



Assessing the Feasibility of Greywater Reuse Projects Using Ablution Water in Riyadh Mosques: A Sustainability Analysis Across Social

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Abstract:

The reuse of treated gray water provides a large amount of potable water, and it is one of the solutions that the countries of the world are currently looking for in light of the lack of decreasing quantities of water with different sources, surface, underground or rain. Saudi Arabia in particular considered limited in water resources and comes at end of the countries in the world in terms of the capita share of water. This paper will deal with the social aspect, which is the first part of a comprehensive study based on three main axes: social, environmental and economic. The social part deals with the awareness of public in towards greywater reuse, it is very important because it speeds up the process of implementation and spread. The social part was studied as a survey in the form of a questionnaire in the city of Riyadh. Riyadh is chosen to present Saudi Arabia because it is the capital and fastest developing city in the Kingdom. A 646 representatives complete the survey by answering 17 structured questionnaires. This paper represents the output of the survey and focusing on two main parameters effect the attitude of the public; age group and level of education.

Keywords: Graywater, awareness, Public, Riyadh, survey

1. Introduction:

The world is currently experiencing a major crisis in the shortage of safe water for use or drinking in light of climate change. The rise in temperatures due to global warming and the lack of rainwater has led to a significant decrease in the level of many waterways and the drying up of some of them around the world. Gray water treatment and reuse is considered one of the most important contemporary alternative solutions, and what distinguishes it from other solutions is that at the same time it reduces the burden on sewage networks and treatment plants, and thus saves the cost

of operation and maintenance and increases the lifespan of different units. The annual person water consumption in KSA is around 278 liter per day, and the percentage of non-renewable groundwater out of the total annual water consumption is 82%.[1]. It can be observed that Saudi Arabia might face challenges in terms of water shortage water scarcity. Due to that The KSA Vision 2030 aims to reduce the annual water consumption around 150 l/c/d .[2]

Grey water Is non-industrial wastewater generated from domestic sources other than toilet wastewater, include landscaping drainage, showers, baths, sinks and washing machines, characteristic with high volume, low strength wastewater with high potential for reuse and application [5, 7, 9].

Al-Jasser [3], showed that around half of the interviewers realize that there is water shortage and recognize the greywater and it can be reused. Also found that half of the interviewees know that treated grey water is suitable for some household uses, such as toilet flushing, watering lawns and gardens, and washing courtyards. Al Harasi et al. [6] conducted a survey in Oman, revealed that 84% of the respondents were in favor of treating and reusing greywater; 74% of the respondents felt that adoption of greywater treatment system would be financially beneficial; 82% of the respondents felt that treated greywater can be used for irrigation; 72% of the respondents felt that treated greywater can be used for toilet flushing and 42% said that it can be used to wash cars. However, another 47% felt that it would be harmful to human health. Surprisingly, 16% responded favorably for treated greywater to be used for potable purposes.

Alhumoud and Madzikanda [4] surveyed public willingness to use reclaimed water for a variety of purposes in Kuwait, the study showed that the main accepted uses are in agriculture and landscaping, and that education level and knowledge of wastewater reuse are the main factors affecting the respondents' choices, other factors include age, nationality and gender.

Belcer-Baykal et al. [8] measured the awareness of public in Istanbul by using survey, The results revealed that the reuse of grey water as flush water was accepted the most with 79% which increased to 92%. The highest impact upon positive opinion was with acceptance on the reuse of grey water from washing machines with 93%.

This work was undertaken to investigate awareness of the public towards reusing grey water for various end uses. The paper will report the results of the survey conducted in Riyadh, focusing on present awareness and willingness of participants to use reclaimed grey water along with changes in their perception and level of acceptance. The major focus of the paper is placed on possible final uses and economic considerations depending on the age and education level of interviewers.

2. Research Problem:

Saudi Arabia suffers from a structural scarcity of freshwater resources, with 82% of the total annual water consumption relying on non-renewable groundwater [1], while the per capita water consumption remains relatively high compared to many countries as, shown in Figure:1.1. At the same time, mosques in Riyadh consume considerable amounts of potable water, a large fraction of which is discharged as ablution water that could potentially be classified as greywater.

Despite the growing interest in greywater reuse as a sustainable solution, there is still a lack of applied studies tha Assess the social acceptance of reusing ablution water in mosques, Therefore, the core problem that this study addresses is the absence of a clear, evidence-based assessment of the feasibility social of reusing ablution water in Riyadh mosques as a means to reduce potable water consumption and support national sustainability goals.

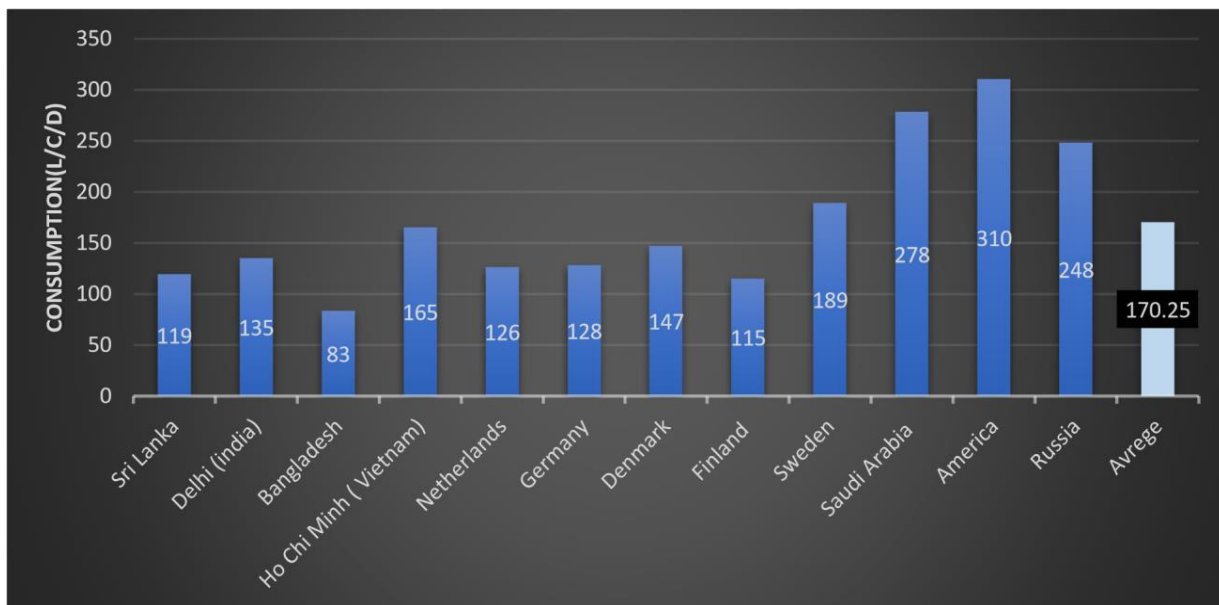


Figure1.1: Show the consumption in several countries [2-7]

3. Importance of the Study:

Scientific Importance

- ❖ This study contributes to the growing body of literature on greywater reuse by focusing on a relatively unexplored source of greywater: ablution water in mosques, which is generally cleaner than other domestic greywater streams.
- ❖ The study enriches the empirical data on public awareness and attitudes towards greywater in Riyadh through a structured survey of 646 respondents, offering statistically descriptive insights that can be used in future research on water demand management and social perception of reuse.

Practical Importance

- ❖ The study offers decision-makers in the Kingdom of Saudi Arabia a practical model for designing and implementing greywater reuse systems in mosques, aligned with Vision 2030 goals to reduce per capita water consumption and increase vegetation cover [8].
- ❖ It provides quantitative evidence on the potential reduction in potable water consumption (up to 50% in some cases, based on previous studies) when ablution water is reused for irrigation and toilet flushing in mosques.

4. Study Objectives:

This study aims to assess the overall feasibility of reusing ablution water in mosques in Riyadh as greywater for irrigation and toilet flushing through a comprehensive analysis of social. In order to achieve this main objective, the study to review and synthesize the relevant literature on greywater reuse, with particular emphasis on its social. to investigate the level of public knowledge, awareness, and acceptance of greywater and ablution water reuse among residents of Riyadh, using a structured questionnaire survey.

5. Review of Previous Studies:

Out of the overall water resources on earth, about 97% can be found in the oceans while the remaining 3% remains available for direct exploitation; however, out of this 3%, the quantity of water that is available for use by humans is estimated at one-hundredth [9,10]. Uneven distribution of water in both time and space sways. The use of water to other geographical areas depriving others of this resource. Biological survival remains one of the key factors of water use with its associated use also for household needs and for food production and other

developmental needs. Many parts of the world are hit by acute water shortage, overexploitation of water resources leading to gradual destruction of these water resources and high levels of freshwater pollution resulting from anthropogenic factors. Currently, it has been estimated that about 800 million people live under a threshold of water stress and this number is expected to reach 3 billion in 2025 [11,12]. Due to urbanization, industrialization and population growth, the demand for water is evident; however, water resources meet the ever-growing needs in a sustainable manner, extra water that is required to sustain human activities come all of that calls for interventions and strategies.

5.1 DEFINITION OF GREYWATER

Previous studies define Greywater as wastewater without any contributions from toilet water [13]. It is considered high volume, low strength wastewater with high potential for reuse and application [14]. The composition of greywater is varied and depends on the lifestyle, fixtures and climatic conditions [15]. Reuse of greywater has been an old practice, and it is still being done in areas that are water stressed. This practice if given the needed attention can help reduce the over-reliance on freshwater resources and reduce the pollution caused by discharge of untreated greywater into freshwater resources. It can also be a supplementary source to existing water sources in areas where there is acute water crisis or in arid climatic regions.

Recycled greywater can be used for different water-demanding activities including potable and nonportable uses such as toilet flushing and agriculture. The major concerns with greywater reuse have been issues with public health perceptions and inappropriate technology for the reuse option [16]. Many researchers have studied characteristics of greywater with respect to fixtures and lifestyle patterns [17].

Grey Water is non-industrial wastewater generated from domestic sources other than toilet wastewater. Sources of greywater include landscaping drainage, showers, baths, sinks and washing machines [18]. Black Water wastewater from toilets, bidet, water used to wash diapers and under some definitions, from kitchens [18]. Dark Grey Water Untreated household wastewater that has not come into contact with sewage but is from lower quality sources such as kitchen sinks and dishwashers Sometimes considered to be part of black water [18].

5.1 SOCIAL PERSPECTIVE OF GREYWATER IN SAUDI ARABIA

There were several studies in public awareness of the advantages of greywater reuse in Saudi Arabia in public: their opinion about the quality of treated greywater [22]. 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. 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. It was 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.

Additionally, 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 [22].

Potential for greywater reuse in the future, and factors that could improve its reuse showed that 35.7% of the consumers would reuse greywater if they built 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) 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%).

5.3 SOCIAL PERSPECTIVE OF GREYWATER IN MIDDLE EAST AND AFRICA

Survey in Oman Assessed Omanis' attitude towards treated greywater reuse, as part of the survey referred earlier [23]. The survey revealed that 84% of the respondents were in favour of treating and reusing greywater; 74% of the respondents felt that adoption of greywater treatment system would be financially beneficial; 82% of the respondents felt that treated greywater can be used for irrigation; 72% of the respondents felt that treated greywater can be used for toilet flushing and 42% said that it can be used to wash cars. However, 61% felt that treated greywater reuse may lead to environmental degradation and another 47% felt that it would be harmful to human health. Surprisingly, 16% responded favourably for treated greywater to be used for potable purposes. Those not in favour of treated greywater reuse cited religion, health, environmental degradation including groundwater contamination and costs as reasons. Another survey conducted among the students of Sultan Qaboos University (SQU) found that 62.5% supported separating greywater from blackwater, 58.5% would use treated greywater for some use at home and 43% would pay extra to change existing plumbing to facilitate greywater use. The survey showed that when asked for main reasons for not accepting unlimited use of treated wastewater, 40% identified health and 37% identified religion as the reasons [23].

In addition, another study was carried out the social perspective in Baghdad, it was found that the participation of people in the survey tends to decline with the age. In terms of age group of the participants who responded to the survey, the highest number of responses was received from participants aged between 18 and 28 year and the lowest number of responses was over 45 years of age. Females responded more than males in 18-28, 28-45 age groups. Overall, 49% of the survey responders in this study were aged between 18 and 28. These differences between service areas are likely due to different socio- demographic characteristics, all respondents in different regions in Baghdad indicated they do not know what is greywater and certainly do

not reuse any greywater. The top reason offered for not reusing greywater is “don't know how.” Another important reason is “need information and assistance.” This suggests that if the legal barriers were lowered and public education and incentives offered, greywater reuse might increase considerably. Several of the reasons offered are similar, by design. The specific reasons can be grouped into five categories. For example, “don't know how” and “need information and assistance” both indicated the respondent needs help. These two categories account for (63%) of all reasons given. “Not sure safe and need treatment” and “water is salty, and it contains chemicals” suggests health or environmental concerns. These account for (18%). Similarly, “isn't worth the trouble”, “not enough time” and “not worth the cost” all indicate a similar lack of motivation. These three reasons account for (11%) of all responses. Legal, and permitting issues account for (7%) of responses. “Water not near use” and “no use for water” indicates reuse is not practical, and account for (1%) of responses. while the votes for ‘increase the price of water’ strategy increased with the increase of age. This indicates that a blanket approach to water conservation strategy may not be very effective across the community.

Moreover, Nearly 65% of the participants think that the reuse of greywater by homeowners can help in sustaining Baghdad's future water supplies, and about 63% of the participants viewed that the greywater reuse will reduce the amount of portable water usage and improve the local environment. Forty-nine percent of participants thought the cost associated with the reuse was a very important consideration for them, while (48%) of participants considered health risk to be very important for any decision on the reuse of greywater. On the other hand, for one in thirty (3%) participants, health risk and cost weren't very important at all, one of the prime concerns of the survey participants was impacts of greywater on soil quality and environment surrounding greywater reuse sites if greywater recycling for irrigation. One of the interesting findings of this study is that about (26%) of the total number of survey participants was not aware of the long-term consequences of greywater reuse for irrigation at their home gardens [24].

Another study conducted in Uganda regarding Greywater reuse, more than 50% of the respondents said that they sometimes kept laundry water for reuse of which more than 90% used it for cleaning their houses and 4% applied it to their gardens. 87% of the respondent's households expressed willingness to reuse treated Greywater [25].

6. Methodology:

The city of Riyadh was chosen to collect the information to represent the Kingdom of Saudi Arabia. 646 data were collected from the survey. One types of questions were planned, which is choice questions. Any outputs that appear logically inconsistent with answers and cowardice are arranged, and each person can use the questionnaire's expressions once. The survey was filled out by publishing it on social networking sites and personal interviews in public places in the city of Riyadh. The collected data was analyzed and presented in various formats showing important results.

The actual descriptive statistics of the sample variables are presented in Table 1.

Table 1. Domegraphic characterstics of sample (646 reponses)

		Frequency	Percent (%)
Ethnicity	National	587	90.9
	Non-National	59	9.1
Age group	Under 19 years old	24	3.7
	20-39 years old	403	62.4
	40-59 years old	209	32.4
	60 or over years old	10	1.5
Level of Education	University Degree	422	65.3
	Secondary education and below	213	33
	other	11	1.7

7.Results:

7.1Respondents General information

The survey data shows (Figure 1.a) the different age groups are represented in the survey and the majority of the survey respondents belongs to the mid-class age from 20-39 years old. Also, the survey data shows that 65% of the respondents are holding university degree (Figure 1.b).

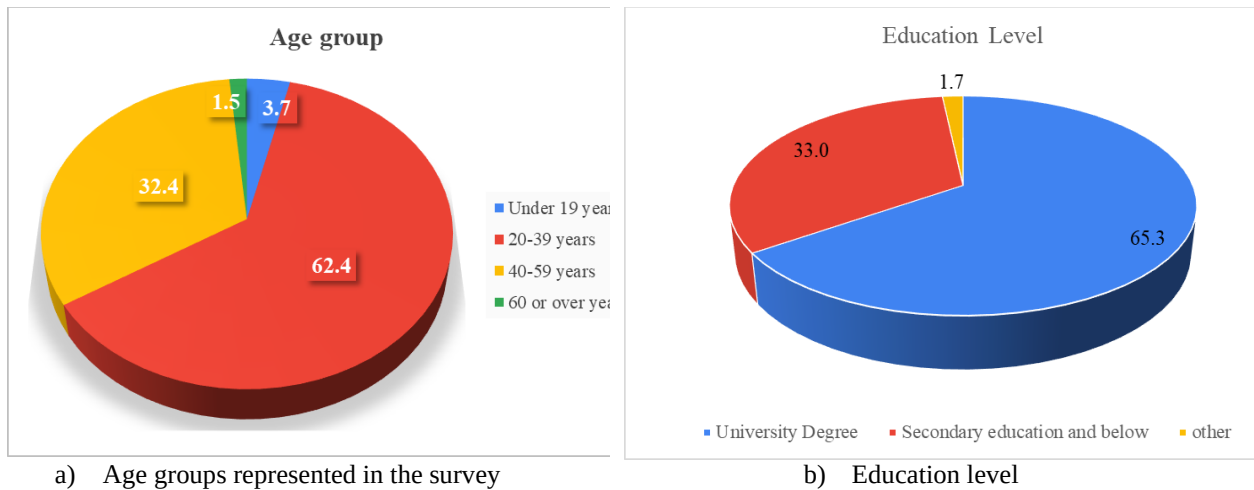
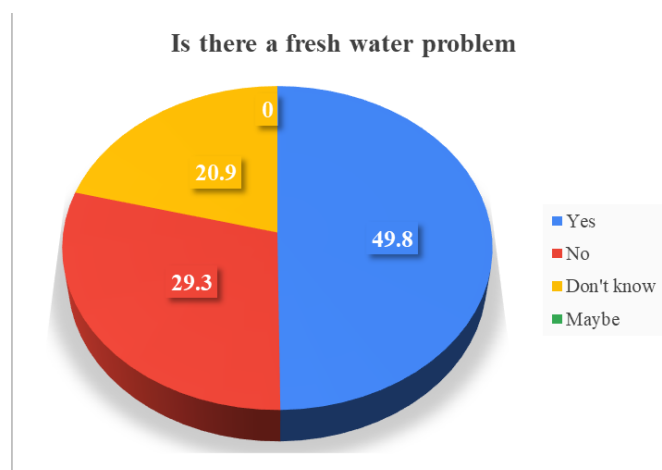


Figure 1. General information about survey respondents

7.2 Awareness of fresh water problem

The collected data (Figure 2.a) has also shown that less than 50% of the survey respondents is aware that there is a fresh water problem in Riyadh. Figure 2b shows the awareness of the existence of the fresh water problem in Riyadh within each age group. It is shown that the 40-59 age group scored the highest awareness of the said problem among the other age groups. Whereas figure 2c shows the awareness of the fresh water problem based on the education level. It is interesting to note that holding a university degree does not result in significant awareness of the problem compared to the other education level classes.



a) General public awareness of the fresh water problem in Riyadh (All classes)

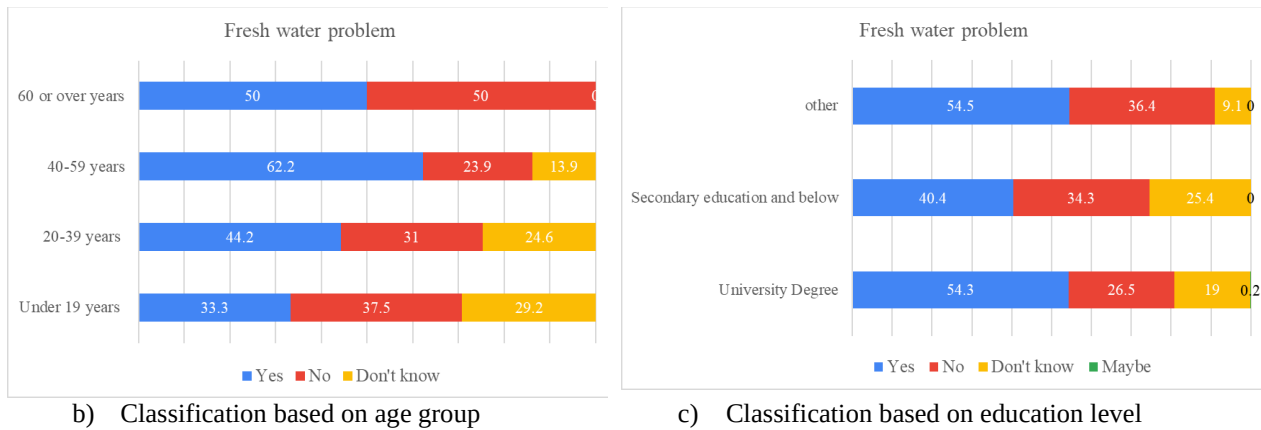
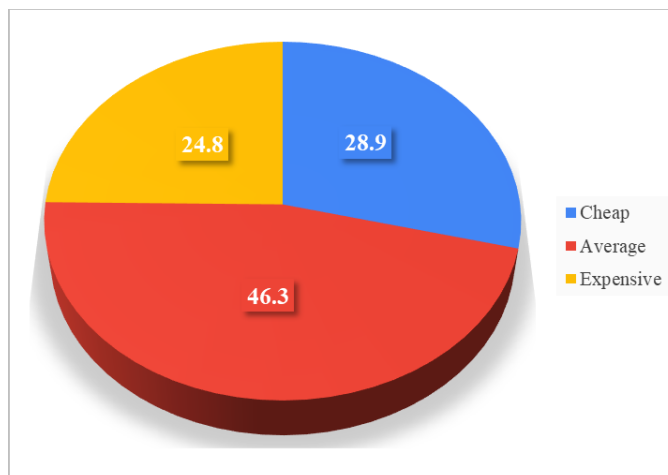


Figure 2. Awareness of the existence of fresh water problem in Riyadh

7.3 Public opinion on potable water price

The collected data (Figure 3.a) has also shown that less than 25% of the survey respondents finds the prices of the potable water in Riyadh is expensive. It is interesting to realize that the 70% of the elder respondents (60 and above) feels that the water price is high. Whereas 91% of those who are unfortunate in education sees that water price is not expensive.



a) General public opinion on the price of the potable water in Riyadh (All classes)

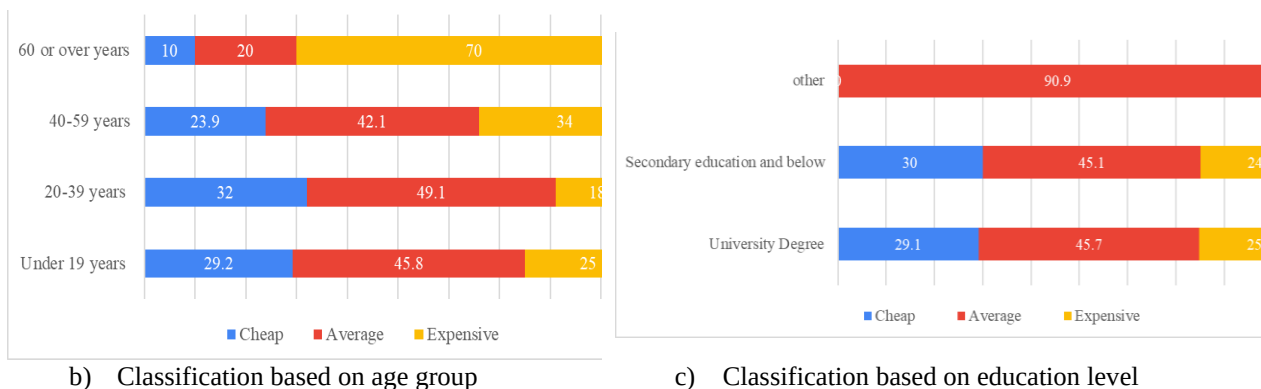


Figure 3. Public opinion on potable water price in Riyadh

7.4 Public awareness of “greywater” definition

The survey data shows (Figure 4.a) that more than 71% of the survey participants were initially not aware of the “greywater” therefore they were obliged to read first the definition of the greywater before continuing the survey. It is also surprisingly to note that the awareness of greywater among the elder or the more educated people is not distinguished (Figure 4.b and c).

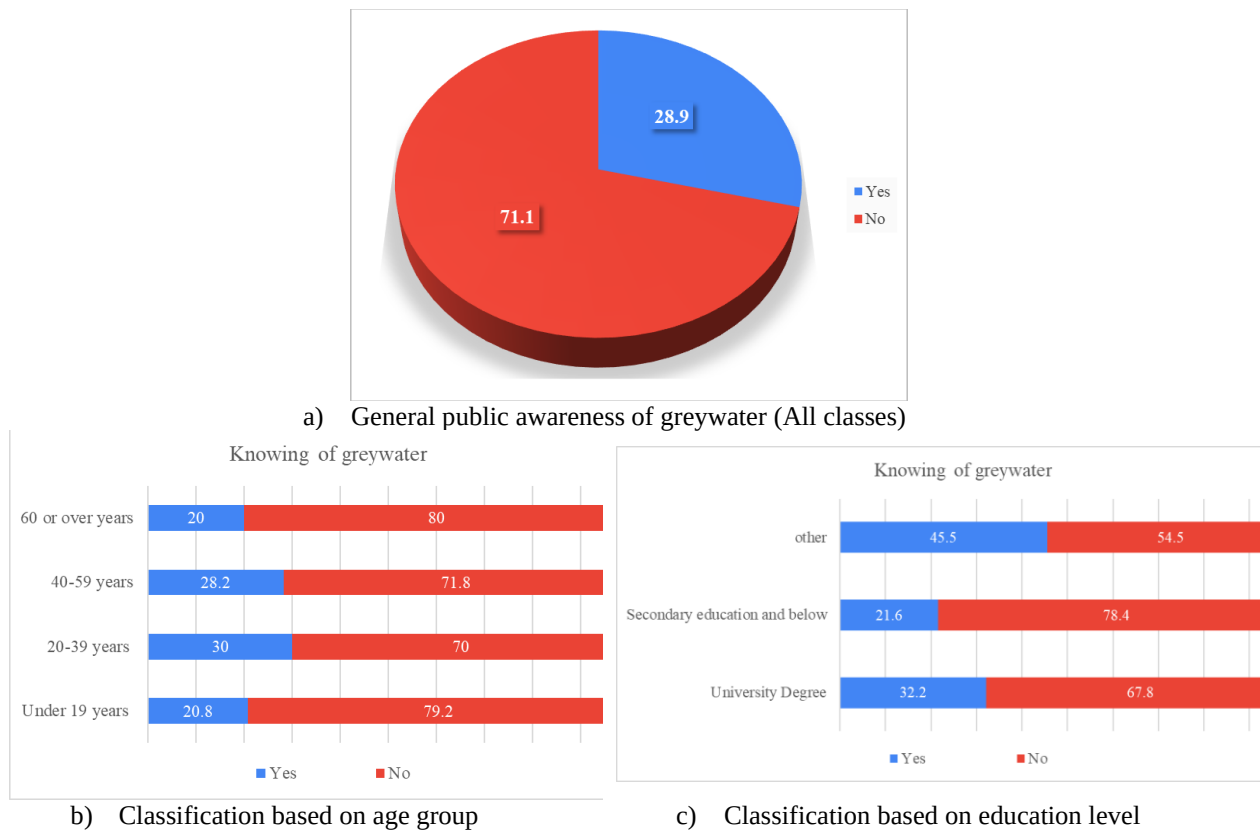
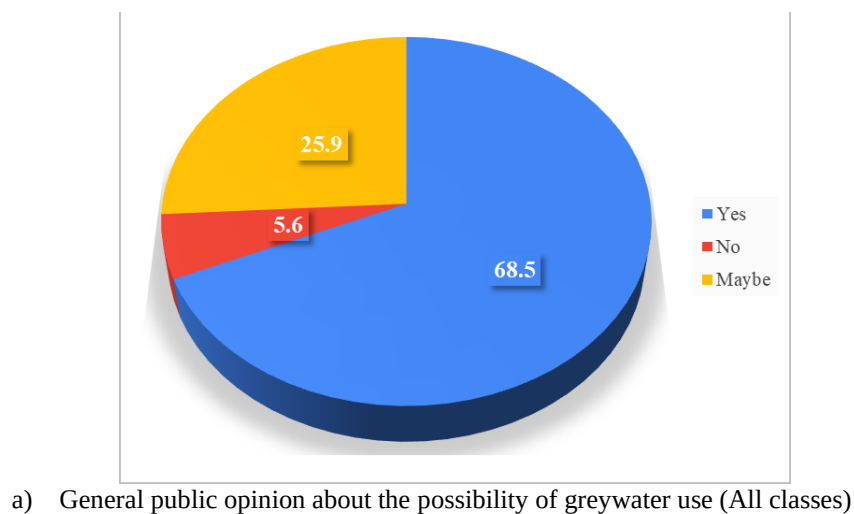


Figure 4. Public awareness of greywater in Riyadh



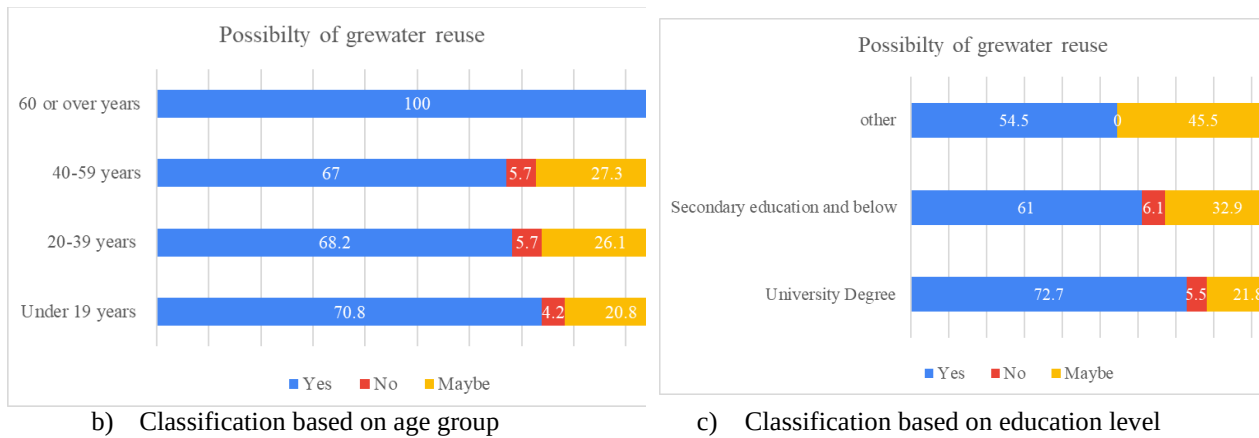
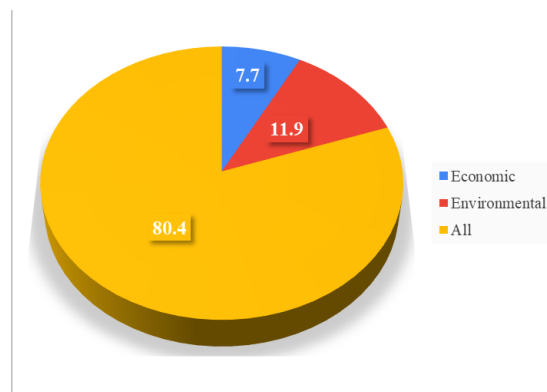


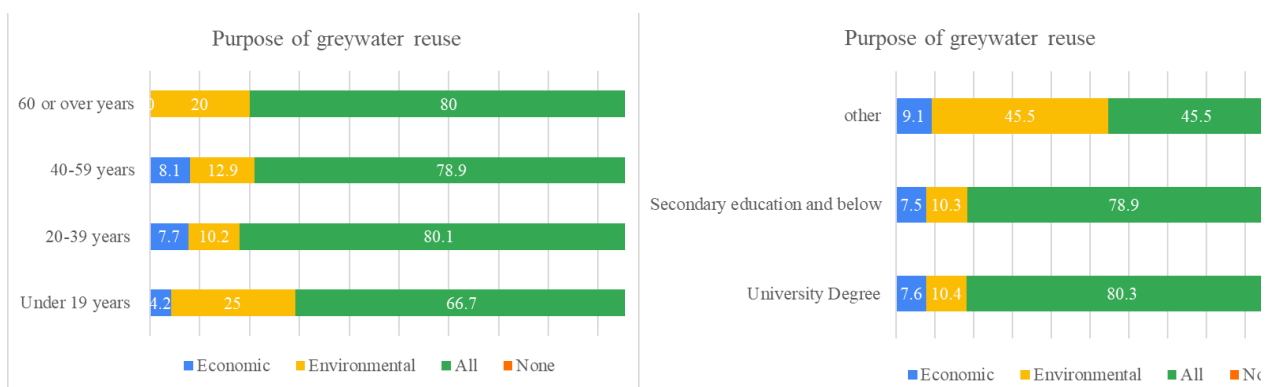
Figure 5. Possibility of greywater use in Riyadh

7.5 Purpose of greywater use

Figure 6 shows the opinion of the public regarding the purpose of greywater reuse. More than 80% of the respondents see that the greywater could be used due to both economically and environmentally reasonings. The classifications based on the age also shows that at least 66% (in each age-group) see that the purpose of using greywater could be economical and environmental as well. It is also shown that as level of education increases, the respondents find themselves more in favor of the double purpose use of the greywater.



d) General public opinion about the possible use of greywater (All classes)



e) Classification based on age group

f) Classification based on education level

Figure 6. Purposes of greywater use in Riyadh

7.6 Conclusions

Saudi Arabia is one of the arid countries that suffers from scarcity in fresh water resources. Therefore, it relies heavily on water desalination to cover the water residential needs. The reuse or recycling of greywater could be one of the ideal solutions to cover the gap in water resources needs for the residential sector.

The study main objective is to assess public acceptance of greywater reuse in Riyadh city and to identify the factors that influence public attitudes towards greywater reuse. For this regard, a survey was conducted and the main findings of the survey are outlined below:

- According to the survey, less than 50% of respondents are aware that Riyadh has a fresh water shortage. It can be also concluded that the 40-59 age group is most aware of the said problem compared to other age groups. It is also important to note that holding a university degree does not lead to significant awareness of the fresh water problem compared to other education levels.
- More than 75% of respondents are satisfied with the prices of potable water in Riyadh. Despite this, it is interesting to observe that 70% of the older respondents (60 years and older) believe that the water price is too high. It is also interesting to note that 91% of those who are unfortunate in their education do not perceive the water prices as being excessive.
- More than 71% of survey participants were initially unaware of the term "greywater" and were required to read the definition before continuing. It is also surprising to note that people with more education or who are older do not appear to be more aware of greywater.
- More than 68% of respondents agree that greywater can be utilized. A classification based on age also indicates that at least 67% of respondents (in each age group) believe greywater can be reused. Further, as the level of education increases, the respondents are more likely to support the reuse of greywater.
- According to more than 80% of respondents, greywater could be used for both economic and environmental reasons. At least 66% (in each age-group) believe that greywater can serve both economic and environmental purposes. The results also indicate that as education levels increase, respondents find themselves more favorable to the use of greywater for both purposes.

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