



MIDOCEAN University
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Master of Project Management

Assessment of Greywater Reuse Sustainability in Mosques in Riyadh across Social, Environmental, and Economic Dimensions

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ANTI-PLAGIARISM DECLARATION

DEDICATION

ACKNOWLEDGMENTS

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... **Next Semester**

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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].

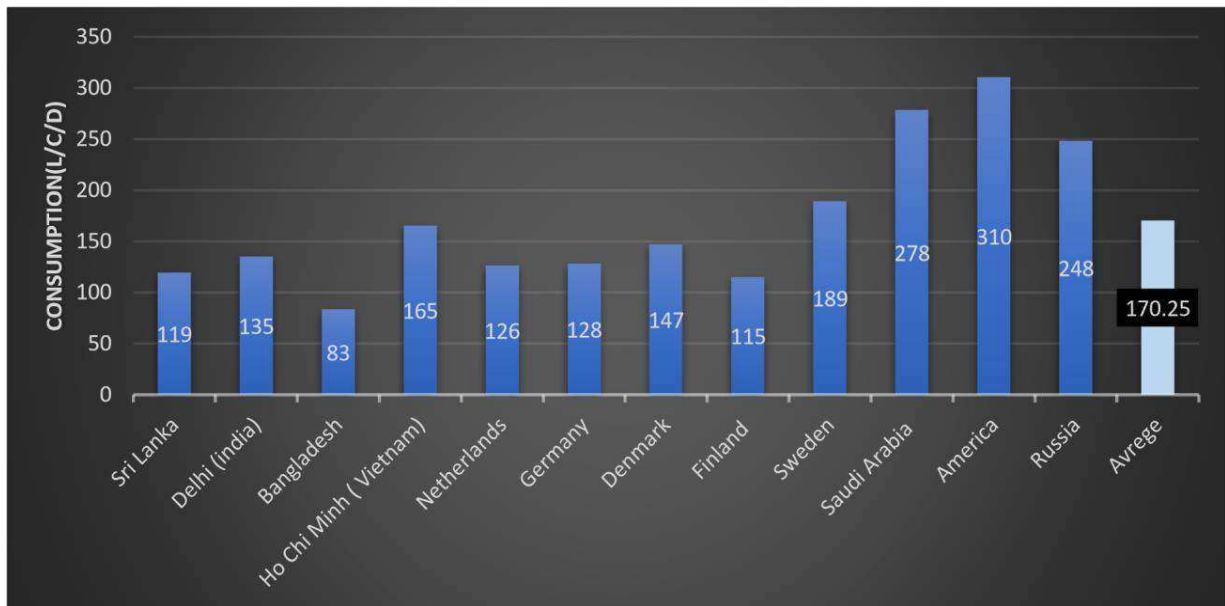


Figure1.1: Show the consumption in several countries [2-7]

1.2 THE AIM OF THIS RESEARCH

The aim of this research is to investigate the ability of reusing ablution water in mosques for agriculture and toilet flushing in order to reduce public water consumption of the potable water to advance sustainability practice in Saudi Arabia.

1.3 OBJECTIVES

- ❖ Review the relevant literature in the reusing of greywater

- ❖ Investigate to what extent the public knowledge of greywater
- ❖ 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

1.4 OVERVIEW OF THE REPORT

1.4.1 Chapter One

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

1.4.2 Chapter Two

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

1.4.3 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.

1.4.4 Chapter Four

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

1.4.5 Chapter Five

This chapter documents conclusion for the graduation project.

1.5 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 houseowners 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

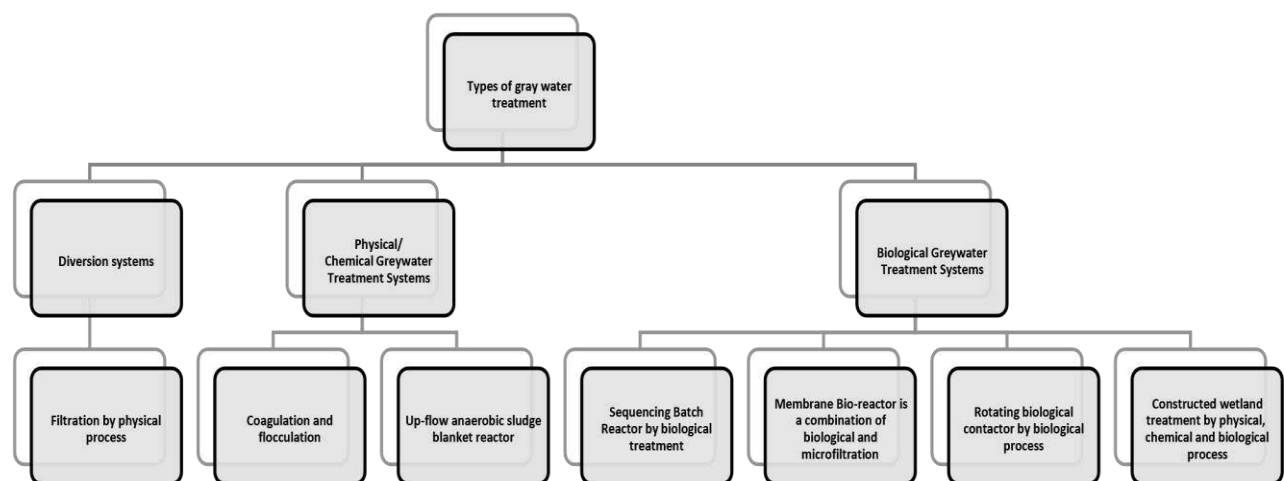


Figure 2.1: Types of Greywater treatment

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, B_t are the benefits and C_t 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.

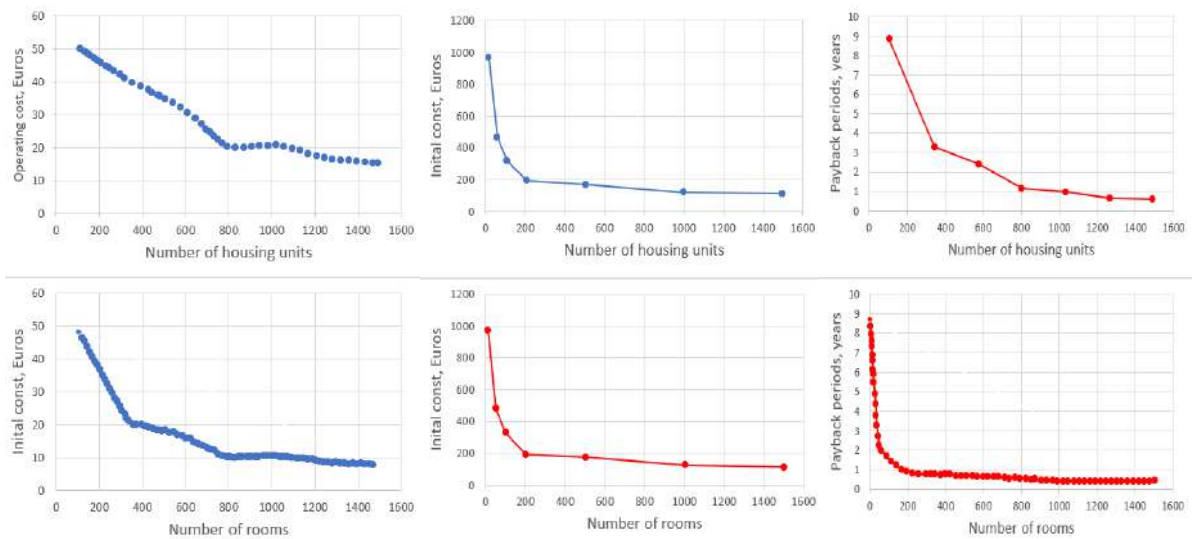


Figure 2.2: Costs and payback periods for MBR treatment for households and hotels in Istanbul [46].

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.

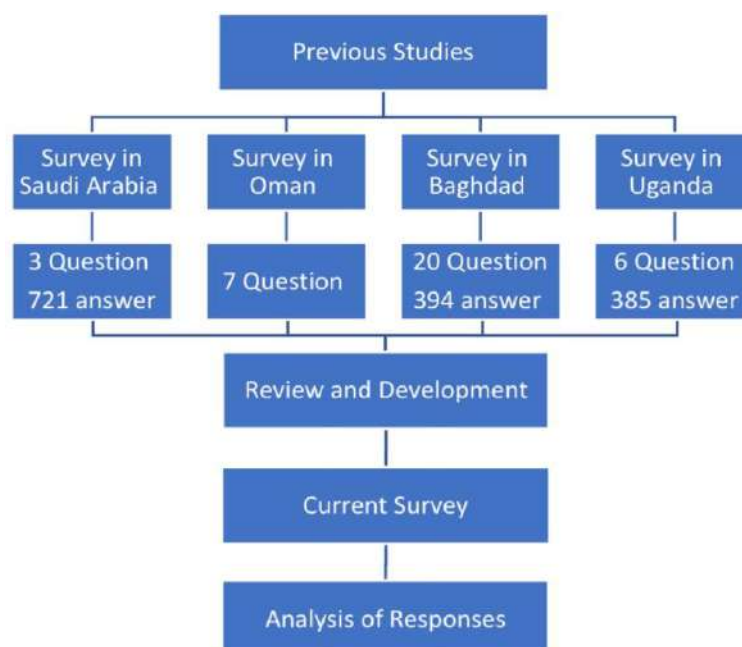


Figure3.1 Research methodology flow chart

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.

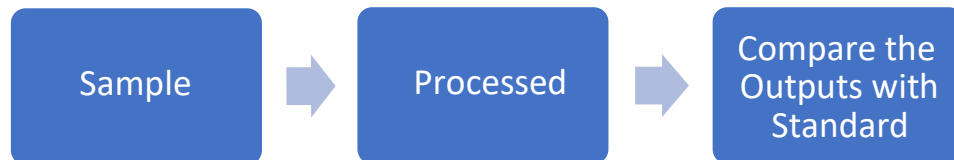


Figure 3.2: Flow chart the sample

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

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

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APPENDICES

Appendix A – 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 people 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

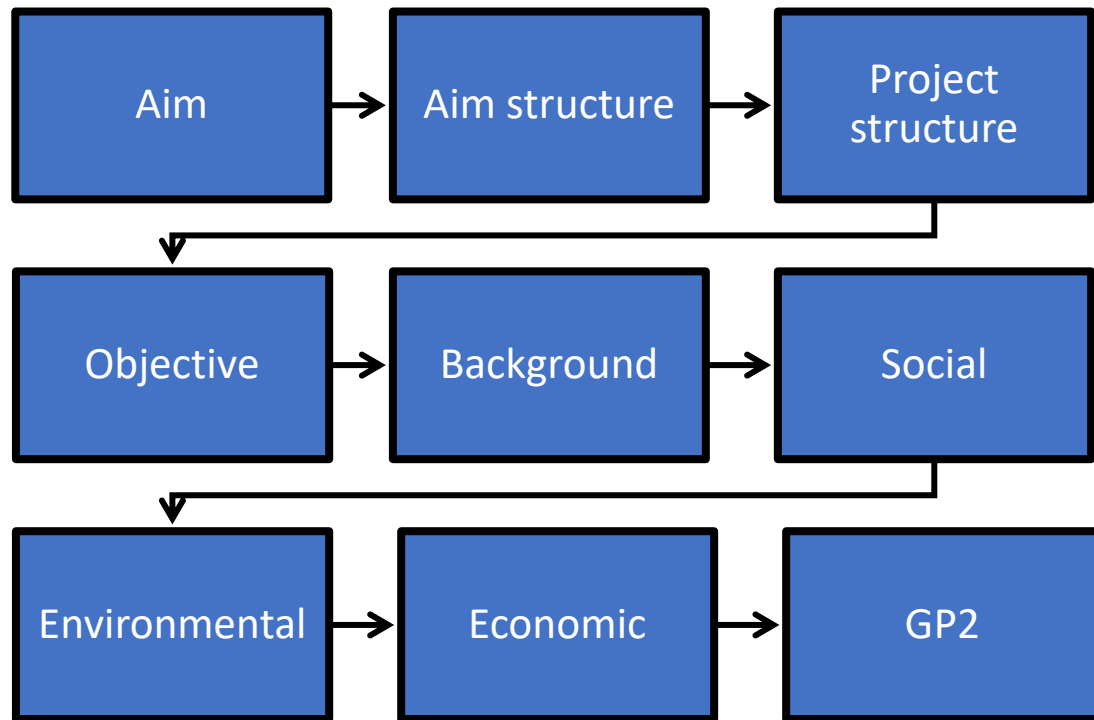
The background image shows a public water station with several brass faucets mounted on a wall. In the foreground, a person's hand is cupped under a running faucet, catching water. Other people's hands are visible in the background, also using the water station. The scene is dimly lit, with a focus on the water and the hands.

Assessment of Greywater Reuse Sustainability in Mosque in Riyadh across Social, Environmental, and Economic Dimensions

Student Name	ID
Ahmed Khaled Bahmid	25000190

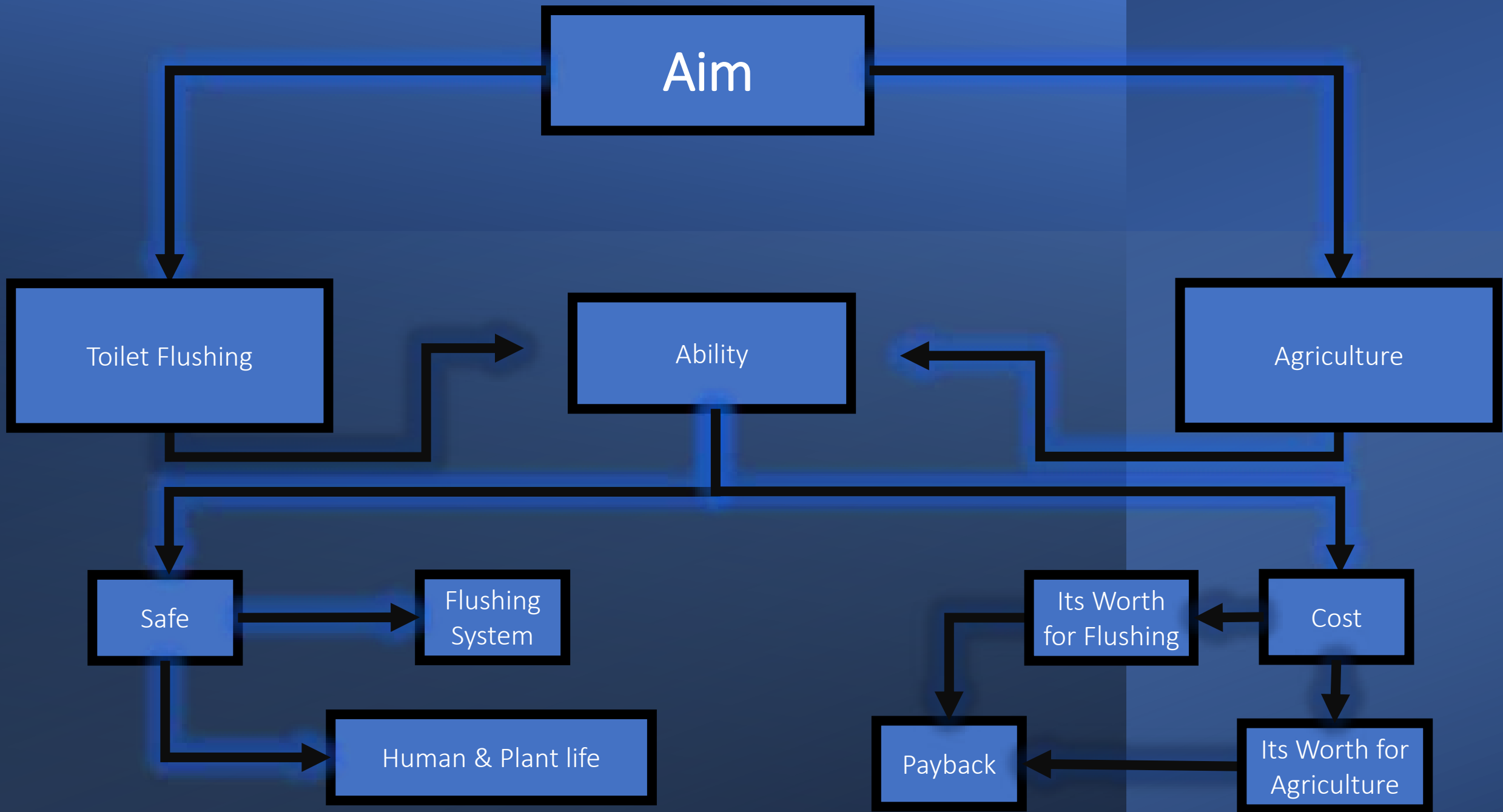
Supervised by: Dr. Al faisal Abdul Hamid & Dr. Fayez Jarad

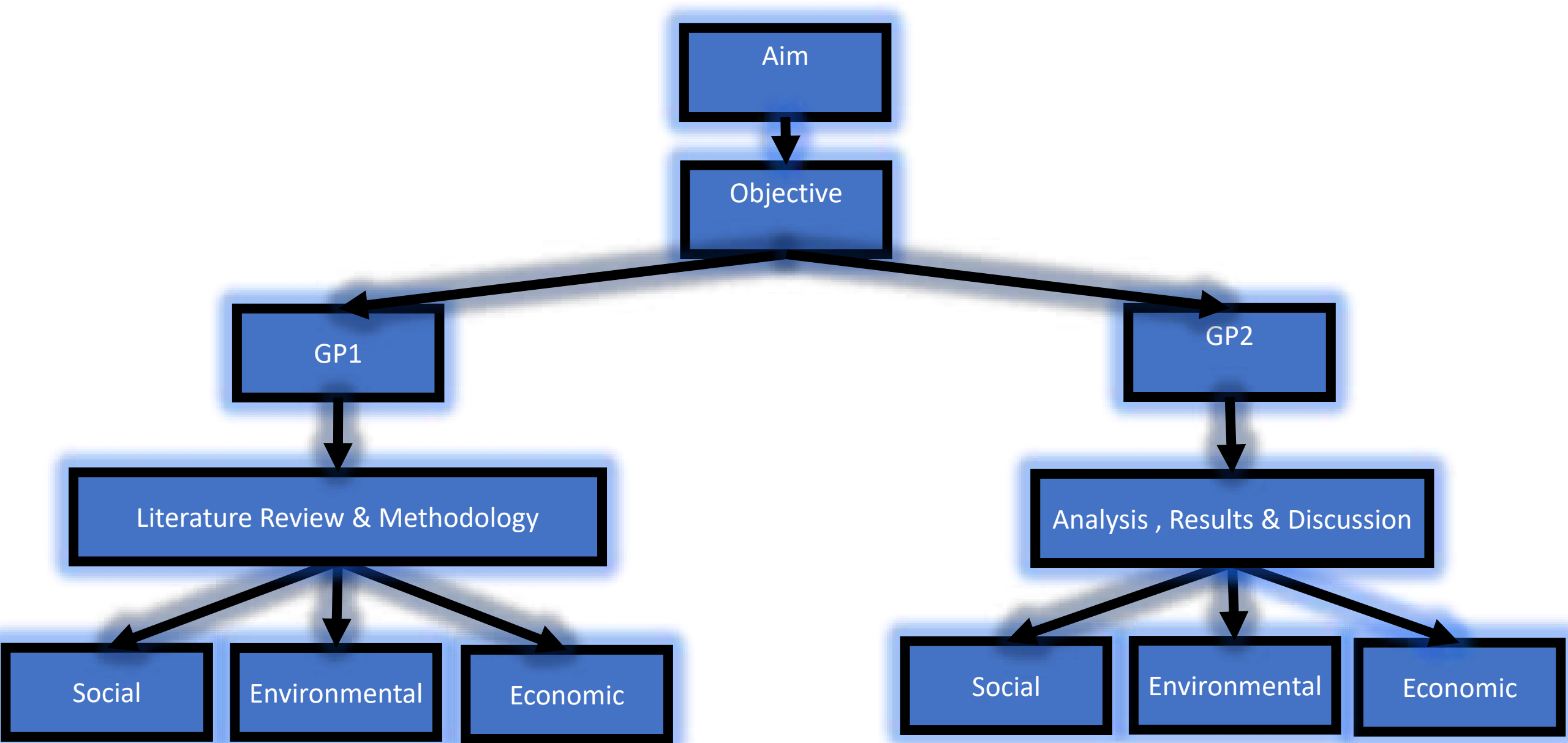
Continent:



Aim:

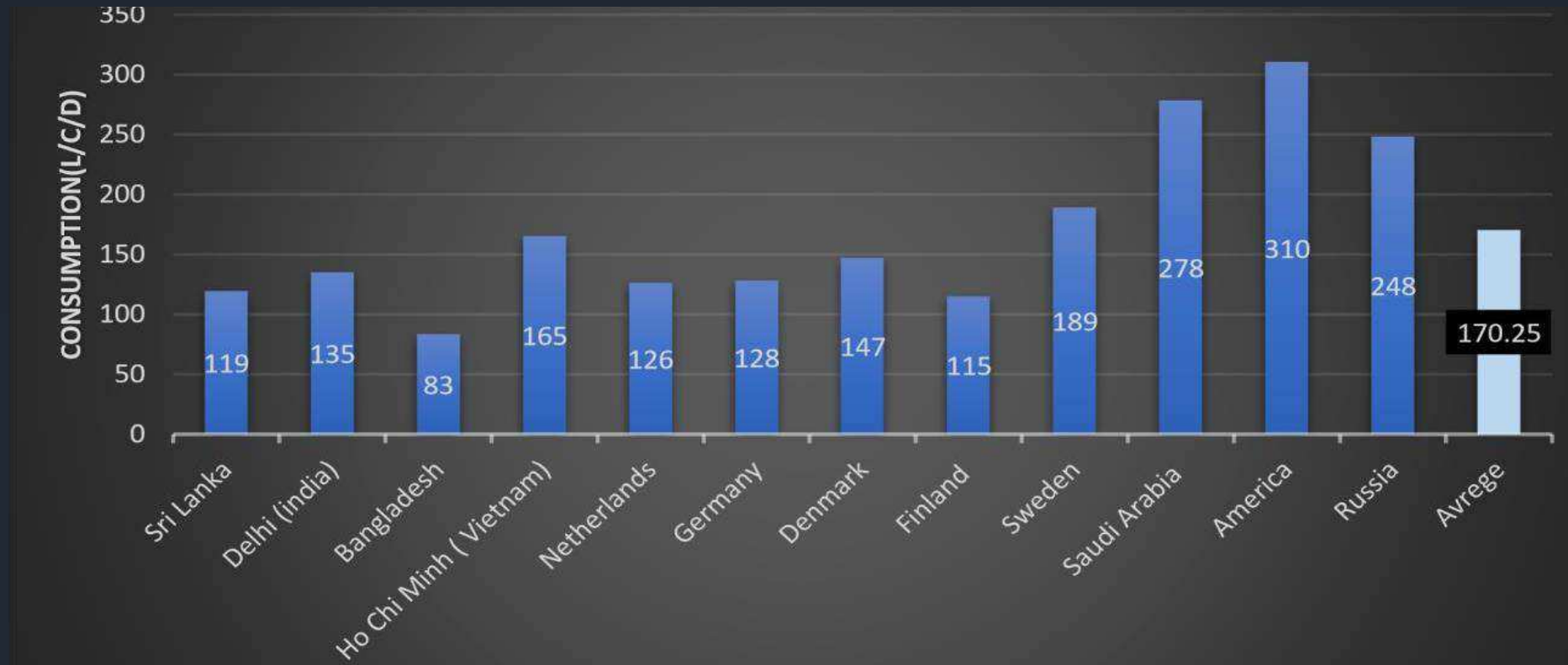
The **ability** of reusing ablution water in mosques for **agriculture** and **toilet flushing**





Objective

- ❖ Review the relevant literature in the reusing of greywater
- ❖ Investigate to what extent the public knowledge of greywater and the reuse of 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



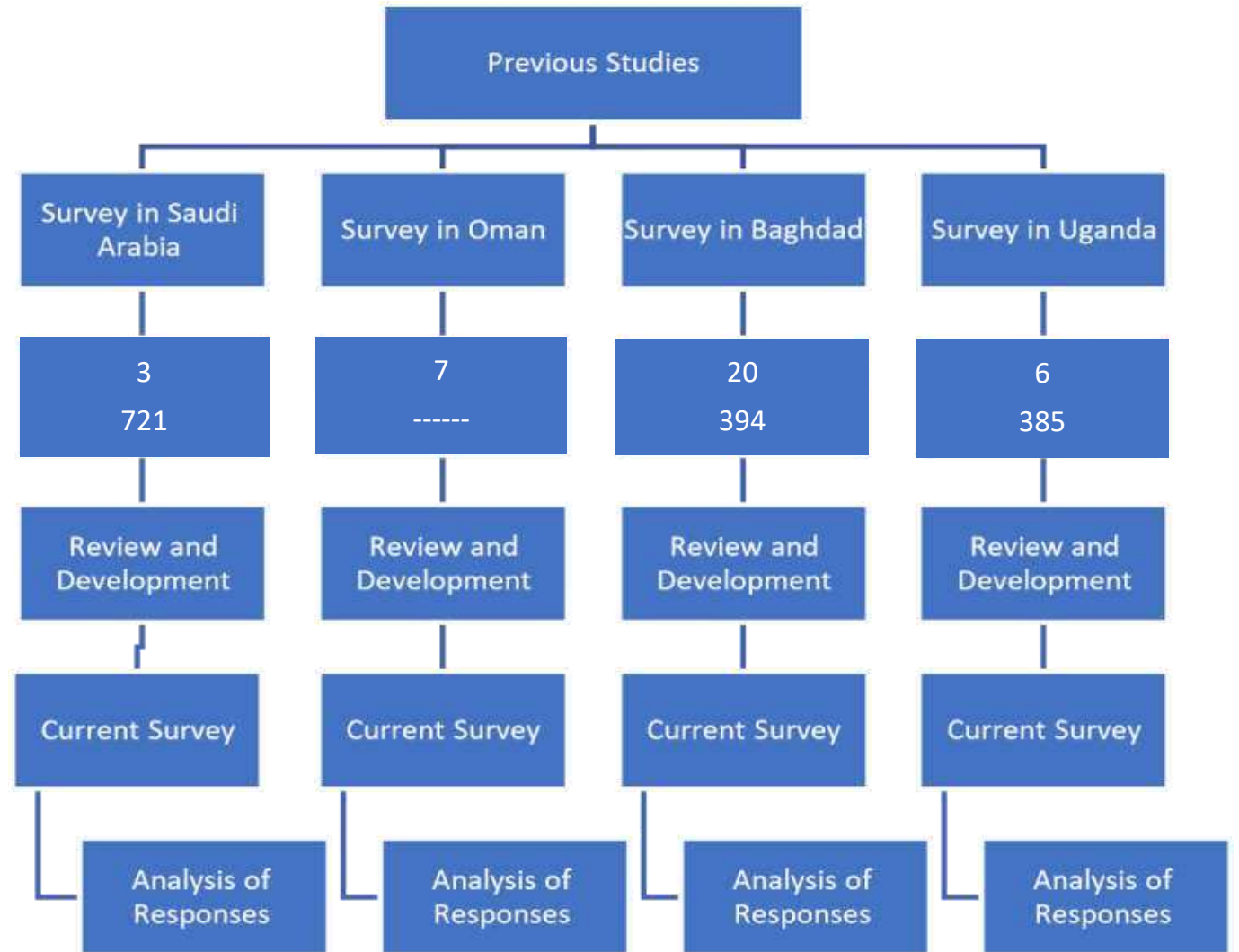
Background

- The annual water **consumption** in the Kingdom of Saudi Arabia (**KSA**) is around **278** L/c/day.
- While the annual average water **consumption in some countries** is around **170.25** L/c/day.

Background

- **Greywater** can be defined as any domestic **wastewater** produced, **excluding toilet**.
- 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**.

Social





Social

You are in Saudi Arabia as ?

Your age ?

Educational degree ?

Do you know what greywater is?

What do you think of water price in Saudi Arabia ?

Is there a water problem Saudi Arabia?

Is it possible to reuse greywater?

What is the purpose of reusing greywater?

Do you think treatment greywater will be financially beneficial?

Can treated greywater be used for irrigation?

Can treated greywater be used to clean the toilet flushing ?

Can treated greywater be reused in car washes

Do you think reusing treated greywater may cause bad environmental?

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

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

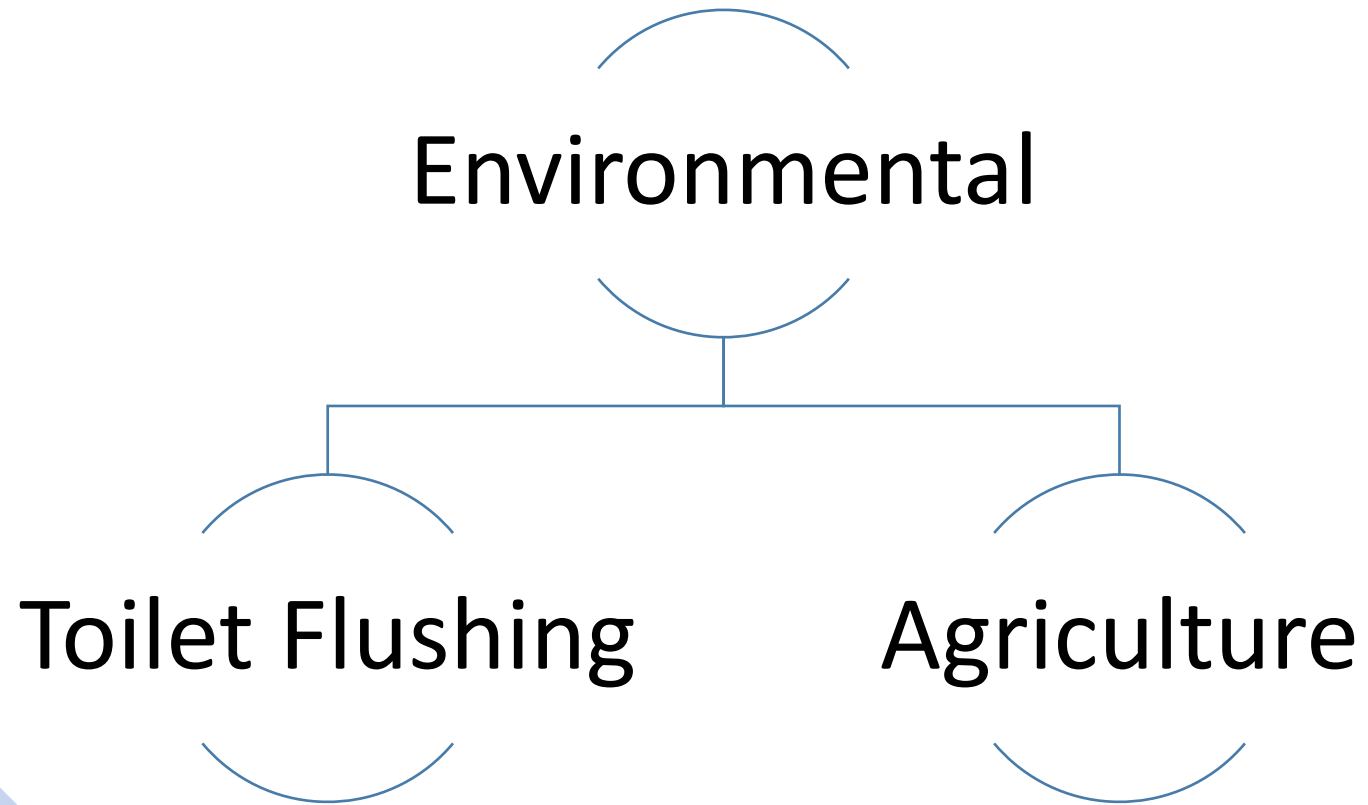
Will reusing greywater save water consumption?

Do you support the treatment and reuse of greywater?

Survey Barcode



Environmental



Environmental

Table5: ACC Standers for agriculture Requirement Chemical compounds:

Parameter	Requirement	Unit
Total dissolved solids (TDS)	<2000	mg/L
Chloride (Cl ₂)	<100	mg/L
<u>Sulfate</u> (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

Table3: 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

Table2: American chemistry council (ACC) Standers for agriculture

Parameter	Requirement	Unit
Floating substances	0	mg/L
Total Suspended Solids (TSS)	<=0.1	mg/L
PH	8.4-6	mg/L

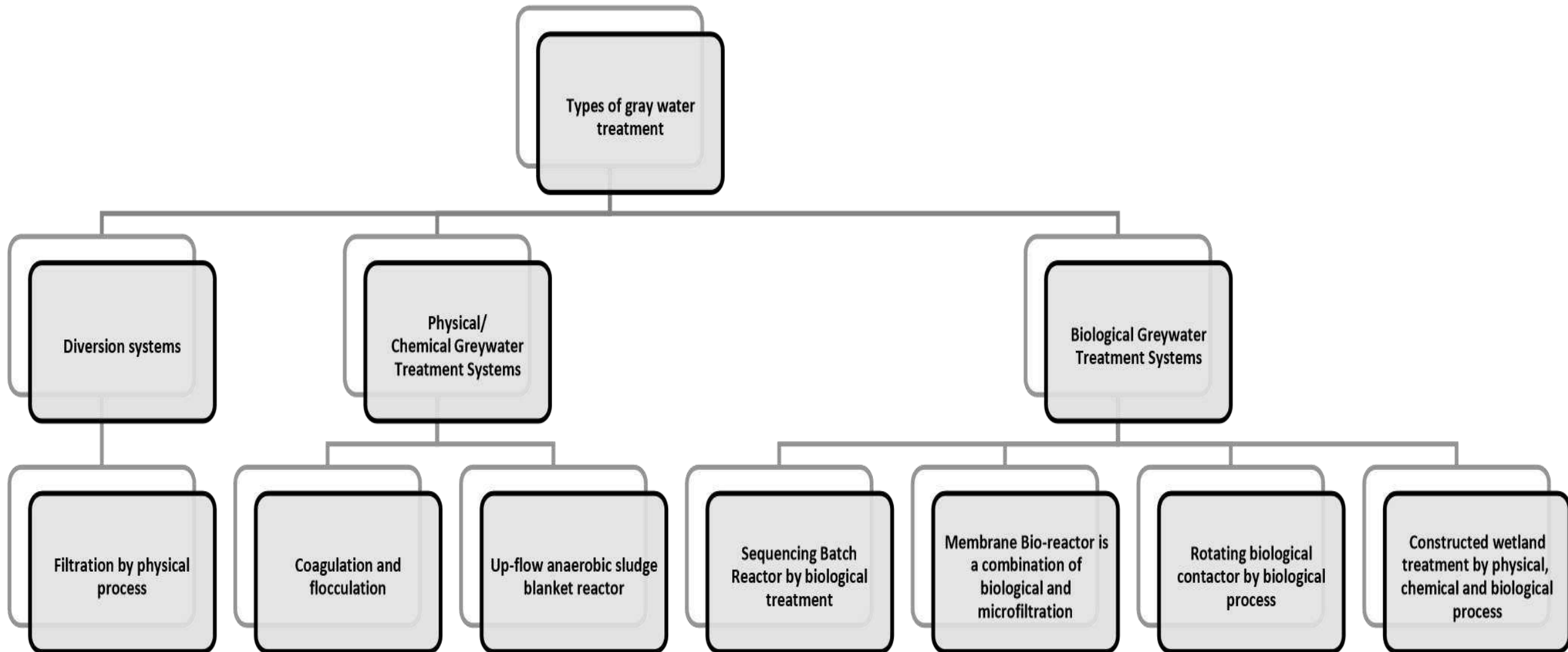
Table4: ACC Standers for agriculture Requirement

Parameter	Requirement
Arsenic	<0.1
Cadmium	<0.01
Chromium	<0.01
Copper	<0.2
Cyanide	<0.05
Lead	<5
Mercury	<0.01
Nickel	<0.02
Zinc	<2

Table1: US EPA Standers for toilet Requirement

Parameter	Requirement
BOD	<=10
Turbidity	<=2
Microbiological Water Quality	<1
Single sample	<14
a (chlorine residual is required.)	>=1

Types Of Greywater Treatment



Environmental



Greywater water System is better than treated water System



Greywater storage

Economic

- Greywater represents a substantial fraction (50-80%) of total wastewater produced in a household
- Demonstrates that the cost of reclaiming greywater is about 30 – 40% cheaper than supplying potable water to houses.
- The implementation cost of greywater treatment system in the Tancredo Neves International Airport buildings was 22,905.75 US\$, with a payback period of 5 years.
- the use of solar energy for pumps functioning and for disinfection device may represent a reduction in operating costs

Economic

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

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

GP2



Social

Collect Data & Analysis



Environmental

TEST & ANALYSIS



Economic

CALCULATION & ANALYSIS

THANK YOU



Any Question
Or
Suggestions For Development?
