: Treated Greywater cost and sale price of drinking water.

DP	Greywater Cost (US$/$m^3$)					Drinking Water Sale Price (US$/$m^3$)		Savings (US$/$m^3$)	
	Construction cost		OC	Total cost					
	R	A		R	A	R	A	R	A
15	0.621 – 0.993	0.807	0.041	0.662 – 1.034	0.848	0.53 – 1.6	1.065	0.132 – 0.566	0.212
20	0.466 - 0.745	0.596		0.507 – 0.786	0.647			0.023 – 0.814	0.419
25	0.373 – 0.596	0.485		0.414 – 0.637	0.526			0.116 – 0.963	0.54

DP: Design period OC: Operation cost R: Range (present-future) A: Average

Estimated greywater costs are based on an initial construction cost of US$ 2720 and 2.5% interest rate, 3 m^3/day, and US$ 240 annual operation cost. Negative value means the system costs more than drinking water supply.

Factors that are expected to encourage greywater reuse in the future include:

1) Religious concepts (religious motive), as the principle of water conservation is grounded in Islam. Islamic principles and ethics, in fact, have always advocated good conduct towards the environment and respect for natural resources.
2) Economical concepts, as more water preservation leads to a lower water sale price,
3) The humanitarian incentive of joining with others to solve the water shortage problem, and preserving water for the next generation.
4) The desire for environmental protection and respect for natural resources, as water conservation results in the reduction of wastewater.

In this study, each interviewee was asked to select the factors that might affect his or her decision to recycle water. The first factor was the most important (70.1%) to interviewees and the third factor was the second most important as 44.3% of the interviewees selected this as a factor that would encourage recycling. The second factor was the third most important (28.1%), and the fourth factor was the least important (20.6%).

Unfavourable factors that contributed to greywater recycling refusal include:

1) Cost of the recycling system,
2) The belief that treated greywater is not suitable for toilet flushing and watering lawns and gardens
3) Fear of smells and diseases
4) Doubtfulness of the need to recycle greywater.

The interviewees were allowed to select more than one factor. In descending order of causing greywater reuse refusal, these are fear of smells and diseases (46.8%), cost of the recycling system (38.1%), doubtfulness of the need to recycle greywater (18.5%), and the belief that treated greywater is not suitable for toilet flushing and watering lawns and gardens (12.8%). Other factors were also noted in this study, including: 1) the unfamiliarity of the consumers with local and international experience with greywater reuse, 2) the unfamiliarity of consumers with the adequacy of the recycling process for water conservation, 3) fear of the operation and maintenance costs and difficulties, 4) insufficient knowledge about the recycling process, and 5) lack of information about companies that build such systems.

It is important to make consumers familiar with local examples, as these are more important to people than those that occur far away. One of the local examples (Millibari [14]) of recycling greywater showed that greywater is a cost-effective alternative source of water. Greywater reuse aids sustainable development and resources conservation without compromising public health and environmental quality (Prathapar *et al*. [17]). The study estimated that the total cost of treating greywater is 11 Hallals or 2.93 Cents per m^3. Therefore, a short payback period is expected, especially for large individual households consuming more than 100 m^3/month.

4 Conclusions and recommendations

Several results were reached in this study, including:

- About 46% of the interviewees did not know about greywater reuse in houses.
- About 18% of the interviewees did not realise that greywater can be reused in houses.
- About half of the interviewees knew that treated greywater is suitable for some in-house uses such as toilet flushing, watering lawns and gardens, and washing courtyards.

- None of the interviewees reused greywater in his or her house, and we are aware that very few people reuse greywater in their own homes.
- About 35.7% of the interviewees state that they would use a greywater reuse system in their new houses in the future, whereas 43.8% were not sure.
- The initial cost of the system was a factor affecting the decision regarding the construction of greywater reuse system in their new houses in the future. The limits were US$ 2670 for 68.7% of the interviewees, US$ 5340 for 18.3%, US$ 8000 for 7%, US$ 10,670 for 2.8%, and US$ 13,330 for 3.2%. A simple complete in-house greywater reuse system was approximately US$ 5129 with an annual operating cost of US$ 240.
- The factors affecting the decision to employ greywater reuse in the future were varied; religious concepts and the humanitarian incentive to solve the water shortage problem were the two most important factors, respectively.
- There were several unfavourable factors that caused greywater recycling refusal, and the fear of smells and diseases and the cost of the recycling system were the most important.
- There is a short payback period for in-house greywater reuse systems for houses consuming more than 100 m^3/month of water.

Based on the results of this study, we can make the following recommendations:

- More awareness campaigns and water conservation programmes, including greywater reuse, must be undertaken.
- New houses during construction should be required to build a greywater reuse system. This would be done by including designs in the plans and making the construction permit conditional on including a greywater system and also by refusing to connect other services such as electricity and drinking water until the reuse system is constructed.
- Subsidising greywater reuse systems for private houses and simultaneously increasing the sale price of water, especially for the first 100 m^3 per month.

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