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استدامة عبر الأبعاد الاجتماعية والبيئية والاقتصادية

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**Assessing the Feasibility of Greywater Reuse Projects Using Ablution Water
in Riyadh Mosques: A Sustainability Analysis Across Social,
Environmental, and Economic Dimensions**

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DEDICATION

I dedicate this project to my parents and am thankful to them for all that they have done for me. I am also grateful to all the people who participated in the survey and provided me with useful information. I am thankful to my friends who helped me in this project. I am also grateful, Dr. Al Faisal Abdul Hamid, and Dr. Fayez Jarad, who supported me throughout this project.

المستخلص

يمكن تصنيف مياه الوضوء على أنها مياه رمادية. يمكن تعريف المياه الرمادية بأنها أي مياه صرف منزلي تُنتج باستثناء مياه المجاري. يكمن الفرق الرئيسي بين المياه الرمادية ومياه المجاري (أو المياه السوداء) في الجمل العضوي. إعادة استخدام المياه الرمادية تُعد من البدائل الرئيسية لتقليل استهلاك المياه في المنازل والصناعات والمباني التجارية والمساجد. يوفر إعادة استخدام المياه الرمادية المعالجة كمية كبيرة من المياه غير الصالحة للشرب (قابلة للاستخدام في أغراض أخرى)، وهي من الحلول التي تتطلع إليها دول العالم حاليًا في ظل تناقص مصادر المياه المختلفة—سطحية أو جوفية أو مطرية. تُعد المملكة العربية السعودية بشكل خاص محدودة الموارد المائية وتحتل مراكز متأخرة عالميًا من حيث نصيب الفرد من المياه. تستند هذه الدراسة إلى ثلاثة محاور رئيسية: الاجتماعية والبيئية والاقتصادية. كانت الأهداف الرئيسية لهذه الدراسة مناقشة الجوانب المتعلقة بإعادة استخدام المياه الرمادية في المساجد. تمت مناقشة أنواع المعالجة بالتفصيل، ودراسة جدوى إعادة استخدام المياه الرمادية. بعد التحليل الإحصائي للمحور الاجتماعي، وُجد أن أكثر من 71% من المشاركين في الاستبيان لم يكونوا على دراية مبدئية بالمياه الرمادية. بعد تعريف المياه الرمادية للمشاركين قبل الإجابة على الاستبيان، تبين أن 76% من المشاركين يدعمون معالجة وإعادة استخدام المياه الرمادية. أظهرت الدراسة أن مياه الوضوء تلتزم تمامًا بمواصفات الكود الأمريكي للاستخدامات الزراعية وتندفق المراحيض، باستثناء العكارة. أثبتت الدراسة وجود علاقة مباشرة بين انخفاض العكارة في مياه الوضوء وكثافة ألياف النخيل المهدرة. من وجهة نظر اقتصادية، أثبتت الدراسة أن فترة استرداد الاستثمار لإعادة استخدام مياه الوضوء في المساجد لأغراض الزراعة وتدفق المراحيض قد تأتي بعد 9 أعوام، مع الاعتماد على دراسات أخرى تشير إلى انخفاض الاستهلاك بنسبة 50%.

ABSTRACT

Ablution water can be classified as Greywater. Greywater can be defined as any domestic wastewater produced, excluding sewage. The main difference between greywater and sewage (or blackwater) is the organic loading. Greywater reuse is one of the main alternatives for reducing water consumption in households, industries, commercial buildings and mosques. The reuse of treated Greywater 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 is considered limited in water resources and comes at end of the countries in the world in terms of the capita share of water. This study based on three main axes: social, environmental and economic. The main objectives of this study were to discuss aspects related to greywater reuse in mosques. The types of treatment are discussed in detail, and study of the feasibility for reusing the greywater. After the statistical analysis of the social axis, it was found that more than 71% of the survey participants were initially not aware of the Greywater. After defining Greywater for how answering the questionnaire, it was found that 76% of the survey participants support the treatment and reuse of Greywater. The study showed that ablution water completely complies with the specifications of the American code for agriculture and toilet flushing, with the exception of turbidity. The study proved that there is a direct relationship between decreasing turbidity with ablution water and the density of wasted palm fiber. From an economic point of view, the study proved that the pay back of the investment to reuse ablution water in mosques for agricultural and toilet flushing uses may come after 9 years, with reliance on other studies that consumption is decreasing by 50%.

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LIST OF SYMBOLS AND ABBREVIATIONS

<i>KSA</i>	<i>Kingdom of Saudi Arabia</i>
<i>L/c/day</i>	<i>Liter per Capita per day</i>
<i>NWA</i>	<i>National Water Company</i>
<i>EEA</i>	<i>European Environment Agency</i>
<i>ACC</i>	<i>American Chemistry Council</i>
<i>SQU</i>	<i>Sultan Qaboos University</i>
<i>TNIA</i>	<i>Tancredo Neves International Airport</i>
<i>NPV</i>	<i>Net Present Value</i>

CHAPTER 1. INTRODUCTION

1.1 BACKGROUND

The annual water consumption in the Kingdom of Saudi Arabia (KSA) is around 278 L/c/day [1]. While the annual average water consumption in some countries is around 170.25 L/c/day [2-7] as, shown in Figure:1.1. It can be observed that Saudi Arabia might face challenges in terms of water shortage because the percentage of non-renewable groundwater out of the total annual water consumption in KSA is 82% [1]. Hence, this study is focusing on taking advantages of greywater by reuse it in order to contribute to water shortage solutions. The KSA Vision 2030 aims to reduce the annual water consumption around 150 L/c/day [8].

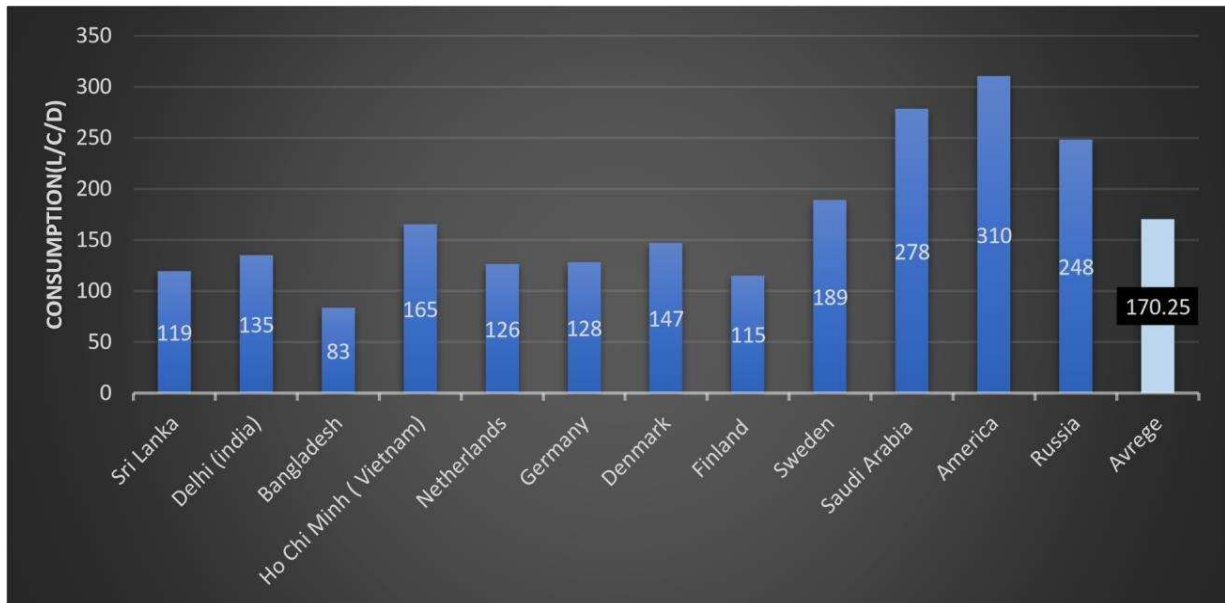


Figure1.1: Show the consumption in several countries [2-7]

1.2 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 that:

- Assess the social acceptance of reusing ablution water in mosques,
- Evaluate the environmental suitability of treated ablution water for uses such as irrigation and toilet flushing, and
- Analyse the economic feasibility and payback period of implementing such systems in Riyadh mosques.

Therefore, the core problem that this study addresses is the absence of a clear, evidence-based assessment of the feasibility (social, environmental, and economic) of reusing ablution water in Riyadh mosques as a means to reduce potable water consumption and support national sustainability goals.

1.3 IMPORTANCE OF THE RESEARCH

1.3.1 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.
- ❖ It provides an integrated sustainability assessment framework that simultaneously considers social acceptance, environmental quality (pH, turbidity, TDS, conductivity), and economic feasibility (cost, savings, and payback period) in one applied case study.
- ❖ 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.
- ❖ By testing a low-cost, natural filtration medium (wasted palm fiber) to reduce turbidity, the research opens a pathway for further scientific investigations into sustainable, locally available treatment technologies suitable for arid regions.

1.3.2 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.
- ❖ The economic analysis, including detailed costing of PVC pipes, storage tanks, and pumps, and the calculation of payback periods under different consumption scenarios, gives mosque administrators and government agencies a realistic financial basis for investment decisions.
- ❖ The survey results regarding public awareness and acceptance of greywater reuse in Riyadh can guide awareness campaigns, policy design, and community engagement strategies to increase acceptance and safe adoption of greywater systems.
- ❖ The treatment findings, especially regarding turbidity and the use of palm fiber filters, provide practical guidance for simple, low-cost improvements needed to meet relevant standards for agricultural irrigation and toilet flushing.

1.4 OBJECTIVES OF THE RESEARCH

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, environmental, and economic dimensions. 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, environmental, and economic aspects.
- ❖ 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.
- ❖ To evaluate the environmental quality of ablution water collected from different types of mosques (residential, commercial, and industrial) and compare the results with international standards for agricultural reuse and toilet flushing.

- ❖ To analyse the economic feasibility of implementing ablution water reuse systems in Riyadh mosques by estimating capital and operating costs, potential water bill savings, and payback periods under different consumption scenarios.

1.5 QUESTIONS OF THE RESEARCH

To what extent is it feasible to reuse ablution water from mosques in Riyadh as greywater for irrigation and toilet flushing from social, environmental, and economic perspectives? In order to address this main question, the study examines the following sub-questions:

- ❖ What is the current level of public awareness and acceptance of greywater and ablution water reuse among residents of Riyadh?
- ❖ What are the main social factors (such as age, education level, perception of water scarcity, and perceived risks) that influence public attitudes towards the reuse of ablution water in mosques?
- ❖ What are the key physico-chemical characteristics of ablution water in Riyadh mosques and how do these parameters compare with international standards for agricultural irrigation and toilet flushing?
- ❖ Can simple, low-cost treatment methods, such as filtration using wasted palm fiber combined with basic disinfection, improve the quality of ablution water to meet the required standards, particularly with respect to turbidity?
- ❖ What are the expected cost components (e.g. pipes, storage tanks, and pumps) and the potential water bill savings associated with implementing ablution water reuse systems in Riyadh mosques?
- ❖ What is the expected payback period for such systems under minimum, average, and high water consumption scenarios, and how does this period support the economic feasibility of the project?
- ❖ How can the findings of this study be translated into practical recommendations and policies that support sustainable water management in the Kingdom of Saudi Arabia, in line with Vision 2030?

1.6 OVERVIEW OF THE REPORT

1.6.1 Chapter One

This chapter introduces the project, discussed the problem statement, and finalized the project's completed objectives.

1.6.2 Chapter Two

This chapter documents the literature review related to sustainability of Greywater. It explains general, social, characteristics, environmental and economic of greywater.

1.6.3 Chapter Three

In this chapter, explained the project's methodology and documented how the objectives were finalized for the survey, quality and suitability and economic feasibility for collecting the data.

1.6.4 Chapter Four

This chapter analyses and gives results for survey, quality and suitability and economic feasibility.

1.6.5 Chapter Five

This chapter documents conclusion for the graduation project.

1.6.6 Summary

This chapter identify the introduction and objective of this project. It provides an overview of the report and project results.

CHAPTER 2. LITERATURE REVIEW

2.1 GENERAL

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.

2.2 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].

2.2.1 The Source of Greywater

According to [19] the sources of greywater are as follows:

1-Automatic clothes washer: Suspended solids (dirt, lint), organic material, oil and grease, sodium, nitrates and phosphates (from detergent), increased salinity and pH, bleach.

2-Automatic dishwasher: Organic material and suspended solids (from food), bacteria, increased salinity and pH, fat, oil and grease, detergent.

3-Bathtub and shower: Bacteria, hair, organic material and suspended solids (skin, particles, lint), oil and grease, soap and detergent residue.

4-Sinks, including kitchen: Bacteria, organic matter and suspended solids (food particles), fat, oil and grease, soap and detergent residue.

2.3 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%).

2.4 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].

2.5 THE ABILITY TO DRINK THE GREYWATER

Nemirov and her colleagues set out to get an idea of whether or not people wanted to drink treated water, A survey of 2,700 people from 5 US states, And the result was: 38% of these people said yes, and nearly 50% say they're hesitant, and 13 of them flatly refused. The respondents were then asked about their desire to drink water, after being subjected to various purification processes such as: Dirt Insulation, and purification, it was found that the percentage

of those who refused and were hesitant did not change significantly, that is, explaining the purification processes was not helpful in convincing them or changing their minds [26].

2.6 CHARACTERISTICS OF GREYWATER

Characteristics of greywater are highly influenced by lifestyle, social and cultural behaviour of the reside availability of water and its consumption [27]. The reuse of greywater may make some effects on the environment, plants and human. Here we will see the effectiveness of that to develop it to meet the standards.

The effect of grey water on the environment

Development which uses and conserves and enhances community resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future can be improved. The reuse of greywater is an example of sustainable development in practice through water conservation. The most obvious benefit of greywater reuse is water conservation. Domestic reuse of greywater will help the environment by reducing demand on higher quality water resources. One of the main environmental risks resulting from greywater reuse is that of groundwater pollution. It is possible that some of the substances found in greywater may find their way into the groundwater reserves underlying the area of reuse. To minimize the adverse effects of greywater reuse on groundwater and in order to ensure that the greywater system is used effectively, according to [28] Grey water poses severe damage to plants and soil. These are the damages that a person may not touch in the near future. Its effect will appear in the future by imbalances in the nature of the soil and the components of cultivated plants. As for the soil, the continuous accumulation of various salts and chemicals affects the effectiveness and fertility of the soil from an agricultural point of view. These salts and toxic chemicals accumulate in the fruits of the plant and then move through the human food and accumulate in the body and affect it [29].

The effect of grey water on plants

According to [30], Plants are affected when greywater is reused for irrigation, This is due to the possibility of the presence of some pollutants in this water, Various greywater sources contain many substances that have negative effects on plants, such as sodium and chloride, which pose a great danger to some types of plants, the effect of sodium is to reduce the ability of the soil to absorb water, And all the damage to the plant can be avoided so that we reuse the greywater in thoughtful ways.

The effect of grey water for human use

Microbial and chemical contamination of greywater poses a threat to health, that is, it can be said that the risks arising from the reuse of greywater increase as the chemical and microbial pollution increases, Diseases may be transmitted to humans as a result of reusing greywater, this transmission of diseases occurs in different ways, including [31]:

- 1-Direct contact with greywater
- 2-Drinking water pollution
- 3-Using vegetables or other food products that have been exposed to contaminated water and soil
- 4-Inhalation of mist from irrigation using greywater.

Types of greywater treatment

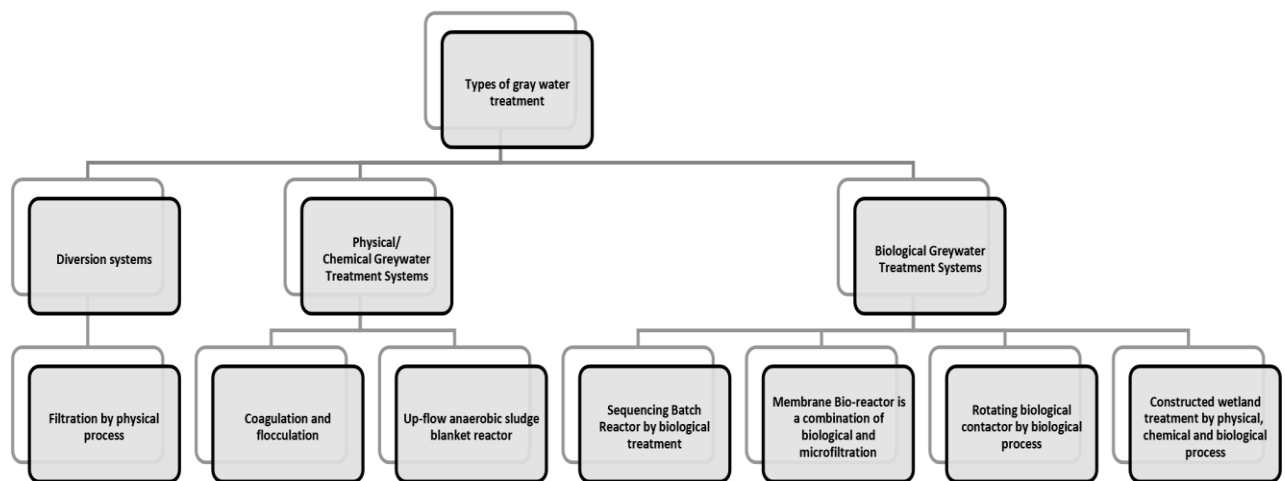


Figure 2.1: Types of Greywater treatment

There are a variety of commercial greywater systems available that filter water to remove hair, lint, and debris, and remove pollutants, bacteria, salts, pharmaceuticals, and even viruses from greywater. Greywater treatment divide into three main categories: diversion systems, physical greywater treatment systems and finally, biological greywater treatment systems [35].

Diversion systems

Which do not store greywater (but may filter and disinfect it) before immediate reuse for example toilet flushing and according to [36] The reuse of greywater for toilet flushing and garden irrigation has an estimated potential to reduce domestic water consumption by up to 50%.

Physical/ Chemical Greywater Treatment Systems

Greywater systems that involve storing greywater must treat the greywater to reduce the bacteria and other microorganisms that can multiply in stagnant water. Physical and chemical greywater treatment systems primarily utilize disinfection and filtration to remove contaminants while biological treatment uses aeration and membrane bioreactors [20].

Biological Greywater Treatment Systems

The processes of biological treatment systems include fixed film reactors rotating biological contactor, anaerobic filters, sequencing batch reactor, membrane Bioreactors and biological aerated filters (BAF) [37].

2.7 GREYWATER STORAGE

In general, it can be said that all forms of wastewater rot when stored unless treated, this also happens when storing greywater. When storing it, it rots and produces unpleasant odors, and bacteria multiply dozens of times when storing from 24 to 48 hours, Therefore, it is necessary when using greywater to use it directly and not to store it [38]. Also, both [39,40] say that untreated greywater cannot be stored for more than 24 hours, because it will turn septic due to microbial activity. Therefore both [39,40] say that the size of the storage tank is at least 2.4 times the maximum expected flow to allow sludge accumulation and sludge loading.

2.8 GREYWATER IS BETTER THAN TREATED WATER

Greywater systems range from simple low-cost devices that divert greywater to direct reuse, such as in toilets or outdoor landscaping, to complex treatment processes incorporating sedimentation tanks, bioreactors, filters, pumps, and disinfection [20]. Some greywater systems are home-built, do-it-yourself piping and storage systems.

2.9 THE EFFECT OF USING GREYWATER ON SEWAGE

On a larger scale, widespread diversion of greywater could potentially be disruptive to wastewater collection and treatment, as a lower volume of wastewater would be diverted for treatment, and it would contain a higher concentration of contaminants and solids. In pipes with low slopes, this could potentially lead to insufficient flows in sewers to carry waste to the treatment plant [21].

2.10 ECONOMIC POTENTIAL OF SAVING GREYWATER

We found in some studies, according to [41], greywater represents a substantial fraction (50-80%) of total wastewater produced in a household. On the other hand [42] state that greywater use in toilet flushing and landscape irrigation can reduce water consumption in at least 50%. therefore, we must see the quantities of the greywater that is produced in the mosques and calculate the cost of the system and the return cost.

The return of the cost of the system

The study was carried out in the Tancredo Neves International Airport (TNIA), in the municipality of Confins, the capital of Minas Gerais State, Brazil. In 2011, the airport consumed 259,470 m³ of water, which is 31% higher than the volume consumed in 2010. [43]. The economic analysis was performed by using the Net Present Value (NPV) and the Payback period. The NPV comprises all expected expenses and revenues at a certain discount rate, presenting the return of the investment in a certain period. The payback is obtained when the NPV is equal to zero and considers many different factors, such as opportunity costs, discount rates and inflation during the analysed period. These indexes are commonly used to evaluate different alternative water system options.

The NPV calculation is shown in Equation (2.1):

The payback period is obtained according to Equation (2.2):

$$NPV = -I + \sum_{t=0}^n \frac{Bt - Ct}{(1+i)^t} \quad (2.1)$$

$$I = \sum_{t=0}^n \frac{Bt - Ct}{(1+i)^t} \quad (2.2)$$

where I is the initial investment, Bt are the benefits and Ct are the costs in the period t and i is the discount rate in both equations. The payback is represented by t and is calculated iteratively until the two sides of the equation are equal. These indexes consider all the costs involving greywater treatment and reuse system construction, the operation and maintenance costs in an established period of time, as well as the financial and environmental benefits of the reduction of the potable water demand.

The implementation cost of greywater treatment system in the TNIA buildings was US\$ 22,905.75, with a payback period of 5 years. Moreover, in a 10 years period, the NPV for the

considered inflation and discount rate was US\$ 1048.00. The period of time required to return the investment in the greywater treatment and reuse system in the TNIA was relatively short, with reduction perspectives considering the cost of a cubic meter of water paid by TNIA, which is relatively low compared to other places. These values were obtained for a specific and welldefined scenario, proving through a widely used numerical method the economic viability of greywater reuse in airports by a simple technology. However, there are other scenarios that can be as, or more viable e both financially and environmentally - than the one described. It is important to highlight the possibility of integration between measures related to water conservation practices and to renewable energy sources. Airport environments have large rooftop areas, which can collect big volumes of rainwater, thereby meeting a greater fraction of non-potable water demand [44]. Furthermore, the use of solar energy for pumps functioning and for UV disinfection device may represent a reduction in operating costs [45].

On the other hand, according to [46] many examples from literature and practice show that reclamation of grey water is technically possible and will contribute to sustainability of water resources. There are several examples in the literature as well as in practice including housing complexes, hotels, dormitories, etc. to show that grey water recycling especially for flushing toilets is reasonable in terms of costs. This is supported by an appreciable number of building installations for grey water recycling for flushing toilets, indicating that costs were perceived as affordable by consumers as well as constructors. As an example, an analysis of costs for MBR treatment of grey water in Istanbul for households and hotels reveals that expenditures and payback periods are reasonable. As Figure 2.2 shows, both the capital and operating costs level out for 200 units both for households and for hotels for MBR treatment at 200 Euros and 10 Euros, respectively. Corresponding payback periods were found as a little over 2 years and 1 year for households and hotels, respectively.

Up to 100% additional costs may be assumed for piping and other expenditures taking the investment cost up to 400 Euros and payback periods less than 5 years and 3 years, respectively. This estimate was confirmed by various users of grey water recycling in Istanbul, actually with shorter payback periods. It is important to keep in mind that economic affordability of grey water recycling is one of the main concerns of consumers as will be discussed in the next subsection. It is important to realize that acceptances towards this practice is about 4 to 9 times higher if the system is installed for free as compared with installation under self-funding, indicating the critical role of subsidy/incentives as economic instruments for encouraging grey water reuse. Another point to consider is that the value of contribution to sustainability of resources, and positive implication on the environment is not reflected in these cost estimations. What may not be desirable as costs for this sustainable practice at this time may be very significant for future conditions where water may not available or reachable.

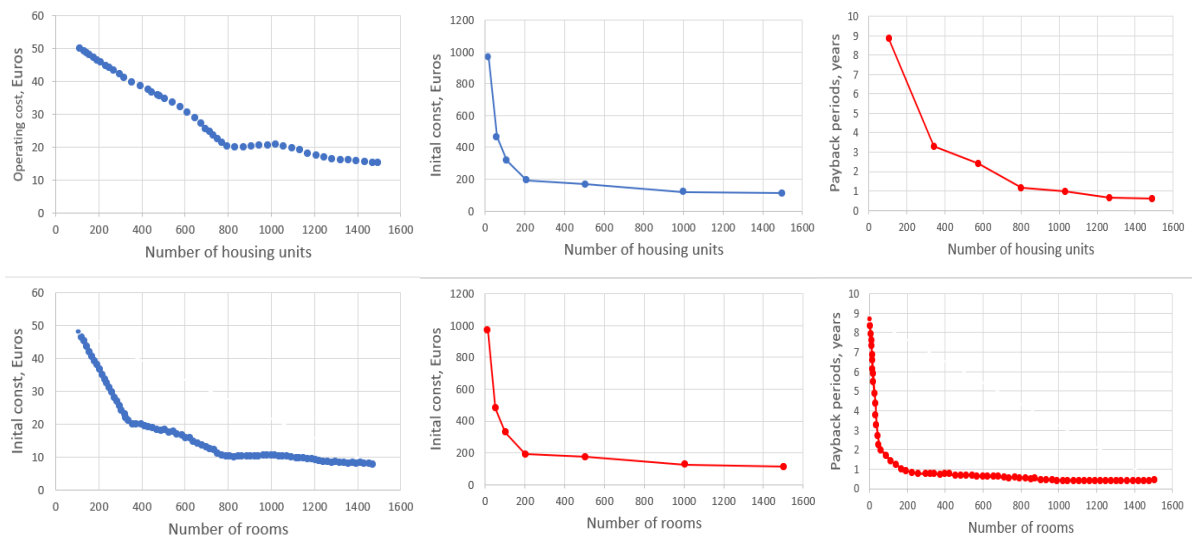


Figure 2.2: Costs and payback periods for MBR treatment for households and hotels in Istanbul [46].

Quantities of greywater produced from mosques

Greywater in the mosque constitutes 55% to 75% of the water used. It is purer than other greywater in the house and others. Recycling and reusing it is not harmful to the environment if the specified conditions and specifications are applied, It can be reused in agriculture, increase the vegetation cover in mosques and gardens, and its treatment is economically

inexpensive compared to sewage water. It constitutes a significant resource and reduces the overall demand for water [47].

Greywater treatment cost

Demonstrates that the cost of reclaiming greywater is about 30 – 40% cheaper than supplying potable water to houses in Melbourne, Australia[48]. The total cost of the SAGWRS system is estimated as the sum of all major component costs including initial capital cost construction of tanks, plumbing, pump, tubing, valves and electrical components, filter cost, and operating cost including energy cost and chemical depreciation cost. The optimum cost has been estimated based on the life of the treatment system, which was supposed to be 30 years old, and the estimated costs for SAGWRS has range from 0.7 to 1.5 US\$/m³, Much less than the cost of fresh water 1.71 US\$/m³ in Saudi Arabia, estimated net values for water savings range from 30 to 626 US\$/month[49].

CHAPTER 3 METHODOLOGY

3.1 METHODOLOGY

In this project there are three objectives to reach the aim of this project. The first is investigate to what extent the public knowledge of greywater by doing survey. The second is ensuring the quality of greywater and suitability for toilet flushing and agriculture uses by doing some test according to American standard. The third and last verify the economic feasibility and if any an estimate of the period needed to recover.

3.2 SURVEY

The survey will include the Kingdom of Saudi Arabia in terms of citizens and residents of various scientific and age groups. The methodology used in constructing the survey was to review and develop several studies that simulate time and space, as shown in Figure 3.1. In conclusion, the questionnaire contains seventeen questions in both Arabic and English, the answers will be multiple-choice, and the number of answers required for analysis is 750.

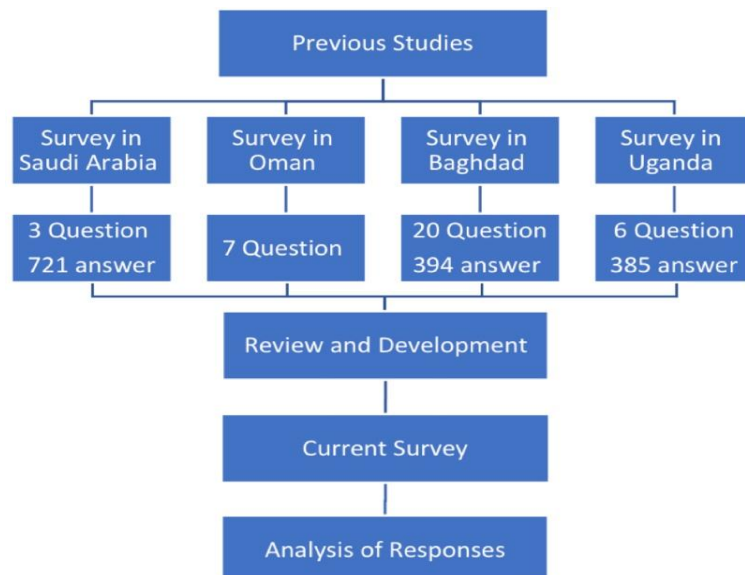


Figure3.1 Research methodology flow chart

Survey link: <https://forms.gle/9mmnoU8aaDQMEdmV8>

3.3 ENVIRONMENTAL

Examining samples of ablution water and comparing it with the American Code of Agriculture and toilet flashing. In case of non-conformity, find a way to processed as shown in the Figure 3.2. Greywater needs a simple fly in order to be able to use it in the toilet or agriculture by mixing it with chlorine and the experiment will prove the amount of chlorine required to disinfect a cubic meter of greywater.

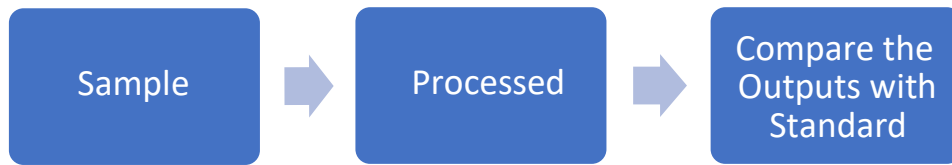


Figure 3.2: Flow chart the sample

3.4 ECONOMIC FEASIBILITY

This research will study the feasibility of the project and use the equation of the payback period (3.1).

$$\text{payback period} = \frac{\text{total cost of the system}}{\text{profit}} = \frac{c}{p} \quad (3.1)$$

Where c is the total cost including the pump, pipes and tank cost, and the unit is SR, P is the profit. the profit is the difference between the water price before the system and the water price after the system. and the profit should be divided by 12, to get the period in years instead months.

CHAPTER 4. RESULTS AND DISCUSSION

4.1 GENERAL

In this chapter, there are the results and the discussion in the three axis, survey, environmental and economic. And shows the ability of reusing the ablution water in mosque and the Investigate to what extent the public knowledge of greywater and the reuse of ablution water and study the environmental feasibility of reusing ablution water and study the economic feasibility of reusing ablution water and provide recommendation to reduce public water consumption of potable water by reusing ablution water in mosques.

4.2 SURVEY

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 type of questions was planned, which is multiple 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 [\[Video documentation\]](#). The collected data was analysed and presented in various formats showing important results. The actual descriptive statistics of the sample variables are presented in Table 4.2.

Table 4.2: Demographic characteristics of sample (646 responses).

		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

4.2.1 Water Price

As shows in the Figure 4.2.1 the different opinions of the water price, and the questionnaire showed if it an expensive or average or cheap. The majority of the questionnaire were the water price is an average price with 299 persons with a ratio of 46.3%, and the other opinions were close to each other, and the second opinion is the water price is cheap with 187 persons with a ratio of 28.9%, and the third opinion is the water price is expensive with 160 persons with a ratio of 24.8%.

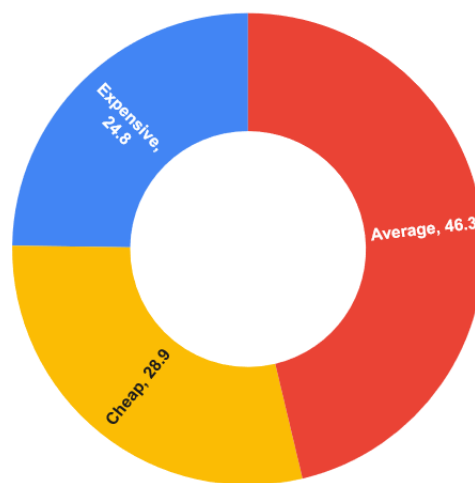


Figure 4.2.1: Water Price

4.2.2 Possibility of Greywater Reuse

The survey data shows Figure 4.2.2 the different opinions of the possibility of greywater reuse, and the questionnaire showed if it a yes or no or maybe. The majority of the questionnaire were the yes with possibility of greywater reuse with 433 person and a ratio of 68.6%, and the answer of impossibility of greywater reuse were 36 persons with a ratio of 5.6%, and 167 persons with a ratio of 25.9 % see maybe there is a possibility of greywater reuse.

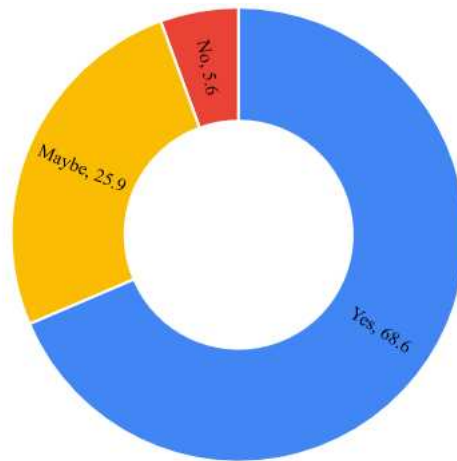


Figure 4.2.2: Possibility of Greywater Reuse

4.2.3 Fresh Water Problem

The survey data shows Figure 4.2.3 the opinion of people in the reuse of fresh water that 76.5% of the respondents support the frequent use of fresh water and 8.0% do not support its use, and the survey data also shows that 15.5% said maybe.

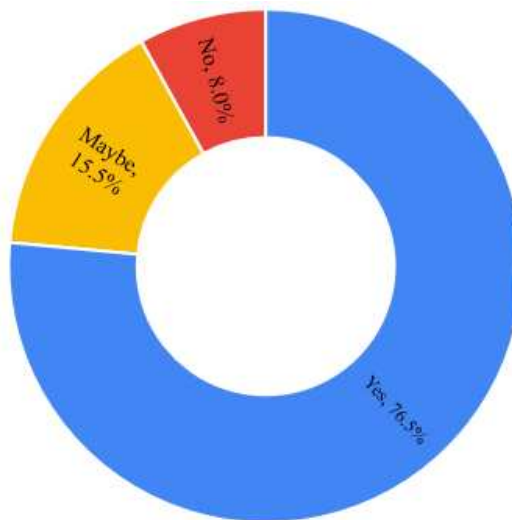


Figure 4.2.3: Fresh water problem

4.2.4 Support the Treatment and Reuse

The collected data Figure 4.2.4 A has also shown that 76% of the survey participants support the treatment and reuse of Greywater and 8% do not support its reuse, and the survey data also shows that 1.5% said maybe. The uses of treated Figure 4.2.4 B Greywater a large percentage do not support drinking it, and a large percentage support its use in washing cars and cleaning the toilet.

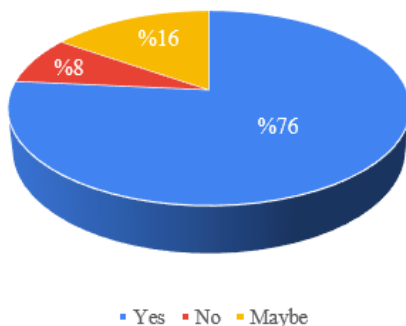


Figure 4.2.4 A: Support of treatment and reuse of greywater

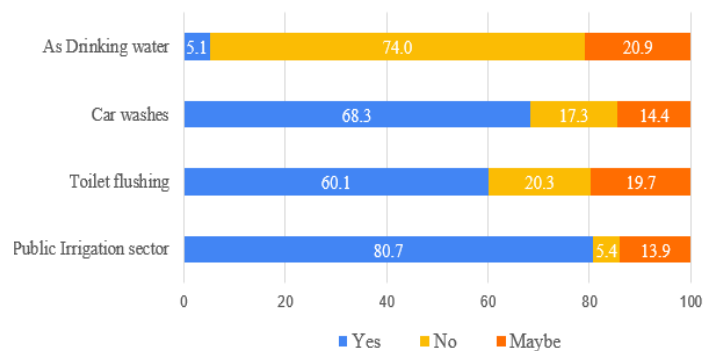
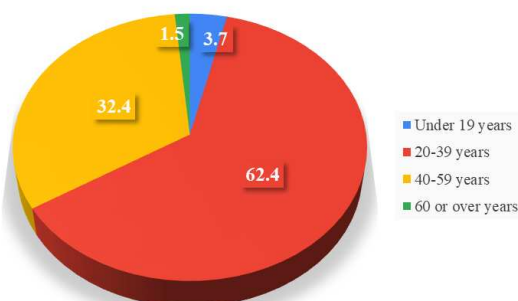


Figure 4.2.4 B: Uses of treated greywater

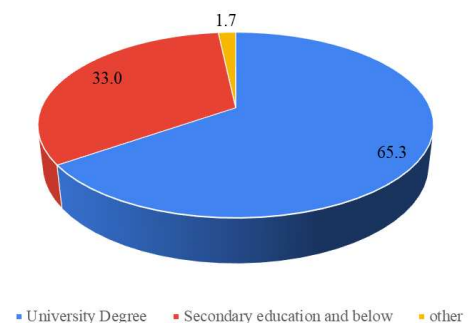
Figure 4.2.4. General information Support of treatment and reuse of greywater

4.2.5 Srespondents General Information

The survey data shows Figure 4.1.5A 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 4.2.5 B.



A) Age groups represented in the survey



B) Education level

Figure:4.2.5. General information about survey respondents

4.2.6 Awareness of Fresh Water Problem

The collected data Figure 4.2.6 A has also shown that less than 50% of the survey respondents is aware that there is a fresh water problem in Riyadh. Figure 4.2.6 B 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 4.2.6 C 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.

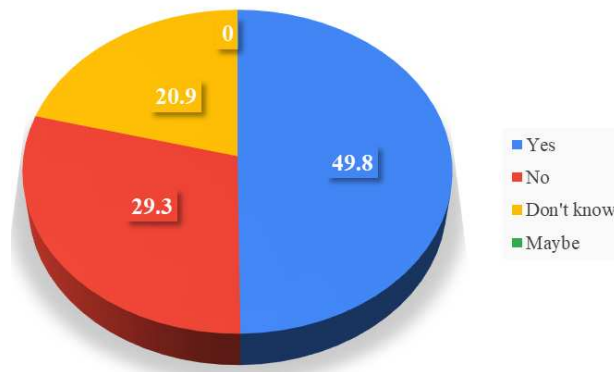
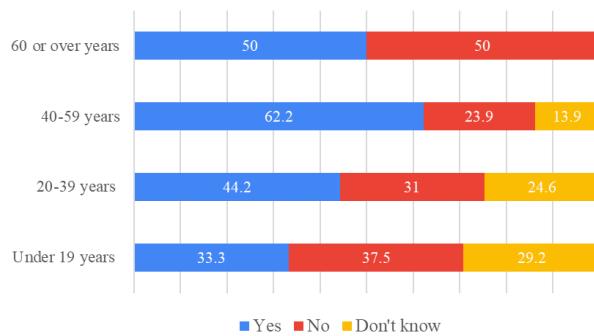
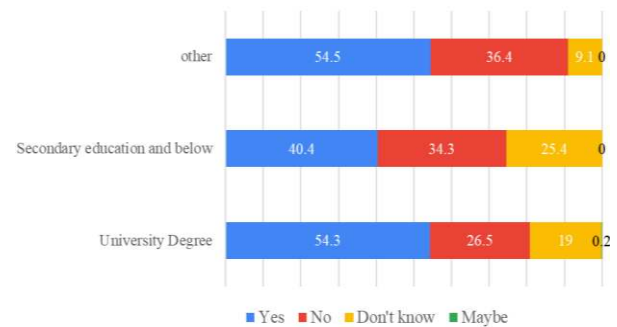


Figure 4.2.6 A: General public awareness of the fresh water problem in Riyadh (All classes)



B) Classification based on age group



C) Classification based on education level

Figure 4.2.6. Awareness of the existence of fresh water problem in Riyadh

4.2.7 Public Opinion on Potable Water Price

The collected data Figure 4.2.1 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.

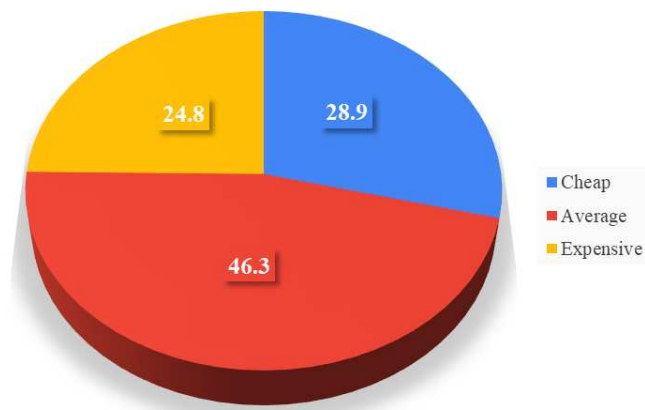
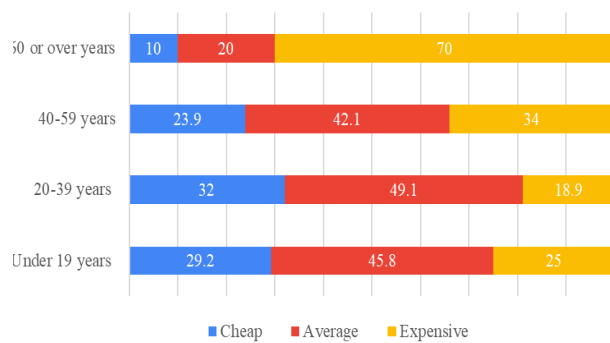
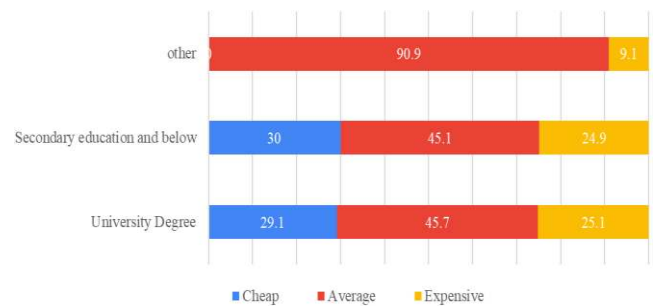


Figure 4.2.7. General public opinion on the price of the potable water in Riyadh (All classes)



B) Classification based on age group

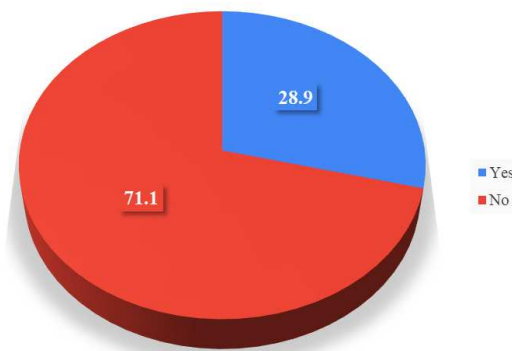


C) Classification based on education level

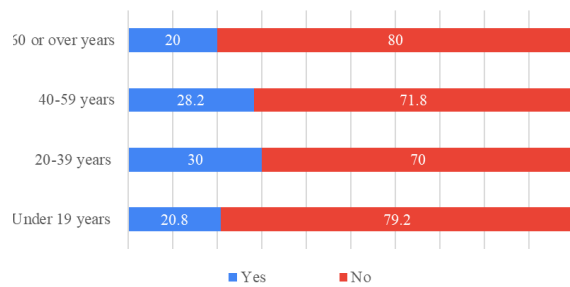
Figure 4.2.1: Water Price

4.2.8 Public Awareness of Greywater Definition

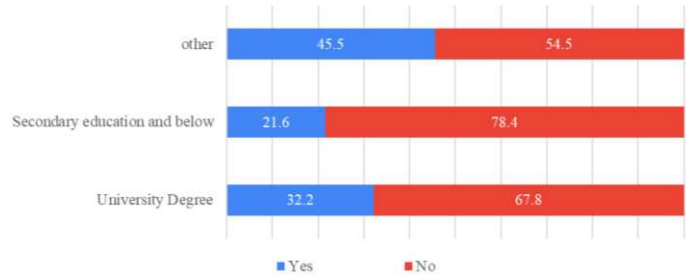
The survey data shows Figure 4.2.8 A that more than 71% of the survey participants were initially not aware of the Greywater therefore they were obliged to read first the definition of the greywater before continuing the survey. It is also surprisingly to note that the awareness of greywater among the elder or the more educated people is not distinguished Figure 4.2.8 B.



A) General public awareness of greywater (All classes)



B) Classification based on age group

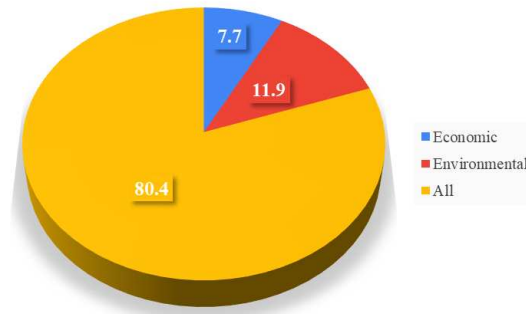


C) Classification based on education level

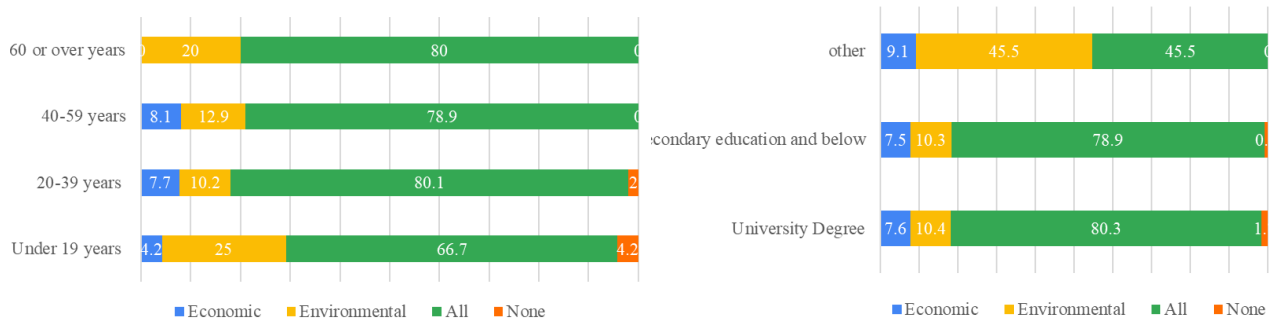
Figure 4.2.8. Public awareness of greywater in Riyadh

4.2.9 Purpose of Greywater Use

Figure 4.2.9 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.



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



B) Classification based on age group

C) Classification based on education level

Figure4.2.9. Purposes of greywater use in Riyadh

4.3 ENVIRONMENTAL

The city of Riyadh was chosen to collect the information to represent the Kingdom of Saudi Arabia. 82 samples were collected from the mosques and houses in Riyadh. The samples were collected from four regions, north, south, west and east of Riyadh. Every region has houses and three types of mosques, Commercial, Residential and Industrial. The samples were taken at the same time from 13 to 19 of September. The actual descriptive statistics of the samples variables are presented in Table 4.3.1.

Table 4.3.1 Demographic characteristics of sample (82 samples)

		Frequency	Percent (%)
Sample source	Houses	5	5.9
	Mosques	81	94.1
Classification of mosques	Residential	24	29.6
	Commercial	24	29.6
	Industrial	24	29.6
	Samples before ablution	9	11.2
Samples before ablution	Residential	3	33.3
	Commercial	6	66.7

4.3.1 Samples

Samples were collected from four regions: North, South, East and West. Mosques in each region were classified into residential mosques, industrial mosques, and commercial mosques. From each region, two samples were taken from each mosque, three samples were taken in application of the American Standard for Sampling. All samples were taken at the same time (Noon Prayer) to ensure the validity of the sample and neglect the time factor. The samples were encoded by writing the code of the person who took the sample, a code for the region, a code for number of mosques and a number for the sample as shown Table 4.3.2. After sampling, the samples were wrapped in a black bag to protect them from light and kept at a temperature of 7-3 C° as shown in the Figure 4.3.1. A, Band C.

Table 4.3.2 Sample coding mechanism

Code of the Person	Ahmed = A	Code for Number of Mosques	Mosques Number1 = M1
	Mohammed = M		
	Abdulaziz = Z		Mosques Number2 = M2
	Saleh = S		
Code for the Region	Residential = R	Number for the Sample	Sample Number1 = 1
	Industrial = I		Sample Number2 = 2
	Commercial = C		Sample Number3 = 3
Example: Ahmed from residential region mosques number1 sample number3 =ARM1-3			



Figure 4.3.1.A: Samples

Figure 4.3.1.B: Covering

Figure 4.3.1.C: Storage Temperature

Figure 4.3.1: collected Samples

Table 4.3.3: Comparison between samples from homes and samples from mosques before ablution

Samples from Homes				
Sample Code	PH	Turbidity	TDS	Conductivity
AH	7.74	0.533	940	1175
MH	7.9	0.705	928	1160
SH	7.02	0.642	940.8	1176
ZH	7.1	0.416	946.4	1183
EH	7.06	0.516	909.6	1137
Samples Before Ablution				
Sample Code	PH	Turbidity	TDS	Conductivity
ARM2-0	7.75	0.45	1040	1300
ARM1-0	7.76	1.62	964.8	1206
MRM1-0	7.85	0.972	860	1075
ACM1-0	7.85	0.715	870.4	1088
ACM2-0	7.05	0.778	938.4	1173
MCM2-0	7.87	0.909	864	1080
MCM1-0	7.86	0.937	865.6	1082
SCM1-0	7.55	0.856	968.8	1211
SCM2-0	7.14	0.877	956.8	1196

In one of the samples, we noticed a significant difference in the results so we took samples before ablution, note and compare the difference of samples before and after ablution, we took samples of the water of the houses to compare them with the samples of the water of the mosques and note the difference between them, we found no difference between the water of homes and the water of mosques before ablution as shown Table 4.3.3.

4.3.2 Samples Analysis

To match the samples with the American Code of Agriculture and toilet flashing, it was necessary to do about ten experiments, but due to the available capabilities, four experiments were worked on, which are PH, Turbidity, Total dissolved solids (TDS) and Conductivity every experience is explained in detail in the Appendix. It was compared with the American Code of Agriculture and toilet flashing, and all results were identical except for the turbidity results, it was bigger than the American Standard. We found that the turbidity in the residential region is the highest value of 13 NTU and the lowest value of 4.8 NTU, while the highest value of the Conductivity in the residential region was 1259 $\mu\text{S}/\text{cm}$ and the lowest value is 1160 $\mu\text{S}/\text{cm}$. TDS can be calculated by multiplying the value of Conductivity by 0.8. About the value of PH in the residential region has the highest value is 7.79 mg/l and the lowest value is 6.48 mg/l as shown in the Table 4.3.4.

Table 4.3.4: Result of experiments on samples of residential region

Region	Person	Mosques	Sample Number	PH	Turbidity	TDS	Conductivity
R	A	M1	1	6.8	11.6	1000	1250
			2	6.6	5.6	915.2	1144
			3	6.6	11.5	972	1215
		M2	1	6.5	17.1	1152.8	1441
			2	6.6	30.1	1077.6	1347
			3	6.7	18.5	1152	1440
	Z	M1	1	7.4	7.83	1002.4	1253
			2	7.3	9.16	1007.2	1259
			3	7.3	8.16	1015.2	1269
		M2	1	7.3	7.22	991.2	1239
			2	7.2	7.1	991.2	1239
			3	7.3	8.32	969.6	1212
	M	M1	1	7.8	7.1	993.6	1242
			2	7.8	7.44	994.4	1243
			3	7.8	6.99	989.6	1237
		M2	1	7.6	10.4	956.8	1196
			2	7.5	10.4	948.8	1186
			3	7.4	10.6	951.2	1189
	S	M1	1	7.5	11.2	968	1210
			2	7.7	13.1	975.2	1219
			3	7.7	13.1	977.6	1222
		M2	1	7.4	5.1	944	1180
			2	7.7	4.8	936	1170
			3	7.8	5.08	928	1160

We found that the turbidity in the industrial region is the highest value is 35.6 NTU which is considered a very high value and the lowest value of 4.4 NTU, while the highest value of the Conductivity in the industrial has the highest value is 1405 $\mu\text{S/cm}$ and the lowest value is 380 $\mu\text{S/cm}$, the PH in industrial region is the highest value is 7.79 mg/l and the lowest value is 7.07 mg/l as shown in the Table 4.3.5.

Table 4.3.5: Result of experiments on samples of industrial region

Region	Person	Mosques	Sample Number	PH	Turbidity	TDS	Conductivity
I	A	M1	1	7.1	35	1124	1405
			2	7.1	35.6	1109	1386
			3	7.4	32.9	1091	1364
		M2	1	7.6	30.4	1089	1361
			2	7.7	26.6	1090	1362
			3	7.7	60	1090	1363
	Z	M1	1	7.4	7.62	334.4	418
			2	7.3	13.3	335.2	419
			3	7.2	12.9	334.4	418
		M2	1	7.2	8.59	324.8	406
			2	7.2	4.8	304	380
			3	7.2	8.5	320	400
	M	M1	1	7.6	9.62	982.4	1228
			2	7.6	9.08	980.8	1226
			3	7.7	8.78	982.4	1228
		M2	1	7.7	4.62	976	1220
			2	7.7	4.89	974.4	1218
			3	7.7	4.4	976	1220
	S	M1	1	7.7	24	1008	1260
			2	7.7	21.9	1002	1252
			3	7.7	44.4	1100	1375
		M2	1	7.8	5.53	1093	1366
			2	7.7	37.4	969.6	1212
			3	7.8	5	1185	1481

We found that the turbidity in the commercial region is the highest value of 21.1 NTU and the lowest value is 2.66 NTU, for Conductivity in commercial region has the highest value is 1439 $\mu\text{S}/\text{cm}$ and the lowest value is 1105 $\mu\text{S}/\text{cm}$, the PH in commercial region is the highest value is 7.63 mg/l and the lowest value is 6.89 mg/l as shown in the Table 4.3.6.

Table 4.3.6: Result of experiments on samples of commercial region

Region	Person	Mosques	Sample Number	PH	Turbidity	TDS	Conductivity
c	A	M1	1	7.6	3.91	884	1105
			2	7.6	3.69	890.4	1113
			3	7.6	4.04	891.2	1114
		M2	1	6.9	8.98	1018	1273
			2	6.9	8.77	1020	1275
			3	6.9	9.42	1019	1274
	Z	M1	1	7.3	3.15	940.8	1176
			2	7.5	3.57	944	1180
			3	7.4	4.8	949.6	1187
		M2	1	7.4	2.66	936.8	1171
			2	7.4	5.16	949.6	1187
			3	7.4	2.7	936	1170
	M	M1	1	7.5	6.89	905.6	1132
			2	7.5	6.76	904.8	1131
			3	7.5	6.19	909.6	1137
		M2	1	7.5	6.72	892.8	1116
			2	7.5	6.85	890.4	1113
			3	7.1	5.44	890.4	1113
	S	M1	1	7.4	7.31	995.2	1244
			2	7.3	16	1081	1351
			3	7.4	6.12	1010	1262
		M2	1	7.3	21.1	1151	1439
			2	7.4	10.6	1029	1286
			3	7.2	7.8	1067	1334

4.3.3 Reprocessing

In American Code of Agriculture and Toilet Flashing the turbidity value does not exceed 5 NTU but in all samples was collected from mosques after ablution the turbidity was more than 5 NTU. Since the turbidity is high, more than one method has been tested, a sustainable filter was produced using wasted palm fiber as shown in Figure 4.3.2 A, taking into account the accuracy, the palm fiber was taken from one of the houses in the Riyadh region it was not purchased from the agricultural shop. Experiments were done on palm fiber as shown in Figure 4.3.2 B. The experiments done by using different layers of wasted palm fiber as shown in Figure C, D and F. It was found to be effective, through experiments, it became clear to us that when we increase the thickness of the wasted palm fiber it reduces the turbidity.



Figure 4.3.2 A: Palm



Figure 4.3.2 B: Tested



Figure 4.3.2 C: One-Layer



Figure 4.3.2 D: Two-Layers



Figure 4.3.2F: Three-Layers

Figure 4.3.2: Photo from lap shows layer of Palm Fibber and tested

4.4 ECONOMICAL

The Kingdom of Saudi Arabia is considered third in the world in the consumption of water in the world. KSA is one of the countries that suffer from shortage and poverty in fresh water. Groundwater consumption constitutes 73% of the total consumption of the Kingdom and is the highest source. It is worrying that 82% of groundwater in the Kingdom is not renewable. For this reason, the vision of the Kingdom of Saudi Arabia for the year 2030 aims to maximize resources and the trend towards sustainability and leadership in all fields. The most important pillars of sustainability is the economic aspect. That is why the return on investment (Payback Period) was studied to reuse ablution water in mosques in Riyadh. The impact on the mosques will be to reduce the mosques need for water with the same consumption by reusing half of the water consumed for agricultural and toilet flushing purposes. The cost has been considered are cost of pipes, cost of tank and cost of pump. The profit is the difference between the bill before and after the reuse of water for ablution.

4.4.1 Cost

A) Searching and collecting data on pipes through specialized stores. and noting that PVC pipes Figure 4.4.1 A are usually used in mosques. The results of the cost research are shown in the Table 4.4.1 A.

Table 4.4.1 A: Data collected form stores for PVC pipes



Figure 4.4.1 A: PVC pipes

No.	Size (inch)	Length (m)	Cost (SR)	Cost (SR/m)
1	0.5	5.8	26	4.48
2	0.75		42	7.24
3	1		66	11.38
4	1.25		102	17.59
5	1.5		175	30.17
6	2		273	47.07

The size that is usually suitable for mosque use are 0.5 or 0.75 inch. The most expensive pipe was taken into account, which is 0.75 inch and cost 7.24 SR per meter.

B) Searching and collecting data on tank through specialized stores and noting that horizontal shop water tank Figure 4.4.1 B are usually used in mosques. The results of the cost research are shown in the Table 4.4.1 B.



Figure 4.4.1 B: Horizontal shop water tank

Table 4.4.1 B: Data collected form stores for tank

No.	Volume(L)	Volume(m ³)	Cost (SR)	Cost (SR/m ³)
1	1500	1.5	870	580.0
2	2000	2	1030	515.0
3	2500	2.5	1250	500.0
4	3000	3	1450	483.3
5	4000	4	1850	462.5
6	5000	5	2350	470.0
7	6000	6	2850	475.0
8	7000	7	3400	485.7
9	9000	9	4390	487.8
10	10000	10	4550	455.0

To facilitate the process of calculating the price, the average price of the tank = 491.4 SR per cubic meter as shown below.

$$Average = \frac{580 + 515 + 500 + 483.3 + 462.5 + 470 + 475 + 485.7 + 487.8 + 455}{10} = 491.4$$

C) Searching and collecting data on pump through specialized stores. The results of the cost research are shown in the Table 4.4.1 C.

Table 4.4.1 C: Data collected form stores for pump

No.	Flow (Liter per Minute)	Force (HP)	Head (m)	Cost (SR)
1	50	0.75	65	314
2	60	1	70	424
3	130	2	41	1600
4	138	0.5	23	750
5	205	1.5	30	962
6	1000	3	18	1300

To

facilitate the process of calculating, the most expensive pump is considered = 1300 SR.

4.4.2 Profit

The profit is to see the difference in the cost of conception before the system and after applying the system, from here we get the profit. To find out the water and sewage bill for the mosques in the city of Riyadh, before reusing the water for ablution, the Ministry of Islamic Affairs, Dawah and Guidance was used, because all the mosques in KSA oblong to this ministry. The Ministry has provided 8 separate mosque bills in Riyadh. The bills are attached in the appendix.

Table 4.4.2 A shows Some information from bills.

Table 4.4.2 A: Data collected from Ministry of Islamic Affairs, Dawah and Guidance

Neighborhood	Average last 13 months	Quantity of consumption	Total cost	Cost per meter cubic
Dirab	11	9	98	10.8
Alshomaisi	66.1	63	658	10.4
Almalaz	142.7	114	1185.85	10.4
Qurtubah	38	101	702.85	7
Alnatheem	80	101	1051.30	10.4

There are more than these mosques but were ignored because on the last 13 month the consumption has completely different consumption in each month as shown on the appendix B. After analyzing the bills, it was found that the cubic meter costs 10.4 Saudi riyals, regardless of consumption, while the government system is supposed to use the following pricing in Table 4.4.2 B.

Table 4.4.2 B: Consumption pricing form government

No.	1	2	3
Consumption(m ³)	<25	25-40	>60
Price (SR per m ³)	5	10	15

Table 4.4.2 C shows below Billing information with pricing used in mosques and regular and average pricing.

Table 4.4.2 C: Average form average last 13 months, Actual and Governmental cost

Neighborhood	Average last 13 months	Actual cost	Governmental cost
Dirab	11	118.8	55
Alshomaisi	66.1	687.44	991.5
Almalaz	142.7	1484.08	2140.5
Qurtubah	38	266	380
Alnatheem	80	832	1200
Average	67.56	677.664	953.4

We assume 67.56 m³ is average consumption for the mosques in Riyadh and 677.66 SR per m³ per month is average consumption price for the mosques in Riyadh. Based on previous studies, the application of the ablution water reuse system reduces consumption by 50% so average consumption for the mosques in Riyadh after reuse ablution water is 33.78 m³ and the average consumption price for the mosques in Riyadh after reuse ablution water by apply actual cost is 351.31 SR per m³ per month, while and the average consumption price for the mosques in Riyadh after reuse ablution water by apply governmental cost is 337.8 SR per m³ per month. Table 4.4.2 D. shows the comparison between the price before and after applying the system. The profit for actual cost is 326.35 SR for each month and the profit for governmental cost is 339.86 SR for each month.

Table 4.4.2 D: Cost of water before and after system

Neighborhood	Before		
	Consumption (m ³)	Actual Cost (SR)	Governmental Cost (SR)
Dirab	11	118.8	55
Alshomaisi	66.1	687.44	991.5
Almalaz	142.7	1484.08	2140.5
Qurtubah	38	266	380
Alnatheem	After		
Neighborhood	Consumption (m ³)	Actual Cost (SR)	Governmental Cost (SR)
Dirab	5.5	57.2	27.5
Alshomaisi	33.05	343.72	330.5
Almalaz	71.35	742.04	1070.25
Qurtubah	19	197.6	95
Alnatheem	40	416	400

In the case of assuming a high cost for pipe and apply it in the minimum comparison, highest comparison and average comparison the Payback will be as shown in the Table 4.4.2 E.

Table 4.4.2 E: The Payback by assuming minimum, average and highest comparison

	Minimum	Average	Highest
Pump cost (SR)	1300	1300	1300
Tank cost (SR)	2702.7	33199	35061.34
Pipe cost (SR)	72	72.4	72.4
Total cost (SR)	4075.1	34571.4	36433.8
Profit (SR/m) A	61.6	326.4	742
Profit (SR/m) G	27.5	339.9	1070.3
PayBack (Year)A	6	9	5
PayBack (Year)G	13	9	3
A: Actual Cost and G: Governmental Cost			

When minimum consumption takes into consideration the cost equal around 4100 SR and the payback comes 6 years for actual cost and 13 years for governmental cost. Put when Average consumption takes into consideration the cost equal around 35000 SR and the payback comes 9 years for actual cost and governmental cost and for highest consumption consideration the cost equal around 36000 SR and the payback comes 5 years for actual cost and 3 years for governmental cost.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

5.1 GENERAL

This chapter shows the conclusion and recommendations of this project, as well as recommendations that are taken in the stage of developing the project and shows the same aim and objectives of this research that are the ability of reusing ablution water in mosques for agriculture and toilet flushing , Investigate to what extent the public knowledge of greywater and the reuse of ablution water, Study the environmental feasibility of reusing ablution water, Study the economic feasibility of reusing ablution water, Provide recommendation to reduce public water consumption of potable water by reusing ablution water in mosques.

5.2 SURVEY

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.

5.3 ENVIRONMENTAL

There are more than 80,000 mosques in the Kingdom of Saudi Arabia, and the average consumption of Riyadh mosques is approximately 66 cubic meters per month. The large consumption in mosques is one of the reasons for the Kingdom of Saudi Arabia to search for alternative and sustainable solutions to reduce water consumption. The main objective of the study is to assess the extent of the ability to reuse the ablution water in mosques for the purposes of agriculture and toilet flushing, based on the. In this regard, samples were collected, analysed and processed and the main findings of the study are presented below: According to the outputs of the tests the highest value of Conductivity for fresh water is 1183 $\mu\text{S}/\text{cm}$ and the lowest value is 12.75 $\mu\text{S}/\text{cm}$, the highest turbidity value for fresh water is 0.705 NTU and the lowest value is 0.416 NTU, the highest value in turbidity for water before ablution is 1.62 NTU and the lowest value is 0.450 NTU, the highest value in turbidity is in the industrial area and the lowest in fresh water. the highest Conductivity value is in the residential region and the lowest in fresh water. The Conductivity, PH and TDS its outcomes were fairly close in all regions, unlike turbidity from one region to another, however turbidity is the only ingredient that did not match the specifications of American code, The problem of turbidity was solved by using a filter made of wasted palm fibre, and after experiments, the fibber proved its efficacy on reducing turbidity in a direct proportion to the density of the fibber. The recommendations of this research are to study the effect of the filter (waste palm fiber) no the waste water to know exactly the size (thickness) of the filter to reach 5 NTU or less of turbidity according to American Code of Agriculture and Toilet Flashing.

5.4 ECONOMICAL

The annual water consumption in the Kingdom of Saudi Arabia is around 278 L/c/day. While the annual average water consumption in some countries is around 170.25 L/c/day. It can be observed that Saudi Arabia might face challenges in terms of water shortage water scarcity because the percentage of non-renewable groundwater out of the total annual water consumption in KSA is 82%. Hence, this study is focusing on taking advantages of greywater by reuse it in order to contribute to water shortage solutions. The KSA Vision 2030 aims to reduce the annual water consumption around 150 L/c/day. The main objective of the study the economic feasibility of reusing the ablution water in mosques for agricultural and toilet flushing uses. What makes the reuse of ablution water in mosques for agricultural and toilet flushing uses an ideal solution for the Kingdom of Saudi Arabia is that its goal for the year 2030 is to increase the percentage of vegetation cover and reduce water consumption. On the same side, reusing the water for ablution in mosques is considered a sustainable solution because it also saves money, and the study proved the size of PVC pipe that is usually suitable for mosque use are 0.5 or 0.75 inch. The most expensive pipe was taken into account, which is 0.75 inch and cost 7.24 SR per meter. The average price of the tank is 491.4 SR per cubic meter. Aaverage consumption price for the mosques in Riyadh is 677.66 SR per cubic meter per month. when minimum consumption takes into consideration the payback comes 6 years for actual cost and 13 years for governmental cost. Average consumption takes into consideration the payback comes 9 years for actual cost and governmental cost. when highest consumption takes into consideration the payback comes 5 years for actual cost and 3 years for governmental cost.the study proved also when consumption increases the payback period comes faster.

REFERENCES

- [1] Annual Water Consumption in The Kingdom Of Saudi Arabia, General Authority for Statistics KSA (2018).
https://www.stats.gov.sa/sites/default/files/9_mtwst_nsyb_lfrd_lywmy_mn_lmyh_lmntqlmml_klrby_lswdy_llwm2009-2018.pdf (accessed April 2022).
- [2] Annual Water Consumption In Srilanka, ResearchGate (2021). www.researchgate.com.net (accessed February 2022).
- [3] Annual Water Consumption In China, CEIC (2020) <https://www.ceicdata.com> (accessed February 2022).
- [4] Annual Water Consumption In United States of America ,USGS (2015).
USGS.gov | Science for a changing world (accessed February 2022).
- [5] Annual Water Consumption In Russia, Wikipedia(2004).
https://en.wikipedia.org/wiki/Water_supply_and_sanitation_in_Russia#:~:text=The%20average%20residential%20water%20use,serving%20the%20entire%20Russian%20population (accessed February 2022).
- [6] Annual Water Consumption In India, Statista (2020).
<https://pib.gov.in/PressReleasePage.aspx?PRID=1604871#:~:text=As%20per%20Ministry%20of%20Housing,to%20higher%20level%20by%20states>. (accessed February 2022).
- [7] European Environment Agency (1999). Annual Water Consumption In Germany and Finland. Introduction To Urban Water Distribution , Unesco-Ihe Lecture Note Series.
Lallana, C. et al. 2001. Sustainable Water Use in Europe, Part 2: Demand Management. European Environment Agency (EEA) – Copenhagen, Denmark <http://www.eea.eu.int>
- [8] The annual water consumption at 2030 in KSA ,National Water Company (NWA) (2018)
<https://www.nwc.com.sa>(accessed February 2022).
- [9] (Eakin and Sharman [2010](#); Gleick
1993) <https://link.springer.com/article/10.1007/s11270018-3909-8>

- [10] (Qureshi and Hanjra 2010; UNDP 2017) <https://link.springer.com/article/10.1007/s11270-018-3909-8>.
- [11] <https://link.springer.com/article/10.1007/s11270-018-3909-8>
- [12] <https://link.springer.com/article/10.1007/s11270-018-3909-8>
- [13] Casanova et al. 2001; Ledin et al. 2001; Ottoson and Stenstrom 2003
- [14] <https://link.springer.com/article/10.1007/s11270-018-3909-8>
- [15] Abedin and Rakib 2013; do Couto et al. 2013; Katukiza et al. 2014
- [16] Vigneswaran and Sundaravadivel 2004
- [17] Alsulaili and Hamoda 2015; do Couto et al. 2013; Katukiza et al. 2014
<https://link.springer.com/article/10.1007/s11270-018-3909-8>
- [18] World Health Organization – Regional Office for the Eastern Mediterranean (WHO-ROEM). (2006). Overview of greywater management: Health considerations. Retrieved September 7, 2010 from
<http://www.emro.who.int/ceha/pdf/Greywter%20English%202006.pdf>.
- [19] World Health Organization (WHO) (2006). Guidelines for the safe use of wastewater, excreta and greywater. Retrieved September 7, 2010 from
http://www.who.int/water_sanitation_health/wastewater/gsuww/en/index.
- [20] NovaTec Consultants Inc. (2004). Greywater Reuse Study Report. File 1027-42.
- [21] Center for the Study of the Built Environment (CSBE). (2003). Graywater Reuse in Other Countries and its Applicability to Jordan.
- [22] A. O. Al-Jasser. (2012). Greywater reuse in Saudi Arabia: current situation and future potential . Civil Engineering Department, College of Engineering, King Saud University, Saudi Arabia.
- [23] Jamrah, A., Al-Futaisi, S.A. Prathapar, M.Ahmad and Ali Al Harasi. 2004. Evaluating greywater reuse potential for sustainable water resources management in the Sultanate of Oman. International Conference on Water Demand Management. Dead Sea. Jordan.
- [24] (The annual water consumption in the Kingdom of Saudi Arabia, 2022)

Stats.gov.sa. 2022. *The annual water consumption in the Kingdom of Saudi Arabia*. [online]
https://www.stats.gov.sa/sites/default/files/9_mtwst_nsyb_lfrd_lywmy_mn_lmyh_lmntqlmml_klrby_lswdy_llwm2009-2018.pdf
 (Accessed 7 April 2018)

[25] National Water and Sewerage Corporation (NWSC), Sanitation strategy and master plan for Kampala city. Vol. 2. Main report. Beller Consult-Germany, Mott MacDonald-UK and M&E Associates of Uganda for NWSC, Kampala, Uganda, 2004.

[26] <https://www.livescience.com/15955-recycled-water-sewage-psychology.html>

[27] Jefferson B, Palmer A, Jeffery P, Stuez R, Judd S (2004) Grey water characterisation and

[28] its impact on the selection. *Water Science and Technology* 50(2):157-164

[29] <https://www.maan-ctr.org/magazine/article/196/>

[30] Ludwig, A. 1995-1999. *Builder's Greywater Guide*. Santa Barbara: Oasis Design.

[31] Dixon, A., Butler, D., and Fewkes, A. 1999. Guidelines for Greywater Re-use: Health Issues. *J.CIWEM*, 13(October):322-326.

[32] Standards for toilet Requirement, US EPA(2020).

<https://www.epa.gov/watersense/residential-toilets> (accessed March 2022).

[33] Standards for reuse of wastewater in agriculture, Nalco Water, an Ecolab Company(2021).

<https://www.ecolab.com/nalco-water> (accessed March 2022).

[34] Chemistry for Environmental Engineering and Science---Clair N. Sawyer, Perry L.

McCarty, and Gene F. Parkin, McGraw-Hill

[35] Kovalio and N.I. Galil. (2005). On-site greywater treatment and reuse in multistorey buildings. *Water Science & Technology*, 51(10): 187–194.

[36] Maimon, A., A. Tal, E. Friedler, and A. Gross. (2010). Safe on-site reuse of greywater for irrigation – A critical review of current guidelines. *Environmental Science and Technology*, 44: 3213-3220.

[37] Maimon, A., A. Tal, E. Friedler, and A. Gross. (2010). Safe on-site reuse of greywater for irrigation – A critical review of current guidelines. *Environmental Science and Technology*, 44: 3213-3220.

[38] Jeffreson, B., Laine, A., Parsons, S., Stephenson, T., and Judd, S. 1999. Technologies for

Domestic Wastewater Recycling . Urban Water, 1(4):285-292

- [39] Surendran, S. and A.D. Wheatley. 1998. Greywater Reclamation For Non-Potable Reuse. J. CIWEM. 12:406-413.
- [40] Surendran, S. and A.D. Wheatley. 1998. Greywater Reclamation For Non-Potable Reuse. J. CIWEM. 12:406-413.
- [41]] Li, F., Wichmann, K., Otterpohl, R., 2009. Review of the technological approaches for grey water treatment and reuses. Sci. Total Environ. 407, 3439e3449.
- [42] Muthukumaran, S., Baskaran, K., Sexton, N., 2011. Quantification of potable water savings by residential water conservation and reuse. Resour. Conserv. Recycl. 55, 945e952.
- [43] INFRAERO, 2013. Empresa Brasileira de Infraestrutura Aeroportuaria. Available at: <http://www.infraero.gov.br/index.php/br/imprensa/noticias/5597-310-aeroportodeconfinsinaugura-mais-uma-ponte-de-embarque.html> (accessed 26.10.13.).
- [44] Swamee, P.K., Sharma, A.K., 2008. Design of Water Supply Pipe Networks. John Wiley, New York
- [45] Moreira Neto, R.F., Carvalho, I.C., Calijuri, M.L., Santiago, A.F., 2012b. Rainwater use in airports: a case study in Brazil. Resour. Conserv. Recycl. 68, 36e43.
- [46] B. Beler-Baykal, N. Oructut, Grey water as reliable/renewable source of water for cities of the future and an appraisal based on Istanbul, Turkey, IWA Cities of the Future Conference:Embrace the Water, June 12–14, 2017, Gothenburg, Sweden. And B. Beler Baykal, An Overview of Results and Conclusions from ITU Segregated Streams/ECOSAN Research Group Experience on Grey Water Management, In: N. Balkaya, S. Guneyasu, Eds., Recycling and Reuse Approaches for Better Sustainability, Environmental Science and Engineering, Springer, Cham, 2019, pp. 257–265.
- [47] <https://www.alwatan.com.sa/ampArticle/1057750>
- [48] Booker, N. 2000. Economic scale of greywater reuse system. http://www.dbce.csiro.au/inno-web/1200/economic_scale.htm .
- [49] **James, R.A.**, “Future Wastewater Infrastructure Needs and Capital Costs”, Biennial

Survey of Wastewater Collection & Treatment, Minnesota Pollution Control Agency ,520

Lafayette Road North Saint Paul, MN55155--4194 (2014).

APPENDICES

Appendix A - ENGINEERING STANDARDS, REALISTIC CONSTRAINTS

Standards for the reuse of grey water

According to [32] Standards for reuse of wastewater the toilet flushing should be on range as shown in table1 and Standards for reuse of wastewater the agriculture should be on range as shown in table2, table3, table4 and table5 [33].

Table 5.1: US EPA Standards for toilet Requirement

Parameter	Requirement	Unit
BOD	≤ 10	mg/L
Turbidity	≤ 2	NTU
Microbiological Water Quality	< 1	fecal coliform CFU / 100 mL
Single sample	< 14	fecal coliform CFU / 100 m
a (chlorine residual is required.)	≥ 1	mg/L (30 minuet)

1- Physical properties

Table 5.2: American chemistry council (ACC) Standards for agriculture

Parameter	Requirement	Unit
Floating substances	0	mg/L
Total Suspended Solids (TSS)	≤ 0.1	mg/L

PH	8.4-6	mg/L
----	-------	------

2- Chemical properties

Table 5.3: ACC Standers for agriculture Requirement Organic chemical properties

Parameter	Requirement	Unit
BOD5	<10	mg/L
COD	<50	mg/L
TOC	<40	mg/L
Oils and greases	0	mg/L
Phenol	<0.002	mg/L

Chemical properties of organic compounds:

Table 5.4: ACC Standers for agriculture Requirement Heavy items

Parameter	Requirement	Unit
Arsenic	<0.1	mg/L
Cadmium	<0.01	mg/L
Chromium	<0.01	mg/L
Copper	<0.2	mg/L
Cyanide	<0.05	mg/L
Lead	<5	mg/L
Mercury	<0.01	mg/L
Nickel	<0.02	mg/L

Zinc	<2	mg/L
Aluminum	<5	mg/L
Barium	<1	mg/L
Manganese	<0.2	mg/L
Silver	<0.5	mg/L
Selenium	<0.02	mg/L
Molybdenum	<0.01	mg/L
Boron	<0.75	mg/L
Vanadium	<0.1	mg/L
Lithium	<2.5	mg/L
Petroleum	<0.1	mg/L
Iron	<5	mg/L
Cobalt	<0.05	mg/L

Table 5.5: ACC Standers for agriculture Requirement Chemical compounds

Parameter	Requirement	Unit
Total dissolved solids (TDS)	<2000	mg/L
Chloride (Cl ²)	<100	mg/L
Sulfate (SO ₄)	<600	mg/L
Ammonia (NH ₃ -N)	<5	mg/L
Nitrate Nitrogen (NO ₃ -N)	<10	mg/L
Free chlorine	<0.2	mg/L

PH

PH is measure of hydrogen ion concentration present by equation 1 and 2 in water and indicates its acidic or basic character by scale show in Figure1. PH Measure BY pH mater

Figure 2[34]. $pH = -\log[H]^+$

(1) $[H^+] = 10^{-pH}$

(2)

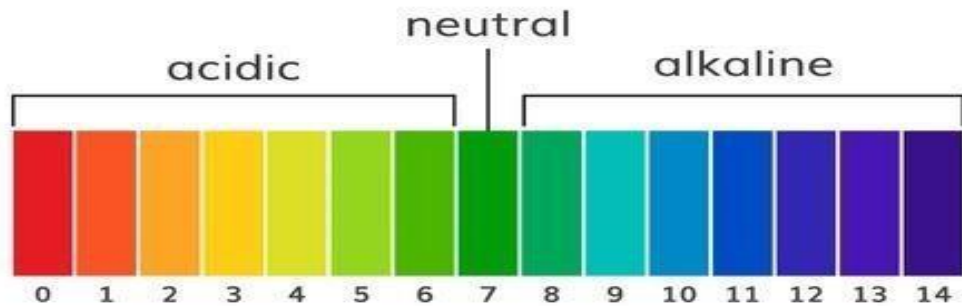


Figure 5.1: Show the concentration of the PH and acidic and alkaline water



Figure 5.2: Show the device that can measure the PH in water

Conductivity (EC)

Conductivity is the ability of water to carry an electrical current. The current is carried by cations and anions. It is a function of the concentration of ions. Increasing the level of ions will increase the conductivity. Most conductivity measurements are made in aqueous solutions. Not all aqueous solutions have conductivity. Sugar or alcohol, have no conductivity because they do not produce ions when dissolved in water. Distilled or

deionizer water can act as an insulator due to its very low (negligible) conductivity value. Sea water, on the other hand, has a very high conductivity. The units of conductivity are Siemens per cm (S/cm). Derived units are $\mu\text{S/cm}$ (one millionth of a S/cm) and mS/cm (one thousandth of a S/cm). S/cm is the same as the older unit mhos/cm [34].



Figure 5.3: Show the device that can measure the conductivity in water (Conductivity meter) Turbidity

Turbidity is a characteristic of water that makes it appear cloudy. Or The amount of cloudiness in the water. Or is an optical property of water based on the amount of light reflected by suspended solids Turbidity measured by electronic turbidity meter. Usually, it measured by nephelometric meter that measures the intensity of light scattered at right angles to the incident of light. The unit for turbidity is nephelometer turbidity units (NTUs) or Jackson turbidity units (JTUs) or Foral turbidity units (FTUs), and all units are roughly equal [34].

فاتورة خدمات المياه

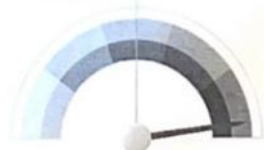
فاتورة مرسية (بموجب خدمة الخدمة الخاصة) 300184159100003

نوع القراءة: عملية
رقم السداد: 138
رقم الفاتورة: 174905014892
تسليم: 78337922
تاريخ الإصدار: 2022/04/12
وقت الإصدار: 10 09 03 مساءً
فترة الاستهلاك: 33 يوماً
كمية الاستهلاك: 109 م³
سهم الفاتورة الحالية: 758.43 ريال
مدونيات سابقة: 0.00 ريال

المبلغ المستحق: 758.43 ريال

تاريخ الاستحقاق: 2022/05/29
الفترة المتبقية: 2022/06/07

57 م³ كمية استهلاك المياه



109 م³ كمية استهلاك الفاتورة

طريقة حساب الفاتورة

حسب الفاتورة الشهرية بكمية 6 ريال يتم السداد



شركة المياه الوطنية
National Water Company



الاسم: وزارة الشؤون الإسلامية والدعوة والإرشاد - مسجد
المنوان: الرياض
الرقم الضريبي: الحائر
رقم الحساب: 1741020000
رقم العداد: 61467137
مياه: ☒ صرف صحي
رقم قراءة الاستهلاك: 2022/03/10
رقم قراءة الاستهلاك: 2022/04/12

عدد الوحدات: 1
نقطر عداد المياه (متر): 19

2428.00
2537.00

الفاتورة (م³)
الفاتورة (م³)

تفاصيل الفاتورة الحالية

بيانات الفاتورة	قبل الضريبة (ريال)	الضريبة (نسبة)	الضريبة (ريال)	بعد الضريبة (ريال)
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خدمة الصرف الصحي	0.00	15%	0.00	0.00
رسم خدمة العداد	5.50	15%	0.83	6.33
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الإجمالي	659.50		98.93	758.43

يوجد قيراني كمية الاستهلاك هي القيم المعطاة
المبلغ خارج لتغطية القيمة المعطاة

استهلاك المياه يعادل

6.10
صهريج بمساحة 18 م²

استهلاك آخر 13 شهر



أدوات الرشيد تساعد على خفض قيمة استهلاكك بنسبة 30% إلى 40%.

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نوع القراءة: **فعلية**
رمز السداد: **138**
رقم الفاتورة: **173213593949**
تسلسل: **79720317**
تاريخ الإصدار: **2022/05/08**
وقت الإصدار: **11:34:55**
فترة الاستهلاك: **30 يوماً**
قيمة الاستهلاك: **508.00 م**
مبلغ الفاتورة الحالية: **3510.95 ريال**
مديونيات سابقة: **0.00 ريال**

المبلغ المستحق: **3510.95 ريال**

تاريخ الاستحقاق: 2022/06/28

42 م قيمة استهلاك المياه



508.00 م قيمة استهلاك الفاتورة

طريقة حساب الفاتورة

تتبع الفاتورة استهنية شحمة 4 ريال لكل متر المالح



شركة المياه الوطنية
National Water Company



وزارة الشؤون الإسلامية والدعوة والإرشاد - مسجد عبدالله الخضير - الرياض

الاسم: **الرياض**
المنوان: **قرطبة**
الرقم الضريبي: **1735375779**

رقم الحساب: **58454166**
رقم العداد: **1**
عدد الوحدات: **19**
شهر عدد المياه (ملم): **مخزون**

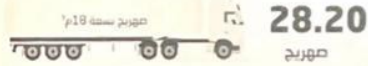
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تاريخ الفاتورة (م): **2022/04/05**
تاريخ الفاتورة (م): **2022/05/05**
تاريخ الفاتورة (م): **2553.00**
تاريخ الفاتورة (م): **3061.00**

تفاصيل الفاتورة الحالية

بيانات الفاتورة	قبل الضريبة (ريال)	الضريبة (نسبة)	الضريبة (ريال)	بعد الضريبة (ريال)
قيمة استهلاك المياه	3048.00	15%	457.20	3505.20
خدمة الصرف الصحي	0.00	15%	0.00	0.00
رسم خدمة العداد	5.00	15%	0.75	5.75
المحالفات	0.00	خارج نطاق الضريبة	0.00	0.00
الإجمالي	3053.00		457.95	3510.95

قيمة استهلاك المياه: 42 م قيمة استهلاك المياه
وتتبع الفاتورة استهنية شحمة 4 ريال لكل متر المالح

استهلاك المياه بعدل



استهلاك آخر 13 شهر



أدوات الترشيد تساعدك على خفض قيمة استهلاكك بشحمة 30 % إلى 40 %.



فاتورة تجارية (رقم تجرید الشیعة المتابعة 300184159100003)

المبلغ المستحق: 212.95 ريال

2022/03/28 تاريخ الاستحقاق 2023/04/07 آخر موعد للمصادق



نحوه استفاده از این کتاب



الاسم	وزارة الشؤون الإسلامية والدعوة والإرشاد - مسجد السويدي - الرياض
الرقم الضريبي	السويدي
رقم الحساب	2911910000
رقم المزداد	61507588
مياه	مرف محلي
1241.00	2022/01/16
1261.00	2022/02/16
	مياه فترة الاستهلاك
	مياه فترة الاستهلاك

بيانات الفاتورة	قبل الضريبة (الريال)	الضريبة (معدن)	الضريبة (الريال)	بعد الضريبة (الريال)
قيمة استهلاك المياه	120.00	15%	18.00	138.00
خدمة الصرف الصحي	60.00	15%	9.00	69.00
رسم خدمة العداد	5.17	15%	0.78	5.95
الخصومات	0.00		خارج نطاق الضريبة	0.00
الإجمالي	185.17		27.78	212.95

تجربة استخدام موقع الصرف الصحي حوالي 50% من نسبة استهلاك المياه
و 40% من نسبة استهلاك الكهرباء
المياه الناتجة من تجربة التجربة



أدوات الترشيد تساعدك على خفض قيمة استهلاكك بنسبة 30 % إلى 40 %.

Appendix C – SURVEY

Questions

Responses

751

Settings

Section 1 of 7

قياس مدى وعي سكان مدينة الرياض بالمياه الرمادية

Measuring the awareness of the residents of Riyadh with gray water

السلام عليكم ورحمة الله وبركاته

نحن فريق بحثي من كلية الهندسة بجامعة الإمام محمد بن سعود الإسلامية . ندعوك للمشاركة في هذه الدراسة التي تهدف إلى قياس وعي سكان منطقة الرياض بالمياه الرمادية .

نأمل أن تمنحنا بضع دقائق من وقتك الثمين

شاكرين ومقدرين لكم تعاونكم
فريق البحث

Dear respected participant,
We are a research team from College of Engineering at Imam Muhammad bin Saud Islamic University.

The study aims to measure the awareness of greywater peopole in Riyadh.
We hope you will spare just a few minutes of your precious time.

Thank you in advance for your cooperation.
Research Team.

اللغة / Language *

☐ العربية

☐ English

General Questions

You are in Saudi Arabia as? *

- ☐ citizen
- ☐ resident

Do you Live in? *

- ☐ Riyadh
- ☐ Other...

Age? *

- ☐ 19-Less
- ☐ 20-39
- ☐ 40-59
- ☐ 60-more

Education? *

- ☐ General Education
- ☐ Higher Education
- ☐ Other

Do you know what greywater is? *

- ☐ Yes
- ☐ No

After section 5 Continue to next section

Section 6 of 7

What is greywater?



Greywater is wastewater with the exception of toilet water. Example of greywater: water from the sink, shower or kitchen.

After section 6 Continue to next section

Greywater



If you don't know the answer, guess the answer

What do you think of water price in Saudi Arabia? *

- ☐ Cheap
- ☐ Average
- ☐ Expensive
- ☐ Cheap because of government support
- ☐ The original water is cheap, but it is sold at a high price

Is there a water problem in Saudi Arabia? *

- ☐ Yes
- ☐ No
- ☐ I Don't Know

Is it possible to reuse greywater? *

- ☐ Yes
- ☐ No
- ☐ Maybe

What is the purpose of reusing greywater ? *

- ☐ Environmental
- ☐ Economical
- ☐ All of the above
- ☐ There is no purpose

Do you think treatment of greywater will be financially beneficial? *

- ☐ Yes
- ☐ No
- ☐ Maybe

Can treated greywater be used for irrigation? *

- ☐ Yes
- ☐ No
- ☐ Maybe

Can treated greywater be used to clean the toilet flushing? *

- ☐ Yes
- ☐ No
- ☐ Maybe

Can treated greywater be reused in car washes? *

- ☐ Yes
- ☐ No
- ☐ Maybe

Do you think reusing treated greywater may cause environmental harm? *

- ☐ Yes
- ☐ No
- ☐ Maybe

Do you think reusing treated greywater is harmful for human health? *

- ☐ Yes
- ☐ No
- ☐ Maybe
- ☐ Yes, in the long time

Do you think it is acceptable to reuse treated greywater for drinking purposes? *

- ☐ Yes
- ☐ No
- ☐ Yes, If I checked it's quality
- ☐ Impossible

...

Do you think it is acceptable to reuse treated greywater for drinking purposes? *

- ☐ Yes
- ☐ No
- ☐ Yes, If I checked it's quality
- ☐ Impossible

Will reusing greywater save water consumption? *

- ☐ Yes
- ☐ No
- ☐ Maybe

Do you support the treatment and reuse of greywater? *

- ☐ Yes
- ☐ No
- ☐ Maybe