Water demand management in mosques in Oman

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School of Architecture, Building, and Civil Engineering

Water Demand Management in Mosques in Oman

By

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A Doctoral Thesis

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Research Supervisors

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Abstract

The six Gulf Cooperation Council (GCC) countries face the most severe water shortages in the world today yet exhibit the highest global water consumption (500 litres per capita per day) combined with minimal efforts or measures to manage or conserve water use. While the literature is rich with practices and recommendations to reduce water use in the private sphere, very little research has been conducted for public buildings such as mosques (public buildings for Muslims to pray). These public buildings are under government management and allow water to be used freely, with no price controls or restrictions. At the same time, an essential preparation for salah (prayer), which Muslims must perform five times a day, is wudu (ablution or washing with water). The Sunnah (which discusses traditional customs and practices of the Islamic community) prescribes that the ideal ablution uses only a small amount of water: the Prophet Mohammed (PBUH) himself used just 0.6 litres. This study, which analyses ways to manage water demand in mosques in Oman, seeks to help address the issue – thus contributing to the literature on water demand management in similar countries worldwide.

This research thesis revealed alarming results, up to 7 litres of water used per wudu. The research involved a combination of qualitative and quantitative techniques, including 41 interviews, 120 observations, 120 measurements of water consumption and analysis of two years of water bills for around 688 of mosques in Muscat (capital city of Oman). It is anticipated the impact of the study could be massive, 80% of water consumption conserved in mosques, achieved via policy recommendations that promote the application of suitable tools and techniques and result in improved efficiency of appliances and water reuse.

This research, which covers three major variables influencing water use (efficient appliances, policies, and reuse), will help decision-makers in taking the most appropriate action for water demand management. The findings provide an example for other GCC countries, as well as contributing to global knowledge.

Keywords: Islam, Water, Demand management, Resource Policy, Reuse, Recycling, Greywater, Blackwater, Mosques, Ablution, Sustainability, Scarcity.

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Definition of terms (Glossary)

The holy Qur'an: Is the book and word of God, the most miraculous in Islam, magnified by Muslims and believe that the word of God sent to Prophet Muhammad for the statement and miracles, which is transmitted frequently as Muslims believe that it is preserved in the breasts and lines of every touch or distortion, which is worshiped in his reading.

Sunnah: The actions and sayings of Prophet Muhammad (PBUH), viewed as complementing the divinely revealed message of the Qur'an, and constituting a source for establishing norms of conduct and, hence, a primary source of Islamic law; the paradigm or model of behaviour embodied in Muhammad's example.

Fatwa: A ruling on a point of Islamic law given by a recognized authority.

Mufti: A Muslim legal expert who is empowered to give rulings on religious matters.

Ifta: Is the act of issuing fatwas.

Wudu: Ritual ablution. Performing ritual ablution using water is an obligation for all the Muslims before praying.

Salah: Praying five times a day. Explained in Chapters 2 and 5.

'Mod' (مُد): a measure of liquid that would fill two hands of a mature moderate man. If this measurement is transferred into modern standards, then many scholars say that it is not more than 600 to 650 ml; this is the amount that Prophet Muhammed ρ used.

'Saa' (صاع): this is four times more than the 'Mod' (مُد). So, if the (مُد) is 600 ml of water, then we can imagine for a general, full wash-up is four times more, than 4 times multiplied by, or 4 multiplied by 600 ml, and obviously, this is compared to what Muslims are using nowadays is very minimal.

'Farq' الفرق: There is minor disagreement on determining this amount, but the majority of scholars said that this is three times 'Saa' ثلاثة أصوع, so three times the amount of the 'Saa' صاع.

'Gosol' (غسل): Is known as the overall washing (a general or full wash).

'Najasa' (نجاسة): If the water is polluted by impure matter.

Tahir: Is that the water is pure by itself.

Mutahir: It has the potential to purify others.

Mosques: A Muslim place of worship. Mosques consist of an area reserved for communal prayers, frequently in a domed building with a minaret, and with a niche (mihrab) or other structure indicating the direction of Mecca. There may also be a platform for preaching (minbar) and an adjacent courtyard in which water is provided for the obligatory ablutions before prayer.

Masjid: These are small mosques with capacity normally of 500 to around 900.

Jame: This is a big mosque with a capacity of over 1000.

Imam: The person who leads prayers in a mosque.

Madhhab: Each of the schools of Islamic law, each of which is based on a particular system of interpretation of Islamic religious and legal texts

Chapter 1 : Introduction

1.1 General introduction

This chapter presents the context of the research to be carried out. It covers the research background in the field of study, including an overview of the nature of water use in the six Gulf Cooperation Council (GCC) countries and particularly in the Sultanate of Oman. It discusses the problem statement, aims and objectives, and finally addresses the research questions.

1.2 Research background

According to the United Nations (2015), the global population reached more than 7 billion in that year, with an increase of around 80 million people per year. This rapid increase in population raises the demand for water globally. In particular, the water sectors in the countries of the Middle East and North Africa face difficulties in managing water resources and providing potable water to their customers (Zehnder et al., 2003). Global population growth increases the stress on freshwater supplies by 64 billion cubic meters per year, given that an estimated 3.3 billion people will be added to the world population by 2050 (90% of them in developing countries) (UN WATER Report, 2011). According to WHO and UNICEF, 663 million people are still using unimproved drinking water. There are many challenges to providing water including water shortages, low water tariffs, regulations poor regulations, unplanned development, shortages in financing, new technologies, and lack of commercial orientation (WHO and UNICEF, 2016).

The countries of the Middle East and North Africa show many more water-stressed conditions than others (Arnell, 2004), because they have the lowest levels of renewable water resources and the highest per capita rates of extraction per year at 804 cubic meters (Jagerskog et al., 2009). The average water resources per capita in the Middle East and North Africa, according to Al-Otaibi (2015), is 1,200 cubic meters per year, compared to 47,000 for South America and 11,000 for Europe. According to the World Bank estimation, 48 countries will be underwater stress by 2025 and by 2035, 3 billion people will be living in water-stressed countries (Al-Otaibi, 2015).

Islam is the religion of the majority of people in the countries of the Middle East, North Africa, and some countries of Asia. Islam has a large number of followers around the world, reaching up to 2.04 billion people distributed across all continents in the world. The Islamic religion is the second largest religion after Christianity. Praying five times a day and performing ritual ablution (wudu) using water before praying is an obligation for all Muslims. The GCC countries (the United Arab Emirates, Bahrain, Saudi Arabia, Oman, Qatar, and Kuwait) and Yemen cover 47% of the Middle East region (AQUASTAT, 2009). The GCC countries face the worst situation regarding water resources and the most severe water shortages in the world (Droogers et al., 2012), with consumption of more than 100% of their resources (Bakir, 2003). At the same time, the GCC countries have the highest water consumption in the world, reaching up to 500 litres per capita per day, combined with an absence of measures and efforts to minimize consumption. To satisfy the need for potable water in GCC countries, desalination of seawater is the main solution to provide adequate water supply (Environment, 2010; Darwish, 2014). Hence, the government solves the problem of high consumption and increasing water demand in GCC countries by expanding existing desalination plants and setting up new desalination units (Al Sharhan and Wood, 2003; Es'haqi and Al-Khaddar, 2015; PAEW in Oman, 2015). Indeed, the GCC countries have collectively become the world leaders in desalination, with more than 50% of the world's production capacity (Abdul Rahman, 2005). Desalination, however, remains, capital-intensive and costly (Al-Maskti, 2011). In terms of wastewater recycling, available treated wastewaters are still not being reused to their full potential, and planning for full utilization of treated effluent is in the early stages (Jasim et al., 2016). This means that there is an urgent need to develop water demand management. Therefore, to contribute to the global knowledge of water conservation, studies on wudu in the Gulf countries are crucial.

The literature is rich with examples of water crises and water demand management practices in the private sector, including in houses. Most of the studies recommend and focus on tariff structures and the importance of pricing to reduce consumption of water (Al Shueili, 2014; Al-Maskti, 2011; Kayaga and Smout, 2011; Chen et al., 2005; Tate, 1990). However, there is *very little research on water demand management in public buildings and even less on religious public buildings*. In the GCC countries, public buildings like mosques (see the glossary for a full definition) are under government management and have free usage of water and electricity, with no controls or restrictions (PAEW in Oman, 2015). There is excessive water usage in mosques, due to Muslims using mosques as a place of worship. Mosques consist of an area reserved for communal prayers, frequently, which needs to be studied and managed (PAEW, 2015; Suratkon et al., 2014; Rahman et. al, 2016).

1.3 Problem statement

GCC countries face the most severe water shortages in the world today, yet they exhibit the highest global water consumption combined with minimal efforts or measures to manage or conserve water use. Managing water demand in public buildings such as mosques in the GCC countries should also be considered to contribute to the global knowledge of water conservation. The findings on water demand management introduced in the literature, regard polices, regulations and techniques that would be sufficient if applied in countries that have similar lifestyles and behaviours, namely the UK, the USA, Canada, Malawi, China, Spain, Uganda, etc. (see chapter 2 in table 2.2 in section 2.4, section 2.4.1.2 and section 2.4.1.3). However, the GCC countries have a Muslim culture with a different lifestyle, needs, and behaviours; an example of this different behaviour is performing ritual ablution (wudu) using water at the time of praying approximately five times a day.

Limited research has been done in developing policies and strategies for water demand management and its consumption in mosques. This research studied water demand management in mosques in GCC countries and covered three main variables influencing water use (efficient appliances, policies and the possibility of reusing) to achieve appropriate water demand management (WDM) in mosques including through regulations, water-efficient appliances and water recycling. This work will help decision-makers in taking the most appropriate action for water demand management in mosques.

Because of limitations in time and resources, this doctoral study focused mainly on mosques in Oman. However, the findings from this study can set an example for other GCC countries, as well as countries all over the world.

According to the annual Oman Public Authority of Electricity and Water (PAEW) 2015 and 2018 reports, it is very clear in the PAEW general approach that water demand management receives the least attention compared to increasing the capacity and number of desalination plants. At the same time, those efforts there are to manage increasing demand focus on increasing desalination capacity and building more desalination plants, rather than managing water demand. PAEW concentrates on the supplying role, as it states in the report (PAEW), 2015 “We are working hard to ensure that capacity is able to keep up with demand in the future and to build additional resilience into our system”. Figures 1.1 and 1.2 indicate the priorities of the Public Authority of Electricity and Water (PAEW) in Oman by the end of 2015 and 2018. The PAEW’s priorities lay in improving and increasing strategy implementation in procurement and supply chain, water quality, quality management, etc. The WDM initiatives being implemented by PAEW were concerned with measures at the service provider end (e.g. non-revenue water) but there were no measures the customers’ end, hence the need for this research.

Figure 1.1: PAEW strategy implementation by the end of 2015

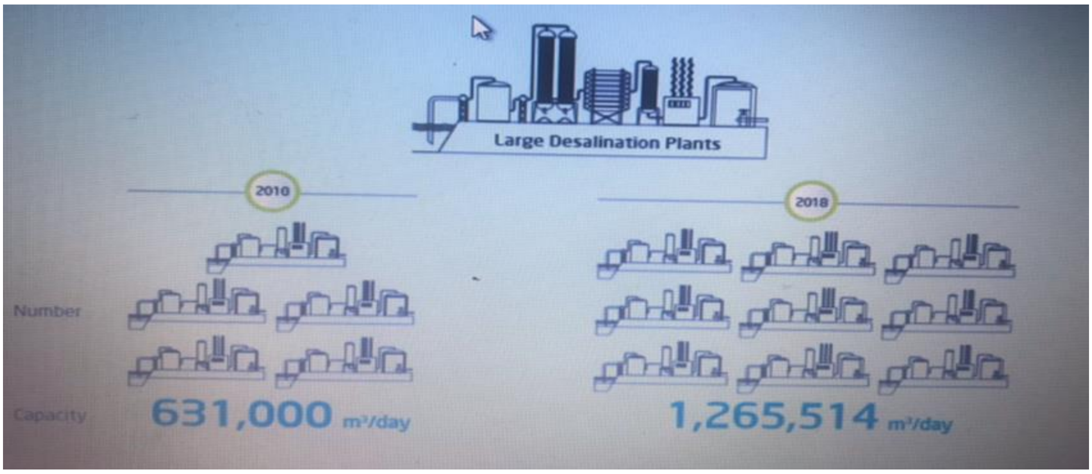

Figure 1.2: Large desalination plants capacity and number increased from 2010 to 2018

The knowledge gap so identified, formulated the objectives and research questions that will be answered by this research thesis – as set out in sections 1.4 and 1.5.

1.4 Purpose of the research

1.4.1 Aim

The main aim of this research is to enable better management of water demand in public buildings, such as mosques in GCC countries. This research specifies the potential savings that could be achieved by recommending policies that can promote the application of suitable tools and techniques in mosques. Specifically, this study quantifies the amount of water used in mosques, including when performing ablution, using rigorous methods and it also identifies the savings that can be achieved. The study identifies possible suitable techniques to conserve water, explores the acceptability for reusing water in mosques, and finally presents policies that can be applied to control water usage in public buildings – such as mosques in GCC countries.

This research was aimed at solving the following research problem:

'How to achieve appropriate water demand management (WDM) in mosques?'

The knowledge gap that was identified formulated the research objectives in this research.

1.4.2 Objectives

The specific objectives of this research are to:

1. Investigate water consumption in mosques, as well as policies, regulations, saving practices, appliances and techniques applied in mosques.

2. Identify effective water demand management policies and measures and techniques that are compatible with the needs of water consumers in mosques.

3. Investigate the acceptability of reusing water in mosques.

1.5 Research questions

To be able to achieve the specific objectives of this study, the following main and sub-research questions need to be answered.

Main research questions

The main research question is 'How to achieve appropriate water demand management (WDM) in mosques, including through regulations, water-efficient appliances, and water recycling?'

Objective no. 1: will be answered through the following sub-questions:

1.1 What are the water-saving policies and regulations that can be applied in the mosque to achieve efficient use of water?

1.2 What are the water-saving practices and appliances applied in mosques?

1.3 What is the estimated water consumption for ablution and toilet flushing per capita?

Objective no. 2: will be answered through the following sub-questions:

2.1 What are consumers' needs when making their ablutions in mosques?

2.2 What are effective water demand management policies and measures and techniques?

Objective no. 3: will be answered through the following sub-questions:

3.1 Is the water quality of ablution water suitable for reuse in toilet flushing and/or landscape irrigation? If so, what type of treatment is required?

3.2 Is water reuse or recycling acceptable to the mosque users and relevant policymakers?

Chapter 2 : Literature Review

2.1 Introduction

The strategy for the literature review sources was to collect from internationally accessible academic journals, articles and reports, relevant literature using Scopus and catalogues plus use of the Loughborough University e-library, books in the Loughborough University Library and the WEDC Resource Centre. All collected journals were saved in the Mendeley database. The strategy was to select a suitable study title and then to read the abstract as a first step for selecting papers related to the current study area.

2.2 Global water scarcity

Many countries are facing the problem of water shortages with a growing urban population. It is estimated that the world population will increase from 7.3 billion to 8.5 billion between 2015 and 2030, which according to the United Nations (2015), is projected to expand to 9.7 billion in 2050. This would lead to a gap between demand and supply in many parts of the world. In this case, "one way of responding to these global pressures on water resources is the application of water demand management (WDM) concepts" (Kayaga and Smout, 2011).

Previously, to guarantee water needs were met given increased demand was by expanding water supply capacity (Kayaga and Smout, 2011). Governments in Australia now look to solve the problem by looking to different solutions that can be utilized to save water, either by reducing demand, increasing efficiency or increasing the available supply (Sountharajah et al., 2017). Many developing countries are facing obstacles in providing water to their consumers, and the main solution to meet increasing demand is by expanding the water supply capacity. These obstacles in providing potable water have coma as a result of reasons such as: population increase, no proper water pricing structure (low water tariffs), regulations, a shortage of financing, absence of commercial orientation, a shortage of water resources or no water resources with seawater desalination being the main source, unplanned development and others (Al Shueili, 2014). However, water demand management has received little attention and all efforts have gone to manage the supply rather than the demand for water (PAEW, 2015; Jamrah et al., 2008; Jamrah et al., 2006; Prathapar et al., 2005). The main responsibility of water sectors is to concentrate on the supplying role (PAEW, 2015; Al-Maskati, 2011). Therefore, to overcome these challenges, it is important to work innovatively to find proper solutions. One effective approach that needs to be considered to address these challenges is integrated water resource management (IWRM).

2.3 Integrated water resource management (IWRM)

Integrated water resources management (IWRM) is defined as a process with many dimensions and involvement of different sectors in society (public and private), of water users and different administrative levels. It includes many conflicting issues and principles such as environmental sustainability to guide the preparation of various management options (Mimi, 1999; Melnychuk et al., 2017; Scott,et al., 2017).

The Global Water Partnership (GWP) Technical Advisory Committee defined IWRM as a process of coordinating development and management of water, land and resources in a manner that maintains economic and social welfare, without compromising the sustainability of vital ecosystems (GWP, 2000; Melnychuk et al., 2017; Veale and Cooke, 2017).

There are many factors influencing water consumption and water use, for example, water use behaviours (Dolnicar et al., 2012), water use motivations, barriers to water conservation, trust in water authorities, and awareness of water saving and behaviours (Savi et al., 2014). The number of occupants in buildings, their ages and their lifestyle (i.e. frequency of use of water demanding applications or activities) influences water use and impacts on water consumption, conservation practices, and behavioural control and on attitudes (Willis et al., 2013). It is thought that this difference in the family composition can be used to explain variations in household water demand (Lee et al., 2011).

Integrated water resource management illustrates the importance of implementing different factors and working with different factors influencing water use to manage water and to reduce demand.

> *"IWRM explicitly challenges conventional, fractional water development and management systems and places emphasis on integrated approaches with more coordinated decision making across sectors and scales. It recognizes that*

exclusively top-down, supply-led, technically based and sectoral approaches to water management are imposing unsustainable high economic, social and ecological costs on human societies and on the natural environment. Business as usual is neither environmentally sustainable nor is it sustainable in financial and social terms. As a process of change which seeks to shift water development and management systems from their currently unsustainable forms, IWRM has no fixed beginnings and will probably never end. As the global economy and society are dynamic and the natural environment is also subject to change, IWRM systems will, therefore, need to be responsive to change and be capable of adapting to new economic, social and environmental conditions and to changing human values" (GWP, 2000).

The Global Water Partnership created tools designed to support the development and application of IWRM based on three categories: (a) Enabling Environment; (b) Management Instruments; and (c) Institutional Roles (Bielsa and Cazcarro, 2014).

IWRM principles include planning for all sources of water; addressing water quantity, quality, and ecosystem needs; incorporating principles of efficiency, equity and public participation; and having a multidisciplinary and multiagent approach, and sharing of information. The implementation process has been described as an iterative spiral of four phases: (1) recognizing and identifying; (2) conceptualizing; (3) coordinating and detailed planning; and (4) implementing, monitoring and evaluating (Bielsa and Cazcarro, 2014).

2.3.1 Integrated urban water resources management (IUWRM)

"Integrated Urban Water Resources Management (IUWRM) is a participatory planning and implementation process, based on sound science, which brings together stakeholders to determine how to meet society's long-term needs for water and coastal resources while maintaining essential ecological services and economic benefits" (UNEP, 2003).

2.3.1.1 The principal components of an IUWRM system include

• **Supply optimization**, including assessments of surface and groundwater supplies, water balances, wastewater reuse, and environmental impacts of distribution and use options.

• **Demand management**, including cost-recovery policies, water use efficiency technologies, and decentralized water management authority.

• **Equitable access** to water resources through participatory and including support for effective water users associations, the involvement of marginalized groups, and consideration of gender issues.

• **Improved policy** regulatory and institutional frameworks, such as the implementation of the 'polluter-pays' principle, water quality norms and standards, and market-based regulatory mechanisms.

• **Intersectoral approach** to decision-making, combining authority with responsibility for managing the water resource (UNEP, 2003).

Water demand management (WDM) is one of the principles of IUWRM which needs to be considered and should receive major attention.

2.4 Water demand management (WDM)

WDM has different definitions from the author's point of view, as is made clear in Table 2.1. However, all of them agree that efforts and work must be done either by users or by governments or both in terms of developing and implementing strategies and policies to achieve WDM. Chesnutt et al. (1997) defined WDM in a very general way as the process of reduction of water use. Louw and Kassier (2002) stated that efforts must be made by governments through forming policies and educating consumers or by consumers through awareness and behaviour change, and by applying better techniques or both.

Whereas Tale (1990) has concerns about the benefit of WDM in educating society, White and Fane (2001) provided a definition approving the important efforts and actions that should be made towards modification and WDM. According to Chesnutt et al. (2007), water demand management can be viewed as a change to existing water consumption. In this doctoral research, the definition by Savenije and Zaage (2002), seems more appropriate by suggesting of policies, measures or other initiatives aimed at influencing demand, to achieve efficient and sustainable use of the scarce water resource.

Table 2.1: Different definitions of water demand management from different authors, as reported by Kayaga and Smout (2011)

Authors	Definitions
(Chesnutt et al, 1997)	"reduction of water use"
(Louw and Kassier, 2002)	"efforts made to save water during situations of water shortages"
(Tate, 1990)	"socially beneficial education of water use or water loss"
(White and Fane, 2001)	"action that modifies the level and/or timing of demand for the water resource"
(Savenije and van der Zaage, 2002)	"development and implementation of strategies, policies, measures or other initiative aimed at influencing demand, to achieve efficient and sustainable use of the scarce water resource"

Demand management measures aim to minimize either the overall or peak demand for water, by increasing the efficiency of water use. There are five major categories of WDM measures (White and Fane, 2001):

(i) increase system efficiency at the utility level;

(ii) physically increase end-use efficiency;

(iii) promote locally available recourses not currently been being used, such as rainwater harvesting;

(iv) promote substitution or resource use, e.g. use of waterless sanitation; and

(v) use economic instruments to bring about an improvement in resource usage, such as the use of tariffs.

Positive results were yielded from WDM measures application in several countries. Many achievements in WDM by different organizations have been reported in the literature, a few examples of which are summarized in Table 2.2.

Table 2.2: Application of WDM measures in several countries, as reported by Kayaga and Smout (2007); Jamrah et al. (2008); Prathapar et al. (2005) and Jamrah et al. (2006)

Countries	Action	Achievement
New York, US	The city council provided rebates for installing low-volume water closets.	Reduction in overall householder use by 29%.
Millennium Dome London	Using a combination of poor groundwater, greywater, and rainwater for toilet flushing.	Saving of about 50% potable water consumption
Lotte World, Seoul, S. Korea	Reclamation of wastewater for toilet flushing.	18% (900m3/day) of the total water supply provided.
Malaysia	Reusing the spent wash in molasses dilution and fermentation.	40% reduction in freshwater consumption.
Mallorca Island, Spain	Recycling of greywater to flush toilets at a local hotel.	23% of water consumption was saved.

The reuse of greywater may be best utilized in urban regions, where a higher level of water management is required. In many countries, including Japan, United States, Australia, UK, Germany, and Sweden, the reuse of greywater is becoming more prevalent (Jamrah et al., 2008; Prathapar et al., 2005; Jamrah et al., 2006). Nearly all the reuse of greywater is for non-potable use. Major water conservation improvements are noted when greywater is used for irrigation and toilet flushing. In London, a water recycling system was installed to recycle rainwater, greywater, and groundwater at the Millennium Dome (Lodge et al., 2000). Another example of a successful greywater reuse programme is in California, where Young and Holiman (1990) introduced greywater reuse for non-potable uses in 380 housing complexes. In Japan, greywater is used in 840 in-building recycling units, 42 different districts, and 27 different municipality-based systems. Within Tokyo alone, many office complexes, apartment buildings, and municipal centres are now using wastewater reuse programmes.

The reuse of greywater can realize major savings in both the demand and the cost of providing freshwater. Water savings may range from 12 to 65%, according to Shiekh (1993), based on a study conducted in Los Angeles. The study examined greywater utilized for irrigation and the savings that could be passed on to each homeowner. Reuse of greywater for toilets and irrigation could lead to 30-50% savings, according to a study conducted in Australia (Jappasen, 1996). As stated by Knight et al. (2000), greywater reuse in Sydney, Australia, could lead to a potential saving of $70 million AUD per year, based on 1998 prices of water. The requirement of water for flushing toilets and doing the laundry could be fully met by re-capturing the water used for showering and laundry (Edwards & Martin, 1995). Also, the water supplied by sink recapture could lead to a reduction in water demand for toilets by 20-30% (Dixon et al., 2000). The reuse of greywater could lead to potential savings by reducing sewage water flows, when combined with better and more efficient garden design, offering up to 38% more potable water (WAWA, 1993).

In the United States, UK, Europe, and Australia, studies of greywater production have been conducted. Surendran and Wheatley (1998) found that in the UK, quantities of greywater and blackwater production were found to be approximately equal. Hodges (1998) found that around 66% of freshwater use resulted in greywater production from domestic use.

Measures and techniques (including policies, water pricing, efficient appliances, and recycling) are important concepts to be investigated in this study to achieve WDM.

2.4.1 Measures and techniques

A measure is defined in the Cambridge dictionary as "a plan or course of action taken to achieve a particular purpose or a way of achieving something, or a method for dealing with a situation".

A technique is defined as "a method of performance; a way of accomplishing or skill; ability to apply procedures or methods so as to affect the desired result".

A combination of measures and techniques are important to achieve WDM, as plans and methods are important. This will be investigated in this chapter by reviewing results and issues from different studies based on their measures and techniques, and concepts to achieve efficient and sustainable use of the scarce water resource in line with WDM for achieving the desired results. From the literature review, the emerging research can be categorized into four key concepts of measures and techniques:

- Policies
- Water pricing

- Efficient appliances
- Recycling

2.4.1.1 Policies

This part of WDM will explore concept of policies more broadly and attempt to gain a better understanding of water demand management policies specifically. It starts with policy definitions, approaches, and examples of policies that have been implemented in developed countries. It is important to attempt to understand what is meant by the term 'policy' exactly, and this is examined next.

Policy definitions and approaches

Policy definitions have been conceptualized in different ways, so there is no single definition for it. Guba (1984) stated that "it is nonsense to ask the question, 'What is the real definition of policy'. All definitions are constructions". Although, it is useful to have some definitions to proceed.

The following are definitions of policy as given by some authors:

> *"A set of interrelated decisions taken by a political actor or group of actors concerning the selection of goals and the means of achieving them within a specified situation where these decisions should, in principle, be within the power of these actors to achieve"* (Jenkins, 1978).
>
> *"Policy sets forth problems to be solved or goals to be achieved and identifies the people whose behaviour is linked to the achievement of desired ends. Behavioural change is sought by enabling or coercing people to do things they would not have done otherwise"* (Schneider and Ingram, 1993).
>
> *"... 'policy'...is a set of shifting, diverse, and contradictory responses to a spectrum of political interests"* (Bacchi, 2000).

There is a difference made in the policy studies in the literature between investigating policy and analyses of policy. It is very important to determine the kinds of questions asked; the kinds of data that are collected either from literature or other sources; and the methodology used. Evaluating the desirability of a change to water consumption requires comparing its benefits with the costs required to produce that water service Simily (2016) so as to convince the government take on such an approach.

Currently, the wastewater reuse regulations in Oman do not differentiate between greywater and blackwater, and all greywater must be properly treated and tested to the standards of potability. But there are multiple households throughout Oman (and the rest of the world) that successfully use untreated greywater for irrigation purposes. Although some consider this to be an illegal practice, any unrealistic laws will typically have little cooperation. Additionally, there is not enough evidence to convince lawmakers that a common practice (although illegal) has caused any societal or individual harm (Prathapar et al., 2005; Jamrah et al., 2008).

Should legal standards be developed to address the use of greywater based on practical factors, Oman would benefit because it is a very water-starved nation. With no proof of harm, lenient greywater use may be implemented. The government may consider developing some legal codes and standards, such as those used throughout the United States and Australia (Jamrah et al., 2008).

2.4.1.2 Water pricing

"Demand management options to reduce water consumption include use of tariffs" (Smout et.al., 2008). Water tariff structures are designed to promote WDM in households and to ensure revenue sufficiency for the service providers (Al Shueili, 2014; Cooley, 2010; Al-Maskati, 2011). According to Kayaga and Smout (2014), implementing tariff structures in the city of **Zaragoza (Spain)** resulted in a 27% reduction of overall water consumption. A similar tariff structure was implemented in the city of **Kampala (Uganda)** and the result was saving 2.5 million m^3 per year of water, generating US$0.68 million extra per year, which could be used to extend water services to unserved household areas.

In Australia, particularly in Victoria, water pricing mechanisms have been introduced at the residential level to drive consumers towards better practices by rewarding water conservation (WaterSmart, 2006). The price for each step tariff for residential customers varies slightly for each water utility, but is currently (Corr and Adams, 2009):

> *"Step 1- (0–440 litres per day): $0.78 per kilolitre,*

Step 2- (441–880 litres per day): $0.92 per kilolitre,

Step 3- (881+ litres per day): $1.36 per kilolitre" All in Australian dollars.

Pricing reforms could reward water conservation at the residential dwelling level (Al Shueili, 2014; Cooley, 2010). Awareness of water scarcity in different countries generates water conservation initiatives by state and local governments and water authorities. Currently, most of these regulations and initiatives have been implemented to residential dwellings.

An arid country with a growing economy and a rapidly growing population, the Sultanate of Oman is experiencing a high demand for freshwater supplies. To address this problem, the Sultanate has installed 623 well fields and build 43 desalination plants around the region. Water production from the well fields is measured at 6,309M gallons/annum (78,500 cubic meters/day, approximately), while the desalination plants are able to produce 44.4M gallons/day (202,000 cubic meters per day, approximately). This freshwater is then distributed according to various prices (between 1.14 USD/cubic meter and 1.71 USD/cubic meter), depending on the region it must be delivered to and the quantities necessary. **Prices are assumed to be subsidized by the government, which indicates that the true cost of treatment, production, and distribution is likely to be higher than that which the selling price reflects.** Additionally, pumping water from the ground for the purposes of domestic, industrial, and agricultural use has caused a decline in groundwater levels and increased coastal salinization. As a result, it can be assumed that the demand for freshwater is putting a tremendous strain, both financially and on the natural resources in Oman (Jamrah et al., 2008; Prathapar et al., 2005).

According to Millock and Nauges (2010) and Randolph and Troy (2008), switching to water-efficient units would be more acceptable by the public compared to other water management policies such as price increases or water restrictions. This policy is examined next.

2.4.1.3 Efficient appliances

In **Australia**, water regulation is the government's responsibility. Each state has a different system. Water efficiency in Australia is done by labelling products with a star rating from one to six for appliances like; showerheads, toilets, taps, washing machines, dishwashers, and urinals. The Building Code in Victoria, Australia, specifies that new residential buildings must have water-efficient showerheads and taps and at least a solar hot water service, greywater system or rainwater tank (Corr and Adams, 2009). Some examples of these measures are outlined below.

The introduction of mandatory efficiency requirements for toilets 1 July 2006, including:

- water pressure limiting devices and restricting water pressure in all new building developments;
- “the introduction of NABERS (National Australian Built Environment Rating System), a performance-based rating system for existing buildings”;
- restrictions on times that watering systems can operate;
- that new houses must be fitted with a solar power hot water system;
- that new houses need to have a rainwater tank with a capacity not less than 2000 L, to meet non-potable water needs or recycling water supply for toilet flushing and watering gardens;
- that new houses must have a 6/3 dual flush toilet installed and 3 A-rated shower roses; and
- the maximum flow rate from a shower, basin, and kitchen sink or laundry trough outlet shall not exceed 9 L/min.

The water efficiency rating is part of and is mandatory for the Water Efficiency Labelling (WELS) scheme followed in Australia in appliances like washing machines, dishwashers, shower taps, kitchen taps, and bathroom basins. WELS appliances are tested at 150 kPa, 250 kPa, and 350 kPa. A lower WELS rating is preferred for a building with below 150 kPa water pressure to ensure that amenity.

According to Sountharajah et al. (2017), the practice of installing rainwater tanks for WDM in Sydney’s households has resulted in saving water by up to 15%. The households were able to save around 24 kilolitres of water annually, just from having a rainwater tank. However, installing water tanks to save water in arid countries is not a WDM option because of low rainfall.

In response to WDM, a study was conducted in Miami, the **USA,** to fill the gap for implementation of **effective water** conservation practices by analysis of water demand data from individual households over time focusing on showerheads, toilets and clothes washers. The reduction in water demand as a result of efficient practices was overall around 6 to 14%. Water saved was 10.9% in the showerheads, 13.3% in toilets and 14.5% clothes washers (Lee et al., 2011).

Looking towards WDM policies in **England** and **Wales**, building regulations require that water consumption for a new dwelling should not be more than 125 litres/ per capita/ day. In order to comply with this, Fidar et al. (2017a) and Fidar et al. (2017b) mention the importance of **economic efficiency, by** which they mean efficient appliances (WCs, showers, basin taps, kitchen taps, baths, dishwashers, and washing machines) in promoting water saving.

From findings of a market survey on **economic efficiencies** in energy/water, according to Fidar et. al. (2017a), **such appliances** need not necessarily be more expensive than conventional devices (less efficient). Similarly, the capital cost of showers and internal taps is independent of the micro-components' water efficiency – that is, low-flow devices are not necessarily more expensive than high-flow models. Commonly, the capital cost of the water tends to reflect design, fashion, and brand, rather than resource efficiency. However, Fidar et. al. (2017b) stated that many water efficiency-based WDM strategies, while saving water, do not necessarily have cost savings; yet combinations of certain water efficiencies (i.e. carefully selected composite strategies) do offer the potential to reduce the cost as well as water and energy consumption.

Water conservation which results from water demand management is one of the Plumbing Code objectives in **Australia**. For example, according to the Plumbing Code in buildings, only dual flush toilets can be installed in Australia. The Plumbing Code, like the Building Code, is given legal effect through state legislation. Using a dual flush toilet 6/3 Litres flush results in a 70% reduction in water flushing (Corr and Adams, 2009).

It can be observed from various studies in different developed countries, e.g. Australia, USA, and England, that implementing water conservation practices efficiently results in saving water and reducing water demand. However, regulations increasingly drive the water efficiency market, and hence the costs to implement water efficiency initiatives are likely to decrease over time. Nonetheless, all the studies mentioned that implementation was carried out at the domestic buildings level, with only a few examples in any other type of building and with no clear methodology of measuring and analysing.

Developed countries have implemented WDM practices at the residential level to achieve sustainable WDM. Such practices have included the use of efficient appliances, as these constitute the majority of indoor household water demand as has been well acknowledged (Lee et al., 2011; Fidar et al., 2010; Balbin et al., 2010; Millock and Nauges, 2010; Olmstead and Stavins, 2009; Kenney et al., 2008; Baumann et al., 1998) and more incentives than tariff structure (Millock and Nauges, 2010; Randolph and Troy, 2008).

The Plumbing Code of **Australia** fosters water efficiency by use of water-efficient fixtures and fittings, but more can be done to ensure that the appropriate water-saving initiatives are incorporated into works. This sets a threshold for the minimum level of water efficiency a developer must achieve. It is important for occupiers to participate in water efficiency initiatives, as there are many initiatives that rely on behavioural change (such as ensuring taps are turned off properly, only turning a dishwasher on when full, and reporting leaks to building maintenance technicians). Such initiatives can result in significant savings in a building. As water awareness becomes more prevalent, occupiers are likely to use appliances more appropriately and to report any leaks/defects as soon as possible to minimize potential water losses (Lee et al., 2011; Corr and Adams, 2009). Behavioural changes generate water saving very quickly and at very little cost. In **East Queensland** in Australia, for example, consumers responded to a drought restriction by going from using 70 gallons per person per day to 34 gallons per person per day; this increased to 43 gallons per person per day after restrictions were eased. Similarly, in **Denver,** the restriction reduced water consumption from 211 gallons per person per day to 170 gallons per person per day and then to 2002 gallons per person per day after the restriction was eased (Cooley et al., 2010).

> *"The benefits of implementing water efficiency initiatives in buildings may include: cost savings in annual water bills, particularly when the price of water is likely to increase, based on the current drought conditions adding to the corporate image of a business/organization reduced energy costs and greenhouse emissions helping to ensure water is available for future generations"* (Fidar et al., 2017b).

Sustainable design principles should meet the needs of the current generation without impacting future generations. These include water conservation and efficiency principles. Thus, developers and contractors that incorporate water efficiency into a building or development will have a market advantage. Any improvements in efficiency are beneficial for managers in the long term, particularly as the price of potable water is likely to increase (Corr and Adams, 2009).

With the current price of water, there are many water efficiency options that, if implemented, have a long payback period or only provide a small return on investment. Undertaking a cost-efficient analysis is beneficial when assessing the feasibility of options; however, in such an analysis, consideration should be given to the likely increase in the cost of potable water. The benefits to the corporate image of a business should also be taken into consideration with such options (Fidar et al., 2017a; Fidar et al., 2017b).

Implementation of new technologies may prove unsuccessful and thus assurances/warranties will need to be obtained from the suppliers. There are alternative technologies that may provide great results in water efficiency, but they may not be widely accepted. An example is a composting toilet that has been used for many years in places such as caravan parks. Although the technology has improved in terms of reducing odours and improving aesthetics, composting toilets are still not widely used or accepted in public buildings. Such options, if considered appropriate, will need to be implemented alongside an educational and marketing campaign (Corr and Adams, 2009).

Effective and efficient appliances

According to a report by Corr and Adams (2009), 1.7 million litres per year was saved from water conservation in **Green Square South Tower**. This involved the use of water-efficient appliances of a minimum of 4A water conservation rating for all taps, showers, and WCs, as well as recycling condensate water in the air conditioning system and fire test water and reused for toilet flushing and irrigation for landscaping. Study in **Sydney** represents 37% of total water consumption from sanitary fixtures (toilets, urinals, basin taps, and showerheads) in public, commercial or industrial buildings. The percentage of water consumption could be much higher than 37%, depending on the building type. While only part of this will be for water used in kitchens, the majority is likely to be for sanitary fixtures (Corr and Adams, 2009).

Most of the earlier studies carried out to evaluate effective techniques were conducted to evaluate on the supply side (White and Fane 2002; Maurer 2009; Hughes et al. 2009). Bochereua et al. (2008) investigated the capital cost of efficient equipment, but from the perspective of water service providers, while Fidar et al. (2011a) evaluated the potential economic implications of water-efficient equipment from the perspective of households at the domestic level. Lee et al.'s (2011) study was of estimations versus observations to implement effective water conservation practices, without consideration of the cost of each practice. Fidar et al. (2017), Fidar et al. (2017b) and Lee et al. (2011) all mentioned the importance of **economic efficiency** in water saving. This doctoral research will start with common parts that have been considered across both studies as being efficient in saving water, which is: taps, WCs, and showers, and will list different types mentioned from different studies and total water savings.

Taps:

In some studies, taps are called faucets. Installation of low-flow tap aerators reduces miscellaneous tap usage (Mayer et al., 1999). Taps with aerator technology save water, but including more than one technique results in a greater reduction in water; for example, faucets with an efficiency aerator, sensor and hand-free controllers save 9.3 gallons per household per day (see Table 2.3).

Table 2.3**: Comparing different taps for water-saving in different studies**

Study	Taps	Water-saving (gallon per household per day)
Cooley et. al. (2010)	Faucet aerator (1.5GPM gallons per minute)	1.7
Mayer et. al. (1999)	Faucet with efficiency aerator, sensor, and hand-free controllers	9.3

Brief of some different taps

Aerators and flow restrictors:

Taps have inbuilt aerators and/or flow restrictors. Aerators and/or flow restrictors can be installed in existing tapware to improve efficiency (Corr and Adams, 2009). This type of tap gives a satisfying feeling to consumers about the water flow which is mixed with air.

Sensor taps:

The sensor tap is an automatic shut off tap that is commonly used. At a set time it shuts off automatically to reduce the possibility that taps are left running too long or not turned off. A 6-star WELS rated tap is set at between 5 and 10 seconds running time at 4 L/s flow rate (Mayer et. al., 1999). This tap type may be more suitable for use in public buildings, as the chance of taps not being turned off is observed more in bathrooms in public buildings. However, in such cases it is important to observe the timing setting and flow rate implementation in respect of WDM.

Showers:

According to Mayer et al. (1999), shower usage is the third largest component of indoor use. The low-flow shower used an average of 20.7 gallons per day per house and 8.8 gallons per day per capita for showering, while the non-low flow shower used an average of 34.8 gallons per day and 13.3 gallons per capita per day. Table 2.4 illustrates water savings from selected low-flow showers from different studies. Showers with a flow of 1.5 gallons per minute show better water savings (Cooley et. al., 2010; Clarke et. al. 2009) than those with 2.5 gallons per minute (Mayer et. al., 1999). The alarming visual display shower monitor has the least water savings compared to other types (Willis et. al., 2010).

Table 2.4: Comparing different showerheads for water saving in different studies

Study	Showerhead	Water savings (gallons per household per day)
Beal et al. (2011)	High-efficient showerheads	9.4
Cooley et. al. (2010)	Low-flow showerhead (1.5GPM)	12.1
Willis et. al. (2010)	Alarming visual display shower monitor	4.1
Clarke et. al. (2009)	Mixer shower (1.58GPM) replace bath and shorter duration (5 min. per use)	12.3
Mayer et. al. (1999)	High-efficiency showerhead (2.5GPM or less)	10.2

Brief of some different showers

Water-efficient showerheads

Under the WELS rating scheme, water-efficient showerheads are those that deliver 9 L/s or less. Showers can also be fitted with digital read-out meters that show the user the amount of water being consumed and the duration of the shower. This can encourage shower users in an office building to reduce water demand for showers (Chanan et al., 2003).

Sensor-operated and automatic shut-off taps

These types of showers are installed for high-usage washrooms (Corr and Adams, 2009). This type of shower should be fitted with digital read-out meters that show the user the amount of water being consumed and the duration of the shower.

Coin-operated showers

These types of showers are often used in caravan parks (Corr and Adams, 2009). Duration (minutes), average flow rate (litres per minute) and frequency of showering are the three parameters of interest.

Toilets:

A study by Mayer et al. (1999) from 12 different toilet sites shows the largest component of mean daily per capita use. A reduction of 20 to 40% was achieved in a **New York** City resident water bill after implementing low-flow models of 1.6 gallons per flush. This saved 70 to 90 million gallons per day from the isolation of 1.3 million low-flow toilets. The implementation resulted in huge water savings and the city was able to plan the need for extending the supply and wastewater treatment capacity (Cooley at al., 2010). According to Reidy and Tejral (2011), 1.6 GPF (gallons per flush) low-flow toilets can save 26.2 gallons per household per day, whereas 1.6 GPF of ultra-low flush toilets saves 29.4 gallons per household per day – as mentioned in Mayer et al. (2004). The water savings from different toilets in different studies is presented in Table 2.5.

Table 2.5: Comparing different toilets in water-saving in different studies

Study	Toilets	Water saving (gallons per household per day)
Reidy and Tejral (2011)	Low-flow toilet (1.6 GPF or less)	26.2
Tsai et. al. (2011)	Low water demand toilet	11.4
Cooley et. al. (2010)	Low-flow toilet	23.8
Clarke et. al. (2009)	Efficient model of toilet	17.3
Mayer et. al. (2004)	Ultra-low flush toilet (1.6 GPF or less)	29.4

Brief of some different toilets

Dual-flush toilets:

Dual flush toilets have become a standard or mandatory in Australia, as mentioned earlier in this section. Most common dual-flush toilets use 3 litres of water on a half flush and 6 litres for full flush (Corr and Adams, 2009). It is very important to replace single-flush toilets consuming up to 13 litres of water per flush with double-flush toilets to save water in buildings. Dual-flush toilets of 3 litres per half flush/4.5 litres full flush are now available on the market.

Waterless toilets:

Although "not very common for commercial buildings, urine-separating toilets separate the waste at source, and as in composting toilets, they reduce the nutrient load on the wastewater treatment system, since approximately 90% of the nutrients in human waste are in the urine" (White, 2001). These toilets are a new concept in Australia, but are quite common in Scandinavia, and have water-efficiency benefits as well as nutrient reduction. Composting toilets are not widely used in multi-story commercial buildings in Australia (Corr and Adams, 2009). "However, it is possible to install and use them in office buildings, and there are examples in Sweden and Germany of their use in multi-story residential buildings and one example in Australia in a two-story building" (the Thurgoona Campus of Charles Sturt University in Albury).

"The main advantages of composting toilets are that they require little or no water for flushing, thus reducing water demand; and they reduce the quantity and strength of the wastewater to be treated or disposed of and return nutrients to the environment" (US Environment Protection Agency, 1999). Waterless toilets operate by collecting wastes in a chamber, where the waste is aerated and mixed. Carbon-rich mulch is also added to assist with the decomposition process. They require significant levels of ongoing maintenance to ensure correct levels of moisture, oxygen, temperature, and carbon are maintained for efficient operation.

Vacuum toilets:

"Vacuum toilets remove waste from the toilet bowl using a vacuum pump. The waste is macerated and either discharged to the sewer or transported to a holding tank or treatment system. These are commonly used in aircraft and marine transportation and are increasingly being used in commercial and public restrooms" (Chanan et al., 2003). This type of toilet uses between 1 and 1.5 litres per flush (Chanan et al., 2003). However, energy use in vacuum toilets is higher than in conventional toilets. A standard flush uses 0.8 kWh for 500 flushes, whereas a vacuum system uses 1 kWh per 500 flushes (Chanan et al., 2003).

Urinals:

Low-water use urinals

In Oman, urinals are not fitted in public buildings. In other countries, men's toilets are fitted with a urinal in addition to a standard toilet in public and commercial buildings. Urinals in public toilets often require a large amount of water and disinfectant chemicals to keep them clean (Savewater, 2006).

> *"In some systems, water is applied automatically through a continual drip-feeding system or by automated flushing at a set frequency, 24 hours a day, 7 days a week, regardless of whether or not the urinal is being used. Water consumption varies with the system model, settings and usage rate, from 50 to 100 kL/year (30 to 70 flushes of 4 litres each per day). Cyclic 'fill and dump' units operating on 24 hours a day, 7 days a week basis can waste over 500 L/year"* (Corr and Adams, 2009).

Other types of urinal systems are described below.

Sensor-operated systems

The sensor-operated mechanism works by detecting the presence of people through a movement sensor (Chanan et al., 2003).

Standard trough system

This type of "urinals in Australia use an average of 6 litres of water per flush, while water-efficient urinals use 2.8 litres per flush" (Chanan et al., 2003).

Single-unit systems

These replaced trough and gutter systems with single-unit systems that have individual flushes.

2.4.1.4 Recycling water

There are four main types of water in commercial, public and industrial buildings that need to be considered, namely potable water, greywater, blackwater and stormwater (Australian Standards, 2003). These types of water are explained below:

Potable water: Defined as water that is suitable for human drinking consumption. The World Health Organization (WHO) defined the acceptable characteristics of potable water in their guidelines for drinking water quality (Corr and Adams, 2009).

Greywater: Refers to wastewater from bathroom fixtures (basins, shower, and baths, but not WCs), laundry fixtures and kitchen facilities (sinks and dishwashing machines) not containing human waste or industrial waste. Greywater can be recycled for toilet flushing or irrigation (Kimwaga, 2014; Casanova et al., 2001).

Although untreated greywater can be used in irrigation, it is recommended generally that some level of treatment should be provided for most end uses. Greywater from kitchen facilities is not usually recycled because it contains fat, oils and caustic chemicals from soap and dishwasher detergent in high levels that may damage soils (Corr and Adams, 2009).

Blackwater: Refers to "wet discharges from the human body" (Australian Standards, 2000), collected through toilets fixtures (WCs) and urinals. Recycling of blackwater can be used for non-drinking purposes. Treatment of blackwater depends on a treated, reliable and safe source and generally the ideal locations for recycling blackwater are close to wastewater treatment plants (City of Greater Geelong, 2006) or can be obtained from a large treatment plant that collects and treats the wastewater from a sewage system and then pipes it to the reuse location once treated. The recycled blackwater can be used for irrigation or flushing toilets through the provision of a third-pipe network.

Stormwater: Refers to rainwater collected from roofs (Australian Standards, 2003). Untreated stormwater can be used for purposes such as irrigation and toilet flushing.

Davidová and Horváthová (2015) stated that:

> *"water recycling is increasingly implemented in various industrial sectors leading to clear improvements in water use efficiency and reduced water expenses. The re-use of treated wastewater***,** *although not currently widely practiced, is growing across* ***Europe****. Significant potential exists for much greater use of treated wastewater. Moving towards sustainable water resource management requires that reliable and up to date information is available at appropriate spatial and temporal scales across Europe. Such information has many benefits including providing an improved overview of the causes, location, and scale of water stress; helping identify trends; facilitating the evaluation of measures implemented to address unsustainable water use; and assisting EU citizens to engage in water issues".*

However, different codes and standards in each state or water authority in **Australia** has developed its own set of guidelines and policies for wastewater recycling, but all the codes and guidelines are at the domestic building level only. According to Horne and Horne (2016) important indirect potable water reuse projects, but no direct potable reuse project was undertaken, and none seems likely in the near future. Corr and Adams (2009) did record an example of wastewater recycling in industrial buildings: "The end result in royal Australian Mint was a reduction of 50% in water use from the previous by re-using water", but nothing is mentioned with regard to examples from public buildings.

The total public industrial and commercial building consumption is around 21% to 30% of the total potable water in Australian urban centres (Corr and Adams, 2009). However, water used within the building depends on the building type; for example, the majority of water used in a restaurant is for kitchen applications and the majority of water used in office buildings, kindergartens, and shopping centres is for cooling towers. By comparison, in mosques, more than 90% of water consumed is for ablution purposes (Suratkon et al., 2014). Recycling water to reduce water consumption in buildings and improving water efficiency is a major aspect of creating sustainable public buildings which will benefit from cost savings in annual or monthly water bills, particularly when the price of water is likely to increase.

Effective techniques for recycling

Greywater recycling

Al-mashallah et al. (2012) present in their study the acceptability of people reusing treated greywater in irrigation by using a method of door-to-door interviews survey in a farming community of Deir Alla in Jordan. The survey responses provided evidence that rural communities are willing to accept reuse of treated greywater for irrigation purposes and are willing to learn more about greywater treatment in order to operate greywater systems for irrigation.

Greywater is often favoured for reuse for several reasons. It contains far fewer nitrogen particles than blackwater, which means it requires less rigorous treatment before it is safe to use. Although medical professionals consider blackwater to be the major source of all human pathogens, when greywater is separated from blackwater, the dangers are significantly reduced. For example, the greywater will be separated from the faeces that carry the human pathogens. Additionally, greywater has organic content that will decompose far more quickly than blackwater content. This means that the content in blackwater will continue to absorb oxygen for a longer time (NSW Health, 2000).

Management decisions can be based on greywater reuse, should these objectives be reached. Although there are still questions about the various contaminants that may be present in greywater, appropriate recycling plans could help to establish adequate parameters among quality measures and help to identify the best treatment methods for each specified use of greywater (e.g., showering, sink use, etc.) (Jamrah et al., 2008; Prathapar et al., 2005; Jamrah et al., 2006).

Greywater and sewage treated can be used for many applications. The applications vary from country to country, depending on specific country requirements and standards. Some applications of greywater include irrigation, toilet flushing, car washing, firefighting systems, industrial uses, cooling water, and washing clothes. Greywater treatment and recycling from washing machine discharged water has been presented by Venkatesh and Senthilmurugan (2017), by using a polymeric ultrafiltration (UF) membrane by reverse osmosis (RO) membrane to treat turbidity of greywater from the washing machine. The process so used was able to produce 300L of treated water for reuse out of 400L of greywater discharged.

Kimwaga (2014) conducted a study with the objective of characterizing the quality and quantity of greywater from three sources, namely bathrooms, laundry, and the kitchen. The results on quantity show that the kitchen contributed only 5%, the bathroom 45% and the laundry 50% of greywater discharge. The quality varied from the different sources, but the result for faecal coli (FC) (Casanova et al. , 2001; Kimwaga, 2.14; Li et al., 2009) was high from the three different sources – with laundry showing the highest FC of 6 × 10^4 /100 ml, followed by the bathroom 3 × 10^4 /100 ml and kitchen 2.5 ×10^4 no/100 ml. Vegetation irrigation requires a standard maximum of FC 1000 no/100 ml and not more than 5000 /100 ml for lawn irrigation. According to the WHO, greywater can be used for irrigation without restriction if the BOD (biochemical oxygen demand) is less than 25 mg/l, TSS (total suspended solids) is less than 50 mg/l and FC is less than 1000 /100 ml (Corr and Adams, 2009).

However, Li et al. (2009) mentioned in their study the importance of combining chemical (aerobic biological) processes with physical (filtration) processes and disinfection as a most feasible solution for greywater treatment. The literature review shows that greywater has good biodegradation. Greywater from the bathroom and laundry are deficient in nitrogen (N) and phosphorus (P), whereas the kitchen has a balanced ratio of chemical oxygen demand (COD): N: P but high in FC risk (Casanova et al. , 2001; Kimwaga, 2.14; Li et al., 2009).

Risks of using greywater

Replacing potable water with alternative sources in a public building can pose some health risks. The risk will depend on the source of the water, the treatment process, and the end-use. Appropriate approvals and risk management systems will need to be in place for such options (Mo et al., 2015).

There have been concerns about disease transmission rise when reusing greywater, which is wastewater, by contact with water bodies or irrigation soil (Casanova et al., 2001; Kimwaga, 2.14; Li et al., 2009). Casanova et al. (2001) conducted a study in America on the effect of microbial quality of greywater and irrigation soil by taking samples of greywater and soil irrigation and potable water, and found that there was a significant increase of faecal coliforms in soil irrigated with greywater when compared with soil irrigated with potable water. A significant increase of faecal coliforms was found more in the kitchen sink and laundry (Casanova et al., 2001; Kimwaga, 2.14; Li et al., 2009). Children also cause a statistically significant increase in faecal coliform levels in greywater and soil, possibly introducing a small amount of additional risk in greywater reuse.

It is important to recognize that greywater is not considered to be completely pathogen-free. In certain cases, it may even have more pathogens than those found in combined wastewater (both grey and black). These instances are most likely to be in places such as hospitals, households with ill individuals, or in areas where diapers are regularly washed. As a result of this potential, a high level of caution is always recommended when greywater is reused (Casanova et al., 2001; Jappesen, 1996).

Reusing greywater at the home/domestic level requires the recycling of water that is generated using sinks, showers, laundry machines, or dishwashers (Casanova et al., 2001). This will require the greywater to be treated before it can be safely reused, as solids and organic compounds must be removed to ensure safety, even when not used as potable water (Nolde, 1999).

Capturing greywater

Reusing greywater requires collecting the greywater, storage in simple diversion sedimentation tanks and irrigation field’s diverter valves, filtering and distribution after the greywater has been treated. Available options for treating greywater include sand filters, aeration, and electro flotation pressure filtration. There are significant innovations likely to be more suitable in public, commercial and industrial buildings. Examples of these innovations are as follows (Corr and Adams, 2009):

Systems that comprise of a diverter valve, a small storage cell, a pump, and an automatic dump after 24 hours can be used for garden irrigation in situations where greywater cannot reach the garden under gravity.

Another product comprises of a diversion, a storage tank, a pump, a filter, a float switch, and an auto-electric controller, as well as daily automatic release to the sewer or garden for excess water.

> *“Significant innovation has occurred within this sector in recent times, with several systems now available that treat greywater to the highest possible*

standards for recycled water (Class A or tertiary treatment level with disinfection). These systems continuously monitor the water quality and system performance and require minimal maintenance by the building owner/occupier, hence reducing risks. Furthermore, these systems are often designed to fit into small spaces, making them ideal for use in buildings. These types of systems are likely to be more suitable for commercial, public and industrial buildings" (Corr and Adams, 2009).

Blackwater recycling

It is very difficult to recycle blackwater at the small single house or small commercial building scale, because of space and land capability limitations and the high risk of such treatment (Hyder Consulting, 2005). However, treatment technologies provide low cost-effective ways of safely reusing black and greywater on the site of the building at the small allotment scale.

Otterpohl (2002) stated that "If blackwater is collected separately with low dilution it can be converted to safe natural fertilizer, replacing synthetic products and preventing spread out of pathogens and other pollutants to receiving waters". On the other hand, McConville et al. (2017) mentioned that although a paradigm shift to wastewater reuse for resource recovery is facilitated by alterative solutions such as source separation for improving treatment capacity and efficiency, these systems are still immature and considered risky by professionals and engineers and are scarcely implemented. Mcconville et al. (2017) state that: "Certainly, to be successful, NoMix toilets must be acceptable to household users. However, the full pathway to implementation still requires significant research and development effort".

Risks of using blackwater

The end quality of treated blackwater is greywater quality. This quality of treated blackwater can present risks to the building occupants, the community at large and the environment. Policies and guidelines are produced to prevent the risks of black and greywater (Casanova et al., 2001; Kimwaga, 2.14; Li et al., 2009). Blackwater contains higher risks than greywater (Mcconville et al., 2017). However, greywater still needs to be used with care and following specific country standards (Casanova et al. , 2001; Kimwaga, 2.14; Li et al., 2009). **In Australia,** treated wastewater is classified from A to D class based on its quality. Table 2.6 below summarises the classifications of treated wastewater, as developed by the Queensland Environmental Protection Agency, on the recommended water quality specifications for Class A to D recycled water. However, the treatment of greywater to a higher class is less expensive compared to the treatment of blackwater to the same class (Corr and Adams, 2009).

Table 2.6: Recommended water quality specifications for Class A to D recycled water

Class	E. coli cfu/100mL (median)	BOD5 mg/L (median)	SS, mg/L (median)	TDS, mg/L or EC, µS/cm (median TDS / EC)	pH
A	< 10	20	5	1000/1600	6-8.5
B	< 100	20	30	1000/1600	6-8.5
C	< 1000	20	30	1000/1600	6-8.5
D	< 10,000	—	—	1000/1600	6-8.5

Innovative products available in Australia include (Corr and Adams, 2009):

> *1. "Wastewater recycling units, which act on raw sewage and separate gross solids and fine solids through continuous deflection separation, followed by submerged aerated filters, a fine sand filter, UV disinfection, and chlorine addition. Sewage is transformed into the water up to Class A standard; those which can treat a range of effluents, including greywater, sewage, and other wastewaters, using flat sheet membrane panels (that are aerated) within an activated sludge treatment tank.*
>
> *2. Screening and de-gritting must occur prior to the use of the unit. These units produce water to a standard for toilet flushing, wash-down and irrigation using a simulated soil matrix (worm farm) to break down sewage and household organic waste, or an on-site, in-ground tank containing a fully aerobic, humic biological filtration matrix, which also incorporates extensive vermiculture (worm) activity for the accelerated decomposition of organics."*

The cleaned water from these biological filtration matrix systems can then be reused on-site, or the effluents can be exported to a pressurized reticulation network. Recycling water in Sydney has increased by 130% from 1995 – from 6,200 ML/year to 14,200 ML/year. The scheme is currently reducing demand by over 1,300 ML/year. This reduction in demand can be attributed to the increasing use of recycled water at Sydney Water's sewage treatment facility (Corr and Adams, 2009).

2.5 Water demand management at the household level

Greywater reuse is among the most advanced methods for water conservation. This greywater is generated in houses through washing water (showers, laundry, sinks, etc.) (Jamrah et al., 2006). The name 'greywater' is derived from the colour the water will turn to after a period of not being properly treated. Although many sanitation experts claim that greywater is of a much lower quality than potable water, it is of much higher quality than blackwater. Greywater accounts for 50-83% of all residential water use (Ericksson et al., 2003; Jamrah et al., 2004).

A study at the household level was carried out in **Jordan** by Jamrah et al. (2006). Water scarcity in **Jordan** has led to incredible pressure on the currently limited water sources. Finding renewable sources of water is becoming a high priority for water management specialists. With such limited renewable sources of water currently available, this study in Jordan in 2006 was intended to evaluate the possibility of utilizing available greywater to improve water resource management. It assessed the sources of greywater in Amman, and parameters that needed to be addressed to improve public acceptance of greywater use. Using a survey method, residents in 38 different areas of Amman were interviewed. From 233 homes, 1,514 people participated in the Jordan study. There were 15 different greywater samples collected in the study, from various geographic regions in the area. Samples were obtained from showers, laundries, and sinks, and water quality was evaluated for each of the samples.

In conclusion, it was determined that per capita water consumption could be assumed to be between **51-115** litres per day, which averaged to **84** litres per day per capita (LPCD). This resulted in the generation of 39-80 LPCD of greywater and accounted for approximately **70%** of total water consumption. Respectively, laundry, showers, and sinks generated 16%, 34%, and 50% of the sources of greywater. According to physical, chemical, and biological analyses, the greywater collected contained significant levels of suspended solids, inorganic constituents, chemical, and biochemical demands, total coliforms, and faecal coliform bacteria. According to the public acceptance survey results, some of the participants were comfortable with the use of greywater for specific purposes, namely vegetable gardens, tree irrigation, toilet flushing, laundry, and washing cars. Others were opposed to greywater reuse, due to concerns about possible health hazards, pollution of groundwater, and the potential for environmental effects.

The perceptions of people related to the reuse of greywater were examined. The main objective of the survey was to evaluate the public perception of greywater reuse initiatives. Using 250 questions, a random sample of residents in the city of Amman was surveyed over the course of a four-month period. The survey evaluated public awareness, willingness, and potential opposition to the reuse of greywater. In order to assess and analyse the data that was obtained via the survey, assumptions were made with regard to how much freshwater needed to be used. All assumptions were consistent with the data used by the Ministry of Water and Irrigation in Jordan. Freshwater consumption was assumed to be approximately 90 litres per use for laundry, 60 litres per use for showers. Brushing teeth was assumed to require 1/3 minute, as was handwashing. **Two minutes** was the assumption for ablution, while one minute was the assumption used for hair washing. On average, the water flow for hand basins was measured at 6 litres/minute. Drinking and cooking were assumed to use approximately 5% of the household totals for water use, and gardening was assumed to use approximately another 6%. **The household assumptions were derived from water bills obtained from the Consumer's Directory of the Water Authority of Jordan in 1999.** Figure 2.1 shows various water consumption patterns known in the city of Amman, considering the scarcity of water available in the area (Jamrah et al., 2006).

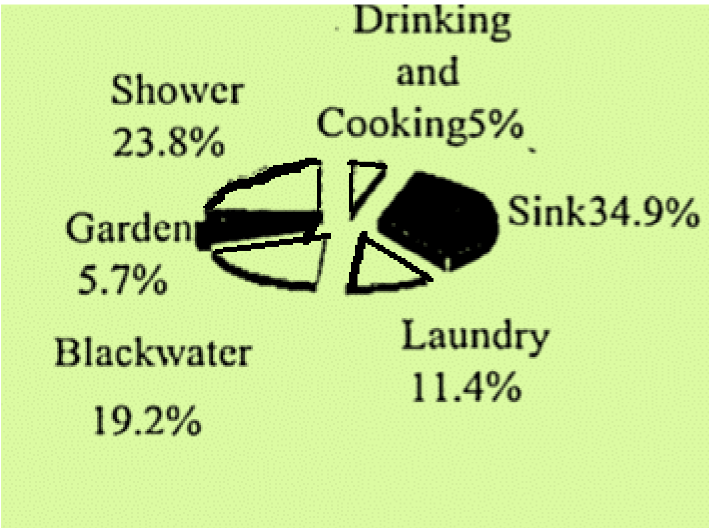

Figure 2.1: Distribution of internal domestic freshwater use in a typical household in the city of Amman (Jordan) (Jamrah et al., 2006)

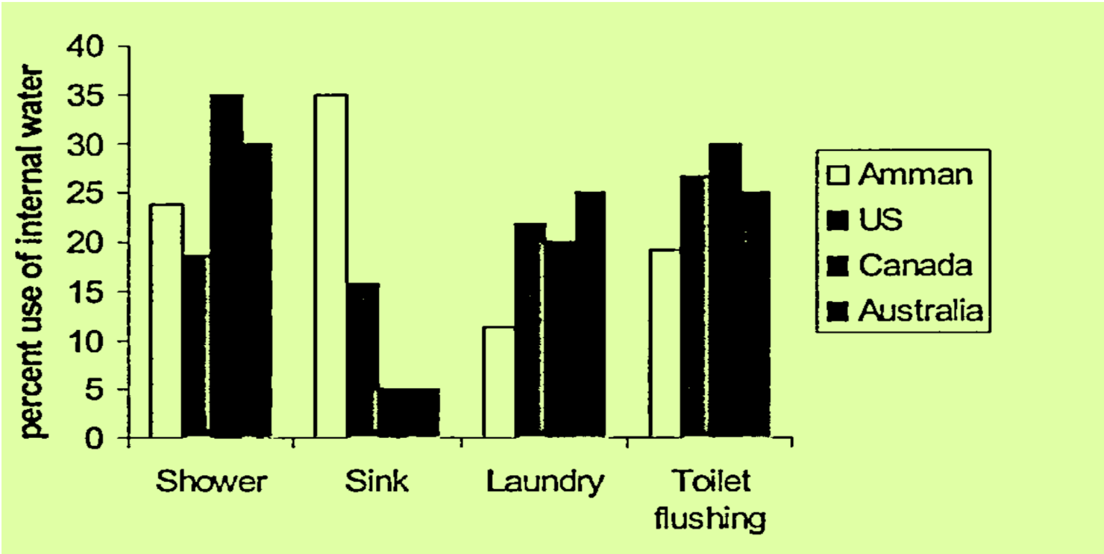

Figure 2.2: **Use of internal water for various purposes in Amman and other countries (Jamrah et al., 2006)**

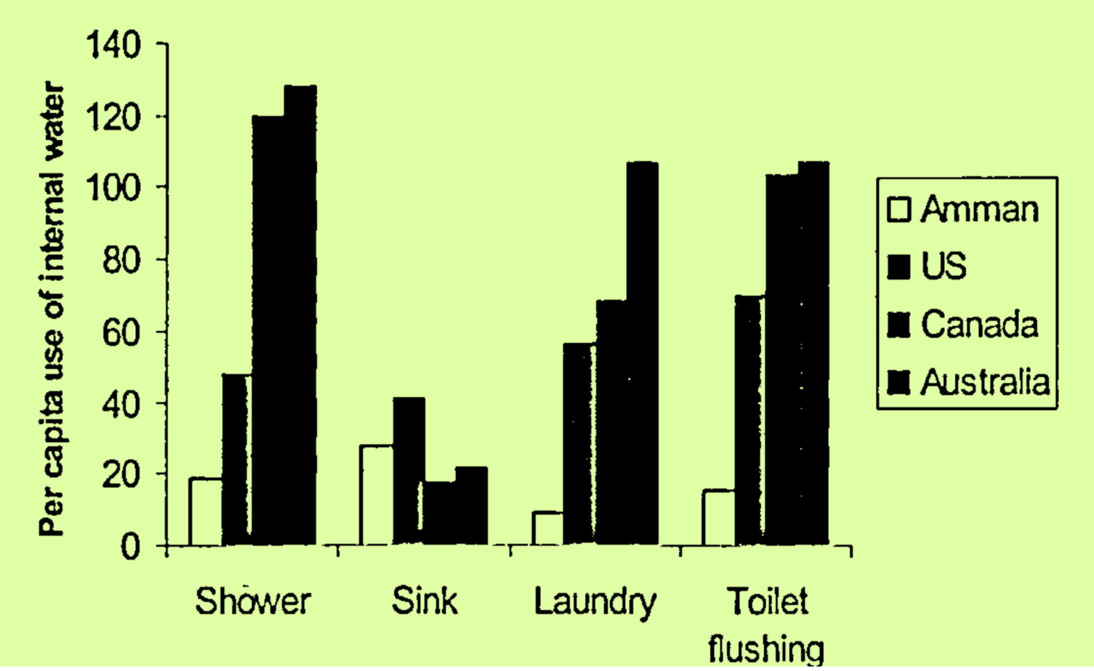

Figure 2.3: Per capita comparison between the rate of internal water consumption for various purposes in Amman and other countries (Jamrah et al., 2006)

From the study carried out by Jamrah et. al in 2006 in Jordan (Amman), it can be clearly seen that usage of water in sinks is much less than for other purposes in most international regions, including the United States and Australia, but is higher in Amman. This supports previously mentioned information in Chapter 1 that Muslim countries have different needs pertaining to water usage: for example, the use of water for ablution is five times per day, prior to praying. In Figures 2.1, 2.2, and 2.3, water consumption in sinks is noted to be higher in Amman than toilet flushing.

It is important to assess the results in Oman for greywater reuse to determine whether such reuse could be adequate to address the demand for toilet flushing.

The following equation helps to calculate the amount of greywater that is generated from household freshwater consumption. Results from this equation confirm the percentage derived from the survey results, 69%: (Jamrah et. al, 2006)

Greywater (LPCD) = 0.690 x Total Water Consumption (LPCD)

The reuse of greywater may be instrumental in decreasing the total water consumption per household and could save large amounts of greywater for other purposes, such as toilet flushing and laundry.

Another study was carried at the domestic level by Jamrah et. al (2008) in the **Sultanate of Oman.** There is a shortage of water in Oman because of its highly irregular and rare rainfall patterns, and the eventual poor regeneration of groundwater. On the coast, there is some proof of high salinity in the groundwater because of the encroachment of seawater. As a result, it is imperative that careful planning is utilized to limit water consumption in these regions. Although there are several potential water management solutions, the use of greywater is the most plausible for making a difference and reducing the consumption of freshwater. Because water is becoming increasingly scarce around the globe, the development of greywater reuse strategies and methods can help both the public and private sectors. According to Jamrah et al. (2008), the implementation of greywater recycling methods will help reduce the pressure on freshwater systems and aid in balancing resources with needs.

In Oman, there is strong governmental interest in developing greywater reuse methods for water conservation. Implementation could occur at a large scale, involving the entire community, or at a more homeowner based, smaller scale (Al-Jayyouse, 2003b). The average Omani home sewer system is already designed for collecting greywater and blackwater from the same pipe source that exits the home. Treating the mixture is expensive, but treating only the greywater may be more cost-efficient (Kreysig, 1996). For new construction of homes, integrating a system capable of separation is not difficult, but converting existing systems could be challenging (Eriksson et al., 2003). The reuse of greywater has not yet been attempted in the Sultanate of Oman. Proper design of an adequate system will require an accurate assessment of the quantities of greywater that may be available (Jamrah et al., 2008).

Therefore, the study of Jamrah et al. (2008) in Oman intended to assess the possibilities related to using greywater in Muscat Governorate in the Sultanate of Oman, develop methodologies related to the estimation of greywater quantities, test the quality of greywater to determine the potential for recycling, and evaluate acceptance of these practices by the public. Throughout the summer and winter, five households were selected, and total freshwater consumption and greywater generation were measured.

In addition, a survey was developed and administered in five different areas in Muscat Governorate, with the intention of evaluating methods for the estimation of greywater generation. The data collected were compared with data collected by the Ministry of Housing, Electricity, and Water, Sultanate of Oman. A total of 169 households were surveyed, with 1,365 people participating. Samples of greywater were collected from showers, sinks, and laundry machines, and the water quality was measured. Statistical analysis revealed no significant variances between the amount of freshwater used among the data analysed by the Ministry and the data obtained during the course of this study. This confirmed the applicability of the methods used for testing.

In conclusion, it was found during the study that 55-57% of the greywater in Omani households came from showers, 28-33% from kitchen use, 6-9% from laundry, and approximately 5-7% from sinks. Combined, this accounted for about 81% of the consumption of freshwater. Samples of greywater were analysed for physical, chemical, and biological properties, revealing that the greywater contained high levels of suspended solids, inorganic compounds, total organic carbon, chemical and biological oxygen demands, total coliform, and Escherichia coliform bacteria.

The composition of greywater is dependent upon several factors, including the water source, plumbing systems, living habits, personal hygiene habits, and type of greywater generated. Because of this, there are variations among the physical, chemical, and biological characteristics of greywater (Jamrah et al., 2008). The composition of greywater will further be impacted by the use of cleaning products, patterns of dishwashing, laundry styles, bathing and hygiene habits, and any disposal of chemicals in the household (Jamrah et al., 2004; Jamrah et al., 2008). There are typically pathogenic microorganisms in greywaters, such as bacteria, viruses, and parasites, and these may be present at high levels leading to health risks. Caution must be used when repurposing greywater to ensure safety (Jamrah et al., 2008).

According to the study done in Oman by Jamrah et al. (2008), within the Muscat Governorate, average water consumption was approximately **186** LPCD, with an average of **151** LPCD of greywater being created. Thus, the production of greywater was approximately **80-83%** of the total amount of freshwater consumed. There was high variability in the quality indicators, and this appeared to be related to several factors, including the source of the greywater, family size, lifestyles, and more.

Physical and chemical factors were often deemed to be at unacceptable levels for effluent standards, further confirming the importance of treating the greywater prior to any reuse.

According to the public survey results, around 76% of those surveyed were in favour of using greywater for gardening, 53% supported car washing, and 66% supported greywater use for toilets. For those reporting opposition to the reuse of greywater, 88.2% were worried about safety, 52.6% worried about the environmental impact, 22.3% worried about groundwater pollution, 60.1% reported religious opposition, and 24.5% indicated that they disagreed with the economic feasibility of such programmes.

The analysis of the two studies carried out in Jordan in (Amman) by Jamrah et al. (2006) and in Oman by Jamrah et al., (2008) found:

- both studies used the same methodology; and
- both were carried out at the domestic level.

Both used approximate assumptions to measure consumption. In the city of **Los Angeles**, Sheikh (1993) conducted a study examining greywater effluents and their use for irrigation. Sheikh (1993) concluded that reusing greywater could lead to savings of between 12% and 65% of freshwater. In addition, water savings could be up to 50% in individual homes. In **Australia**, recycling of greywater was estimated to lead to a potential savings of 30-50%, when used for toilet flushing and gardening (Fittschen and Niemezynowics, 1997; Sheikh, 1993). Average water savings of 0.5-21% was noted when greywater generated from handwashing was repurposed for toilet flushing. According to Dixon et al. (2000), total water consumption savings could be up to 80%.

Table 2.7: Comparing the results from four different countries (Jordan, Oman, Los Angeles, and Australia) in terms of savings percentage of freshwater in reusing greywater

Author	Country	Savings in freshwater	Purpose	Sources of greywater
Sheikh, 1993	Los Angeles	12-65%	Irrigation	showers, laundry, sinks

Fittschen & Niemezynowics, 1997; Sheikh, 1993	Australia	30-50%	Toilet flushing & irrigation	showers, laundry, sinks
Jamrah et al., 2006	Jordan	70%	Not implemented yet	showers, laundry, sinks
Jamrah et al., 2008	Oman	80-85%	Not implemented yet	showers, laundry, sinks

Table 2.7 compares the results from four different countries (Jordan, Oman, Los Angeles, and Australia) in terms of savings percentage of freshwater in reusing greywater. Savings of freshwater are nearly the same in Los Angeles and Australia, whereas it is higher in Jordan where it reaches up to 70%. Oman is much higher in percentage of greywater production and accounted for freshwater savings up to 85%. With a much higher consumption per capita as mentioned in the study, it reaches 185 LPD compared to 115 LPD in Jordan. However, the reasons for the high percentage of greywater production in Jordan and Oman, as compared to Los Angeles and Australia from the researcher's point of view; as mentioned earlier, the usage of water in sinks is far less than for other purposes in most international regions, including the United States and Australia, but is higher in Amman. This supports previously mentioned information within the present research in Chapter 1. Muslim countries (Jordan and Oman) have different needs pertaining to water usage; for example, the use of water for ablution is five times per day, prior to praying. In Figures 2.1, 2.2, and 2.3, water consumption in sinks is noted to be higher in Amman than toilet flushing. This led to the high production of greywater in Muslim countries. Additionally, greywater production is higher in Oman than in Jordan; from the researcher's point of view, this is because of the different climate and weather temperatures in the two countries.

2.6 Water demand management in public buildings

According to Cheng and Hong (2004), public **school buildings** are places to promote effective water-saving initiatives; this is because they involve education and awareness as an important foundation of a nation and influence the development of society. Public school buildings are easier to analyse than any other type of buildings when it comes to water consumption. This is compared with **hospital buildings,** where there is a problem of spreading dangerous bacteria that thrive in hospitals, compromising the health of people who are already sick. The specific equipment and requirements in hospitals and in water-sensitive quality need more concern for the patients to use (Kotay et al., 2017; Levin et al., 1984).

A recent study of **school buildings** in Bologna city "wanted to set a performance indicator trend for pre-school and elementary school" (Farina et al., 2011). The goal of the paper was to set the basis for further conservation and educational interventions on the topic. Total water consumption was estimated using a consumption indicator, expressed by the volume of water divided by consumers. In school buildings, water was consumed in m^3 and the students, teachers and other staff in the school were considered as consumers (Cheng and Hong, 2004; Farina et al., 2011). The final finding on school water consumption showed 30 to 70 litres/student/day in pre-school buildings and 10 to 30 litres/student/day in the elementary schools. The results showed that the demand by pre-school students for water was more than double that of elementary students. The difference in demand was because of the variation of water use in those different school stage buildings.

The research of the school study integrated quantitative data of water consumption through water metering and historical data about users in buildings. The study came out with different consumption results in schools, but no results on saving water by promoting effective water-saving initiatives (Farina et al., 2011). The studies so far indicate that practicing promoting effective water-saving initiatives involving education and awareness in schools is not enough. Therefore, a cooperation including parent awareness would be needed as well.

In GCC countries, this could be integrated with the awareness of different age groups of parents and children at the school level in one type of public building only, that is in mosques. This will be further investigated in this study.

2.7 Water Demand management in mosques

Offering five prayers a day is obligatory for every Muslim and is one of the pillars of Islam. To facilitate the five daily prayers, mosques have proliferated in all parts of the Muslim world and have become a symbol of Islamic civilization (Rahman et al., 2016). Muslims believe God has ordained and exalted purity and cleanliness before each prayer, hence ablution is an essential practice as a Muslim because it is a requirement before performing a prayer.

2.7.1 Water use in mosques

The scholars put it that God has mercy on standards for water that can be used in ablution and that the water should be clean and at the same time antiseptic, colourless and odourless. It could be argued that modern scientific way water standards for ablution must be an approach that was not matching the standards of drinking water, and so, because of the ways of ablution rinsing the mouth and nose (Abu-Rizaiza, 2002).

WDM in mosques not only introduces practical engineering solutions in promoting sustainable living, but is also in line with Islamic principles of using natural resources in a prudent manner. This could be achieved by designing a simple recycling system for ablution water, provided it is not highly polluted (Suratkon et al., 2014) and reusing treated greywater for toilet flushing, general washing, and irrigation. Recycling of ablution water can reduce more than **40% of the water bill** in a single mosque, as reported in a study done in Malaysia (Rahman et al., 2016). Investigating the feasibility of reusing ablution water in mosques and working with measures and techniques of efficient economic equipment will be investigated further in the present doctoral study.

2.7.2 Ablution process

The ablution ritual, known as ‘wudu’, requires a Muslim to wash exposed body parts with clean water. The ablution system is a row of water taps connected with drainage to carry water used for washing body parts to the main drains. The taps are usually left running and a substantial amount of clean water is wasted in the process.

The steps consist of washing hands up to wrists and the entire face and arms to the elbows, then wiping the head and ears and washing the feet to the ankles and rinsing the mouth and nose, as shown in Figure 2.4 (Abu-Rizaiza, 2002).

Figure 2.4**: Steps to make ablution ('wudu') for prayer (Abu-Rizaiza, 2002)**

2.7.3 Water consumer's behaviours in ablution

Around 90% of the water used in mosques is for the ablution ritual (Suratkon et al., 2014; Rahman et. al, 2016; Prathapar et al., 2005). The water used for the ablution ritual is allowed to run free and drain away. A significant amount of treated water is wasted from the ablution ritual (Prathapar et al., 2004). As quoted in the Hadith, Prophet Muhammad reminded Muslims to avoid wastage, even when performing the cleansing ritual of ablution prior to prayer. Recent studies show a significant amount of greywater is produced in the universities' mosques in **Malaysia** (Utaberta, 2014) and in the universities mosques in **Oman** (Prathapar et al., 2005). However, studies on recycling and reuse of this significant quantity of wastewater (greywater) and in WDM specifically in mosques is limited; hence, an investigation into this aspect is required.

2.7.4 Water types in Islam

In Section 2.4.1.4, it was mentioned that there are four main types of water: potable water, greywater, blackwater, and stormwater. By comparison, Islam has also classified water into three types (Mokhtar, 2012):

- 'Tahur': clean and able to cleanse others.

This means clean water which can be used to clean everything.

- ‘Tahir’: clean but unable to cleanse others.

This means treated greywater which may not be enough to clean others.

- ‘Najas’: not clean and unable to cleanse others.

Means untreated grey or blackwater and unable to cleanse others.

In **Malaysia,** two studies on ablution water recycling, both in university mosques, have been carried out by Rahman et al. (2016) using **the ReWudhuk** device and Suratkon et al. (2014) using the **SmartWUDHU** conceptual model. Rahman et al. (2016) in their study aimed to reuse ablution water by using a device called ReWudhuk to reuse water for ablution purposes. Sample testing for untreated ablution greywater from mosques was carried out on six different days by Rahman et al. (2016) to check the quality of the ReWudhuk device and compare it with drinking water quality standards in Malaysia (DWQS).

This present research will check if reusing ablution water for ablution is acceptable in terms of religious opinions, as there are some differences in opinion in some religious branches.

The ReWudhuk device is designed for closed-loop flow with a make-up system. The device includes a screen mesh which acts as a physical treatment to remove other coarse particles and insects; then a water pump is used along with a water filter to remove fine suspended solids, while charcoal is used as a filter to absorb any organic contamination and foul odour; the water is then passed through an ultraviolet (UV) filter to disinfect from micro-organisms, before being transferred back into the main ablution tank. The tank is fitted with an indicator to ensure that the water quantity is constantly over 270 litres. This treatment ensures that the treated water is ready to be reused again for ablution. A float ball is installed as a make-up valve, so that in case of a sudden water drop in the main ablution tank, the external water supply will be triggered and replenished to its desired level. Laboratory tests have been conducted to analyse the pH value, turbidity (NTU), colour change (TCU), total suspended solids (TSS), and the amount of dissolved oxygen (DO) (Rahman et al., 2016). The sampling results were as follows:

- pH: 6.63
- Turbidity (NTU): 1.24
- Color (TCU): 50.67

- TSS (mg/L): 7.33
- DO (mg/L): 6.67
- Drinking water quality standard in Malaysia:
- pH: 6.5–9.0
- NTU: 0–5
- TCU: 0–300
- TSS (mg/L): 0–1500
- DO (mg/L): 1.0–5.0

Comparing sampling results to the drinking water quality standard (DWQS) in Malaysia, the pH from the laboratory test was 6.63, while the pH requirement outlined by DWQS in Malaysia is between 6.5 to 9.0. The sampling result proved that the pH was within the range of DWQS. NTU, TCU, and TSS of the results of the sample were found to be within those of DWQS in Malaysia. A small increase of dissolved oxygen was found in the water.

For turbidity NTU, in accordance with the US standard, must at no time exceed 5 NTU (EPA, 2017). European countries' standards for drinking water do not appear to address NTU (EU, 2017). In addition, the WHO establishes that the NTU should not exceed 5 NTU, in line with Malaysia and the US; however, ideally turbidity should be below 1.0 NTU.

Suratkon et al. (2014) studied recycling greywater from ablution and verified a conceptual model of the ablution water recycling system named 'SmartWUDHU'. The recycling exercise was to take a combination of ablution and rainwater captured and to reuse it for non-potable purposes. The estimated result of the implementation was a reduction of supplied water required from 3,500 litres to 1,500 litres for the existing system used in Figures 2.5 and 2.6. SmartWUDHU was an "attempt to develop a feasible model of the system by examining the engineering features and components concurrently with the review of the religious interpretation of 'pure' water for ablution; a common ground was defined to meet both sets of requirements in providing an effective system. A framework of the approach adopted in this dual-pronged study" is shown in Figure 2.7.

Calculating the total water consumption for ablution per capita and the methodology for calculating this is a gap in all the Rahman et al. (2016) and Suratkon et al. (2014) studies.

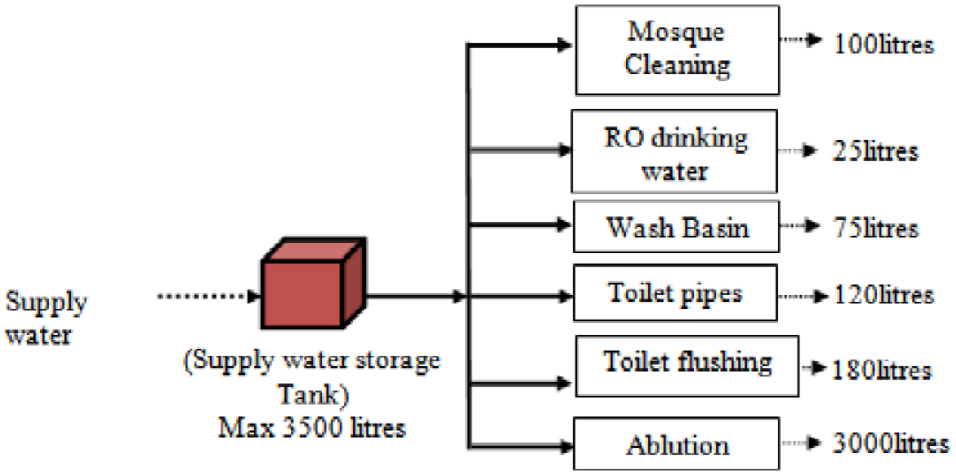

Figure 2.5: Existing water circulation network in **mosque**s (Suratkon et al., 2014)

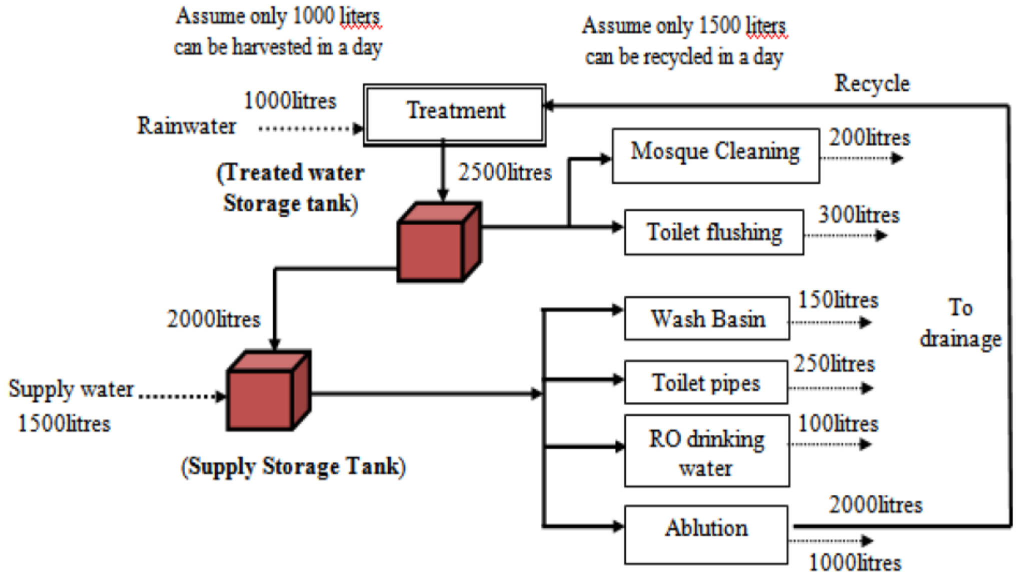

Figure 2.6: Proposed water circulation network in mosques incorporating the SmartWUDHU (Suratkon et al., 2014)

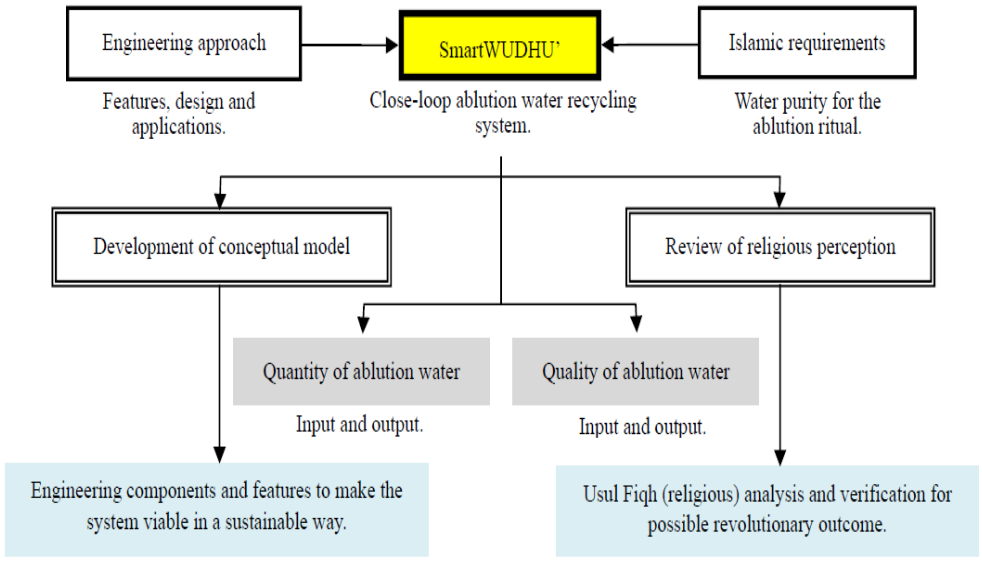

Figure 2.7: SmartWUDHU framework (Suratkon et al., 2014)

All studies of mosques carried out in **Oman was** concerned more in water quality test of ablution water in overcoming constraints in treated greywater reuse (Jamrah et al., 2006; Jamrah et al., 2008; and Prathapar et al., 2005) have all collected recent data to help illustrate the factors involved in treatment and recycling of greywater in Oman. Issues were categorized as relating to quantity, quality, financial, legal, social, and institutional concerns, for the purposes of this paper.

Ablution at mosques is a notable source of greywater in Oman. Those worshipping must wash before each prayer. Mosques usually have ablution rooms with distinct plumbing from the blackwater systems. Prathapar et al. (2005) examined the differences in the quality of greywater from two university mosques in Oman. **The ReWudhuk** study collected data for 25 weeks and the **SmartWUDHU** study collected data for 42 weeks. Ideally, future studies should consider longer time periods of data collection, to avoid variance from seasonality.

When data regarding daily and weekly use of greywater in mosques was analysed, a high degree of variability was noted for water production per day. Thus, the supply of greywater may be variable. However, the reliability of greywater is increased when properly treated and stored (Prathapar et al., 2005).

Ablution water samples were analysed by Prathapar et al. (2005) and measured for pH, electrical conductivity, turbidity, dissolved oxygen, BOD, COD, coliforms, E. coli, total suspended solids, total dissolved solids, and total carbon. At both the mosques, the pH, electrical conductivity (EC), and TDS of the greywater was within the proper range for irrigation. However, BOD, COD, coliform, and E. coli levels were too high, meaning that the greywater required treatment before being safe to reuse.

It is reasonable to assume that greywater quality in Oman has great variability among sources, and must be treated before reuse (Jamrah et al., 2006; Jamrah et al., 2008; Pratahpar et al., 2005). When there is high variability among quantity and quality, there are complications related to the design, operation, and maintenance of any facility intending to treat greywater. These systems require significant maintenance and often fail because of inadequate strategies to keep the facility running.

When greywater is stored untreated, the suspended solids will settle, the aerobic microbial activity will increase, and there will be an increase in the anaerobic release of soluble COD. Additionally, atmospheric reaeration will occur. Within a span of 24 hours, the quality of greywater can improve because of these rapid occurrences. Yet, storage beyond the 24-hour limit will also lead to reduced oxygen levels and aesthetic problems.

The following steps outline the sequential treatment of greywater, according to Prathapar et al., 2005:

- Greywater cannot be stored for more than 24 hours because of the likelihood that it will become septic. Microbial activity occurs quickly. The size of the storage tank is recommended to be at least 2.4 times the maximum amount expected to flow, which will account for proper sludge accumulation and sludge loading.
- The greywater must be balanced and screened for proper pH. It may be alkaline or acidic, depending on the variation of contaminants. Additionally, greywater likely contains solid particles, such as hair, which must be thoroughly screened out.
- Anaerobic treatment allows for the improvement of the biological demands of oxygen in the greywater.
- Aerobic treatment includes aeration, flotation, dilution, and addition of certain chemicals, including alum, lime, and chlorine.

- Slow filtering allows the use of slow sand filters and carbon filters to remove any odours or toxins.
- The final step is storage of the freshwater.

The final design of any greywater treatment programme will depend on many factors including quality, quantity, and timing of the greywater generated, the particular soil and climate conditions, and various legal requirements. The most successful designs are often the simplest and require minimum outlay of energy, allowing them to treat large quantities of greywater efficiently.

In all greywater cases reported throughout Oman, TSS, BOD, COD, DO, coliforms, and E. coli are in excess of Omani standards related to wastewater reuse. Tests conducted by laboratories indicate that quantities of greywater of 200ml containing >200.5 MPN coliform and E. coli can be successfully treated using 0.3ml chlorine solution at 4.5mg/l concentration. Homemade sand filters can effectively remove any suspended solids.

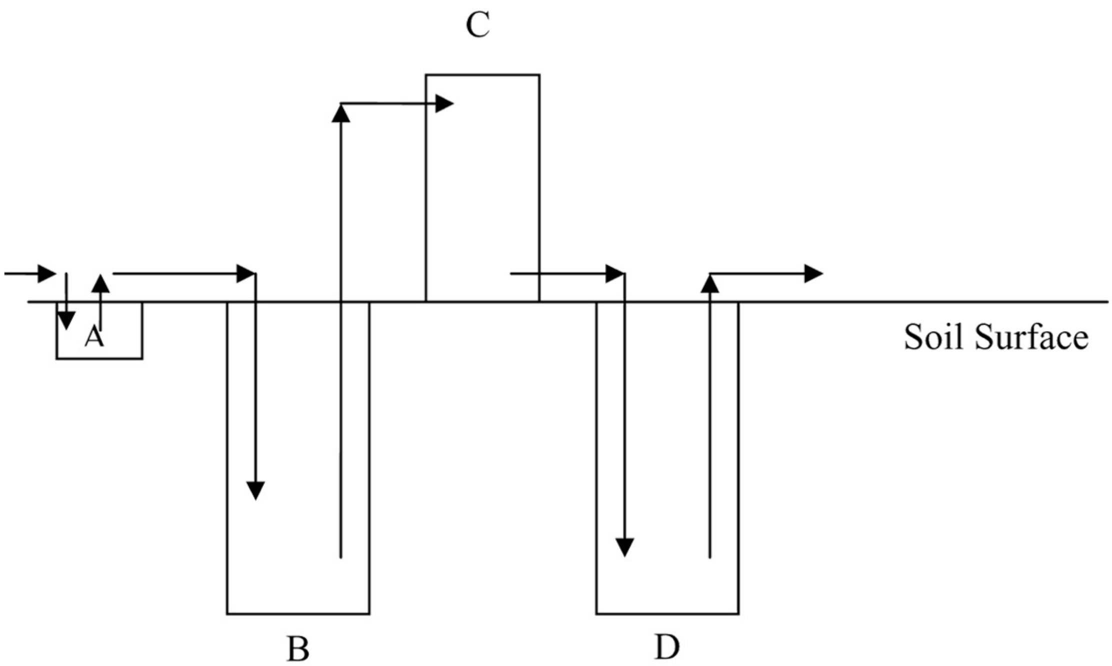

Figure 2.8: A low-cost greywater treatment system (Prathapar et al., 2005)

As a result, low-cost greywater treatment systems are possible (see Figure 2.8). In these systems, the water is initially diverted through a **settlement pond (A)** and **stored in a tank (B)**. Solids are trapped within Pond A, as they are denser than the water. The water must be periodically cleaned. The water is collected and stored within Pond B throughout the day and will be treated with chlorine and lifted through the **sand filters (C)** overnight. The filtered water is then **stored in tank D** for later reuse.

Despite the Omanis' perceptions that greywater reuse may be in opposition to religious teachings, there was a special 'fatwa' (see glossary) issued by a council of leading Islamic scholars in Saudi Arabia in 1978. This fatwa allowed for the use of treated wastewater, even for ablution (wudu). In addition, Imams (religious scholars) promote the reuse of greywater in Jordan and Palestine if the wastewater has been properly treated and tested for adequate levels of purity for use, and no public health risks have been discovered. Additionally, since chlorination has been shown to remove all biological pathogens from greywater, promotional campaigns to address concerns may be helpful in swaying the perceptions of Omanis (Prathapar et al., 2005).

2.8 Summary

The main solution to increasing water demand in Oman is still seen to be expanding water supply capacity. Yet water demand management has received the least attention, with efforts made to manage the supply rather than water demand.

As part of measures and techniques, efficient devices need not necessarily be more expensive than conventional devices (those that are not efficient). Commonly, the capital cost of water-efficient devices tends to reflect design, fashion, and brand, rather than their resource efficiency.

Regulations will increasingly drive the water efficiency market, and hence the costs to implement water efficiency initiatives are likely to decrease over time. All the studies in the preceding chapter feature implementation at the domestic buildings level, with very few examples in any other type of building and with no clear methodology for measuring and analysing.

Pricing reforms could reward water conservation in relation to residential dwellings, as indicated in the examples mentioned from different papers above. However, in the case of mosques in GCC countries, pricing is not an option for water demand management as the water is free to users in all government buildings.

Awareness of water scarcity in different countries generates water conservation initiatives by state and local governments and by water authorities but currently, most of these regulations and initiatives relate to residential dwellings rather than public buildings such as mosques.

Switching to water-efficient units is considered to be more acceptable for consumers and by the public, as compared to other water management policies such as price increases or water restrictions.

However, how water is used within building complexes depends on the building type; for example, most of the water used in a restaurant is for kitchen applications, while most water used in office buildings, kindergartens, and shopping centres is for cooling towers; in mosques, more than 90% of water consumed is for ablution purposes.

Recycling water to reduce water consumption in buildings and improving water efficiency form a major aspect of creating sustainability in mosques, which will benefit from cost savings to bill payers, particularly given than the price of water is likely to increase.

Greywater and treated blackwater can be used for many applications. These applications vary from country to country, depending on the specific country's requirements and standards.

The school study reported by Farina et al. (2011) integrated quantitative data on water consumption through water metering and historical data about users in buildings. The research produced different consumption results from schools, but no results on saving water by promoting effective water-saving initiatives. It should be emphasized that promoting effective water-saving initiatives in GCC countries through policies and techniques is not enough. This would need the cooperation of parents as well. In GCC countries and any other Muslim countries, water-saving initiatives could be integrated into mosques in terms of policies, techniques, and awareness-raising for parents and children, as mosques are a type of public building which includes many different ages.

A large amount of water consumed in mosques is allowed to run free and drain away. A significant amount of treated water is wasted from the ablution ritual, especially during Friday prayers.

WDM in mosques not only introduces practical engineering solutions in promoting sustainable living, but is also in line with Islamic principles of using natural resources in a prudent manner. A simple recycling system could be designed, as ablution water is not considered to be highly polluted, to treat and reuse in toilet flushing, general washing, and irrigation. The study on recycling of ablution water in Malaysia showed that there would be a reduction of more than 40% of the water bill in a single mosque, as mentioned in literature.

Like many countries, in Oman, household plumbing facilities combine greywater and blackwater, and these systems would require conversion in order to properly separate the two. The amount of greywater that is produced by the average Omani household (approximately 1 cubic meter per day) may be too expensive for the average consumer. While potable water is distributed at subsidized costs.

2.9 Highlighting gaps

- There is a lack of research in the analysis of water consumption per capita in mosques for ablution and other purposes (such as for toilets and landscaping) to quantify the amount of water used in mosques (including when performing ablution), using rigorous methods to identify the savings that can be achieved.

- Fact-finding on recycling policies and religious opinions about reusing ablution water in mosques is a notable gap in literature on water demand management.

- There is a research gap in investigations of the plumbing and if there is systematic procedure in Oman and all GCC countries.

- There is a gap in terms of exploration of details on policies and appliances used in Oman. Most of the studies recommend focusing on tariff structure and the importance of pricing, investigating the optimal tariff for reducing consumption and to conserve water (Al Shueili, 2014; Kayaga, S. and Smout, I., 2011; Chen et al., 2005; Tate, 1990; Al-Maskti, 2011), but in the case of water demand management in mosques, a tariff strategy will not work as the water is not charged for or restricted for use in Oman or other GCC countries. There are no available research papers on policies and strategies that would lead to water demand management in mosques.

- There is a lack of scrutiny on users' behaviours regarding water usage in mosques. According to the literature, water consumption is influenced by user behaviour which in turn influences end-use water as there is a positive connection between attitudes, water end-use and water saving (Fidar et al., 2016; Willis et al., 2011; Dolnicar et al., 2012; Savi, and Kapelan, 2014).

Chapter 3 : Research Methodology

3.1 Introduction

The aim of this chapter is to examine key research methodology principles and concepts and to present the adopted research methodology for the present research. The following aspects relating to the research methodology are investigated in the following sections. Figure 3.1 shows a pictorial presentation of the approach in terms of methodology structure, including the study approach. Justification of the adopted research methodology is explained below.

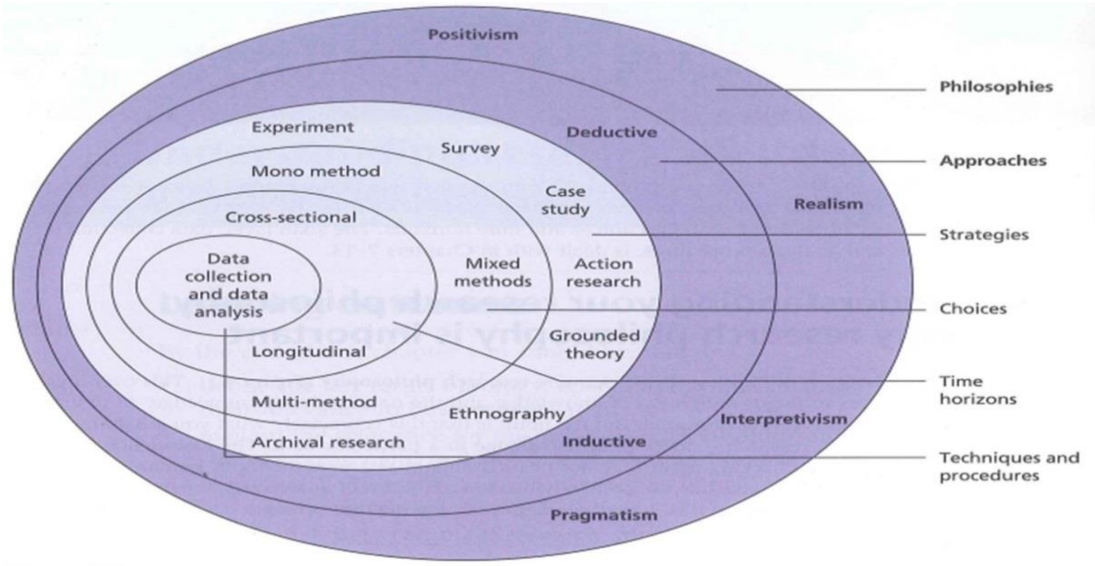

Figure 3.1: Research onion of methodology chapter structure (Saunders et al., 2012)

3.2 Research philosophy

Layer 1 of the onion in Figure 3.1 contains the philosophical stances associated with the philosophies. Belief on the way in which data about a phenomenon will be gathered, analysed and used is known as 'research philosophy' (Galliers, 1991). It is essential to understand research philosophy after selecting a topic to make critical selections for an appropriate research method and strategy to be adopted (Robson, 2002). There are three major research philosophy aspects that relate to social and management research: **ontology**, **epistemology** and **axiology,** as it is shown in Figure 3.2 (Bryman, 2011;

Bryman, 2007; Fellows and Liu, 2016). All are important elements of the philosophy of knowledge.

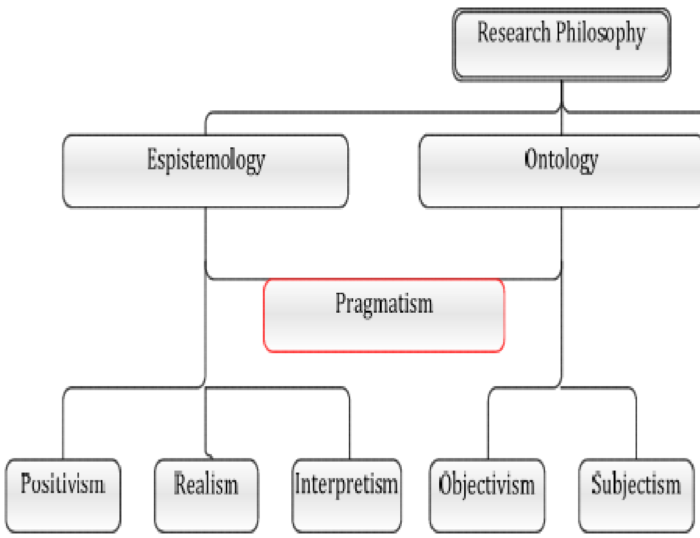

Figure 3.2: Research philosophy concept structure (Ambituuni, 2016)

3.2.1 Epistemology

Epistemology looks into the way we know things and describes how knowledge should be achieved and accepted. There are three types of epistemology, namely, **positivism** (which generates hypotheses [or research questions] that can be tested and allows explanations that are measured against accepted knowledge of the world we live in); **interpretivism** (which refers to approaches emphasizing the meaningful nature of people's participation in social and cultural life); and **realism** (which is a type of epistemological approach as it maintains structures that underpin social events and discourses, but does not prevent them from being used in action to change the society) (Tam et al., 2002; Bryman, 2008; Fellows and Liu, 2016).

3.2.2 Ontology

Ontology looks at what things are; it relates to the nature of reality and its characteristics and describes an assumption about reality and what knowledge is (Bryman, 2008). There are three philosophical positions commonly agreed to work under an ontological worldview. These are **objectivism**, which "asserts social phenomena and their meanings as the independent existence of social actions"; **subjectivism,** which "affirms that social phenomena and their meanings are produced through social interaction which is constantly changing to the nature of social entities"; and **pragmatism,** which " allows a researcher to view the topic from either or both points of view regarding the influence or role of social actors and uses these to create a practical approach to research" (Bryman, 2008; Dainty, 2008; Fellows and Liu, 2016).

3.2.3 Axiology

Axiology is about presenting the value theory by detailing and analysing the investigation of the issue and of analysing the results in different ways according to the chosen approach. Its studies questions and examines the theory of values and problems that relate to nature values (Fellows and Liu, 2016).

3.2.4 Philosophy for this research

As shown in Figure 3.2 on the research philosophy concept structure and according to Saunders et al. (2012), pragmatism is an appropriate way to adopt research philosophy as one approach may be better than the other for answering a research question. This opens the door to multiple methods, different world viewpoints, and different assumptions, as well as different forms of data collection and analysis in a mixed-method study (Creswell and Creswell, 2017). 'Science works' is the process of transforming things believed in and things that are known, which ontology to epistemology (Galliers, 1991). According to Figure 3.2, the present research adopted pragmatism as the approach as it started to investigate existing supplies, policies, facilities and water consumption in mosques. This drives the research towards the ontology philosophy. The research then progressed from ontology towards epistemology to identify effective water demand management policies, measures, and techniques that are compatible with the needs of water consumers in mosques and to investigate the acceptability of reusing water in mosques. This led to epistemology.

Hence, a literature review was undertaken to find out the needs of the study and how to conduct it. This positioned the research within the ontology. However, the research was investigating and developing by consideration of the human community, allowing the contribution of peoples' own beliefs and experiences. This directed the research to used open-ended questions for data collection and towards the interpretive epistemology position.

The inductive approach is opposite to the deductive approach (William and Trochim, 2008). This research study involved both inductive and deductive approaches.

According to Yin (2003), as it clear in Table 3.1, surveys which include questionnaires and interviews are used if the research questions inquire on what, where, who, how and why. The main question of this study started with how: (How to achieve appropriate water demand management [WDM] in mosques, including regulations, water-efficient appliances, and water recycling?). Hence, the appropriate research strategy for this research was to survey different sites around six different mosques. However, it did not treat these as case studies, but dealt with different methods and archives, interviews, observation, and measurement combining qualitative and quantitative methods similar to a case study (Yin, 2014). A case study provides rich and deep descriptions and explanations (Yin 2014) and can be used for any research purpose which uses description or explanation, but not exploratory work (Robson, 2002). The nature of the present research study suits the survey study approach by using interview questions and measurements more than would be used in a case study.

Table 3.1: Different methods depend on the form of research question adopted (Yin, 2003)

	Form of research question	Requires control over behavioural events?	Focuses on contemporary events?
Experiment	how, why	Yes	yes
Survey	who, what, where, how many, how much	No	yes
Archival analysis	who, what, where, how many, how much	No	yes/no
History	how, why	No	no
Case study	how, why	no	yes

3.2.5 Research strategies

Layer 3 of the onion (Figure 3.1) refers to the research style that the researcher uses to collect and analyse data, for example, Grounded Theory. Each one has its benefits and limitations. A research strategy usually has a goal that can be used for a procedure or steps to follow in order to achieve results. Table 3.2 illustrates different research strategy types, including survey studies, experiments, action research, design research and case studies.

A survey study, using interviews and measurements, was the adopted strategy for the present research study. This section outlines the plan in four different sections: different goals, procedures, techniques, and types of research are explained in this section for each strategy type.

Table 3.2: Different Research strategies types adopted from (Hinkelmann and Witschel, nd; Saunders et. al., 2009; Saunders et. al., 2012)

Strategy	Goal
Survey studies	find patterns in data
Experiments	test hypotheses
Action research	interactively solves a problem with a community of practice
Design research	creates artifacts (constructs, models, and methods)
Grounded Theory	predicts and explains behaviour to build a theory
Ethnography	is study of others from a detached point of view
Archival research	data collection on existing data sets
Case studies	study the characteristics of a real-life instance

- Survey studies

The goal of survey studies is to find patterns in data using the procedure of collecting data from a large group of subjects in a standardized and systematic way, evaluating the data by using statistical methods, identifying patterns and interpreting results. A survey study technique type includes observation, measurement, construction, questionnaires, interviews, and literature reviews. The main types of research are inductive and empirical (Saunders et. al., 2009).

Sapsford (2007) stated that a survey strategy is often associated with a deductive approach. It offers the researcher a highly economical way of collecting large amounts of data to address the who, what, where, when and how of any given topic or issue.

- Experiments

The experiment's goal is to test hypotheses using the procedure of formulating a hypothesis, collecting evidence and testing the hypothesis based on evidence. Experiment technique types include benchmarking and statistical significance tests. The main types of experimental research are positivist, deductive and quantitative (Saunders et. al., 2009).

The experiment was not used in the present research, although qualitative data was generated in the consumption measurements.

- Action research

The goal of action research is iteratively solving a problem with a community of practice by using a procedure of planning, action, and reflection. The planning procedure includes analysing the problem with practitioners and developing solutions with the help of theories and planned actions. The action procedure includes implementing solutions or action and learning to improve solutions, as required. The reflection procedure involves deriving design principles from outcomes. Types of action research include interpretivism, constructive and qualitative research (Saunders et. al., 2009).

- Design science (or framework)

The goal of the framework is designing and creating artefacts (constructs, models and methods) using a procedure of analysing the problem and determining research goals, developing artefacts with recognized methodologies, evaluation to validate the approach with respect to research goals. Design science research comes under the interpretivism, constructive and qualitative research types.

A conceptual framework is an analytical tool with several variations and contexts. It is used to make conceptual distinctions and organise ideas (Berlin, 1953). Strong conceptual frameworks capture something real and do this in a way that is easy to remember and apply. Conceptual frameworks are particularly useful as organising devices in empirical research. A conceptual framework is defined as “the way ideas are organized to achieve a research project’s purpose” (Shields et. al, 2013).

Formal hypotheses posit possible explanations (answers to the ‘why’ question) that are tested by collecting data and assessing the evidence (usually quantitative, using statistical tests). Several types of conceptual frameworks have been identified, and line up with a research purpose in the following ways (Shields and Tajalli, 2006):

- Working hypothesis – exploration or exploratory research
- Descriptive categories – description or descriptive research

- Practical ideal type – analysis (gauging)
- Models of operations research – decision-making
- Formal hypothesis – explanation and prediction
- Grounded Theory

Predicting and explaining behaviours using inductive processes to build a theory is known as Grounded Theory. It is ‘grounded’ by existing theory and literature on a specific topic, although it is generating new theory (Strauss, 1998; Wertz, 2011).

- Ethnography

Ethnography is rooted in anthropology. It is about the study of others from different points of view. It requires the researcher to be a part of the situation or the community of the researching things (Saunders et. al., 2009).

- Archival research

Archival research is a strategy whereby data collection focuses on archived documents and existing data sets (Saunders et. al., 2009).

- Case studies

“Case studies are in-depth studies of particular events, circumstances or situations which offer the prospect of revealing the understanding of a kind which might escape broader surveys” (Allison et al. 1996). This research enables the generation of rich, detailed data. [AQ: check deleted clause – repeated from para below]

The goal of a case study is to study the characteristics of a real-life instance using the procedure of selecting an instance to study, collecting data, analysing and interpreting it in a systematic way, and understanding the reasons for the characteristics of the instance. A case study technique type includes interviews, discussions, observations, and questionnaires. The types of case studies research include interpretivism, inductive, empirical and qualitative research (Yin, 2014).

3.3 Data collection

The process of collecting data to identify a knowledge gap and reviewing the available literature related to the subject known as 'non-empirical'. Another type of research method knows as 'empirical' involves gathering data from fieldwork observations (Easterby-Smith et al., 2002).

This study used both methods; empirical and non-empirical, for collecting data with reference to:

- ✓ Secondary data from documents, materials, reports.
- ✓ The PAEW annual report, and available reports, records on water consumption and water bills for mosques from PAEW.
- ✓ Royal Decrees and legislation relevant to the development of the water sector and protection of water resources from the Ministry of Legal Affairs.
- ✓ Detailed legislation to protect the water resources and plans for development. These are issued by the Ministry of Regional Municipalities and Water Resources, and included municipality regulations on water consumption in mosques and regulations on devices (taps, toilets, etc.), information from design consultancies on consumption for mosques, actual consumption, suppliers of equipment (taps, toilets, etc), devices which were available and data on water consumption, if there were more water-efficient alternatives, how these could be introduced, and how much water could be saved. Data collection here asked if there were regulations on water-efficient appliances? And if information on water consumption of appliances was provided to mosque management?

Therefore, it was required to refine this data and classify them based on their importance in relation to the problem. The credentials of sources of secondary data are very important in providing high quality and further details.

Open-ended interview questions are open to describe and give a brief and deep answer to the questions which are mainly used in qualitative research. A mixed questionnaire involves a combination of close-ended and open-ended questionnaires, including qualitative and quantitative research.

In general, the “Interviews may be unstructured or semi-structured or structured” (Robson 2002). **Unstructured interviews** allow the researcher to gain a deeper understanding of an interviewee’s point of view, which involves an in-depth interview, while **semi-structured interviews** are the type that is commonly used for qualitative research. They incorporate highly specific questions, but allow more flexibility and detail in the responses given. The **structured interview** contains fixed questions, which often involves ticking boxes. Close-ended questionnaires are the types mainly used for large samples and a large amount of data. Close-ended questionnaires are used in quantitative research to generate statistical data.

According to Bryman and Bell (2007), the following important features and practical details must be considered while preparing interview questions and conducting an interview.

The interview questions must be designed and properly structured in a manner that will allow the design to flow reasonably with the questions and lead to answering the research questions, removing communication barriers to reach the objective of the interviewer and also encouraging the interviewees to provide more information.

Communication should be in a simple language which is easily understandable, and the interviewer should rephrase or repeat the questions when required.

Recording (name, gender, age, position, and experience) is important for contextualizing interview answers, but no names should be mentioned in the recorded data.

Practical details required for interviews include:

(i) to be on time by being present earlier than the time of conducting the interview, with the interview duration time depending on the interviewee’s knowledge, interests, and interaction;

(ii) an effective recording device and microphone to record a clear interview; the recording should be in a comfortable environment, avoiding noise that could affect the recording (Cavana et al., 2001); and

(iii) having the required interviewing skills to complete a successful interview.

Semi-structured interviews were conducted in the present research study with the key personnel who had experience and a high degree of responsibility, and were familiar with the research topics. The interview guide was semi-structured, thus giving interviewees the freedom to speak for themselves in their own words on the research area as the interviewer is more likely to control the interview with a certain set of questions.

A good microphone was used to make a clear recording to enable transfer of the recorded interview to a written format. The interviews were conducted in the interviewee’s office as this was an ideal, safe, comfortable and confidential environment for the interviewees. The interviewees were staff involved in decision-making and policy formulation holding posts of general managers, senior managers, consultants, experts, civil engineers and designers from PAEW, the Ministry of Legal Affairs, higher colleges of technology, civil engineers from consultancies, and users of water in mosques.

Interviewees needed to agree for the next stage of the research. The interviews were done for a range of people from different places, as mentioned in Table 3.4 and Table 3.3 as well.

An official request letter was given to the participants of the interview to get the approval necessary to conduct the interview and to gain access.

In this research study, the qualitative method interviews were conducted to answer the inquiries on:

1. What are the policies and water consumption in mosques? This answered by investigating the current water-saving practices, rules, and policies applied by the Government of Oman. And what are the future strategies and measures that the Government of Oman aims to apply to achieve efficient use of water?

2. What are effective measures and techniques that are compatible with the needs of water consumers in mosques? This answered by investigating the current tools, appliances, and techniques applied in mosques and the latest water-saving tools, appliances and techniques available.

The quantitative part involved measuring water consumption for different purposes in mosques.

The nature of this research study suited using interviews and measurements. This research needed a deep investigation to study how to achieve appropriate water demand management (WDM) in mosques. In order to get a proper analysis of the results and an effective solution from the original fieldwork, the work is explained in a detailed plan with the justification of methods used (see below).

3.4 Justification of the research methodology

The major reason for choosing the mix of research tools was because of the background and nature of the defined problems which could not be assessed with the help of just one or two tools. Another reason was that the results produced from the application of one tool could be used to verify results acquired from other tools. The mix of tools accommodated the qualitative, quantitative (water measurements) and archives analysis research methodologies in different chosen sites. The rationale behind choosing these methodologies was that it is assumed that neither application of a qualitative or quantitative methodology alone would be enough to understand urban water systems and related issues in water-stressed countries.

In other words, a most comprehensive assessment was needed in order to understand urban water issues in this context. Therefore, semi-structured interviews and measurements and comparative analysis were found to be the most appropriate set of tools to answer the research questions.

3.5 Research plan

The plan for this research is contained in sequential sections that follow as stages to get the desired results, i.e. overview, procedures (fieldwork, interviews), and reporting.

3.5.1 Overview

In this research study; six different mosques in Oman were studied: three big mosques called ‘Jame‘ (see glossary) and three small mosques called ‘Masjid‘ (see glossary). It involved investigating the users’ behaviours, their needs, opinions on recycling and measuring total consumption per capita for ablution from each site to compare the results and to come out with proper solutions of measures and techniques and to check possibilities to reuse or recycle. There was no control over behavioural events in this study.

The fieldwork was done in two different cities in Oman, at six different sites: five sites were in the capital city of Oman (Muscat) and one was in in a rapidly growing intermediate-sized city in Sharqiyah Governorate. Muscat and Al-Sharqiya are governorates of Oman.

‘James‘ in Oman fall under two different organization’s management (the Ministry of Endowments and Religious Affairs and the Ministry of Diwan of Royal Court). The rationale for selecting these specific study sites for ‘Jame’s‘ was to have:

- Four Jame’s from two different organizations responsible for Jame’s in Oman
- Two Jame’s under the Ministry of Endowments and Religious Affairs
- Two Jame’s under the Ministry of Diwan of Royal Court

All with a capacity of more than 1000.

‘Masjid‘ in Oman are under one organization’s management only, which is the Ministry of Endowments and Religious Affairs. The rationale for selecting these specific study sites for ‘Masjid‘ was to have:

- Two Masjids from one organization responsible for Masjid in Oman

Both with a capacity of not less than 400.

Jame’s and Masjid sites are the only ones that were permitted and approved by the Ministries of Endowments and Religious Affairs and Diwan of Royal Court. They were within the research specifications.

Oman has an area of 309,500 Km^2, with a total population of 4,741,304. **Muscat Governorate** has an area of 3,500 Km^2, with a total population of 1,560,330. The Governorate in Muscat is divided into five administrative areas: Al-Amirat, Muscat, Al-Seeb, Mutrah, and Boushar. The region represents an important part of Oman for development. **Sharqiyah Governorate** has an area of 36,400 Km^2, with a total population of 350,514 (mofa.gov.om, 2017).

The rationale here was that it is essential to understand the lifestyle of the capital city of Oman (Muscat) in order to understand the factors which are helpful in water demand management within a country, as it has the highest population with a large number of mosques in Oman. There are around 16,004 mosques in Oman. Around 240 Jame's are located in Muscat out of a total of 1,419 Jame's in Oman; 1,327 Masjids are located in Muscat out of a total of 14,367 Masjids in Oman (National Center for Statistical and Information, 2017).

A similar study was to be conducted in a second city (Sharqiyah Governorate) which has a higher number of mosques than Muscat. This rapidly growing city facilitated the exploration of lifestyle in other cities and enabled comparison with the capital city to prevent forming a misleading picture from studying in one city only. The total number of mosques in Sharqiyah is up 2,000, as it has a much larger area compared to Muscat (mofa.gov.om, 2017).

The regions in Oman receive potable water through pipelines from desalination plants, although the pipelines yet to reach all areas. Groundwater is generally supplied to consumers in some parts of the region by pipelines and tankers (Moosa, 2005; PAEW, 2015).

3.5.2 Procedures

This section contains details of the provisional source of data from interviewees, departments/specialization, numbers of interviews, interviewees' specifications and places where interviews took place. Also mentioned is the competence of ministries and selected companies, as well as the fieldwork consumption measurements.

3.5.2.1 Fieldwork in measuring total consumption per capita

Qualitative research may have weak points, unscientific or only exploratory methods (Denzin and Lincoln, 2008) but this research included working on measurements and tests which enhance the validity of results needed.

The research design further investigates into the practicalities of data collection and analysis. This research applied a mixed method of qualitative and quantitative research. It consisted of measuring water consumption per capita in parallel with carrying out interviews with policymakers, mosque management, engineers, and water users in mosques, analysis of water bills for two years of all the mosques in Muscat, and archival analysis – as it is shown in Table 3.6. Measuring total water consumption per capita was carried out in mosques and in houses.

1- In mosques

Fieldwork was conducted to collect observations on users' behaviour practices in the mosque, type of appliances, techniques applied and appliances, the flow rate, as well as taking measurements of total consumption per capita with users in mosques. The observations were taken from six mosque sites. The measurements of total consumption per capita in this research were done for a total of 120 users (20 users in each mosque). Five mosques were in Muscat and one was in Al Sharqiya. The basis for selecting the sample size of 20 users per mosque was because while conducting the measurement in the first mosque, 20 users agreed to contribute measurements while doing their ablution. From then on, this was taken as a base by doing 20 measurements in each mosque to have equal numbers of measurements from each. The measurements were done by fixing instruments to the taps of the mosques to measure total consumption of water for ablution per capita. The instrument is available in the market for measuring the consumption of water in gardening. This research used the instrument for the first time for this particular reason.

2- In houses

Assessing total consumption per capita was done for five people only in the researcher's home with the researcher's friends, just to demonstrate that there is a relationship between total consumption in ablution and tap types and techniques used – as observed at the end of the process of analysing measurements of consumption per capita in mosques. The relationship between total consumption in ablution and tap types and techniques was confirmed by the first five ablution measurements.

The results of the analysis in the mosque showed that there is a relationship between total consumption in ablution and tap types and techniques used. This led to the decision to continue the measurements of total consumption per capita in the houses, to include another type of modern normal tap which is not available in the mosque but can mostly be found in houses. The addition of this type of tap consisted of a study of the consumption of water in ablution with all types of taps. Participants were also asked to change their technique in preforming ritual ablution by using a pot with a capacity of 1L to compare the user's habits and consumption using both methods. The measurement was done for five people in the researcher's house; the age range was between 32 and 60 years.

Regarding the measurement of total consumption from a home tap, the instrument that was used was the same as that used in the mosque. The instrument was fixed on an ablution tap to measure the ablution consumption per capita.

The users of water in the mosque and in houses were aware of the instrument being there. The researcher did explain for them the purpose of this; i.e. that the instrument was being used to measure water flow. The researcher tried to prevent the influence of installing the instruments on the users' behaviour by asking them to carry out their ablution exactly as they normally would.

The measurements were done by setting up a timer and pressing the start button on the instrument to start to measure the consumption and then taking the reading of total water consumption after the users had finished their ablution and total time taken for the ablution. Another reading was taken when the controlled sensor taps stopped water flowing, as some of the taps were controlled by a timer to close – so water still flowed although the users had finished their full ablution. This procedure of measuring and recording were followed for every user.

The users were being observed, and the study did consider the likelihood of observer effect on user behaviour; however, this was avoided by explaining that there was no need to perform an 'ideal' ablution. Rather, behaviour needed to be normal, with ablution carried out just as it normally was. It was also considered that the observed effect on users if there was any such effect would be to encourage them to consume less but not more water (to be more 'ideal'); this would not affect the results which intended to show minimum consumption.

3.5.2.2 Interviews

The interviewees were policymakers, engineers, mosques' management and users of water in mosques. The interviews were done with individuals for policymakers, engineers, and mosques' management, while group interviews were conducted with users in mosques. The results of the planned interviews led to the decision to conduct an interview with the **Assistant to the Grand Mufti** (see glossary) of the Sultanate of

Oman to obtain clear responses in matters of the water recycling ‘Fatwa‘ (see glossary), to cover the knowledge gap in this area of research.

As mentioned in Tables 3.3, the interviews with policymakers and engineers were conducted with three different organizations and from different departments (civil and mechanical). The particular engineers were selected because of the information needed for water management, i.e. with civil engineers who had experience and mechanical engineers who were aware of the mechanisms and their application of appliances in terms of tap flow and pressure. Informants were selected and recruited, most of them senior managers with not less than five years’ work experience in the Muscat main branch of the ministry. The interviews were done in two different departments to cover all related phenomena in a mosque in terms of behaviours, pricing, appliances and policies, and in terms of techniques of maximum or minimum flow, plumbing, recycling, and any other techniques. Altogether interviews were conducted with 16 policymakers and mosques’ management from three different organizations and different mosques, and those responsible for mosques and water in Oman. The interviews with mosque management were conducted with the ‘Imam‘ (see glossary) in a mosque or any other member of the mosque’s management. By comparison, around 26 interviews were conducted with engineers from six different organizations, as mentioned in detail in Table 3.4. The individual interviews usually took around 45 minutes. The interviews were conducted by the study researcher, in person in the interviewee’s office.

Table 3.3: Provisional source of data for interviews with policymakers

Interviewees	Numbers	Interviewees’ specifications	Places
Policymakers	4	1. Senior manager 2. Not less than five years’ work experience	1. Ministry of Endowments and Religious Affairs.
	3	1. Senior manager. 2. not less than five years’ work experience	2. Diwan of Royal Court
	6	1. Senior manager 2. Not less than five years’ work experience	3. Public Authority of Electricity and Water (PAEW).

Mosques' management	3	Imam or mosque management	4. Three different mosques
Total	16		

Table 3.4: Provisional source of data for interviews with engineers

Interviewees	Interviewees' specifications	Numbers	Places
Civil engineers	1. Senior manager 2. Not less than five years' work experience	3	1. Ministry of Endowments and Religious Affairs
Civil and mechanical engineers	1. Senior manager 2. Not less than five years' work experience	4	2. Diwan of Royal Court
Civil engineers	1. Senior manager 2. Not less than five years' work experience	2	3. Public Authority of Electricity and Water (PAEW)
Civil engineers	1. Senior manager 2. Not less than five years' work experience	4	4. Haya Water Treatment Company
Civil engineers	1. Senior manager 2. Not less than five years' work experience	2	5. Parsons International consultant company
Civil and mechanical engineers	1. Senior manager 2. Not less than five years' work experience	10	6. Higher College of Technology
Total	25 interviews		

Group interviews were conducted with people who were normally praying at the mosques in order to investigate users' needs, behaviours and their opinions about reusing and recycling water in the mosque. A total of three group interviews were conducted in Masjid and Jame's, as mentioned in Table 3.5. The interviewees were selected randomly with the help of the Imam (see glossary) and the mosques' management by asking the worshippers after completion of their praying to participate in a group interview conducted in the Imam's office in the same mosque. The group interviews took around 2.5 to 3 hours. The groups consisted of six worshippers, two females and four males. The ratio of males and females was the same for all groups as the mosques were mainly for males, but to avoid bias the study included females in each group. The age range was from 19 to 45 years, as the mosque is diverse with different worshippers belonging to different ages in the same place. The Imam was not allowed to participate or to attend the group interviews with users, to avoid any potential for bias or influence on users' ideas and views.

To ensure that all interviewees participated in the discussions, the researcher followed one of the strategies interchangeably: (1) politely intervene and summarize what the respondent was saying – then refocus the discussions; or (2) take advantage of a pause and say that the issues raised were of vital significance and should be discussed in a separate session.

To minimize group pressure, which inhibits dissenting participants from expressing their views, the researcher asked for other ideas, explanations or recommendations compared to those already discussed, suggesting new ideas for discussion. The researcher also looked at the participants who appeared to be sceptical of the views of the group and encouraged them to speak. The groups interviews were recorded. The notes included: (1) records of the discussions, and (2) the researcher's own ideas and thoughts generated during the interview.

The researcher had begun by recapping the purpose of the research and the objectives. The researcher was careful not to be biased by her own opinion by thinking about the way to phrase the question and trying to move from general broad questions to more specific questions, to allow the discussion to flow naturally and feel less intrusive to the participants and to ensure all views could be freely expressed and captured.

Table 3.5: Provisional source of data of groups interviews with users

Interviewees	Numbers	Interviewees' specifications	Places
Users	1 group	Those who are normally praying there	Masjids no.1
	2 groups		Jame's no. 1 and 2
Total	3 groups		

Justification for selecting key informants’ ministries and companies:

- Ministry of Endowments and Religious Affairs: Specialized in constructing and supervising small mosques called Masjid and some big mosques called Jame.

- Diwan of Royal Court: Specialized in constructing and supervising Royal mosques called Jame.

- Ministry of Regional Municipality, Environment and Water Resources (MRMEWR): Responsible for developing policies, plans, and programmes for the municipal and water resources sectors.

- Public Authority of Electricity and Water (PAEW): Responsible for distributing water across the Sultanate of Oman, setting rules and requirements for water-related activities in the country, and approving and monitoring the technical specifications for water equipment and tools.

- Haya Water Treatment Company: Responsible for developing, designing, implementing, operating and maintaining the wastewater facilities in Muscat Governorate.

- Parsons International Consultant Company: International consultant company in Oman focusing on infrastructure projects, deliver design/ design-build and programme/construction management.

Higher College of Technology: Second biggest government university in Oman, providing bachelor level degrees. It has seven branches in different regions in Oman.

3.5.3 Reporting:

Thematic analysis uses method of analysing qualitative methods researches and allows flexibility in the research; this allows for detailed, rich and complex descriptions as the data (Barun and Clarke, 2006). Thematic analysis is defined as a “method for identifying, analysing is reporting patterns within data” (Braun and Clarke, 2006, p.79). The thematic analysis used for analysing and reporting the qualitative data for this research study followed six defined steps of thematically analysis carried out to ensure clarity in the reporting process (Barun and Clarke, 2006).

Step 1: Familiarizing data

Reading and re-reading to familiarize with data before coding and searching for meanings and patterns.

Step 2: Generating initial codes

Production of initial codes for the research data. The coding was done manually by using highlighters and posting notes, to take notes in the text for analysis and use with software (Mindjet).

Step 3: Searching for themes

Following the coding stage. The different coded long list of data was sorted into potential themes and sub-themes using visual mind maps, which helped to capture a relation between each other using a mind map.

Step 4: Reviewing themes

The next step involved work on reviewing themes and refinement of the themes to find out if they needed to be broken down into smaller components or collapsed into other themes.

Step 5: Producing the report

Final analysis and production of the report and write-up was done in this last stage of thematic analysis; by the end of this stage, the final report was ready. The report was done in a concise, coherent, logical, non-repetitive and interesting manner following the objectives and sub-research questions, order in analysis, discussion and conclusion.

3.6 Methods to obtain research objectives

The research contains three objectives, as mentioned in Chapter 1. This section explains the complete plan of data required, data sources, research methods that were used to obtain each objective, and explains the ways and methods to answer all sub-research questions related to each objective, as mentioned in Table 3.6.

Table 3.6: Conceptual structure of the research

Objectives	Sub-research questions	Methods	Source of data
1. Investigating the current water-saving practices, policies, appliances, techniques applied in mosques and water consumption in mosques	1.1 What are the water-saving policies and regulations that can be applied in the mosque to achieve efficient use of water? 1.2 What are the water-saving practices and appliances applied in mosques? 1.3 What is the estimated water consumption in ablution and toilet flushing per capita?	Literature review Document analysis Total water consumption per capita and analysing water bills Interviews: - Policymakers - Users and management team in mosques Quantitative: - Investigation - Per capita water consumption (ablution) - Water use for toilet flushing - Analysing mosques' water bills	Ministry of Endowments and Religious Affairs Diwan of Royal Court Public Authority of Electricity and Water (PAEW). Policymakers, mosques' management, engineers Observation Measurement
2. Identify effective water demand management policies and measures and techniques that are compatible with the needs of water consumers in mosques	2.1 What are consumers' needs when making ablution in mosques? 2.2 What are effective water demand management policies, measures and techniques?	Literature review: - Archival analysis of water quality standards Document analysis Interviews: - Policymakers - Engineers - Users - Management team from mosques	Literature Islamic books Measurement Ministry of Endowments and Religious Affairs Diwan of Royal Court Public Authority of Electricity and Water (PAEW). Policymakers, mosques' management, engineers

3. To investigate the acceptability of reusing water in mosques	3.1 Is water reuse or recycling acceptable to the mosque users and relevant policymakers?	Literature review: - Archival analysis of water standards - Document analysis Interviews: - Interviews with policymakers - Interviews engineers - Interviews with users - The management team in the mosques Quantitative investigation of consumption measurements	Ministry of Endowments and Religious Affairs Diwan of Royal Court Public Authority of Electricity and Water (PAEW) Policymakers, mosques' management, engineers

3.7 Ethical consideration for this research

The research was undertaken in accordance with Loughborough University's ethical standards. Ethical consideration was taken during and after data collection, as this research was conducted in the researcher's country in the Sultanate of Oman. This consideration covered all risks assessment, as follows:

- The research was based on sound research methods that were appropriate to the research question and carried out to the highest standards of quality and to meet the clearly defined aims.
- It conformed to professional and ethical standards to protect against distortion and bias in the interpretation of findings.
- Participants involved in primary data collection were asked for their consent to take part.
- It was made clear that participation was voluntary and that participants had the right to refuse to answer individual questions or to withdraw from the research process at any point, for whatever reason.

- Potential participants were not pressurized to take part in the research. They were given enough information to enable them to make an informed decision. Participants' agreement was required before equipment (such as a tape recorder) was used.

- The research considered the potential impact of choices in research design (such as sample design, data collection method and so on) on participation.

- The identity of, and data belonging to, participants and potential participants (including information about the decision whether or not to participate) were protected throughout the research process, including respondent recruitment, data collection, data storage, analysis, and reporting.

3.8 Summary

In summary, Figure 3.3 was developed from the general methodological framework shown in Figure 3.1 and provides a pictorial representation of the approach that was used in this study, starting from the philosophical stance for water scarcity in GCC countries discussed in Chapter 2 section 2.2 and then looking for WDM as a solution. Therefore, this drives the research towards the ontology philosophy, and then from ontology to epistemology to identify effective water demand management policies, measures, and techniques that are compatible with the needs of water consumers in mosques, while investigating the acceptability of water reuse in mosques. This led the research area to adopt pragmatism, using both inductive and deductive reasoning processes. The mixed-method strategy was selected as a means of understanding and developing bounds in a research context involving integrating the contributions from relevant organizations and users of water in mosques, employing numerous levels of analysis. The strategy adopted both primary and secondary sources of data and a mixed method of data collection using a cross-sectional time horizon.

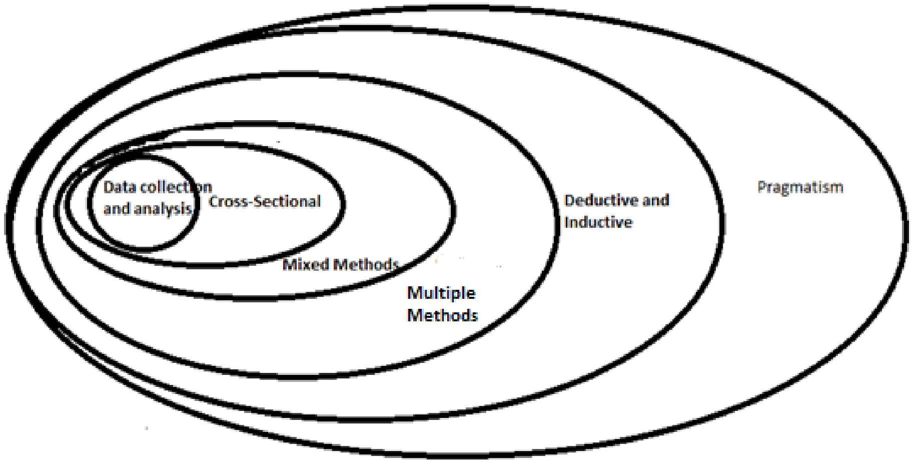

Figure 3.3: Onion research representation of the approach used in this study (adapted from Saunders et al. 2012)

The analysis and presentation of the research data comprise three chapters, as shown in Figure 3.4 below.

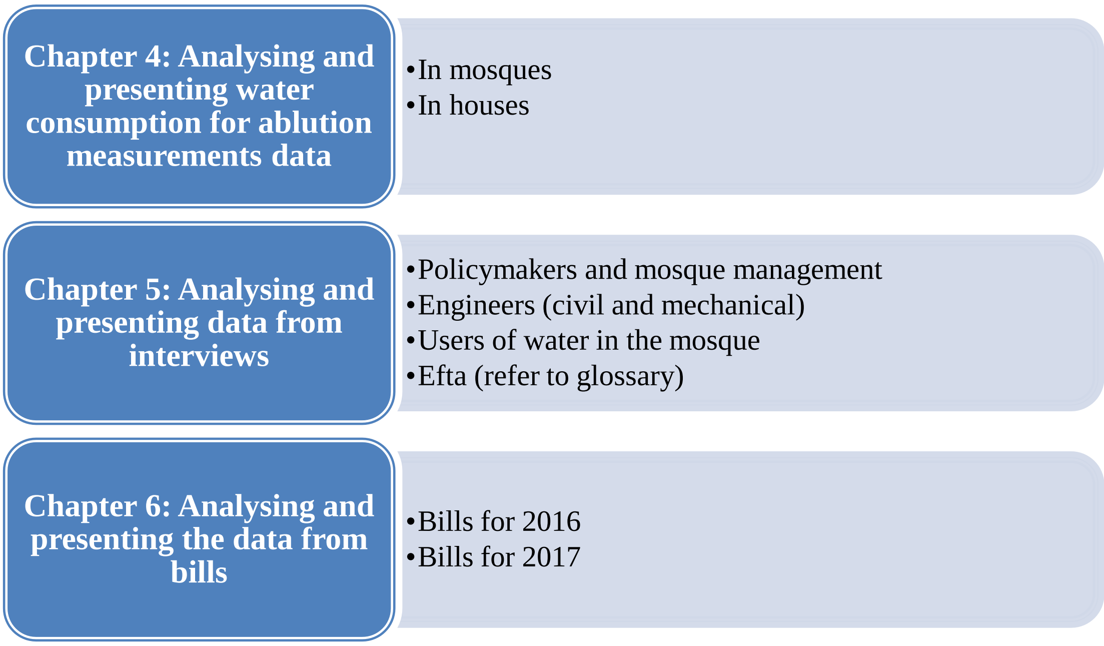

Figure 3.4: Analysis and presentation of data

Chapter 4 : Presenting and Analysing the Water Consumption Measurements Data

4.1 Introduction

This chapter is dedicated to analysing the data gathered from ablution water consumption per capita measurements. The measurements in this research were carried out in six mosques: five were in Muscat in masjids and Jame's and one was in the Al Sharqiyah region in a masjid. The measurements for ablution were done for a total of 120 users (20 users in each mosque). The results analysis included observation of the results of users' behaviours and examined the appliances in different mosques. **The purpose of taking measurements and examining the appliances was to quantify the amount of water used in each mosque, including when preforming ablution, and to find out whether appliances were efficient or not and whether they could save water or not.**

The measurements were done by fixing an instrument to the taps to measure the consumption from different taps in the mosques: the appliances in three of the mosques were normal, with old taps whereby the water could be controlled by users in opening and closing; the other three mosques had sensor or push taps controlled with a timer (Table 4.1).

4.2 Comparing different appliances for ablution in all mosques (Jame's and Masjids)

The comparison of different appliances for **ablution** in all Jame's and masjids is clearly shown in Table 4.1 with the help of two groups, group 1 and group 2. The grouping was done in a systematic manner in Table 4.1 regarding appliances, tap type, and management organization. Group 1 (highlighted with blue in Table 4.1) is under the same government organization 1; as mentioned before, the mosques in Oman are under two government management organizations. All the mosques under group 1 of management organization 1 have very modern types of appliances, push taps and laser sensor taps, both of which are controlled with a timer. On the other hand, group 2 (highlighted with green in Table 4.1) is under government organization 2. All the mosques under group 2 of management organization 2 have the normal type taps, which are controlled by users for opening and closing.

Table 4.1: Comparing different appliances for ablution in all Jame's and masjids

Group no.	Management organization	Jame's code	Type of tap
Group 1	Management organization 1	Jame 1	Push taps
		Jame 2	Laser sensor taps
		Jame 3	Laser sensor taps
Group 2	Management organization 2	Jame 4	Normal taps
		masjid 1	Normal taps
		masjid 2	Normal taps

4.3 Data analysis of Jame's water consumption

The measurement of water consumption during ablution was carried out in 4 Jame's in Muscat. The total number of measurements in Jame's was around 80 measures of ablution. Other measurements were done to calculate total consumption per capita.

4.3.1 First mosque (Jame) data analysis

The first measurement of consumption for ablution was in a Jame with **push taps** controlled by a timer, as shown in Figure 4.1.

Figure 4.1: Push taps controlled by a timer in the first mosque (Jame)

Measurement of total consumption for ablution done for around 20 users, as mentioned in Table 1.1 (Appendix B). Other measurements of flow in litres and time taken for one push of an ablution tap were taken in the **first Jame.** The results were found to be around 1.2L / 17s with a push tap, which was opened and closed for different lengths of time depending on the water pressure, as it shown in Table 1.2 (Appendix B). This means the measurement results for the push taps in the first mosque consumed 1.2L in one push which continued to flow for 17s.

Total water release varied with each push and from one tap to another in the first mosque. Once pushed, the taps stayed on for a very long time and this varied from one tap to another. And each time a tap was pushed, water amount differed depending on the starting and ending of the main pressure system in the mosque. There was no systematic procedure in terms of flow, pressure and time in the first mosque, either through observations or measurement results.

The maximum timing for ablution was the maximum consumption in a push tap, highlighted as shown from the measurement results from the first mosque in Table 1.1 (Appendix B). Maximum timing was 1 minute and 13 seconds, with the total water consumption for the user's requirements being 5.4L with four pushes of the tap to complete a full ablution. However, the water continued to run from the tap and stopped after 5.5L had flowed, as it was controlled with the timer to continue running for another 10 seconds after each push. The minimum timing was around 00:42 seconds to carry out a full ablution, with total water consumption of 3.1 L, but as mentioned before the water from the last push continued to run until it reached 3.5L. The average timing for ablution in the first mosque was 00:54 seconds, with average total water consumption for each user's requirement being 4.045 L. The average timing water consumption once the tapped stopped running was 4.5L over an average of three pushes, as shown in Table 4.2

Table 4.2: Average, max. and min. results timing, consumption, and number of pushes for ablution in first mosques

First Jame	Minutes	Litres for ablution	Litres of water from the last touch of the tap	Number of pushes
Average	00:54.00s	4.04L	4.5L	3

Max.	01:13.20s	5.4L	5.5L	4
Min.	00:42.92s	3.1L	3.5L	2

The average time for three pushes of the tap was 00:47 seconds, which was the average number of pushes in the first mosque. Consumption of four readings was taking in a fixed time of 00:47 seconds in the first mosque from the ablution tap without any user but with the same number of pushes, as mentioned in Table 1.3 (Appendix B). The results were 3.7L and 3.8L per 00:47 seconds with two to three pushes of the tap. The observed pressure in the tap was different from one tap to another and with different timings. The measurements for this research was done with taps that had close to similar stopping times as with other taps.

On the other hand, in the mosques, there were two other appliances inside the toilet – the W/C flush toilet and water tap, as shown in Figure 4.2. Three different readings were taken in terms of the timing of the flush for the first mosque. The W/C flush in the first mosque was around 7 seconds per flush using 8 litres of water per flush, as mentioned in Table 4.1 (Appendix B).

Figure 4.2: Appliances inside the toilet: W/C flush toilet and water tap in the first mosque (Jame)

The inside toilet tap consumption was measured by filling a jug of 1.4L max to the limit and 0.7L for half a jug. It took around 00:08 seconds to reach half the jug and around 00:11 seconds to reach a maximum of 1.4L, as shown in Table 1.5 (Appendix

B). The observed pressure while carrying out the measurement was very high and not comfortable for use. Filling the 1.4 litre jug took less than twice the amount of time to fill half the same jug; this was because of less accuracy in starting and ending with timing of tap opening, which was controlled by the researcher.

4.3.2 Second mosque (Jame) data analysis

The **second** measurement of consumption for ablution was done in a Jame as well, but one that used a laser, **sensor tap,** as shown in Figure 4.3. It had a sensor for starting only; for stopped there was a timer – similar to the push tap but with a slight difference in timing duration. The sensor taps were controlled with timing. So, with the first touch, the water runs, and then it does not stop immediately once the user moves his/her hand. The most efficient sensor tap appliances stop immediately once the user moves their hand. These efficient taps were found in the market. But within the mosque, with the ablution, once the users remove their hands from the sensors, the tap doesn't stop. Rather, stopping is controlled by a timer.

The observation of how sensor taps in the second mosque worked was recorded by video as an example of a person carrying out the full ablution process using the sensor tap in the second mosque. A brief description of the content of the video: the person did his full ablution in 1 minute and 15 seconds (01:15), with total water consumption of 5.6L taking five touches to the sensor; the water continued to run from the tap following the final touch and stopped after 6.5L of water flow. This continued water flow depended on the behaviour of user and timing of the last touch.

Here, behaviour plays an important role because some people take a very long time to scrub their hands, their hair, their head, and their face. For example, although a user has taken a little bit of water for his hand, the water continues running while he is scrubbing his hand. Once he finishes scrubbing, he again goes back to take a little more water for his other hand or head. The timing of the sensor stops while he is scrubbing, so he needs to touch the sensor again and takes a little more water while the rest continues to run free.

By comparison, different behaviours were observed at the site, where some people just took the water and washed without scrubbing in a short time; however, the problem of water continuing to run from the sensor tap controlled by a timer was still present.

Figure 4.3: The laser sensor taps in the second mosque

Measurement of total consumption during ablution was done for around 20 users, as mentioned in Table 2.1 (Appendix B). Other measurements of the flow per litre and time taken for one touch to trigger the sensor was calculated in the **second Jame.** The results found that around 0.6L flowed for around 10 to 12 seconds with the sensor tap, with opening and closing taking different lengths of time, depending on the pressure (see Table 2.2, Appendix B).

Total litre amounts varied with each touch, from one tap to another in the second mosque as well. The sensor tap stayed on for a very long time and it varied from one tap to another and from one touch to another, depending on starting and ending the of the main pressure system in the mosque. The sensor taps were controlled by a timer, but it was observed that some of the sensors continued to flow for a long time with less than controlled flow from touch to touch. This was explained by the mosque management as caused by the pressure of pumping at that time.

The maximum timing for an ablution was the maximum consumption with a sensor tap, as shown from the measurement results in Table 2.1 (Appendix B). The maximum timing was 1 minute and 31 seconds, with total water consumption by users to finish ablution being 7.2L with seven touches to the sensor tap. But the water continued to run from the tap and stopped after 7.7L of water flow as it was controlled with a timer; it continued to run for another 12 seconds after each touch. The minimum timing was around 00:59 seconds to do a full ablution, with total water consumption of 4.2L; but as mentioned before, the water continued to run, reaching 5.3L after the third touch.

The average timing for ablution in the second mosque was (1:03) 1 minute and 3 seconds, with average water consumption of users to finish ablution being 5.2L. On average, the tap stopped running after 5.8L, with an average of four sensor touches (see Table 4.3). The difference between the amount of average water after users finished ablution and the amount of average extra water which continued to run was equal to the total amount of water consumed by **Prophet Mohammed**, which equalled **0.6L (600ml).**

Table 4.3: Average results for timing, consumption, and number of pushes for the second mosque

Second Jame	Minutes	Litres for ablution	Litres of water from the last touch of the tap	Number of pushes
Average	1:03.00s	5.2L	5.8L	4
Max.	1:31.00s	7.2L	7.7L	7
Min.	00:59.12s	4.2L	5.3L	5

Four readings for water consumption were taken in a fixed time of 00:47 seconds in the second mosque from an ablution sensor tap without any user, but with a number of touches. The timing of 00:47 seconds was fixed again in the second mosque to have the same fixed timing as the first mosque and the same was followed for all other mosques, as mentioned in Table 2.3 (Appendix B). The result varied from 2.4L to 2.8L per 00:47 seconds with four touches of the laser sensor tap. For another sensor tap, four readings was taking. The results varied from 3.5L to 3.9L per 00:47 seconds with two touches of the laser sensor tap, as shown in Table 2.4 (Appendix B). The observed pressure in the two taps was different in the two different timings. The observed pressure in the tap was different from tap to tap and with different timings in the second mosque also.

There were two other appliances inside the toilet (the W/C flush toilet and water tap) in the second mosque as well. Three different readings was taken of the timing of the flush in the second mosque. The W/C flush in the second mosque was around 00:9 to 00:10 seconds per flush, with 8 litres of water per flush, as mentioned in Table 2.5 (Appendix B).

For the tap inside the toilet, water consumption was measured by calculating the time taken for filling a jug of 1.4L max and 0.7L (half the jug). It took around 00:07 seconds to fill half of the jug and around 00:11 seconds to reach a maximum of 1.4L of the (Table 2.6, Appendix B). The observed pressure while doing the measurement was very high and not comfortable for use.

4.3.3 Third mosque (Jame) data analysis

The **third** measurement of consumption for ablution was also carried out in a Jame and for laser **sensor taps** as well. The taps worked in the same, was as the second mosque laser sensor, where the sensor was for starting only, with a timer for stopping. It was exactly the same controlled by timing as the push tap in the first mosque and laser sensor tap in the second mosque, but varied slightly in duration of the timing.

Measurement of total consumption for ablution was done for around 20 users, as shown in Table 3.1 (Appendix B). Other measurements of litre flow and time were taken for one push of the ablution tap in the **third Jame**. The results were found to be around 0.6L for around 15 to 17 seconds with the sensor tap, which opened and closed for different lengths of time depending on the pressure, as it shows in Table 3.2 (Appendix B).

Total litre amounts varied for every push, and from one tap to another, in the third mosque as well. The sensor tap stayed on for a very long time, and this varied from one tap to another and from one touch to another depending on the starting and ending of the main pressure system in the mosque.

The maximum timing for an ablution was the maximum consumption in the sensor taps, as shown from the measurement results in Table 3.1 (Appendix B). The maximum timing was around 1 minute and 00:50 seconds, with total water consumption by users to finish ablution being 3.8L. However, the water continued to run from the tap and stopped at 4.0L as it was controlled with a timer; it continued to run for another 00:15 seconds after each touch. The minimum timing was around 00:56 seconds to do a full ablution, with total water consumption of 1.9L. The water continued to run up to 2.5L following the third touch. This meant this tap was a different style – instead of touch, it was a push tap to start but it was the same as the sensor tap – i.e. controlled by a timer – to close; however, the length of time the water flowed was different, as it was a different mosque and because there was no systematic procedure.

The average timing for an ablution in the third mosque was (01:23) 1 minute and 23 seconds, with the average total water consumption by users to finish an ablution being 3.1L. The average timing for the tap to stop running was at 3.3L, as shown in Table 4.4.

Table 4.4: Average results timing, consumption, and number of pushes for the third mosque

Third Jame	Minutes	Litres for ablution	Litres of water from the last touch of the tap
Average	01:23.00s	3.1L	3.3L
Max.	1:50.08s	3.8L	4.0L
Min.	0:56.42s	1.9L	2.5L

There were two other appliances inside the toilet, the W/C flush toilet and the water tap in the third mosque as well. Three different readings were taken in terms of the timing of the flush for the third mosque. The W/C flush in the third mosque was around 00:09 seconds per flush, with 20 litres of water used with each flush, as mentioned in Table 3.3 (Appendix B).

The water consumption from the tap in the toilet was measured by calculating the timing to fill a jug of 1.4L max and 0.7L (half the jug). It took around 00:06 seconds to fill half the jug and around 00:09 second to reach the maximum in 1.4L, as shown in Table 3.4 (Appendix B). The observed pressure from the taps inside the toilet while doing the measurement was very high and not comfortable for use.

4.3.4 Fourth mosque (Jame) data analysis

The **fourth** measurement of consumption for ablution was done in another Jame, but with normal taps, as shown in Figure 4.4. With the normal tap, the behaviour of the user again played a significant role, even more than with the sensor laser and push taps. This was because some people opened and controlled the flow of water, so the water used was very little; they did their ablution without wasting any water. On the other hand, other people opened the tap to the maximum or to more than needed, and they continued with their ablution while the water was running. Some people opened the tap to the maximum, but then when they were scrubbing, they closed the water; they then opened the tap again to continue washing and kept opening and closing the tap until they finally shut off the water. So, we have three different behaviours:

- some who open the tap very little water to carry out their ablution;
- some open the tap to the maximum and do their scrubbing while the water is running; and
- some, though they open the tap to the maximum, who keep closing and opening the tap, while they are doing the scrubbing.

So, the behaviour played a major role in when users opened the tap, while with the sensor taps, users don’t have much control. In the case of the sensor taps, there is a lot of water wasted while users are washing.

Figure 4.4: The normal tap in fourth Jame mosque

Measurement of total consumption during ablution was carried out for around 20 users in the fourth Jame, is mentioned in Table 4.1 (Appendix B).

Total litres of water varied from user to user, depending on the way they opened the tap. The sensor taps and push taps stay on for a set time that cannot be controlled, but in the case of normal tap, the timing and the running of water was controlled by the behaviour of the users.

The maximum timing for ablution shouldn’t mean a maximum consumption of water for the normal taps, unlike what is seen in the cases of a sensor tap and push tap, as shown from the measurement results in Table 4.1 (Appendix B). The maximum timing was 1 minute and 20 seconds, with total water consumption to finish ablution being 3.4L for the continuous way of opening the tap. In the normal tap to do a full ablution, and the water stops running from the tap with the completion of the ablution, with the same amount of water (3.4L) and the same timing. Other users spent less time, around 00:40 seconds, with total water consumption of 4.0L for continuous way of the opening tap. This is because as mentioned before, different behaviours of users in opening the tap and the way of opening played a major role compared to the other sensor laser and push tap appliances. The minimum timing was around 00:31 seconds to do a full ablution, with total water consumption of 1.3L for the continuous way of opening the tap.

The average timing in ablution in the fourth Jame mosque was 00:54 seconds, with total water consumption by users to finish ablution being 2.7L for the average continuous way of opening taps. Maximum and minimum timings in ablution, consumption, and the way users opened the taps are also shown in Table 4.5.

Table 4.5: Average results timing, consumption, and ways of opening the taps for fourth Jame mosques

Fourth mosque (Jame)	Minutes	Litres for ablution	Way of opening taps
Average	00:54.00s	2.7L	Continuous
Max.	00:40.22s	4.0L	Continuous
Min.	00:31.36s	1.3L	Continuous

Water consumption over four readings was taken in a fixed time of 00:47 seconds in the fourth Jame mosque from ablution using a normal tap, without any user and with a number of the different tap openings, so a different amount of water was left to run in a fixed time, as mentioned in Table 4.2 (Appendix B). The results varied from 1.9L to 3.4L (same for 2 reading) and to 4.8L per 00:47 seconds with four different openings of the normal tap. The observed pressure in all the taps was the same in in the fourth Jame.

There were two other appliances inside the toilet, the W/C flush toilet and the water tap, as with the other Jame's. Three different readings were taken of the timing of the flush for the fourth mosque. The W/C flush in the fourth mosque was around 4 to 5 seconds per flush with 5 litres of water (see Table 4.3, Appendix B).

The water consumption from the tap inside the toilet was measured by calculating the timing for filing a jug of 1.4L max and 0.7L (half the jug). It took around 00:05 seconds to 00:08 seconds to reach half of jug and around 00:11 to 00:15 seconds to reach the maximum limit of 1.4L, as is shown clearly in Table 4.4 (Appendix B).

4.4 Comparing average consumptions in ablutions in four Jame's

A comparison of the average results for timing, consumption and number of push/touches in Jame's 1,2 and 3, and the way of opening the taps in Jame 4, is shown in Table 4.6 and Figure 4.5. As mentioned before, the first Jame had push taps, the second and third Jame's use laser sensor taps, and the fourth Jame has normal taps which can be controlled by users.

The average results for timing for Jame 1 were 00:54 seconds for 4. 5L of water from the last push of the tap in a total of three pushes. The averages for the second Jame were slightly more: four touches of sensor laser tap and average timing at about 01:03 seconds and average water consumption of 5.8L. The difference between the first Jame with push taps and second Jame with sensor laser taps is normal, with a slight difference in average timing between 00:54s and 01:03s. Surprisingly, the third Jame showed a greater average timing of 01:23s but less consumption of 3.3L compared to the first and second Jame's. That difference was due to the different timings per push or per sensor touch from one Jame to another, with different pressure and consumption.

However, the second and third Jame's were under the same organization management in Oman. It is clear from the results that there were no systematic procedures followed in terms of timing, pressure or consumption from one Jame to another under the same organization management. The fourth Jame with normal taps was from a different organization management and had the least average in terms of consumption of around 2.7L for 00:54s of average timing. That was because of the possibility of controlling the normal tap by users. There was 3.1L extra water consumption when comparing between the fourth Jame, which has minimum average consumption, and the second Jame, which has maximum average consumption; this was 1.8L difference compared to first Jame and 0.6L compared to the third Jame.

The order of Jame's from maximum to minimum in average consumption for **ablution** was the second Jame had the maximum water consumption, then the first Jame and then comes the third Jame. The minimum water consumption average for ablution was for the fourth Jame, which had normal taps.

Table 4.6: Comparing average results for timing, consumption and number of pushes/touches or ways of opening taps for ablution in all Jame's

Jame's code	Minutes	Litres for ablution	Litres of water from last push/touch of a tap	Number of pushes/touches or ways of opening
Average Jame 1	00:54s	4.04L	4.5L	3
Average Jame 2	01:03s	5.2L	5.8L	4
Average Jame 3	01:23s	3.1L	3.3L	-
Average Jame 4	00:54s	2.7L	Same 2.7L	Continuous

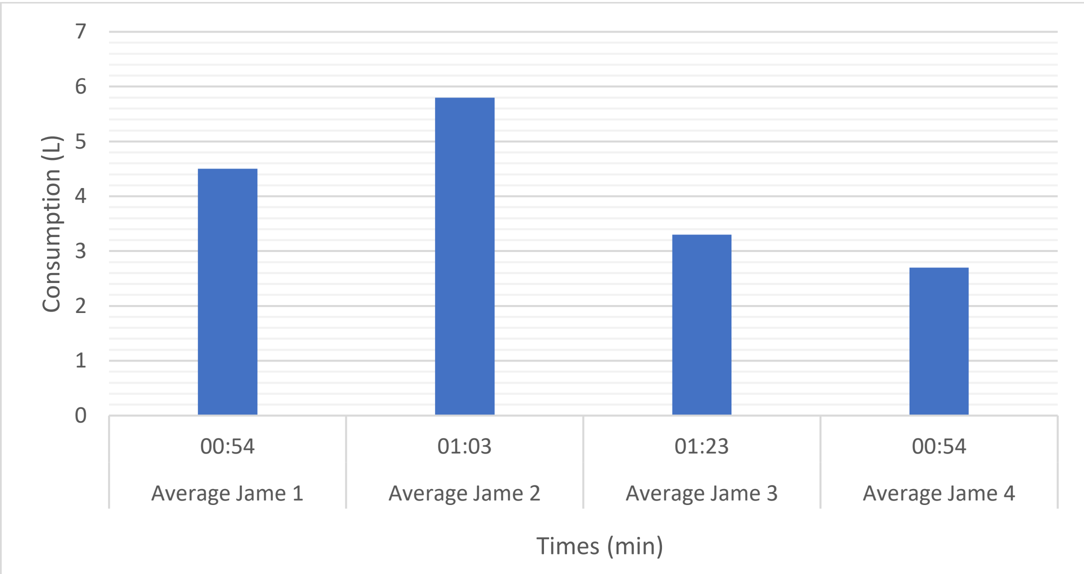

Figure 4.5: Comparing timing and consumption for ablution in all Jame's

Table 4.7: Average total consumption per capita in Jame 1

Jame 1	Ablution tap types	Ablution consumption	Flush toilet	Tap in toilet	Total average
Average consumption per capita	Push	4.5L	8L	0.7L min 1.4L max	Min. 13.2L Max. 13.9L

Average water consumption per capita including ablution, the flush toilet and tap in the toilet in the first Jame is illustrated in Table 4.7. The minimum total average consumption per capita is 13.2L while the maximum average consumption is about 13.9L. The minimum and the maximum values are measured depending on the users' usage of the toilet tap. So, if users use around 0.7L, there is a minimum total consumption and if it is around 1.4L, there is a maximum consumption.

Table 4.8: Average total consumption per capita in Jame 2

Jame 2	Ablution taps type	Ablution consumption	Flush toilet	Tap in toilet	Total
Average consumption per capita	Laser sensor	5.8L	8L	0.7L min. 1.4L max.	Min. 14.5L Max. 15.2L

Average total consumption per capita including ablution, the flush toilet, and tap in the toilet in the second Jame is illustrated in Table 4.8. The minimum total average consumption per capita is equal to 14.5L and maximum average consumption is around 15.2L. The minimum and the maximum values are measured depending on the users' usage of toilet tap.

Table 4.9: Average total consumption per capita in Jame 3

Jame 3	Ablution taps type	Ablution consumption	Flush toilet	Tap in toilet	Total
Average consumption per capita	Laser sensor	3.3L	20L	0.7L min 1.4L max	Min 24L Max 24.7L

The average of total consumption per capita including ablution, the flush toilet, and tap in the toilet in the third Jame is illustrated in Table 4.9. The minimum total average water consumption per capita is 24L and maximum average consumption is 24.7L.

Table 4.10: Average total consumption per capita in Jame 4

Jame 4	Ablution taps type	Ablution consumption	Flush toilet	Tap in toilet	Total
Average consumption per capita	Normal	2.7L	5L	0.7L min 1.4L max	Min 8.4L Max 9.1L

The average of total consumption per capita including ablution, the flush toilet, and the tap in the toilet in the fourth Jame is illustrated in Table 4.10. The minimum total average water consumption per capita is 8.4L in fourth Jame and maximum average consumption is around 9.1L.

4.4.1 Minimum total consumption per capita in all Jame's

Minimum total consumption per capita in all Jame's is illustrated in Table 4.11; as mentioned before, minimum results come from using around 0.7L from the toilet tap. In Table 4.6, the order of Jame's from maximum to minimum in terms of average water consumption during **ablution** is the second Jame, which has the maximum average water consumption for ablution, followed by the first Jame. It is followed by the third Jame, while the minimum water consumption average is in the fourth Jame, as mentioned before. This is comparing with the minimum total consumption per capita, including the flush toilet and tap in the toilet, is shown in Table 4.11. The third Jame, which is placed third in order of ablution consumption has the maximum total consumption per capita at 24L. That difference is because of the very high flush toilet consumption in the third mosque, which equals to 20L per flush (Table 4.9). The fourth Jame still has the lowest minimum total water consumption per capita at 8.4L. The second Jame is second in order of minimum total consumption per capita (14.5L), while first Jame came third with 13.2L.

Table 4.11: Minimum total consumption per capita in all Jame's

Jame codes	Jame1	Jame2	Jame3	Jame4
Total consumption per capita	13.2L	14.5L	24L	8.4L

4.4.2 Maximum total consumption per capita in all Jame's

Maximum total consumption per capita in all Jame's is illustrated in Table 4.12, with maximum results coming from using around 1.4L in the toilet tap. Table 4.6 shows the order of Jame's from maximum to minimum in average water consumption for **ablution**; this is also described above.

When comparing this with the maximum total consumption per capita, including the flush toilet and tap in the toilet, the third Jame (which is third in order of ablution consumption) has the maximum total consumption per capita at 24.7L. That difference is because of the very high flush toilet consumption in the third mosque, which is 20L per flush (see Table 4.9). The fourth Jame still has the lowest maximum total consumption per capita, even with inclusion of the flushing toilet and toilet tap – with 9.1L. The second Jame had the second highest maximum total consumption per capita (15.2L), while the first Jame came third with 13.9L.

Table 4.12: Maximum total consumption per capita in all Jame's

Jame codes	Jame1	Jame2	Jame3	Jame4
Total consumption per capita	13.9L	15.2L	24.7L	9.1L

4.5 Data analysis of Masjids' water consumption

The measurement of water consumption for ablution was carried out in two masjids in Muscat. The total number of measurements in the masjids was around 40 measurements for ablution, with other measurements were made to calculate total water consumption per capita.

4.5.1 Fifth mosque (masjid) data analysis

The **fifth** measurement of consumption for ablution was done in a masjid (small mosque). The fifth masjid is illustrated in Figure 4.6. The measurement of ablution consumption in the **fifth** masjid was done for **normal taps,** as this was the type of tap available in the fifth masjid, as shown in Figure 4.7.

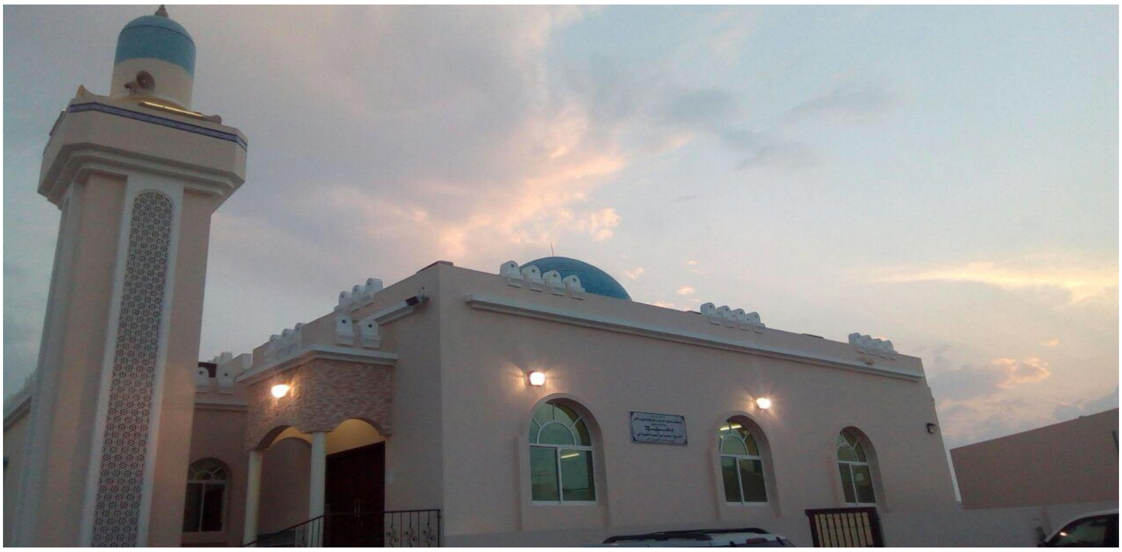

Figure 4.6**: Fifth mosque (masjid)**

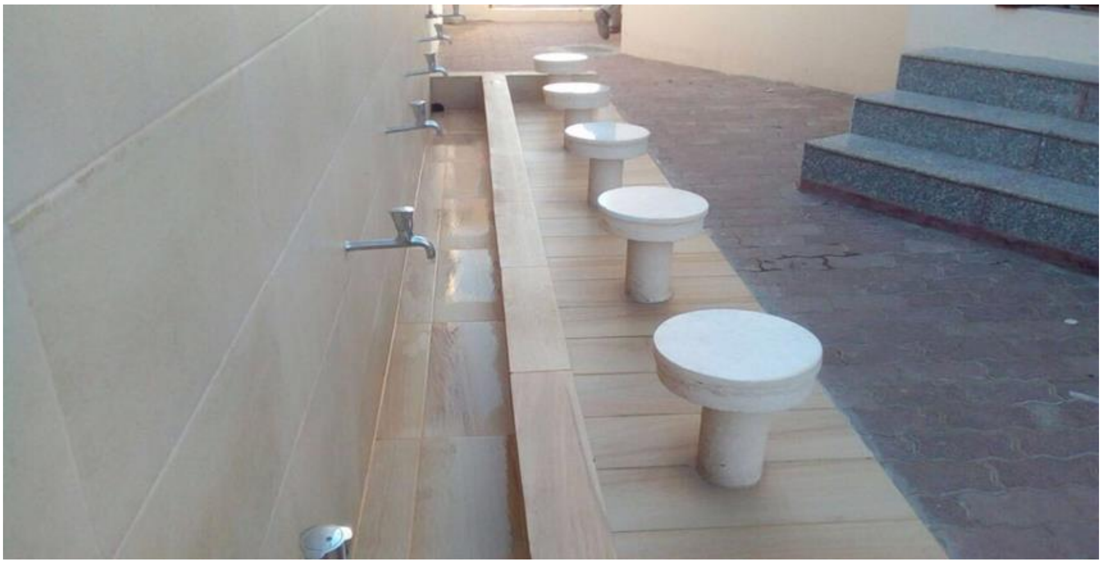

Figure 4.7: Normal taps controlled by users for opening and closing in the fifth mosque

With the normal tap, the behaviour of the user plays a very important role, more than when using sensor laser or push tap appliances – as mentioned before in the case of the fourth Jame. Measurement of total consumption for ablution was done for around 20 users in the fifth masjid (Table 5.1, Appendix B).

Total litre amounts varied from user to user depending on their way of opening the tap. The maximum timing for ablution had less consumption than the minimum timing in the fifth masjid, with the measurement results shown in Table 5.1 (Appendix B).

This proves what was mentioned before in the case of the fourth Jame, that maximum timing does not necessarily mean maximum water consumption in normal taps (unlike what can be seen with the use of sensor taps and push taps in the first, second and third Jame's). The maximum timing was 1 minute and 28 seconds, with total water consumption to finish ablution being 2.1L with the continuous way of opening tap. In this case, the water stops running when the user finishes the ablution (same amount of water, 2.1L, and same timing). Other users spent less time, around 1 minute and 16 seconds, but with more total water consumption of 7.3L when using the continuous way of opening the tap. This was because, as mentioned before, different behaviours of users in opening the tap and the way of opening play a major role in case of normal taps.

The minimum timing was around 00:43 seconds to carry out a full ablution, with total water consumption of 2.6L using the continuous way of the opening tap. Surprisingly, one user finished a full ablution with total consumption of around 0.5L only in 1 minute and 12 seconds. The observed behaviour of the user was different compared to most users in the way of opening the tap in terms of quantity and the way of opening. He opened and closed the tap and controlled the amount of water, so the water used was very limited and he did not waste any water.

The average timing for ablution in the fifth masjid mosque was (01:05) 1 minute and 5 seconds, with average total water consumption for users during their ablution of 3.5L, with their using the average continuous way of opening the taps. The maximum and minimum timing for ablution, consumption, and the way opening the taps is shown in Table 4.13. The total consumption of 0.5L for the user in the fifth masjid is excluded from the average results in Table 5.2 (Appendix B). This was done because of the large difference from the other usual results: adding this into the results would have made a significant difference in the average outcomes in an unrealistic way.

Table 4.13: Average results for timing, consumption, and ways of opening the taps for fifth (masjid) mosque

Fifth mosque (Masjid)	Minutes	Litres for ablution	Way of opening taps
Average	01:05.00s	3.5L	Continuous
Max.	01:16.27s	7.3L	Continuous
Min.	00:43.27s	2.6L	Continuous

Four readings for water consumption were taken in a fixed time of 00:47 seconds in the fifth masjid mosque using a normal tap, without any user and with a number of different openings of the tap so that a different amount of water ran in a fixed time. As mentioned in Table 5.2 (Appendix B), the result varied from 2.4L to 4.2L, and from 4.3L to 5.8L per 00:47 second with four different openings of the normal tap. The observed pressure in all taps was the same.

In the mosque, there were two other appliances inside the toilet, a W/C flush toilet and the water tap, as seen in Figure 4.8. Three different readings were taken in terms of the timing of the flush for the fifth mosque. The W/C flush in the fifth masjid was around 00:4 seconds per flush, with 3 litres of water per flush – see Table 5.3 in Appendix B. It was observed that the flushing tank took around 01:25.18 to refill again, which is a reasonable time for the next person to come and need to use the flush again.

Figure 4.8: Appliances inside the W/C flush toilet and water tap in the fifth masjid mosque

The toilet tap consumption was measured by filling a jug to 1.4L max and 0.7L (half the jug). It took around 00:20 seconds to fill half the jug and around 00:33 seconds to reach the maximum of 1.4L (see Table 5.4, Appendix B). The observed pressure while doing the measurement was comfortable for use.

4.5.2 Sixth mosque (masjid) data analysis

The **sixth** measurement of consumption of water for ablution was carried out at a masjid (small mosque) as well. The measurements for ablution consumption in the

sixth masjid was done with very old **normal taps,** since this was the type of tap used in the sixth masjid – see Figure 4.9.

Figure 4.9: Very old normal taps in the sixth mosque

With the very old normal tap, the behaviour of the user played an important role as with the other normal taps. Measurement of total consumption for ablution was done for around 20 users in the sixth masjid (Table 6.1, Appendix B).

The total amount of water used varied from one user to another depending on the way the tap was opened. The minimum water consumption for ablution was 2.5L with three different timings to carry out a full ablution. The three different timings had the same consumption of 2.5L, with the timings around (01:30) 1 minute and 30 seconds, 0:55 seconds and 0:54 seconds, all using the continuous way of the opening tap. The difference in timing with the same consumption in the sixth mosque proves that the behaviour of the user plays a highly significant role.

The maximum timing for ablution was (01:45) 1 minute and 45 seconds, but the consumption was not maximum. The consumption for the maximum timing was 3.0L, slightly more than minimum consumption (2.5L) in the sixth masjid (see Table 6.1, Appendix B). This proves what was mentioned before in the case of the fifth masjid and fourth Jame, that maximum timing doesn’t necessarily mean a maximum consumption for normal taps or very old normal taps. Maximum consumption was 5.0L in (01:16) 1 minute and 16 seconds, using the continuous way of the opening tap. The maximum timing for the sixth masjid took place in less time, (01:30) 1 minute and 30 seconds, during which time the minimum consumption was of 2.5L. This proves the observation from earlier: that different ways of the users opening the taps played a significant role in the normal taps in the fourth Jame and fifth masjid, and as well as in the sixth masjid with very old normal taps.

The average timing for an ablution in the sixth masjid mosque was (01:11) 1 minute and 11 seconds, with average total water consumption by users on finishing their ablution being 3.3L with the average continuous way of opening the taps, as shown in Table 4.14. Maximum and minimum timings for an ablution, water consumption, and the way of opening the taps are also included in Table 4.14.

Table 4.14: Average results for timing, consumption, and ways of opening the taps the sixth (masjid) mosque

Sixth mosque (masjid)	Minutes	Litres for ablution	Way of opening the taps
Average	1:11:00s	3.3L	Continuous
Max.	0:54.29s	2.5L	Continuous
Min.	1:16.29s	0.5L	Continuous

Four readings for water consumption were taken in a fixed time of 00:47 seconds in the sixth masjid mosque using the very old normal taps, without any user but opening the tap numerous times with a different amount of water being let out within a fixed time limit (Table 6.1, Appendix B). The results varied from 2.5L to 4.2L and 5L per 00:47 seconds, with four different openings/shutting of the taps. In general, the observed pressure in all taps was the same in the sixth masjid as seen in the fourth Jame and fifth masjid.

In the mosque, there were two other appliances inside the toilet, a W/C flush toilet and the water tap, in the sixth masjid as well. Three different readings were taken of the timing of the flush. The W/C flush in the sixth masjid was around 00:04 seconds per flush, with 5L litres of water per flush, as it is mentioned in Table 6.3 (Appendix B).

The consumption from the tap in the toilet was measured by filling a jug to 1.4L max and 0.7L (half the jug). It took around 00:15 seconds to fill half the jug and around 00:30 seconds to reach the maximum limit of 1.4L (Table 6.4, Appendix B). The observed pressure while doing the measurements was comfortable for use.

4.6 Comparing average consumption of masjids

A comparison of the average results for timing, consumption and way of opening the taps in masjid 1 and 2 is shown in Table 4.15 and Figure 4.10. As mentioned before, the fifth mosque (masjid 1) had normal taps, while the sixth mosque (masjid 2) had very old normal taps. Both types of tap could be controlled by users in terms of the amount of water let out and the way of opening and closing. The average results for timing for masjid 1 were (1:05) 1 minute and 5seconds for 3.5L of water used via a continuous way of opening the tap.

In case of the average timing for masjid 2 (also with continuous opening of the taps), this was about (1:11) 1 minute and 11 seconds, but with lower consumption – an average of 3.3L. The difference between masjid 1 with normal taps and masjid 2 with very old normal taps was normal due to slightly different water pressure at the respective sites.

However, masjid 1, masjid 2 and the fourth Jame’s (which had the least consumption of all the Jame’s) are all under the same organizational management in Oman. The order of masjids from maximum to minimum in average consumption for **ablution** is: masjid 1 had a higher maximum consumption average for ablution than masjid 2; masjid 1 also had lower average timing for each ablution than in masjid 2.

Table 4.15: Comparing average results for timing, consumption and ways of opening taps for ablution in all masjids

Masjid code	Minutes	Litres for ablution	Way of opening
Average masjid 1	01:05.00s	3.5L	Continuous
Average masjid 2	01:11.00s	3.3L	Continuous

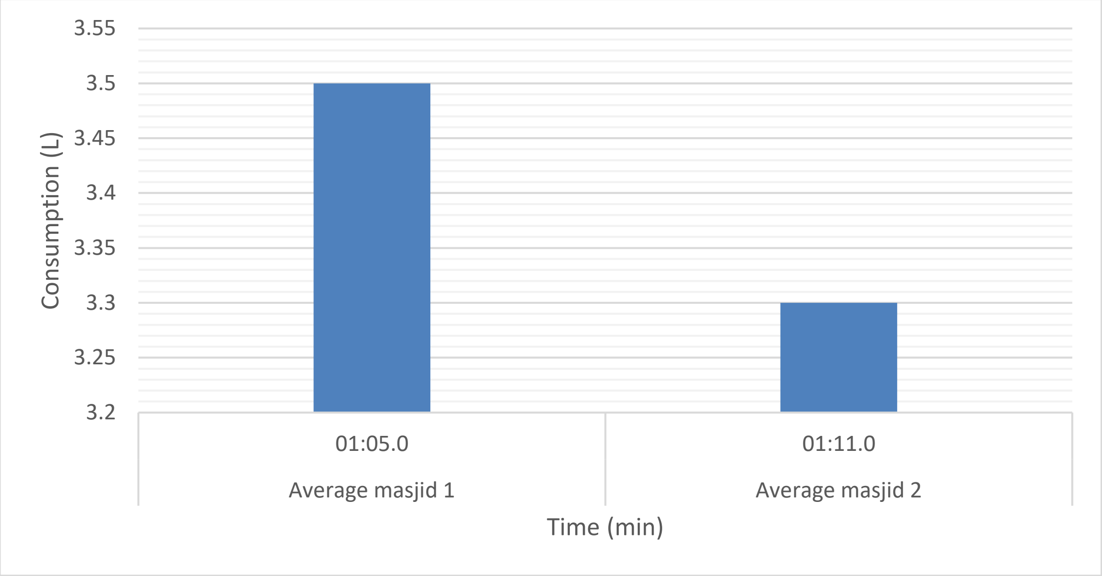

Figure 4.10: Comparing average results for timing and consumption for ablution in all masjids

4.6.1 Average total consumption in the first masjid

The average of total consumption per capita including ablution, the flush toilet, and the tap in the toilet in masjid 1 is illustrated in Table 4.16. The minimum total average consumption per capita was 7.2L in masjid 1 and the maximum average consumption was about 7.9L. The minimum and maximum values were measured depending on the consumption of users using of the toilet tap. So, if users used around 0.7L, this gave a minimum total consumption and if they used around 1.4L, this gave a maximum consumption. The total average consumption figures include one toilet flush per user as it is normally the users required going to toilet only one time before praying.

Table 4.16: Average total consumption per capita in masjid 1

Masjid 1	Ablution tap type	Ablution consumption	Flush toilet	Tap in toilet	Total Average
Average consumption per capita	Normal tap	3.5L	3L	0.7L min 1.4L max	Min 7.2L Max 7.9L

4.6.2 Average total consumption in second masjid

The average of total consumption per capita including ablution, the flush toilet, and the tap in the toilet in masjid 2 is illustrated in Table 4.17. The minimum total average consumption per capita was 9L in masjid 2 and maximum average consumption was around 9.7L. The minimum and the maximum values were measured depending on the consumption of users using the toilet tap, as above. As mentioned before, the total average consumption figures include one toilet flush per users as it is normally the users required going to toilet only one time before praying.

Table 4.17: Average total consumption per capita in masjid 2

Masjid 2	Ablution tap type	Ablution consumption	Flush toilet	Tap in toilet	Total
Average consumption per capita	Very old normal tap	3.3L	5L	0.7L min 1.4L max	Min 9L Max 9.7L

4.7 Comparing minimum and maximum total consumption per capita in masjids

The minimum total consumption per capita for the two masjids is illustrated in Table 4.18 and, as mentioned before, the minimum results come from using around 0.7L at the toilet tap. According to Table 4.15, masjid 1 had a higher maximum consumption average **for ablution** than masjid 2. However, when comparing this with the minimum total consumption per capita, including the flush toilet and tap in the toilet, masjid 2 had a higher total consumption per capita at 9L (see Table 4.18). The difference between the maximum and minimum water usage for ablution and per capita consumption was more because of higher flush toilet consumption in masjid 2 compared to masjid 1.

Table 4.18: Minimum total consumption per capita in two masjids

Masjid code	Masjid 1	Masjid 2
Total consumption per capita	7.2L	9L

Maximum total consumption per capita in the two masjids is illustrated in Table 4.19. As mentioned before, the maximum results come from using around 1.4L at the toilet tap. In terms of the order of masjids from maximum to minimum in average consumption for **ablution**, masjid 1 had a higher maximum consumption average than masjid 2. However, when comparing this with the maximum total consumption per capita, including the flush toilet and tap in the toilet, masjid 2 had a higher total consumption per capita at 9.7L compared to 7.9L for masjid 1 (see Table 4.19). That difference was because of the higher flush toilet consumption in masjid 2, which was 5L per flush, compared to masjid 1 at 3L per flush.

Table 4.19: Maximum total consumption per capita in two masjids

Masjid code	Masjid 1	Masjid 2
Total consumption per capita	7.9L	9.7L

4.8 Comparing total consumption in ablution in all the mosques (masjids and Jame's)

A comparison of the average results for timing, consumption and the number of pushes/touches and ways of opening the taps in the fourth Jame's (highlighted in blue) and in the two masjids (highlighted in green) is displayed in Table 4.20. As mentioned before, the Jame's have different types of taps like push taps, laser sensors and normal taps and are managed by two different organizations. There are two different government management organizations in Oman which are responsible for mosques: Jame 4 falls under a different organization compared to than Jame's 1, 2, and 3.

By comparison, the masjids had almost the same type of normal taps and came under the same government management organization – which is the same organization responsible for Jame 4; all three mosques featured the same type of tap.

It can be clearly seen that there are variations in the average water consumption for ablution in some of the mosques, like the average total consumption in Jame's 2 and 4 is nearly the same in Jame 3 and 4 and masjid 1 and 2. The highest average consumption in Jame 2 was 5.8L, then Jame 1 at 4.5L. Jame 3 and masjid 2 have the same average water consumption for ablution at 3.3L. Masjid 1 featured slightly greater consumption than masjid 2 at 3.5L. On the other hand, the least average total consumption was in Jame 4 with 2.7L.

It was observed that the variation in average water consumption for ablution as seen in Table 4.20 was affected by a mosque being under a different management organization. It is very clear that there is a difference in Jame's 1 and 2, which have the same management organization as Jame 4.

Jame 3 had least average of total consumption compared to Jame 1 and 2, although it was under same management organization. The reason for this was probably the different timings in the laser sensor taps and different water pressures between the mosques.

As observed before, although mosques may be under the same organization, they don't follow systematic procedures in terms of timings, water pressure, or water consumption from mosque to mosque.

Table 4.20: Comparing average results timing, consumption and number of push/touch or way of opening tap in ablution in all Jame's and Masjids

Jame's code	Minutes	Litres for ablution	Litres of water from last push/touch of a tap	Number of pushes/touches or way of opening
Average Jame 1	00:54s	4.04L	4.5L	3
Average Jame 2	1:03s	5.2L	5.8L	4
Average Jame 3	1:23s	3.1L	3.3L	-
Average Jame 4	0:54s	2.7L	Same 2.7L	Continuous
Average masjid 1	1:05s	3.5L		Continuous
Average masjid 2	1:11s	3.3L		Continuous

4.9 Comparing total consumption per capita in all the mosques (masjids and Jame's)

The average of total consumption per capita including ablution, the flush toilet, and tap in the toilet, in all the mosques is illustrated in Table 4.21. As can be seen, the effect of management organization on water consumption was evident. The effect was obvious in the total consumption per capita, then in the consumption during ablution only, as seen in Table 4.20. Jame's 1, 2 and 3 had the same organization (highlighted in blue) in Table 4.21. Jame 4 as well as masjids 1 and 2, had the same organization (highlighted in green) . Surprisingly, Jame 3, which had the least consumption for ablution among the Jame's (3.3L) was from same management organization. On average, for total water consumption per capita, Jame 3 had a maximum average total consumption per capita of 24L and a minimum value or 24.7L. This difference in order between the mosques was because of high WC toilet flush consumption per capita, which was 20L per flush for Jame 3, 3L per flush in masjid 1 and 5L per flush in masjid 2.

On the other hand, masjid 1 had a higher maximum consumption for ablution compared to masjid 2 and Jame 4 (both from same management organization), which was 3.5L (Table 4.20). In terms of the average of total water consumption per capita, masjid 1 had a minimum average total consumption per capita of 7.2L as a minimum value or 7.9L as a maximum value (Table 4.21). This difference in order between the mosques was because of the lower WC toilet flush consumption per capita: 3L per capita in masjid 1, and 5L in masjid 2 and Jame 4.

This difference proves what was mentioned before, that the mosques do not have any systematic procedures which are followed in terms of timing, water pressure, and consumption from mosque to mosque whether under different or the same organizational management. Jame 4 and masjids 1 and 2 all averaged total water consumption per capita of below 10L and ranging between 7.2L to 9.7L. By comparison, Jame's 1, 2 and 3 averaged total water consumption per capita all over 13L, ranging between 13.2L and 24.7L (Table 4.21) and (Figure 4.11).

Table 4.21: Average total consumption per capita in mosques

Mosques Code	Ablution tap type	Ablution consumption	Flush toilet	Tap in toilet	Total average
Jame 1	Push	4.5L	8L	0.7L min 1.4L max	Min 13.2L Max 13.9L
Jame 2	Laser sensor	5.8L	8L	0.7L min 1.4L max	Min 14.5L Max 15.2L
Jame 3	Laser sensor	3.3L	20L	0.7L min 1.4L max	Min 24L Max 24.7L
Jame 4	Normal	2.7L	5L	0.7L min 1.4L max	Min 8.4L Max 9.1L
Masjid 1		3.5L	3L	0.7L min	Min 7.2L

	Normal tap			1.4L max	Max 7.9L
Masjid 2	Very old normal tap	3.3L	5L	0.7L min 1.4L max	Min 9L Max 9.7L

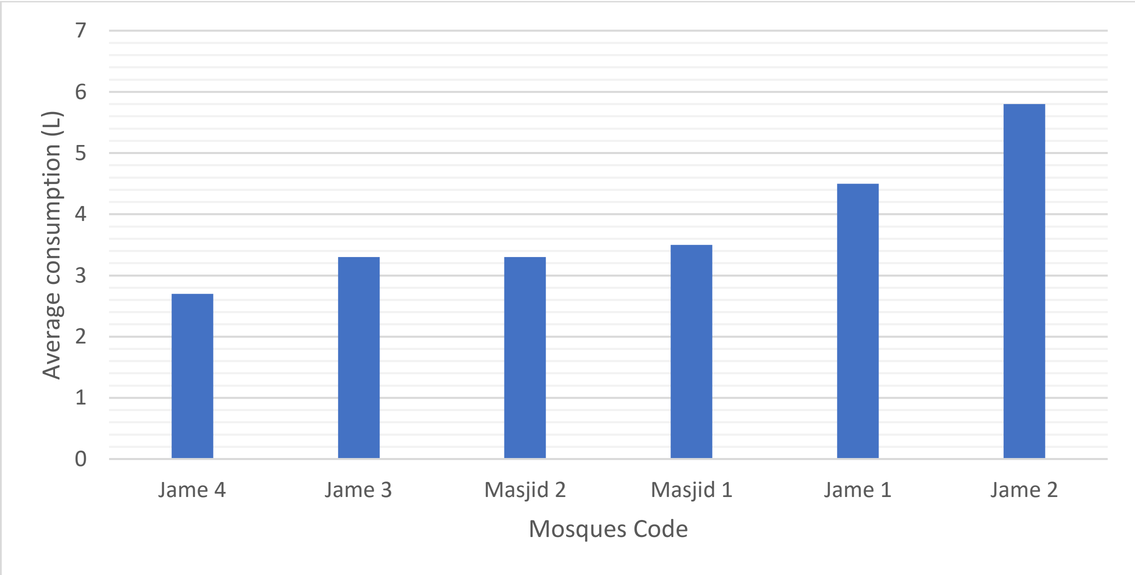

Figure 4.11: **Average total consumption for ablution for all mosques**

The total of average maximum water consumption per capita for all Jame's is illustrated in Table 4.22. This figure for Jame's 1, 2, 3 and 4 was 15.7L total per capita.

By comparison, the total of average consumption per capita for masjids 1 and 2 was 8.8L, as is clearly shown in Table 4.23.

In the section comparing between the total of average consumption in Jame's and masjids, it has been seen that there is an effect of the management organization on ablution water and total water consumption. That effect could be due to the management organization's choice of appliances, which in turn depends on budget.

Table 4.22: Total average maximum consumption per capita for all Jame's

Jame	Jame 1	Jame 2	Jame 3	Jame 4	Total average
	13.9L	15.2L	24.7L	9.1L	15.7L

Table 4.23: Total average maximum consumption per capita for masjids

Masjid	Masjid 1	Masjid 2	Total average
	7.9L	9.7L	8.8L

Average water consumption for **ablution** for groups 1 and 2 is illustrated in Tables 4.24 and 4.25. It can be clearly seen that in terms of savings, there was less consumption in group 2 (under management organization 2) than group 1 (under management organization 1) as shown in Figure 4.12. Average total consumption for ablution for group 1 was 4.5L, for Jame's 1, 2 and 3, as shown in Table 4.24. The average consumption for ablution for group 2 was 3.1L, for Jame 4 and masjids 1 and 2, as shown in Table 4.25. There was an average of 1.4L of extra consumption in group 1 with modern appliances compared to group 2 with normal appliances. This difference is twice the amount of water used by Prophet Mohamed to do his ablution.

Table 4.24: Average consumption in ablution for group 1

Group1			
Jame 1	Jame 2	Jame 3	Total average
4.5L	5.8L	3.3L	4.5L

Table 4.25: Average consumption in ablution for group 2

Group2			
Jame 4	Masjid 1	Masjid 2	Total average
2.7L	3.5L	3.3L	3.1L

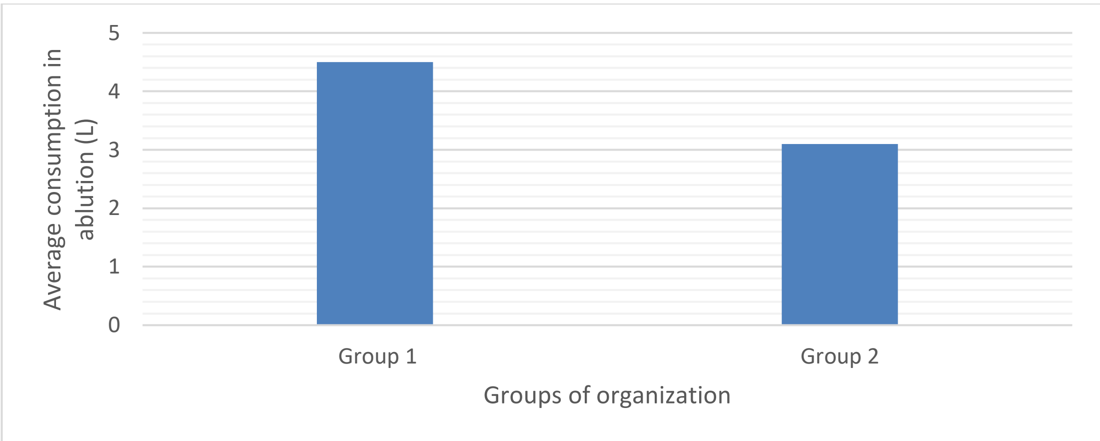

Figure 4.12: Compering average consumption in ablution for groups of organizations

The average total consumption **per capita,** including flushing toilets and taps in the toilet, along with ablution consumption, for groups 1 and 2, is illustrated in Tables 4.26 and 4.27. The difference in total average consumption between group 1 and 2 is more obvious now as is the effect of the management organizations in groups 1 and 2. Average total consumption per capita for group 1 was 18L for Jame's 1, 2 and 3, as shown in Table 4.26. Average total consumption per capita for group 2 was 9L for Jame 4 and masjids 1 and 2, as shown in Table 4.27. The difference between group 1 and 2 was exactly double in consumption. There was an average of 9L extra in group 1 using modern appliances in comparison to group 2 with normal appliances.

Table 4.26: Average maximum total consumption per capita for group 1

Group1			
Jame 1	Jame 2	Jame 3	Total average
13.9L	15.2L	24.7L	18L

Table 4.27: Average maximum total consumption per capita for group 2

Group2			
Jame 4	Masjid 1	Masjid 2	Total average
9.1L	7.9L	9.7L	9L

4.10 Possibility of recycling

In order to study the possibility of recycling, it was important to know total consumption in mosques per capita. Average total consumption per capita including ablution, flush toilet, and the taps in the toilet in all mosques is illustrated in Table 4.21 in section 4.9. This research will present the possibility of recycling greywater in the mosque for flushing the toilet and the possibility of irrigation.

4.10.1 Possibility of recycling ablution water for flushing toilets

Jame 3 has the least consumption for ablution between Jame's from same management organization (3.3L). And the average of total water consumption per capita in Jame 3 has a maximum average of total consumption per capita of 24L minimum or 24.7L maximum (Table 4.21). This difference in order between the mosques is because of high WC toilet flush consumption per capita (20L per flush in Jame 3, compared to 3L per flush in masjid 1 and 5L per flush in masjid 2). This difference, and the difference between flushing toilets in all the mosques in general, shows that they don't have systematic procedures for water consumption, pressure or timers. As observed on site, the different flushing amounts (3L, 5L or 20L) do the required amount of flushing. This means that both 3L and 5L are sufficient for flushing and cleaning.

In terms of the possibility of greywater recycling from mosques, ablution consumption only studied, as it is greywater, not total consumption which includes greywater from ablution and blackwater from the toilet tap and flushing toilet. The ablution water consumption column is highlighted with yellow in Table 4.21. Before checking the possibility of recycling of greywater (ablution water) in a mosque, taking the flushing toilet as an example for use of such water, it is important to fix the high consumption water during flushing of the toilet. In the current situation, without fixing the high consumption during flushing, the ablution water could cover and save more than half of water consumption for flushing. But fixing the unnecessarily high water consumption in some of the mosques for flushing the toilet would lead to water being saved and covered fully with greywater from ablution consumption.

Other than that, in all the situations the possibility of recycling of greywater (ablution water) for flushing toilets is high, even if the consumption for flushing toilets is done more than ablution consumption. That is because, from around 120 users in this study, only 30 users were observed visiting the toilet before carrying out ablution, since most of them were coming from home and ready to do ablution only.

Table 4.28: Total average of flushing toilet

Jame 1	Jame 2	Jame 3	Jame 4	Masjid 1	Masjid 2	Total average
8L	8L	20L	5L	3L	5L	5.8L

The total of average for flushing the toilet was 5.8L of water, excluding Jame 3 (red column), highlighted in Table 4.28. Ablution water consumption in all the mosques could cover more than half of the averages needed to flush the toilets.

4.10.2 Possibility of recycling ablution water for irrigation

Ablution water could be used fully for irrigation and to increase the green space in some Jame's and masjids which don't have any grass or trees to save water consumption. The strategy observed in many mosques in Oman is to exclude or to reduce the green space to save water and to reduce consumption of water. Excluding green space in mosques in a country which has very hot weather (where temperatures reach 49ºC) can affect the environment and increases the heat in mosques.

Through observation during the present study, the researcher found that there was green space in the big Jame’s under organization 1, but no or very few such spaces in Jame’s and masjids under organization 2, wherein all mosque from both organizations have a large amount of open land which can be covered and made into a green space. Recycling ablution water to be used for irrigation would help Jame’s in organization 1 to save water and would also help to add green space in Jame’s and masjids under organization 2. This study helps the management, mosque organizers, engineers, and planners to design green space of the correct area to be maintained with measured greywater from ablution consumption.

4.11 Measurement of ablution consumption in the household

The research plan at the beginning was to measure total water consumption for ablution and to check the most efficient appliances that could be used in mosques. When the fieldwork commenced, it was found that there were different types of taps and appliances in different mosques. This led to studying and measuring the amount of water consumption from different ablution taps and with different user behaviours. The previous consumption results for ablution from the six different mosques show the relationship between the type of tap and the total consumption for ablution with different behaviours. The relationship between taps and water consumption encouraged the inclusion of all types of taps in this research. The six mosques included all types of modern and normal taps, while the remaining type falls into the normal category that is present more in houses than in mosques (see Figure 4.13).

Figure 4.13: Modern household tap controlled by the user in opening and closing

The seventh set of measurements in this research was carried out in a household of five users. The measurement was taken from the most modern normal tap, which can be controlled by users by moving it up and down. The measurements result for ablution consumption can be seen in Table 7.1 (Appendix B). As mentioned before for the mosques' measurements, it was explained to the household members that there was no need to be ideal, but behaviour needed to be normal like at any other time. The observed effect took into account that the users would try to be ideal and use less water but not more; this would not affect the results of showing minimum consumption.

Total amount of water used varied from one user to another depending on the manner of opening the tap. In case of using a normal tap, as it done here, the measurement, timing and the flow of water was controlled by the behaviour of the users.

The maximum timing for ablution did not necessarily mean a maximum consumption because of this being a normal tap. As mentioned before, this differs for normal taps, as shown from the measurement results in Table 7.1 (Appendix B). The maximum timing was 1 minute and 45 seconds, with total water consumption to finish ablution being 1.2L, and using the continuous way of opening the tap. The water stopped running from the tap at the same time as the ablution was completed, with the same amount of water (1.2L) and the same timing.

Another user spent less time, around (01:07) 1 minute and 7 seconds, with total water consumption of 3.9L, and using the continuous way of the opening tap. This was because, as mentioned before, different behaviour patterns in terms of the extent and way of opening the tap play a major role (unlike with sensor laser or push tap appliances). The minimum timing was around 00:54 seconds to carry out a full ablution, with total water consumption of 2.5L and a continuous opening of the tap.

In general, the measurements from the modern normal tap were no different from the other normal taps and proved that the outcome was the same from normal taps in general.

4.12 Measuring ablution consumption using a pot

The different results between modern and normal taps for ablution encourages the inclusion of a measurement for ablution using a pot for the same five household users from the modern normal taps measurement – see Table 8.1 (Appendix B). The maximum limit of the pot was 1000ml (1L), as shown in Figure 4.14.

Figure 4.14: Measuring ablution consumption using pot of 1000ml max

Surprising results showed the measurement for ablution using a pot that the range was between 0.5L and max of 0.73L. This is the same amount of water consumption by Prophet Mohamed for carrying out ablution, which was about 0.6L.

The results, in general, show that development of taps has contributed to the increase in water consumption.

There follows a comparison between water consumption for ablution using a normal tap controlled by manual opening and closing and consumption by users using pot.

4.13 Comparing consumption of ablution in modern normal taps and by using pot

As mentioned before, the five users were the same individuals in the case of the measurements of using a pot and those from using a modern normal tap to check behaviour changes in a different way of ablution – see Table 4.30.

Table 4.29: Comparing water consumption in ablution with users in a house using a modern normal tap and a pot

Users codes in house measurement	Litres for ablution/modern normal tap	Litres for ablution/pot
1	1.6	0.5
2	2.5	0.7
3	3.9	0.73
4	1.2	0.6
5	2	0.65

Total litre amounts varied from one user to another, depending on the way of opening the tap. Surprisingly, however, even with maximum consumption for ablution which was 3.9L, this reduced to 0.73L without asking the user to save water, just by changing the manner of washing. Instead of using the tap, this was replaced by a pot for all users.

In terms of studying users' behaviour, derivation from these results confirmed that humans adapt themselves and their actions to what is available. Although the water in the pot was filled to a maximum limit at the beginning and they were asked to feel free to add more, no one even used a full pot of 1L.

4.14. Consumption summary

This part of data was collected to examine the appliances in different mosques. The purpose of examining the appliances was to find out whether they were efficient or not and whether they could save water or not.

The study found that the advanced devices like sensor and push taps controlled by timers and techniques used currently in Oman are consuming more water than regular water taps, which can be controlled while opening and closing by users. Nor do mosques in Oman have any systematic procedures that are followed in terms of timing, water pressure, or water flow from mosque to mosque under different or the same organizational management.

The results, in general, show that the development of taps has contributed to the increase in water consumption. A comparison was made between modern sensor taps and push taps controlled by a timer and normal taps, followed by further measurements of water consumption between normal taps controlled by manual opening and closing and users carrying out ablutions using a pot.

In this research, it has been found that the number of averages for ablution per capita depends on the devices in the mosque (Jame or masjid). This research shows that the important elements that affect water consumption for ablution in mosques and which cause high water consumption and bills are devices and techniques. This leads in proving that ablution per capita cannot be taken as one number or as an assumption, as it has been in all other studies. This research study is very clear in the methodology used. The research had the innovation of arranging for a consumption measurement instrument to be fixed to taps of mosques to measure more than 150 readings of consumption per capita in six different mosques in Oman.

In terms of studying users' behaviour, derivation from these results confirmed that humans adapt themselves and their actions to what is available.

Chapter 5 : Presentation and Analysis of Data from Interviews

5.1 Introduction

This chapter is dedicated to analysing of the data gathered from interviews with policymakers, mosque management and engineers. It also includes group interviews with users. There were three different sets of interview questions prepared for this research study: one set for policymakers and mosque management, one set for engineers, and the last set was for the group interviews with users.

Presenting data and the analysis was done by following the main research questions and sub-research questions, starting with research question no.1 then 2 and 3. All the interview questions from the different sets were asked to answer research question 1 and this will to be analysed first. In this manner, the sub-research question order of 1.1 then 1.2 and 1.3 follow on from research question 1. The same pattern is followed to analyse and present the data for research questions 2 and 3.

5.2 Research question 1 - data analysis

The main research question no.1 in this thesis is:

'What is water consumption in mosques, policies, regulation, saving practices, appliances, techniques applied in mosques and water?'

The main research question no.1 is further divided into three sub-research questions.

5.2.1 Sub-research question 1.1 – data analysis

Starting with sub-question no.1.1 of the main research question, which is:

'What are the water-saving policies and regulations which can be applied in mosques to achieve efficient usage of water?'

Sub-question 1.1 was answered by policymakers in the interview. Questions 2, 7 and 11 were answered by 16 policymakers and mosque management from three different organizations and different management organizations, who were responsible for mosques and water supply in Oman. The details are presented in Table 5.1.

Table 5.1: Analysing research question 1.1 of main research question 1

Research question no. 1	What is water consumption in mosques, policies, regulation, saving practices, appliances, techniques applied in mosques and water?
Sub-research question 1.1	What are the water-saving policies and regulations which can be applied in mosques to achieve efficient usage of water?
Targeted interviewees	Policymakers
Organizations & number of policymakers interviewed	Organization responsible of masjids and Jame's (4 interviews)
	The organization responsible for supplying water in Oman (6 interviews)
	Organization responsible for Royal mosques (Jame's) (3 interviews)
	Mosque management (3 interviews)

Interview question no.2 was asked to the same number of policymakers (16 policymakers) and mosques management to find out current policies and measurements in Oman. The question was:

'What are the policies on water demand management, measures, and techniques in Oman?'

This meant in terms of plumbing, in appliances, in recycling (greywater) for irrigation and flushing toilets, in reusing (greywater) for irrigation and flushing toilets, as shown in Table 1.1 (Appendix C).

All 16 policymakers from the organization which is responsible of masjids and Jame's, the organization responsible for supplying water in Oman, the organization responsible for Royal mosques (Jame's) and mosque management responded that there were no policies for saving water from plumbing or recycling of greywater, as summarized in Table 1.2 (Appendix C).

In continuing to answer sub-question 1.1, the policymakers and mosque management were asked: ‘What, according to them would be the most effective water demand management policies?’

Their suggestions were recorded in question number 7 to the policymakers and management interviews (Table 1.3, Appendix C).

One of the policymakers from the organization responsible for masjids and Jame’s suggested that there was a need for a database to make such laws or policies. And the database needed to be on the usage of water and on the number of the people using water in mosques. Another policymaker suggested establishing policies for appliances to be used in the mosques. And one from the same organization mentioned putting a limit on the amount of water to be used in mosques. One of the interviewees suggested that the water bill should be paid by the users (worshipers).

A policymaker from the water organization mentioned enforcing the use of sensor taps in the mosques to save water. One suggestion from the same organization was establishing policies on water-saving tools. Another suggestion was to use efficient appliances like sensor taps, and some even suggested to strictly follow the new method of using greywater. One suggestion was for the water bill to be paid by the users, while stressing on the importance of working in effective cost-saving for water.

The policymakers from the organization responsible for Royal mosques (Jame’s) mentioned the importance of working on policies towards recycling greywater and one of the policymakers from the same organization suggested putting policies in place for appliances. The last one refused to give any answer.

One of the mosque managements personnel suggested to supply a limited amount of water, depending on the needs of the users and the number of users present in the mosque, and also to be made responsible for mosque management. A couple of mosque management personnel answered that rules should be implemented for users to save water. All the answers from the different organization and policymakers are recorded in Table 1.4 (Appendix C).

Overall, the responses from the various policymakers and different organization's management can be summarized as follows:

- six answers were about policies for appliances,
- two were about rules to be implemented in general,
- two regarded restrictions to be imposed on usage of water,
- two suggested water bills to be paid by the users,
- one mentioned to work on policies for recycling,
- one on recycling water,
- one of them mentioned the need for a database before starting work on any policies or rules, and
- one suggested the importance of working for the effective cost-saving of water.

One of the interviewees refused to give any answers, even after explaining the questions for them. While trying to understand why he didn't want to give an answer, the researcher came to know later that this was because of sensitivity of the position and the place where he worked.

Some refused for the interview to be recorded by a tape, with some of them accepting the researcher taking notes provided their name was not mentioned, and the information would be used for research purposes only.

The final part of answering sub-question 1.1 was in question number 11: 'What are the policies and standards of recycling greywater, not blackwater?'

The policymakers and mosque management interview questions can be found in Table 1.5 (Appendix C).

Four of the policymakers from the organization responsible for masjids and Jame's had the same answer for this question and mentioned that there were no policies or standards for recycling greywater.

The same question had been asked to the policymakers from the organization responsible for supplying water in Oman. Two of the policymakers mentioned that there were no standards and policies for recycling greywater and four of them said that they were unaware of any standard or policy for greywater.

The policymakers in the organization that was responsible for the Royal mosques (Jame's) had the same answers as that of the policymakers of the organization responsible for masjids: that there were no standards or policies for treating greywater in Oman. Mosque management from the mosques mentioned also had the same answer.

All the answers from the different organizations and policymakers are presented in Table 1.6 (Appendix C).

In general, all responses from the different policymakers and organizations were that there were no policies or standards for greywater in Oman, although some respondents said they didn't know. The answers show that there is no awareness in Oman towards recycling of greywater as yet. This is because greywater pipes in Oman are not separated from blackwater pipes.

5.2.2 Research question 1.2 – data analysis

Continuing with the second part of the main research question no.1: 'What is water consumption in mosques, policies, regulation, saving practices, appliances, techniques applied in mosques and water?'

The second part of the sub-research question 1.2 of the main research question is: 'What are the water practices and appliances applied in mosques?'

As mentioned in Table 5.2, sub-research question 1.2 was answered during the interview question session with policymakers, mosque management and engineers. The interview questions nos. 3 and 5 were asked to 16 policymakers and mosque management from three different organizations and different mosques management, as well as those responsible for mosques and water in Oman. The engineers interviews (conducted with 25 engineers) answered question nos. 1, 3 and 4. The details are given in Table 5.2. The selection criteria of the engineers were based on their experience (see section 3.5.2.2)

Table 5.2: Analysing research question 1.2 of the main research question 1

Research question no. 1	What is water consumption in mosques, policies, regulation, saving practices, appliances, techniques applied in mosques and water?
Sub-research question 1.2	What are the water practices and appliances which are applicable in mosques?
Targeted	Policymakers, mosque management, and engineers
Collected data	Observation, photos, videos, and interviews
Organizations & Number of policymakers, mosque management and Engineers interviewees	The organization responsible for masjids and Jame's (4 interviews with policymakers, 3 with engineers)
	The organization responsible for supplying water in Oman. (6 interviews, 2 engineers)
	Organization responsible of Royal mosques (Jame's) (3 interviews with policymakers, 4 with engineers)
	Mosque managements (3 interviews)
	The government company responsible for treating water (4 interviews with engineers)
	International company working in water piping design (2 interviews with engineers 2)
	University College, Engineering Department (10 interviews with engineers)

Interview question no.3 was asked to a total number of 16 policymakers and mosques management to find out the current policies and measurements in Oman. The question was: 'What are the current tools, appliances, and techniques applied in mosques?'

This meant in terms of specification of the appliances (taps, WCs, irrigation systems) and techniques applied in mosques, as shown in Table 1.7 (Appendix C).

Policymakers from the organization responsible for masjids and Jame's responded as follows:

- PE1 mentioned that there were no specifications, but in terms of appliances they answered to use a good-quality one.
- PE2 mentioned that there was no fixed specification which they were forced to use, but always suggested sensor taps which allowed the flow of water when the user put their hand near and stopped once it was removed.
- PE3 mentioned that there was no specific system for what was to be used in mosques and he didn't think that there was a relation between what they chose and saving water, as the choice was always related to the brand and the expense.
- PE4 also mentioned that there was no specification and they always looked for a brand which would last for a long time.

Policymakers from the organization responsible for supplying water in Oman responded as follows:

- (PW1) mentioned that there were no specifications, but they usually advised customers and building owners to put in sensor taps.
- PW2 also mentioned that no specifications or techniques were followed.
- PW3, PW4, and PW6 answered that there were no specifications or techniques right now.
- On the other hand, PW5 mentioned that there were no specifications but there were new taps which worked by sensors but with a low speed of flow, and that these are applied in some mosques.

Policymakers from the organization responsible of Royal mosques (Jame's) responded as follows:

- PR1, PR2, and PR3 mentioned sensor and push taps as the preferred specification and techniques.

- PR1 also mentioned the technique of using a small tank for WCs or a direct-flush valve in Royal mosques Jame’s.

Mosque managements M1 and M2 answered that there were no specifications and in general, normal taps were being used. M3 mentioned that there was no specification, but that sensor and push taps were used. See all responses in Table 1.8 (Appendix C).

From interviews with policymakers of the different organizations, it was understood that the majority of small mosques which fell under the responsibility of the organization (PE) were masjids and Jame’s. Not all mosques are constructed by the government, but by society which donates to build them. Hence there are no specific requirements from the government; it undertakes only the major planning of the mosque, but not the other details. So, the donors building the mosque use products which match their budget, because it’s not about the government. Likewise, in terms of saving water, the donors who are building the mosque for society are also responsible for choosing the appliances. Yet then paying the water bills is the responsibility of the government organization, which did not choose the appliances or the techniques.

In continuing to answer sub-question 1.2, the policymakers and mosque managements were asked: ‘Do you have any information or test results of total water consumption for landscape irrigation and for WC toilet flushing?’

This is question number 5 for policymakers and management interviews, as mentioned in Table 1.9 (Appendix C).

All the four policymakers from the organization responsible for masjids and Jame’s and the sixth policymaker from water organization gave similar answers, i.e. that there was no information or test results for total water consumption for landscape irrigation or for WC toilet flushing.

Nonetheless, policymakers from the organization responsible for Royal mosques (Jame’s) and mosque management did have some approximate figures and information:

- PR1 mentioned that treated effluent water (STP) was used for irrigation in some of the mosques, but there was no exact figure for consumption.

- PR2 answered that WC flushing consumed between 7L to 10L per flush approximately.
- A different approximation of 3L per flush came from PR3.

Information from mosque management related to each specific mosque management team, so:

- M1 from the specific mosque said that each WC flush consumed 5L.
- M2 from another mosque said 8L per flush.
- M3 answered 3L per flush.

All the answers from the different organizations and different policymakers and management are summarized in Table 1.10.

The answers to question no. 5 from policymakers and mosque management interviews proves what has been discussed before. The outcome of the previous part of question no. 3 was answers of no information from ten policymakers from two different organizations, i.e. the organization responsible for masjids and Jame's and the organization responsible for supplying water in Oman. As mentioned before, the reason for this is that there are two sides to the building and running of mosques: the donor who builds the mosque on behalf of society and the government organization that is then responsible for management and paying the bills.

Yet the situation was different in case of the organization responsible for Royal mosques (Jame's). All the policymakers had some approximate figures, because in this case it is one organization that is responsible for constructing and management of the Royal mosque; they are responsible for both choosing the appliances and paying the bills. Although that they don't have any specific rules or policies, there is greater clarity.

Continuing to the interviews with engineers for the second part of sub-research question 1.2 – see Table 5.2. Sub-research question 1.2 was answered through interviews question nos. 1, 3 and 4 asked to 25 engineers from six different organizations. The engineers were from two different specializations, civil and mechanical engineering. The details are listed in Table 5.3.

Table 5.3: Total number of engineers interviewed from different organizations and different specializations

Organizations	Civil engineers	Mechanical engineers	Total number of interviews
Organization responsible for masjids and Jame's	3	-	3
Organization responsible for supplying water in Oman	2	-	2
Organization responsible for Royal mosques (Jame's)	3	1	4
The government company responsible for treating water	4	-	4
International company working in water piping design	2	-	2
University College, Engineering Department	5	5	10
Total	19	6	25

In answering sub-question 1.2, the engineers were asked: 'What are the current water-saving practices applied by the Government of Oman?'

This question appears in Table 1.11 (Appendix C).

Table 1.12 (Appendix C) provides the interviewees' answers to question no.1 of the engineers' interviews from different organizations. The engineers from the organization responsible of masjids and Jame's answered "*Self-close tap and awareness through media*" (EE1, EE2, and EE3).

The same question was asked to two engineers from the organization responsible for supplying water in Oman. Both answered, "*To create awareness through public gatherings and schools*".

On the other hand, the policymakers from the organization responsible for the Royal mosques (Jame's) answered as follows:

- to store stormwater in dams (ER1),
- not giving attention to saving water (ER2),
- sensor taps (ER4 and ER5, who is a mechanical engineer), and
- sensor taps and two bottoms of flush in WC (ER4).

The government company responsible for treating water had the same answers as the three engineers EH1, EH2 and EH3, i.e. "*Treating wastewater and reusing",* while "*Leak detection system",* was the answer given by EH4.

The international company for designing water piping's responses were, "*Treated effluent networks"* (EP1) and "*No idea"* (EP2).

The same interview questions were asked to ten academics - civil and mechanical engineers from the University College, Engineering |Department. The civil engineers' answers were:

- to advise users through the media and public (EU1),
- no saving practices or very limited (EU2 and EU5), and
- no idea if there is saving water practices currently in Oman, treating wastewater and reusing (EU4).

The mechanical engineers answers were:

- wastewater treated and reusing by (EU6 and EU9),
- no idea if there are saving water practices currently in Oman (EU7),
- water cost scheme and reusing wastewater (EU8), and
- sensor taps – automated water taps (EU10).

It can be clearly seen that most of the responses from the interviewees depended on the experience in the organization. For example, the response of most engineers from the government company responsible for treating water were, "*treating wastewater* *and reusing"*. "*Treat effluent networks"* was the answer from international company for designing water piping, and which was concerned with networks. The academic point of view was that '*there is no or very small limit on saving water practices"* in terms of research.

Engineering interviews formed part of the answer to sub-question 1.2. The engineers were asked: 'Do you have any information or test results of total water consumption for landscape irrigation and for WC toilet flushing?'

Question number 3 of the engineers' interviews appears in Table 1.13 (Appendix C).

Table 1.14 (Appendix C) illustrates the interviewees' answers to question no.3, as follows:

The Engineers from different organizations had no information or test results for total water consumption for landscape irrigation or for WC toilet flushing.

EH4 from the government company responsible for treating water mentioned the same answer as others, but said there is an international standard 10 L/m^2 for irrigation.

EU4 provided a general information about flushing for older toilets, which can use 3.5, 5, or even up to 7 gallons of water with every flush. But the American Water Works Association, Federal Plumbing Standards now specify that new toilets can only use up to 1.6 gallons per flush (GPF), and there are high-efficiency toilets that use up to 1.28 GPF.

That the engineers all gave the same answers, in terms of there being no information or test results, indicates the importance of this research in Oman as the first part of water management in general.

The Engineers were also asked: 'What is the current tool, appliances, techniques, and policies applied in mosques?' This was question number 4 of the engineers interviews, as mentioned in Table 1.15 (Appendix C).

Table 1.16 (Appendix C) illustrates the interviewees' answers to question no.4. The engineers from the organization that is responsible of masjids and Jame's and the organization responsible for supplying water in Oman, answered as follows:

- normal tap,

- flush tank, and
- no policy applied in mosques.

On the other hand, the policymakers in the organization responsible for Royal mosques (Jame's) answered:

- sensor and push taps,
- flush valve and double flush, and
- no policy applied in mosques.

Other answers were the same. This was because they were experts, but were international engineers in the organization for designing the mosques and were not Muslims.

The answers from the government company responsible for treating water and others were as follows:

The two female engineers (EH1 and EH2) had no clear idea. As mentioned before, the mosques were mainly male dominated, so the women didn't want to give a general answer given the limited number of times they went to the mosque. The same answer was given by the two engineers from the international company for designing water piping: both had no idea (EP1 is female and EP2 is not a Muslim).

The same interview question was asked to ten academics, civil and mechanical engineers from University College, Engineering Department. The basis for selecting the ten university engineers who completed the questionnaires was to gain a research perspective. Five of the academics were civil engineers and five were mechanical engineers. Their answers varied between normal and sensor taps and between double and normal flush WCs. In terms of policy, all of them had the same answer, that there was no policy.

5.2.3 Research question 1.3 – data analysis

Table 5.4: Analysing research question 1.3 of the main research question 1

Research question no. 1	What is water consumption in mosques, policies, regulation, saving practices, appliances, techniques applied in mosques and water?
Sub-research question 1.2	What is the estimated water consumption for ablution and toilet flushing per capita?
Targeted	Policymakers, mosque management, and engineers
Collected data	Observation, photos, Videos, measurement of total consumption per capita and interviews
Organizations & number of policymakers, mosque Management and engineering interviewees	The organization which is responsible for masjids and Jame's (4 interviews with policymakers, 3 with engineers)
	The organization which is responsible for supplying water in Oman (6 interviews, 2 with engineers)
	Organization which is responsible of Royal mosques (Jame's) (3 interviews with policymakers, 4 with engineers)
	Mosque management (3 interviews)
	The government company responsible for treating water (Interviews with 4 engineers)
	International company for designing water piping (Interviews with 2 engineers)
	University College, Engineering Department (Interviews with 10 engineers)

The third sub-research question 1.3 of the main research question is: 'What is the estimated water consumption for ablution and toilet flushing per capita?

Sub-research question 1.3 was answered by interview questions with policymakers and mosque management and engineers. The policymakers and mosque management interview questions no. 4 and 7 were asked to 16 policymakers and mosque management from three different organizations and different management organizations who were responsible for mosques and water in Oman. The engineers interview questions no. 2 was asked to 25 engineers (see Table 5.4).

Interview question no.4 for policymakers and mosque management was asked to a total number of 16 policymakers and mosque management staff, to find out if there were any test results on total water consumption for ablution per capita.

The question asked was: ‘Do you have any information or test results on total water consumption for ablution per capita?’ (See Table 1.17, Appendix C).

All 16 policymakers from the organization responsible of masjids and Jame’s, the the one responsible for supplying water in Oman, the organization responsible for Royal mosques (Jame’s) and mosque managements of all the mosques in Oman responded that there was no information or test results on total water consumption for ablution per capita, as summarized in Table 1.18 (Appendix C).

A few did estimate information. PR1 from the organization responsible for Royal mosques (Jame’s) mentioned that they had information on total water consumption in ablution and toilet, which was 250L/day, this taken from a master plan used for planning. Other approximate information from PR2 was that it is equal to 15 to 20 litres per ablution per capita per day approximately.

Both information proved that the piping system for grey and blackwater in Oman was not separated but mixed into one pipe. As a result, they do have some figures for the total black and greywater amount or consumption, but not for greywater or ablution water by itself. It was understood from the interviews that it was very difficult to know the consumption of greywater or ablution water only, without the blackwater.

Sub-question 1.3 which was asked to policymakers and mosque management was: ‘What effective water demand management policies can they think of?’

Suggestions were taken in response to question number 7 of the policymakers and management interview. Answers to question number 7 were analysed previously in sub-question 1.2 of research question 1.

Interviews were continued with the engineers for the third part of sub-research question 1.3, as mentioned in Table 5.4. Sub-research question 1.3 has been answered by interview questions no. 2 with 25 engineers from six different organizations.

To inform sub-question 1.2, the engineers were asked: ‘What are the current water-saving practices applied by the government of Oman?’

Question number 2 of the engineers’ interviews is mentioned in Table 1.19 (Appendix C).

Question number 4, in an interview with policymakers and mosques management was asked and during the engineer interview in question number 2. Table 1.20 (Appendix C) illustrates the interviewees’ answers of question no.2, which was: ‘Do you have any information or test results on total water consumption for ablution per capita?’

During the engineers’ interviews from different organizations, the respondents had no information or test results on total water consumption for ablution per capita. EH1 and EH2 from the government company responsible for treating water mentioned 245L/ capita, since the details were from a company master plan estimation.

The same answers were given by a majority of policymakers, mosque management and engineers, that there was no information or test results on total water consumption for ablution per capita.

All the respondents indicated the importance of this research in Oman as the first part of water management. The approximate figures which were given by some organizations were also in the same range – around 245L to 250L. But ablution and water for toilet flushing means black and greywater, as put into the master plan of the government company responsible for treating water. It was also observed from the interview with engineers and policymakers, when answering the same question, the five from the organization mentioned that it was the responsibility of the organization in charge of supplying water in Oman to have an answer to this question. Yet the organization responsible for supplying water in Oman said that they were just a supplier company and not accountable; rather, the responsibility lay with the company which treated water.

5.3 Research question 2 – data analysis

The main research question no.2 in this thesis is: ‘What are the effective water demand management policies, measures, and techniques that are compatible with the needs of water consumers in mosques?’

Research question no.2 is divided into two sub-research questions, 2.1 and 2.2.

5.3.1 Sub-research question 2.1 – data analysis

Starting with sub-question no. 2.1: 'What are consumers' needs and behaviours while performing ablution in mosques?'

This sub-question was answered by a focus groups interview question nos. 6, 7, 11, 12, 13, 14, 15 and 16, with three groups of users of water in the mosques and policymakers. Interview question no. 1 was with 16 policymakers and mosque management from three different organizations and different mosques managements who were responsible for mosques and water in Oman. Interview question no. 4 was with 25 engineers, the details of which are given in Table 5.5.

The data are also explained in other sections, with data taken from observation, photos, videos, measurement of total consumption per capita and interviews; again, the details are given in Table 5.5.

Table 5.5: Analysing research question 2.1 of main research question 2

Research question no. 2	What are the effective water demand management policies, measures, and techniques that are compatible with the needs of water consumers in mosques?
Sub-research question 2.1	What are consumers' needs and behaviours while performing ablution in mosques?
Targeted	Users, policymakers, mosque management and engineers
Collected data	Focus group interviews, observation, photos, videos, measurement of total consumption per capita and interviews
Organizations & number of policymakers, mosque Management and engineers' interviewees	(3 focus groups with users)
	The organization responsible for masjids and Jame's (4 interviews with policymakers, 3 with engineers)
	Organization responsible for supplying water in Oman. (6 interviews, 2 with engineers)
	Organization responsible for Royal mosques (Jame's) (3 interviews with policymakers, 4 with engineers)
	Mosque management (3 interviews)

	The government company responsible for treating water (4 interviews with engineers)
	International company for designing water piping (2 interviews with engineers)
	University College, Engineering Department (10 interviews with engineers)

Question no.6 was put to the groups of water users in the mosques; there were 18 users split into three groups. The question asked was: ‘What is consumers water needs while performing ablution in mosques?’ See Table 1.21 (Appendix C).

Table 1.22 (Appendix C) illustrates the answers from the groups interviews to question no.6. Each of the three groups consisted of four males and two females from different mosques in Oman. The users from the three groups were asked about their needs when performing ablution in mosques. The participants gave their responses to multiple-response questions; some answered by a show of hands and some started answering after the question was raised. The researcher made sure that everyone answered the question and was able to express their independent views, providing them with note paper to record any further opinions (if there were any) while others were talking (see section 3.5.2.2).

Focus group number 1’s response was that they just needed sufficient clean water in the mosque.

Focus group number 2 also mentioned the needs for sufficient clean water in the mosque, adding the importance of the type of valve, continuous water for washing legs with less pressure.

Focus group number 3’s response was the same as those from group numbers 1 and 2 in terms of needs of sufficient clean water, but added the importance of suitable pressure and type of valve. Group number 3 also mentioned that they needed less time than that provided by the sensor taps and push taps, which are controlled by a timer. They said to reduce the water flow, since it was difficult to perform the ablution using high-pressure taps and with a high flow of water.

As can be seen in Table 1.22 (Appendix C), the response from group number 1, which was from users in the masjid, was just the need to provide clean and sufficient quantity of water. By comparison, groups number 2 and 3, which were from Jame’s, came with suggestions and requirements to reduce water pressure and amount of water provided.

This was because of the normal taps in the masjids, which can be controlled by users in terms of pressure and timing. With groups number 2 and 3 from Jame’s, the sensor and push taps are controlled automatically. According to the answers of users when asked about their needs when performing ablution in mosques, it was understood that the users were getting more water at a greater pressure than that needed. Hence, they requested a reduced service and to reduce energy and water. This indicated that the users were aware of the level of water wastage in the mosque.

Question no.7 was asked to the 18 users of water in the mosques (split into three groups) to understand the consumers’ water behaviour when performing ablution – see Table 1.23 (Appendix C).

Table 1.24 (Appendix C) provides the answers of the users from the group interviews to question no.7. The users from the three groups were asked: ‘What are consumers’ water behaviours when making ablution in mosques?’

- Group number 1’s response was – Opening the water tap even before they were ready for ablution, taking a long time to do ablution, some of them not understanding what ablution was and not closing the water tap while doing ablution.

- Group number 2 also mentioned – Wasting a lot of water, different ages and different thinking patterns, opening the tap three times more than what was needed, that people didn’t understand what ablution was, and they were not doing ablution in the manner Prophet Mohamad did.

- Group number 3’s responses were similar to group numbers 1 and 2 – Wasting a lot of water, opening water and doing something else, that behaviour depended on the users of water, no care for the water bill and some kids who thought sensor taps were for playing.

The users' answers proved that there was a lot of water wastage in the mosques from consumers' water behaviour while performing ablution, specifically in mosques and the reasons are mentioned in Table 1.24 (Appendix C).

Question no.11 to the groups of users of water in the mosques were asked to 18 users (divided into three focus groups), to understand how they would describe themselves regarding water usage – see Table 1.25 (Appendix C).

Table 1.26 (Appendix C) illustrates the answers to question no.11. The users from the three groups were asked: 'How would you describe yourself regarding water use? Example?'

- Group number 1's response was – Depending on the mosque appliances, normal and not wasting water; at home very normal, not wasting water, but in public places like in mosques, it depended on the appliances.

- Group numbers 2 and 3 also mentioned – Normal and medium level of water, depending on the mosque appliances and pressure.

The users' answers in describing themselves regarding water use were mostly normal and using water at a medium level, mentioning that there was not a lot of water wastage in the mosques by themselves during ablution, unless this could not be controlled because of the appliances and pressure – as mentioned in Table 1.24 (Appendix C).

It can be clearly seen that the users' response in question 6, towards other behaviours in the mosque, proved that there was a lot of water wastage. On the other hand, the answers were totally different when they were asked about their own behaviours in carrying out ablution.

Question no.12 to users of water in the mosques were asked to 18 users (split into three groups) to find out more about users' behaviour – see Table 1.27 (Appendix C).

Table 1.28 (Appendix C) provides users' responses to different statements:

- The first statement was if it was difficult to reduce the amount of water used in the mosque. All three groups disagreed with the statement and mentioned that it was not difficult and to start with appliances and water pressure.

- The second statement was if they had ever thought about the amount of water that they used in mosques. All users in group no.1 disagreed, whereas group nos. 2 and 3 gave mixed answers, with some agreeing while the others disagreed.

- The third statement was if they thought people used more water than they needed to do ablution (wudu) in the mosque. All three groups agreed with the statement.

- The fourth statement was if they would try to save on the water bill by using water outside the home – for example, by showering at work or at the gym, or taking the car to a car-wash or doing ablution in mosques. All three groups disagreed with the statement.

- The fifth statement was if they were satisfied with the facilities they received from mosques. Groups 1 and 2 agreed and group 3 mentioned that it depended on the mosque and facilities provided.

Question no.13 to the groups of users of water in the mosques (18 users, split into three groups) sought to find out more about users' behaviour – see Table 1.29 (Appendix C).

Table 1.30 (Appendix C) provides users' responses to different statements:

- The first statement was if they kept closing and opening the tap during ablution. Groups 1 and 2 answered that sometimes they did, whereas group 3 said that they didn't shut the tap while performing ablution.

- The second statement was if they limited the amount of time spent in ablution. All three groups' answers were negative.

- The third statement was if they left the toilet unflushed. All three groups' answers were negative.

- The fourth statement was if they closed the tap after use. All the three groups' answers were affirmative.

Question no.14 to users (18 users, split into three groups) also sought to understand some more about users' behaviour – Table 1.31 (Appendix C).

All the users from all three groups had the same answers for the different statements – see Table 1.32 (Appendix C).

Their answers were affirmative for the first statement of whether others opened the tap continuously without turning it off and on during ablution; and were again affirmative for the second statement that others did not limit the amount of time spent for their ablution. The answer was ‘sometimes’ from all three groups to the third and fourth statements about leaving the toilet unflushed and leaving the tap open.

It can be clearly seen that the users’ responses are totally different when they were talking about others (question 14) and when they were talking about themselves (question 13). This was in the same way as when they were responding to question 6 about others and question 7 about themselves.

Question no.15 was also asked to the groups: ‘Think about how you use water during ablution, would you say that you use more or less water in comparison to when you were younger? Why?’

The users of water in the mosques were asked this question to gain a better understanding of their intentions – see Table 1.35 (Appendix C). All three groups gave the same answer, that they used considerably more water when they were younger. Justifying that they were less aware of the importance of water and less matured by the importance of conserving natural resources.

Question no.16 was asked to the groups to understand more about the users’ thoughts – see Table 1.33 (Appendix C).

Table 1.34 (Appendix C) illustrates users’ response to the different statements.

- The first statement was if the people of Oman were not interested enough in saving water. Groups 2 and 3 agreed with the statement, mentioning that there were very simple things that the government and users could do to save water, but they didn’t. By comparison, group no.1 disagreed with the statement, mentioning that the government would be happy to adopt any studies for this purpose and that they were trying to save water by putting sensor taps and more such taps which are controlled by a timer.

- The second statement was if the government needed to implement water restrictions for water management in mosques. All users in group 1 disagreed, whereas group no.2 agreed completely and group 3 gave mixed responses.

- All the three groups agreed with the third, fourth, sixth and seventh statements – that is, if it was important to protect the natural environment, that using less water was good for the environment, there was wastage of water in mosques, and that the water companies should work more in water recycling in mosques.

- For the fifth statement of whether they lived in an area that was likely to face a drought, group no.1 agreed while the other two groups gave mixed responses.

In the policymakers and mosque management interview, participants were asked to answer sub-question 2.1. The policymakers and mosque management from different organizations were asked: 'What are the current **water-saving practices**, rules and policies applied by the Government of Oman?'

Question number 1 to policymakers and mosque management interviews is shown in Table 1.36 (Appendix C). Table 1.37 (Appendix C) illustrates the interviewees' answers this question.

The policymakers and mosque management from the organization responsible for masjids and Jame's answered question no.1 as follows:

- PE1 said that very few mosques which belonged to the Royal mosques saved water compared to the other around 16,400 mosques in Oman.

- PE2 and PE3 answered that there were no savings, rules or policies applied by the Government of Oman.

The same question was asked to six policymakers from water supply organizations in Oman. All policymakers and mosque management answers were that the tariff structure was different (every 3,000 gallons has a different tariff).

By comparison, all the policymakers in the organization responsible for Royal mosques (Jame's) answered saying sensor and push taps were used; and mentioned that there were no rules or policies by the Government of Oman for water saving.

Mosque management from three different mosques gave similar answers, that there were no savings, rules or policies.

It can be clearly seen – as mentioned before in answers to the same question, but put to the engineers (question no.1 in section 1.2) – that most of the responses from the interviewees depended on the experience in their organization.

5.3.2 Sub-research question 2.2 – data analysis

Table 5.6: Analysing research question 2.2 of the main research question 2

Research question no. 2	What are effective water demand management policies, measures, and techniques that are compatible with the needs of water consumers in mosques?
Sub-research question 2.2	What are effective water demand management policies and measures and techniques and what saving tools and appliances are available on the market?
Targeted	Users, policymakers, mosque management, and engineers
Collected data	Focus group interviews, observation, photos, videos, measurement of total consumption per capita and interviews
Organizations & number of policymakers, mosque Management and engineering interviewees	(3 focus group interviews with users)
	The organization responsible for masjids and Jame's (4 interviews with policymakers, 3 with engineers)
	The organization responsible for supplying water in Oman (6 interviews, 2 with engineers)
	Organization responsible for Royal mosques (Jame's) (3 interviews with policymakers, 4 with engineers)
	Mosque management (3 interviews)
	The government company responsible for treating water (4 interviews with engineers)
	International company for designing water piping. (2 interviews with engineers)
	University College, Engineering department (10 interviews with engineers)

The main research question no.2 in this thesis is: ‘What are effective water demand management policies, measures, and techniques that are compatible with the needs of water consumers in mosques?’

The second sub-research question is: ‘What are effective water demand management policies and measures and techniques and what are saving tools and appliances are available on the market?’

The sub-question was answered for interview questions no. 5 and 8 with 25 engineers. Policymakers during the interview answered question nos. 6 and 7 with 16 policymakers and mosque management from three different organizations and different mosques management and those responsible of mosques and water in Oman. Focus group interviews answered questions no. 8 and 9 with three groups of water users in the mosques – see Table 5.6.

Another way that the data are explained in other sections was by using observation, photos, videos, and measurement of total water consumption per capita.

In the engineer interviews to answer sub-question 2.2, the engineers where asked question no. 5: ‘What are the appropriate water-saving tools, appliances, techniques and policies?’ – see Table 1.38 (Appendix C).

Table 1.39 (Appendix C) illustrates the interviewees’ answers to question no.5 from the engineers’ interviews from different organizations. The engineers from the organization responsible for masjids and Jame’s, the organization responsible for supplying water in Oman, and the majority of the University College, Engineering Department answered the same, that it was a sensor tap.

On the other hand, the policymakers from the organization responsible for Royal mosques (Jame’s) answered saying that they had no idea. For most of them, sensor taps were already existing in most of Royal Jame’s – so they didn’t have any appropriate ideas for water-saving tools or appliances other than sensor or push taps.

Half of the personnel from the government company responsible for treating water answered that this question was not applicable to them, as they were not looking to save water. They also said that this was not a company target and that profits increase with increases in the water sales (increasing sales means increasing profits). So, the answers to the question were for the benefit of the company.

The sorry part of the story is that selling of water at a much lower price than the manufacturing cost means selling at a loss, but because water treatment companies have government support that covers the loss, they consider it profits. This might benefit the company, but not the country.

In the engineers' interviews to answer sub-question 2.2, the engineers were asked question no.8 ('How do you think wasted water can be invested by the government?') – see Table 1.40 (Appendix C).

Table 1.41 (Appendix C) provides the interviewees' answers to this question.

The engineers from different organizations answered irrigation, recycling, and using the latest technology, while some of them suggested separating the pipes for greywater from blackwater in Oman. These answers indicated that most of them agreed with the idea of recycling water.

In the policymakers and mosque management interviews to answer sub-question 2.2, they were asked question no.6 ('What are effective water demand management techniques, tools, and behaviours that are compatible with the needs of water consumers in mosques?') – see Table 1.42 (Appendix C).

Table 1.43 (Appendix C) provides the interviewees' answers to this question.

The policymakers from the organization responsible for masjids and Jame's and the organization responsible for Royal mosques (Jame's) mentioned that the users needed to realize the importance of water first and that could be done by educating and raising awareness. They also mentioned the importance of the new technology of sensor and push taps, water tap aerators and reducing water pressure. A majority of policymakers in the organization responsible for supplying water in Oman answered similarly to the engineers to question 5, that this question was not related to their organization.

Surprisingly, mosque management answered to question no.6 that normal taps with less pressure could be effective.

The groups of users of water in the mosques (18 users split into three groups) were asked question no.8 ('How to achieve efficient use of water?') in order to better understand these people – see Table 1.44 (Appendix C).

Table 1.45 (Appendix C) provides the group interview answers to question no.8.

The users from the three groups responded as follows:

- Group number 1's responses were limited suggesting using water in a bottle for ablution, sensor taps with screens and recycling.
- Group number 2 also mentioned that awareness of water conservation was important. The awareness should be towards the amount of water used for ablution, the manner and time needed, and opening the tap only partially while using.
- Group number 3's response was to use a normal tap, recycling and education.

Question no.9 was also asked to a group of users, this time to investigate effective water demand management policies – see Table 1.46 (Appendix C).

Table 1.47 (Appendix C) provides the group interview answers to question no.9.

The users from three groups were asked: 'Do you think there are roles that could be played with users of water in the mosque to increase the chance of water demand management in mosques? What are those roles?'.

All three groups had the same view, that it would be difficult to have roles to be played with users to save water. They suggested working in controlling the amount of water and pressure or by limiting the amount of water to be used, but not roles and policies.

5.4 Research question 3 – data analysis

The main research question no.3 in this thesis is: 'How to investigate the acceptability of reusing water in mosques?'

The first sub-research question, as mentioned in Table 5.7, is: 'Is the water quality of ablution water suitable for reuse in toilet flushing and/or landscape irrigation? If so, what type of treatment is required?'

5.4.1 Sub-research question 3.1 – data analysis

Sub-question 3.1 has been answered by engineers' interviews question no. 14 and engineers' interview questions no. 2 and 11. There are also 16 policymakers and mosque management staff who have already been analysed in sub-question 1.1 from three different organizations and different mosques management, those responsible of mosques and water in Oman – see details in Table 5.7.

The data are also explained in other sections, with data taken from observation, photos, videos, measurement of total consumption per capita.

Table 5.7: Analysing research question 3.1 of the main research question 3

Research question no. 3	How to investigate the acceptability of reusing water in mosques?
Sub-research question 3.1	Is the water quality of ablution water suitable for reuse in toilet flushing and/or landscape irrigation? If so, what type of treatment is required?
Targeted	Policymakers, mosque management, and engineers
Collected data	Interviews with engineers and policymakers
Organizations & number of policymakers Engineering interviewees	The organization responsible for masjids and Jame's (4 interviews with policymakers, 3 with engineers)
	The organization responsible for supplying water in Oman (6 interviews, 2 with engineers)
	The organization responsible for Royal mosques (Jame's) (3 interviews with policymakers, 4 with engineers)
	Mosque management (3 interviews)
	The government company responsible for treating water (4 interviews with engineers)
	International company for designing water piping (2 interviews with engineers)
	University College, Engineering Department (10 interviews with engineers)

The engineers' interviews answer sub-question 3.1. The engineers were asked question no.14 ('If there is need to treat recycled greywater from ablution water in mosques, what is a suitable treatment?') – see Table 1.48 (Appendix C).

Table 1.49 (Appendix C) provides the interviewees' answers to question no.14. The engineers from the organization responsible for masjids and Jame's, the organization responsible for the Royal mosques (Jame's) and those from the international company for designing water piping answered the same. They said they had no idea if there was a need to treat recycled greywater from ablution water in the mosque, and they also had no idea of what a suitable treatment would be.

On the other hand, the engineers from the government company responsible for treating water answered saying that the type of treatment depended upon the quality needed. They all agree that a simple treatment only would be needed.

University College, Engineering Department also answered that only a simple treatment would be needed, with sand filtration as primary treatment. One of the engineers mentioned that recycling greywater from ablution water in the mosque was not recommended for religious reasons. This point will be investigated in the following sections to provide clarity on the subject.

5.4.2 Research question 3.2 – data analysis

Table 5.8: Analysing research question 3.2 of main research question 3

Research question no. 3	How to investigate acceptability of reusing water in mosques?
Sub-research question 3.2	Is water reuse or recycling acceptable to mosque users and relevant policymakers?
Targeted	Users, policymakers, mosque management and engineers
Collected data	Interviews with engineers and policymakers and focus groups with users
Organizations & number of policymakers Engineering interviewees	The organization responsible for masjids and Jame's (4 interviews with policymakers, 3 with engineers)
	The organization responsible for supplying water in Oman (6 interviews, 2 with engineers)
	The organization responsible for Royal mosques (Jame's) (3 interviews with policymakers, 4 with engineers)
	Mosque management (3 interviews)
	The government company responsible for treating water (4 interviews with engineers)

	International company for designing water piping (2 interviews with engineers)
	University College, Engineering Department 10 interviews with engineers)
	Focus groups with users

The main research question no.3 for this thesis is: 'How to investigate acceptability of reusing water in mosques?'

The second sub-research question of main research question no.3 is, as mentioned in Table 5.8: 'Is water reuse or recycling acceptable to mosque users and relevant policymakers?'

This sub-question has been answered by engineers' interviews questions nos. 9, 10, 11, 12, 15, 16, 17 and 18.

The 25 engineers' interview questions nos. 8, 9, 10, 15, 16, 17, 18, 19 and 20 in interviews with 16 policymakers and mosques management. The interviews were conducted with three different organizations and different mosques management which were responsible for mosques and water in Oman – see Table 5.8.

Another way of data collection was with three focus groups with users of water in mosques.

To answer sub-question 3.2, the engineers were asked questions number 9, 10, 11, 12, 15, 16, 17 and 18 – see Table 1.50 (Appendix C). Table 1.51 (Appendix C) illustrates the interviewees' answers to these questions. There were 18 engineers who were interviewed from different organizations.

The engineers from the organization responsible for masjids and Jame's, the organization responsible for Royal mosques (Jame's), the international company for designing water piping and those from University College, Engineering Department answered question no. 9: 'What is your opinion on the idea of recycling (treated water) greywater in mosques for flushing toilets and landscape irrigation?'

The answers were the same from most of them. They agreed to the idea of recycling (treated water) greywater in mosques for flushing toilet and landscape irrigation. This was with the exception of two mechanical engineers from the University College who did not agree with using recycled water for flushing toilets for religious reasons.

The study decided to conduct more investigation into this issue; this was done and the analysed results can be found in the last part of this chapter.

The 25 engineers were asked question no. 10: ‘What is your opinion on the idea of reusing (not treated) greywater in mosques for flushing toilets and landscape irrigation? Why?’

This question is similar to question no.9, if the ablution water could be reused without treating, for flushing toilets and landscape irrigation. The answers varied from those who accepted the idea to those who did not accept it due to religious reasons.

Question no. 11 is: ‘What is your opinion in using treated greywater that is compatible to the standard of drinking water; For drinking? Why? For washing cars. Why? And For ablution? Why?’

The answers varied from those who accepted the idea and those who did not accept the idea and those who mentioned the need for a ‘Fatwa‘, which means needing an answer from those who understood the religion well enough to decide if it was accepted in Islam or not. Surprisingly, 12 engineers out of 25 accepted that the recycled water was good, even for drinking.

Mentioning the need for a ‘Fatwa‘ is evidence that the subject was unclear to the majority of the engineers, and they were not aware of the religious opinions. This gap will be covered later in this research area.

Question no. 12 is: ‘What is your opinion in separating the pipes and drainage of greywater from blackwater? Why?’

All of the engineers agreed to the idea and mentioned the importance of separating the pipes and drainage of greywater from blackwater, especially in new constructions.

The engineers were then asked for their thoughts on questions nos. 15, 16, 17, and 18.

- Question 15 – ‘Do you think reusing (without treating) or recycling (with treating) ablution water in mosques for flushing toilets and landscape irrigation will reduce water demand in the mosque? Why?’

- Question 16 – ‘Do you think reusing or recycling ablution water in mosques for flushing toilet and landscape irrigation would be financially beneficial? How?’

- Question 17 – ‘Do you think reusing or recycling ablution water in mosques for flushing toilets and landscape irrigation will lead to environmental degradation? How?’

- Question 18 – ‘Do you think reusing or recycling ablution water in mosques for flushing toilets and landscape irrigation would be harmful to humans? Why?’

The answers were ‘**yes’** from most of the engineers to question nos. 15 and 16 and ‘**no’** from most of the engineers to question nos. 17 and 18.

Engineer interviews to answer sub-question 3.2 for the main research question number 3. The engineers where asked question numbers 8, 9, 10, 15, 16, 17, 18, 19 and 20 from the policymakers and mosque management interviews, as mentioned in Table 1.52 (Appendix C).

Table 1.53 (Appendix C) provides interviewee answers to these questions from the policymakers and mosques management interview from different organizations. The engineers from the organization responsible for masjids and Jame’s, the organization responsible of Royal mosques (Jame’s), the organization responsible for supplying water in Oman and mosques management answered question numbers 8, 9,10 ,15 and 16, as follows:

- Question. 8 – ‘What is your opinion on the idea of recycling (treated water) greywater in mosques for flushing toilet and landscape?’

All of them agreed with the idea of recycling (treated water) greywater in mosques for flushing toilets and landscape irrigation.

- Question. 9 – ‘What is your opinion on the idea of reusing (not treated) greywater in mosques for flushing toilets and landscape irrigation? Why?’

This was the same as for question no. 8 but the ablution water was to be reused without treating for flushing toilets and landscapes. The answers varied between those who accepted the idea to those who did not accept the idea for religious reasons.

- Question. 10 – 'What is your opinion on using treated greywater that is compatible to the standard of drinking water; For drinking? Why? For washing cars. Why? And For ablution? Why?' and Question. 15 – 'Do you accept the idea of unlimited use of treated greywater? Why?'

The answers varied between those who accepted the idea to those who did not accept the idea and those who mentioned the need for a 'Fatwa' (to see if it was accepted in Islam or not). Surprisingly, four policymakers out of 18 accepted that the recycled water was good even for drinking, and three answers were a '**yes'** to accept unlimited use of treated greywater because it is treated and ensured no harm for drinking.

- Question. 16 – 'What is your opinion on separating the pipes and drainage of greywater from blackwater? Why?'

All of them agreed to the idea and mentioned the importance of separating the pipes and drainage of greywater from blackwater. One of the respondents thought this should be only in recent mosques or new constructions.

The policymakers and mosques management where also asked for their thoughts on questions 17, 18, 19 and 20.

- Question 17 – 'Do you think reusing (without treating) or recycling (with treating) ablution water in mosques for flushing toilets and landscape irrigation will reduce water demand in mosques? Why?'

- Question 18 – 'Do you think reusing or recycling ablution water in mosques for flushing toilets and landscape irrigation would be financially beneficial? How?'

- Question 19 – 'Do you think reusing or recycling ablution water in mosques for flushing toilets and landscape irrigation will lead to environmental degradation? How?'

- Question 20 – Do you think reusing or recycling ablution water in mosques for flushing toilets and landscape irrigation would be harmful to humans? Why?’

The answers were a ‘**yes’** from all of the policymakers and mosque management for question nos. 17 and 18 and ‘**no’** from all of the policymakers and mosque management for question nos. 19 and 20.

It is clear that there is similarity in thoughts and opinions of policymakers and mosques management and the engineers, given that they gave the same answers to the same questions. But the answers also show that there is a lack of knowledge from people on religious opinions about recycling in general. Only two out of 41 mentioned that recycled water was not accepted for ablution. Others mentioned either their own opinions by accepting or not accepting or by saying there was a need for a ‘Fatwa‘ on this, proving that there is a lack of knowledge.

Question nos. 10, 17 and 18 were put to users of water in the mosques (18 users, split into three groups) to understand consumers’ opinions regarding recycling in mosques and in general – see Table 1.54 (Appendix C).

Table 1.55 (Appendix C) provides answers from these focus groups to questions 10, 17 and 18.

The users from three groups were asked their opinions regarding recycling in mosques and in general. The questions and answers were as follows:

- Question 10 – ‘Do you accept reusing (same water without treatment) or recycling (doing some treatment) ablution water in mosques for flushing toilets and irrigation?’

The answer was an affirmative from groups 1 and 2. However, five of the users from group no.1 and six from group no.2 agreed to recycling with treatment, mentioning the need for only a simple treatment for water reused for flushing toilets and irrigation. One of those from group no.1 said ‘**yes’** with the conditions if it was approved and did not affect people. Four participants from group no.3 answered with a ‘**yes’** for flushing toilets and irrigation and two of them mentioned irrigation only.

Group nos. 1, 2 and 3 had the same answers to questions no. 17 and 18. All the three focus groups answered ‘**no’** to question 17 (‘Do you accept the idea of unlimited use of treated greywater? Why?’). This was because they didn’t want to accept it for drinking or human use for psychological reasons. Their answer was a ‘**yes’** for question no. 18 **(‘**Do you support the idea of separating greywater from blackwater? Why?’), mentioning that it would help with treating water easily.

From the focus group answers it was understood that the recycling process was acceptable for users and no one refused to use recycled water categorically without a reason. They did not want to accept recycled water for drinking or for human use for psychological reasons, but no one from the groups mentioned religious reasons.

5.5 Religious opinion in recycling water in mosques

Accreditation and standing most questions in the opinion of religion made the researcher decide to carry out an interview with the **Assistant to the Grand Mufti of Sultanate of Oman** to obtain clear responses on matters such as the water recycling ‘Fatwa‘ and other things would help fill knowledge gap in this area for the present study. The Assistant to the Grand Mufti has a D.Phil. from the University of Oxford in Islamic studies and his permission for any disclosure of identification was approved. His religious opinion on the recycling water in mosques ‘Fatwa‘ is explained by the Mufti in Box 5.1.

Box 5.1: Religious opinion in recycling water in mosque ‘Fatwa’

The religious opinion on the recycling water in mosques ‘Fatwa’ is that the used water can be recycled, and can be reused for agricultural uses and for all different uses ***except for religious uses*** *such as ablution and washing up. This is not because the water is recycled, there is another reason that it cannot be used for ablution. Although they do add water in the process of purifying, and they do add materials and originally also most of this used water is not mainly water and that’s it. So, it is used water and used water cannot be used for ablution ‘wudu‘ according to the correct opinion. There is disagreement between scholars, but there are authentic narrations where it was found Prophet Muhammed ρ: ”* ***نهى عن الوضوء من فضل الماء*** *”* ***prevented the use of used water (فضل الماء):*** *it is the remaining of water. So, although it was originally pure water, once it is used for ablution then it cannot be reused for ablution ‘wudu‘. However, it can be used for other purposes. And that is* *why we urge society and we hope that it is known to be a culture at the individual level as well as the societal level, first of all, to be wise in using the water, and second not to worsen the use of this water, but to really use it, to recycle it.*

So, there are two main points that were understood and recommended from the interview with the Mufti:

- To be moderate in using water, right from the first instance, not to exaggerate, not to overuse water, and have been quote it to the Prophetic Sunna on using water for ablution.
- To recycle the wastewater from ablution, for other purposes such as the domestic use of water.

The Mufti was asked if there was a standard for greywater not blackwater, the ablution water. The researcher knew there to be a standard for blackwater to be treated for irrigation, for standard aims. But if this is now greywater, ablution water, was there any standard?

The Mufti said:

> *"We haven't issued a standard. We have examined the way by which this water now is recycled in Hayah, and we have approved the way because it's a three phases methodology or mechanism used, and we can see no evidence to prevent using Islamic to stop using or reusing this water. Except, I mean the reason why not to use it in 'wudu' or غسل because it's used water, and there is evidence, a different set of evidence, that prevents using فضل الماء which is the remaining water."*

5.6 Process and purpose of ablution

The first question to the Mufti was: 'What is the process and purpose for making ablution for prayer in different Mazhab' (glossary)? And 'Is there any reference?' The Mufti explained the purpose and process of ablution as detailed in Boxes 5.2 and 5.3.

5.6.1 Process of ablution

Process of ablution: the physical way of performing ablution was explained by the Mufti as in Box 5.2.

Box 5.2: Physical way of performing ablution as explained by the Mufti

"The first thing: is to mention the name of Allah, and this is a must-do. *And then if a person was asleep as an example, to rinse one's hand. And this is not part of the ablution. Before commencing the ablution,* *person male or female is highly recommended to rinse the hands.* *And then as I said: chanting the name of Allah.* *And then rinsing one's mouth, and nose, three times for each, and some scholars, and here that there is, this is a place of disagreement. Some scholars say that it's three times, but mouth and nose should be done together. And this is not the way by which masses of Muslims perform the ablution, so it's considered the sound opinion, respected opinion, but it's not applied by the masses of Muslims. So, the way by which Muslims are making their ablution is three times for the mouth rinsing the mouth, and for the nose three times as well.* *And then washing one's face three times again.* *And then washing one's hand three times, the right hand first and then the left hand.* *And then as I said one being over one's head, including the ears.* *And then washing the feet, and here again a minor issue of difference between Muslim scholars, where there it's must do washing one's feet, and because this is what's mentioned in the holy Qur'an. Or is it allowed, is it permissible to wrap over one's shoes? So, some scholar says washing the foot is must do, other say it's better, but there is no harm on wrapping over one's shoes."*

The Mufti continued, saying:

> *"the set-up order as received from the way Prophet Muhammed has taught his companions and Muslims later. Then this is the way we do it. Here comes the question: why it's in that order? Why this is the process in the ablution? And the answer is: this is how we are taught to do it, so there is no rational, there is no purpose, there is no hundred percent answer for this. It's exactly as we perform the prayer itself, the Sala (صلاة)itself differently. So 'Al-fajr' as an*

example we perform it in two Rakaa' (ركعة), 'Al-Zuhr' in four Rakaa', 'Al-Asr' in four Rakaa', 'Al-Maghreb' three Rakaa'. This is how it was revealed, and this is how we received it, and this is how we were taught to perform it. But if we are to search for some wisdom, for some purposes behind it, then a part of it is a general tendency in Islam for purification, and not only the physical purification but also the spiritual purification."

5.6.2 Purpose of ablution

Performing ritual ablution is one of the acts of the worship that's irrational. The Mufti's explanation and answer for the purpose of ablution is explained in Box 5.3.

Box 5.3: Purpose of ablution been explained with Mufti

'Irrational' – this is a technical term used when it comes to acts of worship in Islam, that it's purely spiritual. So, we do not know for sure and for certainty what is the wisdom and what is the purpose behind that act in that way.

One of these is ablution, it exactly as, and this is true and applicable for all spiritual acts of worship, unlike financial transactions, as an example. The purpose, as well as the wisdom, are very clear, and this is also true when it comes to social conducts family affairs. Then in many occasions, we do find that there is a purpose and there is a wisdom and are mentioned in the textual evidence from the Qur'an itself or in the Prophetic Sunna.

But when it comes to what we call as pure acts of worship like the prayer, the performance of Haj, the fasting in the month of Ramadan, then in these cases it's solely spiritual. So, we perform it as we have received it through revelations either in the Qur'an or Prophetic traditions.

So, for the purpose of ablution, the pure purpose isn't clear, it's irrational. We do understand that it's part of the purification, the physical purification, and the spiritual purification. But then comes the question: why it is in this way? Why it's done in this order? And we all know that the process itself, now this part is about the process, which is adapted by the majority, if not all Muslims from different schools of thought.

5.7 Total time for ablution in Islam

The Mufti was also asked: ‘Do you know approximately how many minutes it takes for doing ablution?’ His answer follows in Box 5.4.

Box 5.4: Mufti’s answer on the total time for ablution in Islam

“It depends, there is no, and this is very important to realize, there is no determination in Islam. There isn’t any evidence in the Qur’an, in the Prophetic Sunna that determines for how long one should spend in making the ablution. But when it comes to the amount of water to be used in ablution then, yes. There is a set of evidence that is urged Muslims, not to overuse water. So, in general, because it’s an active worship and it’s an active worship by itself, and it’s must-do condition for performing another active worship, which is obligatory active worship, which is the praying (Sala), then in this case it should not consume a lot of time, it has to be put into its framework. And it should not as I said, it can be active worship by itself, but it’s also a means for performing another obligatory active worship. And because of that and through examining the practices of Prophet Muhammed ρ and his sayings as well, so his doings and his sayings we can conclude comfortably that it should not consume much time, as a general tendency. Prophet Muhammed ρ has warned against drawing doubts. When a person is about to commence. When a person is starting the ablution, then they might have some doubts, whispers, that we haven’t mentioned the name of Allah, we are not adherent to the number required, three times, and they will restart and restart over and over again. This is known as (وسوسة), whispers, and Prophet Muhammed ρ has warned against surrendering to such whispers. And his advice was not to look at these, not to give any attention to these whispers and these doubts. To go ahead with the ablution.”

5.7.1 The amount of water that Prophet Muhammed ρ used for ablution

The Mufti’s answer on what amount of water Prophet Muhammed ρ used for ablution was as follows:

> *“The Prophet Muhammed ρ has recommended the three times and that was his pattern, may think that this is an exaggeration in using and this is the overuse of water. But this is not true; because the amount of water that Prophet*

*Muhammed ρ used is 'Mod' (مُد), and the (مُد) it's the filling of two hands of a mature moderate man. If this measurement is transferred into modern standards, then many scholars say that it's not more than 600 to 650 ml., this is the amount that Prophet Muhammed ρ had used. Now one might say: was it because of a lack of water? That Prophet Muhammed ρ in Makkah or in Al-Madinah, we know that droughts and a problem of water at this time as it is now? No, it's not; because that was his example, that was his pattern, that was his tradition, whenever they have water or whenever they don't have water. Indeed, there are other narrations that even this amount Prophet Muhammed ρ hasn't reached, because some narrations say that it's one-third of a (مُد), other narrations said that it's two-thirds of a (مُد). So, they said that there isn't one tradition, but the point is not to exceed, not to exaggerate, not to overuse water, and there is a narration although some Hadith scholars draw doubts about its authenticity, yet it's acceptable. It's accepted by jurist Muslims, jurists they do accept this narration in which Prophet Muhammed ρ so a companion who was making ablution at a river, and he urged him not to overuse water, and he said to him: «**Do not overuse water, even if you are by a passing river**».*"

5.8 Islamic measurements

'Gosol' (غسل) is known as the overall washing (a general a full wash), the amount the Prophet Muhammed ρ used in '(غسل)Gosol'. And the 'Saa' (صاع): is four times more than the 'Mod' (مُد). So, if the (مُد) is 600 ml of water, then we can imagine a general full wash is four times more than this: four multiplied by 600 ml. Obviously when this is compared to what Muslims are using nowadays, it is very minimal.

So, there is a great emphasis given to the amount of water to be used in ablution, not to overuse, not to exceed the limits, not to cross the borders, and to be always moderate and to minimize the amount of water as far as possible.

5.9 Technical concepts in Islam

There are two concepts from a technical point of view:

'Tahir'طاهر: which is that the water is pure by itself

'Mutahir' مُطهّر: which has the potential to purify others

Recycling ablution water is not مطهّر although it is طاهر, but not because it has been contaminated; rather it is because it has been used. There is a Prophetic authenticity and sound Prophetic tradition in which Prophet Muhammedρ said that Muslims **cannot reuse the water for ablution**.

The Mufti was asked, if with reusing water without treatment, not recycled with treatment, is it acceptable to reuse the water from ablution to flush toilets and for landscape irrigation?. He answered:

> *"No harm. It can be used without treatment. Unless of course, we have to consider other elements in Islamic ruling that if it can, it may affect the wellbeing of the individuals or the environment then this is a different issue, because these elements are also under consideration in Islam, so it's going to be governed, it's to be looked at through a different angle. But by itself, if it's not going to cause any harm for individuals or for life or harm for the environment, then there is no harm, and no one can claim not to use them. It's just used water, so it has not been polluted by impure stuff, and that's the point. If the water is polluted by impure stuff 'Najasa' (نجاسة) then it's a different issue, otherwise, if it's not, then it's 'طاهرTahir' ' it's pure."*

It is important to differentiate between two things: Clean and Pure.

> *"Now I have insisted in using the word 'pure', now doesn't mean because water or any other material, liquid material, may not be clean yet it's pure, because the stuff that contaminated the liquid or the water is originally clean stuff, pure stuff. But if it's polluted by impure stuff it's going to be unclean and impure. Now, this water is like using right away, directly, the wasted water from ablution, might not be clean but it's still pure. And therefore, I said we need to examine other elements, where it does any harm, it causes any harm to individuals, to the environment in general, because there is great recognition for not causing any harm to the environment or to individuals."*

The Mufti was also asked, **'What's your opinion in using treated water that's compatible to the standard of drinking water for drinking, and why?'** He replied:

"Now as far as Islamic rulings are concerned there is no harm. But only for hygienic reasons. So, if it may cause any harm and this harm is proven by expertise then again, it's not because of the treated water, it's because the process or the material contained, the ingredients contained there. Otherwise as far as it is concerned, so there are two angles here, and it's applicable for water or any other stuff: By itself, it is something that is allowed or not, then, in this case, it's allowed. Now the other angle: does it cause any harm, any damage? And this is based on the consequences of using it. So, action or something might be prevented Islamically, not because by itself it's not allowed but because of the consequences. So here it's going to be mainly related to hygienic issues. Otherwise in terms of purity, yes."

And on being asked about the use of treated water **for washing a car, he said, of course, yes.** But when the Mufti was asked about the use of treated water **for ablution,** he said **for ablution no**, and again he emphasized the reason: "**it's not because it has been treated, it's because it has been used".**

5.10 Other measurements in Islam

The Mufti did mention other measurements in Islam that Prophet Muhammed ρ used occasionally to for general washing غسل with his beloved wife Aisha السيدة عائشة at the same time. Here there is the narration that the amount they used was 'Farq' الفرق, الفرق. 'Mod' المد – the water that would fill two hands of a mature man – has already been discussed. And then comes 'Saa' صاع – four times 'Mod' المد. Then there is 'Farq' الفرق; there is minor disagreement on determining this amount, but the majority of scholars say that this is three times 'Saa' ثلاثة أصوع, so three times the amount of 'Saa' صاع.

For two persons again this shows and proves the tendency in Islam not to overuse water, but minimize the amount to its minimum level. Yet for ablution or 'wudu', that reused water cannot be used according to this narration, the sound narration of Prophet Muhammed.

Finally, it was explained to the Mufti that the majority of people didn't know if the recycled water could be used or not, as discovered when the researcher was carrying out interviews with them.

The Mufti answered:

> *"I said it on different occasions live on TV, in a live Fatwa programme known as سؤال أهل الذكر, I think the last time was during the last Ramadan. And it seemed that it was received by some people as something weird, and that's why they re-raised the question the other day. And I, of course, confirmed my answer, and I support the answer with different evidence. So now back to the question, yes, this can be, I mean for better results particularly socially talking, otherwise if it's going to waste our resources while it will add to nothing, no value to the recycled water then again, we have to look after our resources. So, if there are any good consequences, good results out of this separation between black and grey, then why not? Otherwise, we shouldn't waste also the resources."*

5.11 Interviews summary

Presenting the data and analyses was done through following the main research questions and sub-research questions.

Research question no.1: 'What is water consumption in mosques, policies, regulation, saving practices, appliances, techniques applied in mosques and water?'

Research question no.2: 'What are the effective water demand management policies, measures, and techniques that are compatible with the needs of water consumers in mosques?'

Research question no.3: 'How to investigate the acceptability of reusing water in mosques?'

The same answers were given by all policymakers, mosque management and engineers, that there were no policies or standards in terms of saving water through plumbing or recycling of greywater in mosques in Oman.

The research analysis results also indicate that there is a gap between the donor who builds the mosque and the organization that runs/ manages it. This gap leads to the organization not having information about appliance specifications or the causes of high water consumption, and that is because not all mosques are constructed by the government but rather by society, which donates to build mosques. So no specific requirements/standards need to be provided from government to the donor in order to build the mosque.

The part of the present research study that provides water consumption per capita data could work as a database for policymakers to implement policies and to suggest recycling projects in mosques. In fact, this research project has covered the points mentioned in interviews with decision-makers as reasons for the lack of laws and foundations. Studying the relationship between water consumption and appliances has demonstrated the importance of having policies for:

- plumbing
- appliances
- recycling (greywater) for irrigation and flushing toilets
- reusing (greywater) for irrigation and flushing toilets

In terms of ***investigating the acceptability of reusing water in mosques,*** the answers varied from those who accepted the idea and those who did not, to those who mentioned the need for a 'Fatwa' or an answer from those who understood the religion well enough to decide if it was accepted in Islam or not. A surprising answer from some of the engineers was that they accepted the recycled water even for drinking. Mentioning the need for a 'Fatwa' was evidence that the subject was unclear to the majority of interviewees, and that they were not aware of religious opinions on the subject. This gap has been covered in this section of the present research.

Chapter 6 : Bills Analysis

6.1 Introduction

Chapter 6 discusses the third part of the data analysis, water bills analysis from mosques in Muscat. The data were analysed using Excel software to measure total cost by given data for water consumption. Total consumption and cost were analysed from the water bills from around 688 mosques in 2016 and around 661 mosques in 2017. The total costs were calculated, with and without government support for production.

6.2 Total consumption and cost of 2016 water bills for mosques in Muscat

In Table 6.1, the total consumption and cost the water bills from 688 mosques were for 11 months only in 2016. The consumption data were taken from January to November. Total water consumption during this period was 158,339,867 gallons (712,529,401 litres). The rate for one gallon was 0.0025 baisa in Oman (around 0.005p in UK currency) but the rate had changed to 0.0035 baisa by March 2016. The consumption for January and February was multiplied by 0.0025 baisa to get the cost in riyal, Oman's currency, and then multiplied by around two (depending on the currency exchange rate) to get this in UK £. Then from March to November, the consumption was multiplied in 0.0035 baisa in Oman (around 0.007p).

The total cost for water consumption of was **511,787 OMR (£1,023,574)** for the 688 mosques over the 11 months in question**.** These water prices were supported by the government by around 50% of real cost for water production. The real cost of production is the true cost of water without government support. The cost for 158,339,867 gallons (712,529,401L) of water without government support is **1,108,379 OMR (£2,216,758)**.

Table 6.1: Total consumption and cost for 2016 water bills for mosques for 11 months

Year	Total no. of mosques	No. of months	Total consumption, in gallons	Total consumption in litres	Rate with support in OMR and £, in gallons	Rate without support in OMR and £
2016	688	11	158,339,867	712,529,401	511,787 OMR £1,023,574	1,108,379 OMR £2,216,758

6.3 Total consumption and cost for 2017 water bills for mosques in Muscat

In Table 6.2 the total consumption and cost for the water bills in 2017 varied every month from 611 to 548 mosques across the 12 months. The consumptions data were from January to December. Total consumption this period was **217,901,095** gallon (**980,554,927** litres). The rate of one gallon was 0.0035 baisa in Oman (around 0.007p in the UK). The total cost for consumption of **217,901,095** gallons was **763,974 OMR (£1,527,949)**. These price of water was supported by the government by around 70% of the real cost of production, as mentioned before. The cost for **217,901,095 g**allons (**980,554,927** litres) without government support was **1,525,307 OMR (£3,050,615).**

Table 6.2: Total consumption and rate for 2017 water bills for mosques for 12 months

Year	Total no. of mosques	No. of months	Total consumption, gallons	Total consumption, litres	Rate with support in OMR and £, in gallons	Rate without support in OMR and £
2017	661 to 548	12	217,901,095	980,554,927	763,974 RO £1,527,949	1,525,307 RO £3,050,615

To compare the consumption and bills between 2016 and 2017 is difficult, as the 2016 data was just for 11 months and the 2017 for 12 months. However, the comparison can still be done by comparing the data from January to November in total consumption and in cost for 2016 and 2017. To do that, total consumption and the total cost of 11 months for 2017 needs to be measured. Figure 6.1 and Figures 6.2 shows the comparison in consumption and rate without support in OMR for year 2016 and 2017 respectively.

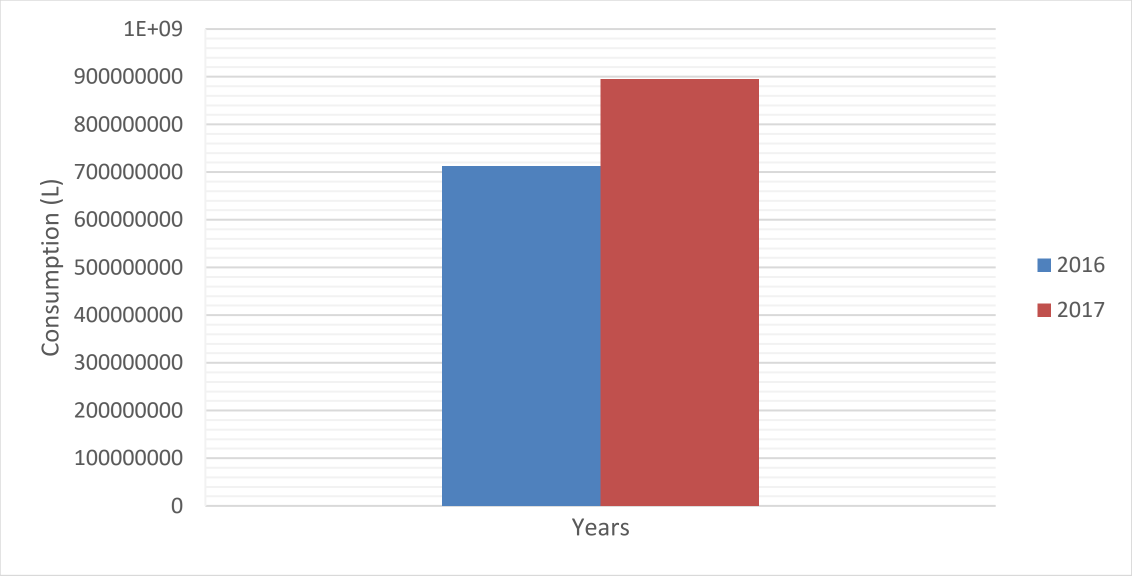

Figure 6.1: Total consumption of years 2016 and 2017

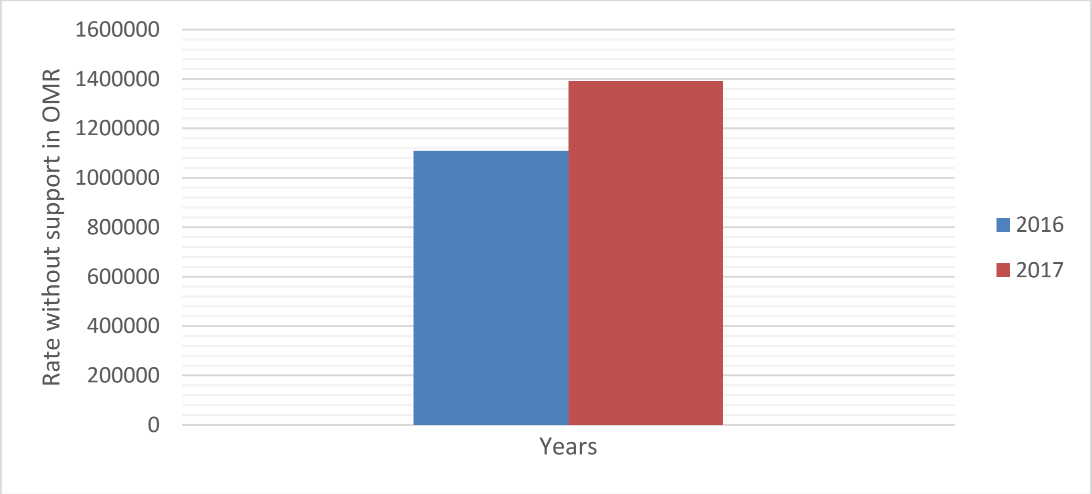

Figure 6.2: Comparison total rate without support in OMR for years 2016 and 2017

6.4 Total consumption and cost for water over 11 months in 2017 for mosques in Muscat

In Table 6.3, the total consumption and cost for 2017's water bills for between 661 and 548 mosques were measured for 11 months only (January to November). Total consumption for 2017 for the 11 months was 198,807,075 gallons (894,631,837 litres). The rate for one gallon was 0.0035 baisa in Oman (around 0.007p in the UK). The total cost for consumption of 198,807,075 gallons equalled 697,145 OMR (£1,394,291). These prices of water were supported by the government by around 50-70% of the real cost of water production. The cost for 198,807,075 gallons (894,631,837 litres) without government support was 1,391,649 OMR (£2,783,299).

Table 6.3: Total consumption and rate for 2017 water bills for mosques for 11 months

Year	Total no. of mosques	No. of months	Total consumption, gallons	Total consumption, litres	Rate with support in OMR and £, gallons	Rate without support in OMR and £
2017	661-548	11	198,807,075	894,631,837	697,145 OMR £1,394,291	1,391,649 OMR £2,783,299

6.5 Comparing consumption and cost of water in 2016 and 2017 over 11 months

Comparing water consumption and costs for 2016 and 2017 over the 11 months is illustrated in Table 6.4. It can be clearly seen that the consumption for 11 months in 2017 was greater than in 2016, and that could be accounted for as normal with the population increase every year. Comparing the cost with or without government support between 2017 and 2016 again shows costs are greater 2017 than in 2016. This is because the consumption was greater in 2017 and the rate changed from 0.0025 baisa (0.005p in UK currency) to 0.0035 baisa (0.007p in UK currency) from March 2016. Lifestyle could be another reason as if comparing a number of mosques in 2016 bit more than in 2017 but the consumption more in 2017.

Table 6.4: Comparing consumptions and rates of 2016 and 2017 for 11 months

Years	Consumption		Rate with support		Rate without support	
	Gallon	Litre	OMR	£	OMR	£
2016	158,339,867	712,529,401	511,787	1,023,574	1,108,379	2,216,758
2017	198,807,075	894,631,837	697,145	1,394,291	1,391,649	2,783,299

6.6 Possibilities for saving water around the world and in water bills

In the present study, the researcher found from an interview with the **Assistant Mufti of Oman in** Chapter 5 that reusing ablution water for ablution is not acceptable in Oman, in terms of religious opinion, although there are some differences in opinion in the same religious branches.

Meanwhile, from the literature it was mentioned that round 90% of the water used in mosques is for the ablution ritual (Suratkon et al., 2014; Rahman et. al, 2016; Prathapar et al., 2005). So, the possibility of saving on water bills could certainly be made by 10% from the recycling of ablution water for flushing toilets etc. (but not ablution, which should be carried out using clean water and not from recycled water).

The measurements evidence in Table 4.27 in Chapter 4 from this research contradicts the literature statement that 90% of water from mosque is for ablution. By contrast, the present study measurements show that around **25% to 35%** of the water used in mosques is for the ritual ablution.

According to this study investigation, half of the water currently provided for ablution is more than enough. Working to improve water efficiency in mosques – as well as working to recycle ablution water for flushing toilets, cleaning and irrigation – would benefit in saving more than 50% of water bills, while at the same time gaining green space around mosques – which is not available in most of the mosques, currently because of the water issue.

6.7 Percentage saving by recycling ablution water for flushing toilets

Recycling water to reduce water consumption in buildings and improving water efficiency is a major aspect of creating sustainable public buildings, which will benefit from cost savings in annual or monthly water bills, particularly when the price of water is likely to increase.

Greywater can be used for many applications. The applications vary from country to country, depending on specific country requirements and standards. Some applications of greywater include irrigation, toilet flushing, car washing, firefighting systems, industrial uses, cooling water, and for washing clothes.

According to the present study, measurements show that around **25% to 35%** of the water used in mosques is for the ritual ablution.

Average total consumption per capita using modern sensor devices controlled by a timer = 18L with 4.5L for ablution per capita.

Average total consumption per capita using normal devices controlled by users = 9L with 3.1 for ablution per capita.

25% to 35% saving for 18L per capita:

25% to 35% x 18L per capita = **4.5L to 6.3L**

25% saving in recycling ablution water for toilet flushing, assuming all the taps are modern sensor taps:

2 million is represents number Omanis in Oman so, this is a value represents the number Omanis who would be practicing ablutions.

25% x18L ablution per capita with toilets x 2 million people (refer to L.R for Oman population) x 5 times a day = **45 million L**

25% saving per ablution in sensor taps:

25% x 4.5L per ablution = **1.1L**

25% x 4.5L x 2 million people x 5 = **11.25 million L**

According to the 2016 water bills, which came to 511,787 OMR (£1,023,574) per year with government support, 25% to 35% of this water bill could be saved from **recycling ablution water for flushing toilets.** This comes to 127,946 OMR (£255,893) to 179,125 OMR (£358,250).

According to 2016 water bills, which came to 1,108,379.1 OMR (£2,216,758.1) per year without government support, 25% to 35% of this water bill could be saved by **recycling ablution water for flushing toilets.** This comes to 277,094 OMR (£554,189) to 387,932 OMR (£775,865).

According to 2017 water bills, which came to 697,145 RO (£1,394,291) per year with government support, 25% to 35% of this water bill could be saved from **recycling ablution water for flushing toilets.** This comes to 174,286 OMR (£348,572) to 244,000 OMR (£488,001).

According to 2017 water bills, which came to 1,391,649.5 OMR (£2,783,299.0) per year without government support, 25% to 35% of this water bill could be saved from **recycling ablution water for flushing toilets.** This comes to 347,912 OMR (£695,824) to 487,077 OMR (£974,154).

6.8 Percentage saving by changing techniques in existing appliances

According to the study investigation through observation, half of the current water flow is more than enough for users ablution. Also, according to literature mentioned in Chapter 2 in Table 2.2 on water demand management (WDM) measures or applications in several countries – as reported by Kayaga and Smout (2007); Jamrah et al. (2008); Prathapar et al. (2005) and Jamrah et al. (2006) – around 50% could be saved from changing techniques in existing appliances. Average total consumption per capita using the modern sensor device (tap) controlled by a timer in closing = 18L and 4.5L for ablution per capita. Average total consumption per capita using the normal device (tap) controlled by users in opening and closing = 9L and 3.1 for ablution per capita. Savings in different appliances by changing techniques in this study are illustrated in Table 6.5

Table 6.5: Savings in different appliances by changing techniques

Savings in different devices in this study	Sensor and push taps controlled by a timer	Normal taps
50% saving per capita ablution and toilet	50% x 18L per capita = 9L	50% x 9L = 4.5L
Total 50% saving in toilet and ablution all over the world	50% x 18L x 2.04 billion people x 5 = 91.8 billion L	50% x 9L x 2.04 billion x 5 = 45.9 billion L

50% saving per ablution only, per capita	50% x 4.5L per ablution = 2.25L	50% x 3.1L = 1.55L
Total saving in ablution all over the world	50% x 4.5L x 2.04 billion people x 5 = 22.95 billion L	50% x 3.1L x 2.04billion x 5 = 15.81 billion L

According to the 2016 water bills, which came to 511,787.3 OMR (£1,023,574.8) per year with government support, 50% of this water bill could be saved from changing techniques in existing appliances. This comes to 255,893.6 OMR (£511,787.3).

According to 2016 water bills, which came to 1,108,379.1 OMR (£2,216,758.1) per year without government support, 50% of this water bill could be saved from changing techniques in existing appliances, This comes to 554,189.5 OMR (£1,108,379.1).

According to 2017 water bills, which came to 697,145.7 OMR (£1,394,291.3) per year with government support, 50% of this water bill could be saved from changing techniques in existing appliances. This comes to 348,572.8 OMR (£697,145.7).

According to 2017 water bills, which came to 1,391,649.5 OMR (£2,783,299.0) per year without government support, 50% of this water bill could be saved from changing techniques in existing appliances. This comes to 695,824.7 OMR (£1,391,649.5).

6.9 Percentage saving by changing ablution device method to using a pot

Average total consumption per capita using pot = 0.6L for ablution (Chapter 4 section 4.12), which saved up to 80% of total ablution water consumption.

Ablution using pot: 2.04 billion (population from L.R) x 5 (praying and ablution 5 times day) x 0.6L (consumption of full ablution using pot) = 6.12 billion L

This gives an 80% saving in water bills using a pot for ablution instead of a normal tap.

6.10 Water bills summary

The measured consumption for ablution per capita with advanced appliances like a sensor or push taps controlled by a timer in closing is **4.5L**. For normal taps controlled by users in opening and closing, this measure is **3.1L**. The annual consumption of mosques in Muscat is **894,631,837.5L** at a cost of **697,145.6 OMR** (**£1,394,291.33)**. This is the price of consumption with support of around 60 to 70% from the government. By comparison, the cost of water production without government support reaches **1,391,649.5 OMR** (**£2,783,299.05).**

The research results also indicate that 80% could be saved from water bills if people were to use a pot for ablution instead of a normal tap.

Chapter 7 : Discussion

7.1 Introduction

This chapter discusses data from different sources and methods; interviews, consumption measurement results, observation and water bills. The main objective of the study is to identify ways to manage water demand in mosques in GCC countries. This research specifies the potential savings that can be achieved by recommending policies that can promote the application of suitable tools and techniques in mosques. The discussions are designed to follow the order of the objectives and sub-objectives by following the same procedures of analysing chapters.

7.2 Discussions of objective 1

Objective 1 for this research study was (Investigate the water consumption in mosques, policies, regulation, saving practices, appliances, techniques applied in mosques and water).

7.2.1 Discussion of sub-research question 1.1

Objective 1 was answered through the following sub-questions. The discussion starts with data gathered to answer sub-research question 1.1, which is (What are the water-saving policies and regulation which applies in mosque to achieve efficient use of water?)

The answers of policymakers and mosque management in three different organizations, was that there were no policies or standards in terms of saving water in plumbing or recycling of greywater in mosques in Oman.

However, greywater still needs to be used with care and following specific country standards (Casanova et al. , 2001; Kimwaga, 2.14; Li et al., 2009). **In Australia,** treated wastewater is classified from A to D based on its quality. Currently, the wastewater reuse regulations in Oman do not differentiate between greywater and blackwater, and all greywater must be properly treated and tested to the standards of potability. Yet there are multiple households throughout Oman (and the rest of the world) that successfully use untreated greywater for irrigation purposes (Prathapar et al., 2005; Jamrah et al., 2008). Legal standards need to be developed to address the use of greywater based on practical factors. Oman would benefit from this because it is a very water-starved nation. Jamrah et al. (2008) suggested in their study of water management in Oman in houses that the government may consider developing some legal codes and standards from those used throughout the United States and Australia.

Similarly, from the findings of this research study as observed from mosque appliances and techniques in around six mosques in Oman, it has been proved that there are no water-saving policies or regulations applied in the mosque to achieve efficient use of water. All six mosques had different appliances, techniques, and others. The observation also proved that there are no systematic procedures followed in mosques in Oman. This research highlights the importance of having policies and systematic procedures in mosques to achieve efficient use of water. In **Australia**, water regulation is under government responsibility. Each state has a different system. The Building Code in Victoria, Australia, specifies that new residential buildings must have water-efficient systems (Corr and Adams, 2009). On 1 July 2006, the introduction of mandatory efficiency requirements included water pressure limiting devices and restricting water pressure in all new building developments; that new houses have a 6/3 dual-flush toilet installed and 3 A-rated shower roses; and that the maximum flow rate from a shower, basin, and kitchen sink or laundry trough outlet shall not exceed 9L/min. This is as an example from the literature of implementing regulations that lead to a systematic procedure.

The part of the present research study that provides water consumption per capita data could work as a database for policymakers to implement policies and to suggest recycling projects in mosques. In fact, this research project has covered the points mentioned in interviews with decision-makers as reasons for the lack of laws and foundations. Studying the relationship between water consumption and appliances has demonstrated the importance of having policies for:

- plumbing
- appliances
- recycling (greywater) for irrigation and flushing toilets
- reusing (greywater) for irrigation and flushing toilets

Water conservation which results from water demand management is one of the Plumbing Code objectives in **Australia**. For example, according to the Plumbing Code in buildings, only dual flush toilets can be installed in Australia. The Plumbing Code, like the Building Code, is given legal effect through state legislation. Using a dual flush toilet 6/3 litres flush results in a 70% reduction in water flushing (Corr and Adams, 2009).

7.2.2 Discussion of sub-research question 1.2

The discussion continues with the second part of main research objective 1 in this thesis – sub-research question 1.2, which is (What are the water-saving practices and appliances applied in mosques?).

In this research the policymakers' and mosque management answers to this question were that there was no specification. From interviews with policymakers in the different organizations it was found that in the case of the majority of small mosques which were under the organization responsible of masjids and Jame's (PE), not all the mosques had been constructed by the government; instead, most had been constructed by society, which donates to build mosques. So that is why no specific requirements are needed from the government to the donor to build the mosque. The government provides only the major/broad planning for the mosque, but not the details. So, the donors building the mosque use products which match their budget, because this is not a matter for government. Likewise, in terms of saving water, the donors who are building the mosque for society are also responsible for choosing the appliances. Yet then paying the water bills is the responsibility of the government organization, which did not choose the appliances or the techniques.

This creates a gap between the donor who builds the mosque and the organization. This gap leads to the organization not having the necessary information about appliance specifications or the causes of high water consumption. They are unaware if the high consumption is due to a high number of users or because of the type of appliances and techniques in their use.

This study recommends that the government should intervene/oversee what the donors are allowed to build and install by having an agreement in law specializing in plumbing regulations in terms of tap flow, quantity of water per minute and fixed timing in sensor taps controlled by a timer. This government intervention would cover the gap mentioned and would ensure that all the mosques have systematic procedures in place in terms of water consumption over a particular time.

This situation is different for the organization responsible for Royal mosques (Jame’s); they have some approximate information in terms of specifications of appliances, because it was not a society donor that was responsible for building the mosque. The organization responsible for Royal mosques (Jame’s) is least concerned with saving water, as they are under Royal mosques. So, there is no lack of budget for paying the bills or for choosing the type of the appliances. The Royal mosques want to have ‘5-star’ luxury, with the most advanced devices and techniques. These vary from one Jame to another, as there is no systematic procedure in terms of flow, sensor timing, pressure or irrigation methods for agriculture in either organization. All decisions depend upon the contractor or the designer of the mosque.

In the literature, it is mentioned that sensor taps are used often at a set time to shut off automatically to reduce the potential for taps to be left running too long as a result of not being turned off. For example, a 6-star WELS rated tap was set between 5 to 10 seconds running time at 4L/min flow rate (Mayer et. al., 1999). This tap type may be more suitable for use in public buildings, as the chance of a lot of taps not being turned off is observed more in public building bathrooms. However, close attention should be paid to timing setting and flow rate implementation with respect to WDM in mosques.

In this research, it was found that studying the same set of timing and flow of a 6-star WELS rated sensor and push tap controlled by a timer in mosques wasted a lot of water in ablution. This tap type may be more suitable for use in public buildings, but not in mosques for ablution. The reason was explained in the observation of users’ consumption in Chapter 4, i.e. that most of the water flows without being used – as the users need an only a small quantity of water, which they can take in not more than a second; then they spend the rest of the time in washing while the water continues to flow. So, the specification of a 6-star WELS rated sensor tap does not save water in mosque according to study measurement results.

The water needs of other public buildings are different to those of mosques, although this depends on specific requirements in the mosque and also varies from country to country. The variation is dependent on each specific country’s religion, behaviour, culture and requirements, which have been shown in the ritual ablution example in this study. So, for example, timing and flow of a 6-star WELS rated sensor and push tap controlled by a timer could work in any other building and save water, even in Oman, for other purposes like washing hands – but not for ablution. In the case of the ablution tap, the flow and timing of the sensor needs to be more strictly controlled, depending on the usual manner of practising ritual ablution, to control the amount of water that flows and is wasted while scrubbing or washing is taking place.

In general, this problem needs to be addressed in Oman by working at integrated water resource management (IWRM). IWRM involves working in a process with many dimensions and the involvement of different sectors in society (public and private), of water users and different administrative levels, including many other conflicting issues and principles like environment sustainability to guide for the preparation of various management options (Mimi, 1999; Melnychuk et al., 2017; Scott,et al., 2017).

Using the most advanced devices and techniques does not prevent thinking about saving water to manage water demand, but also not all advanced devices save water. This depends on the techniques used in those devices, even if the purpose behind putting them in was to save water. Factors like pressure, flow and timing of the devices are as important as the device itself. Otherwise, advanced devices work contrary to their intended purpose and waste water instead of saving it. There are many advanced devices which could save water.

On the other hand, thinking about devices for saving water does not always mean that they are more expensive. It was observed while collecting data during this research study that in most Royal Jame's had the most advanced devices like sensor and push taps controlled by a timer. Then, while carrying out the interviews with engineers and policymakers, the interviewees did mention that the main purpose of these devices was saving water, but they had no idea about the techniques being used. The results of the measurements of water consumption for these devices (such as sensor taps) showed that they actually consumed more water than a normal tap. This was because of the devices being used in the incorrect way in terms of techniques, pressures, flow and timer control (setting up long and different timings from touch to touch for sensor taps or push to push in the case of push taps) with no systematic way to fix the problems.

Same what have been observed and analysed in mosques in this study in Oman that choosing the appliances tends to reflect appliance design, fashion, and brand, rather than resource efficiency.

According to a report by Corr and Adams, (2009), 1.7 million litres per year were saved from water conservation in Green Square South Tower. This was achieved by using water-efficient appliances of a minimum of 4A water conservation ratings for all taps, showers, and WCs, as well as recycling condensate water in the air conditioning system, while fire test water was reused for toilet flushing and irrigation for landscaping.

7.2.3 Discussion of sub-research question 1.3

Sub-research question 1.3 was (What is the estimated water consumption in ablution and toilet flushing per capita?).

According to Jamrah et al. (2006), it is assumed that that the ablution ritual takes **two minutes**. This means the total ablution water consumption per capita given this study assumption would be equal to 12L per person. This figure is very high compared with the present study measurement results for 120 users in 150 readings in mosques. Most similar studies work to get total water consumption using an assumption to carry out measurements of greywater etc. They give the less attention to work in measuring consumption to get the right figure. The main aim for most of the studies in this field of ablution water are concerned with water quality testing or the proper type of recycling. Yet they do not measure the real consumption of water and time taken for ablution which would lead to misleading in getting many important elements for any WDM projects.

In the present research, it was found that the averages for ablution per capita depended on the devices in the mosque (Jame or masjid). This research shows the important elements that affect water consumption for ablution in mosques and which cause high water consumption and bills. The elements which affect water consumption in this case are devices and techniques. This leads to proving that ablution per capita cannot be taken as one number or as an assumption, as has been the case in all other studies.

This research study is very clear in terms of methodology used. The research had the innovation to arrange for water consumption to be measured via an instrument fixed in the taps of mosques providing more than 150 readings of consumption per capita in six different mosques in Oman. Other studies, Prathapar et al. (2005); Jamrah et al. (2006); Jamrah et al. (2008), estimated consumption per capita measured by dividing the total number of worshippers and total consumption from the water bill, with no clarity in methodology. This study proves the importance of knowing the devices and techniques used in mosques to achieve accuracy in estimation.

This research could help the government to estimate consumption per capita in mosques more easily in the future. It could work as a database of consumption, depending on the devices and techniques used, which would help implement policies in plumbing and techniques or for any water demand management projects and policies.

7.3 Discussion objective 2

Objective 2 for this research study was to (Identify effective water demand management policies and measures and techniques that are compatible with the needs of water consumers in mosques).

7.3.1 Discussion of sub-research question 2.1

Sub-research question 2.1 for this research was (What are consumers' needs when performing ablution in mosques?). The answers from the group interviews led to it being concluded that the users get more in terms of water services than they actually need. This is proved by the measurement results of high consumption per capita and also by observation for investigation by the author of this research in mosques. As a result, users requested a reduced service to reduce energy, flow, water pressure and to reduce timing in sensor taps and even with normal taps controlled by users in opening and closing . This also indicates that the users are aware of water wastage in the mosques.

In answer to describing themselves regarding their water use, most users said theirs' was normal usage with the tap open to a medium level. By mentioning this, they meant that there was not a lot of water wasted by them during ablution, unless this could not be controlled because of the nature of the appliance or water pressure. However, it can also be clearly seen that users believe that there is a lot of water being wasted in mosques as a result of others' behaviour. This contrasted with people's opinions of their own behaviour.

The variation in measurements of water consumption per capita as a result of different devices and methods proved that there is a huge wastage of water. This research work proves that the ritual of ablution could be done using 0.6L instead of 4L to 7L per capita. One surprising result in the measurement of ablution using a pot ranged between 0.5L and a maximum of 0.73L. This is the same amount of consumption by Prophet Mohamed for carrying out ablution (which was 0.6L).

The research showed how the method and device used to perform ablution could change the user's behaviour and have an effect on consumption. These research results show that the development of taps has contributed to a general increase in consumption; this was from comparing modern sensor and push taps controlled by a timer and normal taps, then comparing consumption between a normal tap controlled by users when using a pot.

In terms of studying users' behaviours, it can be derived from these results a confirmation that a human adapts himself and his actions to what is available. Although the water in pots was filled to a maximum at the beginning and the users were asked to feel free to add more water, no one even used a full pot of 1L. This confirmed that it is possible to achieve the perfect ablution without wasting water and following the Prophet Mohamed in using just 0.6L, despite the changing times and ages.

The observation of how sensor taps in mosques work was recorded and the video of the recording is presented as an example of a person performing a full ablution process from a sensor tap in the second mosque. The person did his full ablution in 1 minute and 15 seconds (01:15) with a total water consumption of 5.6L in five touches to the sensor. However, the water continued to run and stopped after 6.5L had flowed, as it was controlled with a timer and took another couple of seconds to stop. Here the behaviour plays a major role because some people take a very long time to scrub their hands, hair, head, and their faces. So, this demonstrated a behaviour and amount of water usage while performing ablution, although the user took very little water in his hand, but the water ran while he was washing. And once he finished scrubbing and went back again to take a little bit more, the sensor had stopped the flow, so he needed to touch it again and, in this manner, while he carried out his ablution the water continues to flow.

There were different behaviours observed on this site; for example, some people just took the water and washed without scrubbing over a short period of time. But the problem of the continuous flow of water from a sensor tap controlled by a timer is still there.

7.3.2 Discussion of sub-research question 2.2

The sub-research question 2.2 for objective 2 was (What are the effective water demand management policies and measures and techniques?).

First of all, there is an urgent need from the government side to implement water demand management policies, measures, flow, techniques and plumbing, particularly in mosques; this includes researching details of water saving tools and appliances available in the market. In light of the water consumption results and the investigations in this research, effective water demand management policies in mosques need to take account of the following:

- Half of the currently provided water flow and pressure in mosques is more than enough for ablution taps. With regard to successful WDM measures mentioned in the literature review (Chapter 2) – for example, in Australia the maximum flow rate from a shower, basin, and kitchen sink or laundry trough outlet is regulated to not exceed 9 L/min. This consideration of flow rate to not exceed 9 L/min is quite a lot in mosque taps and according to this research study measurement. Considered that result from this research this goes against the need in mosque.

- A fixed water pressure for all the mosques should be agreed (as in, for example, Australia's Plumbing Policy mentioned in Chapter 2). Particularly in the case of ablution, this fixed pressure needs to be reduced, as users need focus and accuracy for ablution but not high water pressure which confuses the users.

- There should be a fixed flow consumption in mosques by having a systematic procedure to manage this. This could be achieved by having plumbing policies. Looking at WDM policies in England and Wales, building regulations require that water consumption for a new dwelling should not be more than 125 litres/ per capita/ day. In order to comply with this, Fidar et al. (2017a) and Fidar et al. (2017b) mention the importance of economic efficiency, by which they mean using efficient appliances (WCs, showers, basin taps, kitchen taps, baths, dishwashers, and washing machines) in promoting water saving.

- The high flow of water, as mentioned before, is confusing and distracts users from focusing on doing their ablution in the proper way.

- Measures and techniques must be the same across all the mosques from the same organization to ensure having a systematic and researched procedure employed in all mosques in Oman. The current situation shows that every mosque has different measures and techniques in terms of flow, consumption and controlled timing, even from mosques under the same organization. This situation makes it very difficult to measure consumption and to make possible savings. Having a systematic procedure in terms of measures and techniques would help in providing clear measurements of water consumption and potential savings. This in turn would help WDM or any other investments in mosques – either for all mosques in Oman or at least for mosques under the same organization.

- The water pipes for greywater need to be separated from those for blackwater from the design stage itself, to make it easy to reuse greywater in mosques. Whereas this project is specific to mosques in Oman, the ideas and the results would work perfectly in other mosques in GCC countries, because they are Muslim with similar lifestyles in terms of preforming ritual ablution five times a day and in terms of their having a similar water resource shortage and the same weather. The main source of water for all GCC countries is from desalination of sea water.

- Ablution water can be reused in flushing, irrigation, landscaping or in car wash businesses, which are connected to the mosque ‘Waqf‘ or saved in a tank for selling. As an example, greywater could be sold on a weekly basis at a lower price than that of potable water to farmers or it could be used for government projects.

Plumbing policies could contribute to the regulation of the whole system and could help to change the Omani market automatically in a rational and environmentally friendly direction, as it has been done in Australia and as mentioned in the literature review (Chapter 2).

7.4 Discussion objective 3

Objective 3 for this study was (Investigate acceptability of reusing water in mosques) contained in sub-research question 3.1.

7.4.1 Discussion of sub-research question 3.1

The research question for objective 3 was (Is water reuse or recycling acceptable to the mosque users and relevant policymakers?)

The literature review chapter (Chapter 2) clearly outlines the steps for the sequential treatment of greywater (Prathapar et al., 2005). The final design of any greywater treatment plan will depend on many factors including quality, quantity, and timing of the greywater generated, the soil and climate conditions, and various legal requirements. The most successful designs are often the simplest and require minimum outlay of energy, allowing them to treat large quantities of greywater efficiently.

According to Prathapar et al. (2005), in all greywater cases reported throughout Oman, wastewater treatment reuse standards were excessive. The author's point of view in the present research study is that Oman's standards related to greywater reuse need to be implemented to work in a greywater quality test and to be compared with greywater standards (rather than wastewater reuse standards) to decide if the parameters tested are disproportionate or not. However, Prathapar et al. (2005) conclude that low-cost greywater treatment systems are possible, as a result of their own greywater treatment designs (see Figure 2.8, A low-cost greywater treatment system, in Chapter 2).

In terms of recycling, the thoughts and opinions of policymakers, mosque management and engineers, and even users, are similar – their having given the same answers to the same questions. All of them agreed on the idea and mentioned the importance of recycling and separating the pipes and drainage for greywater from blackwater and recycling ablution water in mosques to flush toilets, and for irrigation and car washing. Additionally, all of them agreed that recycling would reduce water demand in mosques, would be financially beneficial, and would save the environment. They also all agreed that recycling of ablution water would not be harmful to humans as it is greywater, not blackwater. Based on users' answers from the focus groups, it was understood in the present research that the recycling process was acceptable to users and no one refused to use recycled water, categorically without reasons. They did not accept recycled water for drinking or for human use for psychological reasons, but not mentioning religious reasons.

Positive results have resulted from the application of WDM measures in several countries. Many achievements in WDM by different organizations have been reported in the literature, a few examples of which are summarized in Table 2.2 in Chapter 2, entitled **Application of WDM measures in several countries, as reported by Kayaga and Smout (2007); Jamrah et al. (2008); Prathapar et al. (2005) and Jamrah et al. (2006).** Measures and techniques (including policies, water pricing, efficient appliances, and recycling) are important concepts to be investigated in Oman to achieve WDM.

However, religious opinion is the foundation when it comes to the subject for a Muslim country. Even if a practice of, for example, reusing ablution water for ablution were approved as being efficient and saving water, if the religious opinion disagreed – as is the case in Oman – then such a policy could not be implemented.

From the answers in this study, it was found that there was a lack of knowledge on the part of the public on religious opinions about recycling in general. Only two out of 41 interviews with policymakers, engineers and mosques management and three focus groups with users mentioned that recycled water is not accepted for ablution purposes. Others mentioned either just their own opinions in terms of accepting or not accepting, or said there should be a 'fatwa' on the subject. This proves there is a general lack of knowledge of religious opinion on this important aspect.

The literature mentioned that there was a special 'fatwa' issued by a council of leading Islamic scholars in Saudi Arabia in 1978, and this fatwa allowed for the use of treated wastewater, even for ablution ('wudu'). Also, Imams, religious scholars, promote the reuse of greywater in Jordan and Palestine if the wastewater has been properly treated and tested for adequate levels of purity for use, and provided no public health risks are discovered. Additionally, chlorination has been shown to remove all biological pathogens from greywater (Prathapar et al., 2005). This ‘fatwa’ which mentioned in literature inconsistent with ‘fatwa’ from Oman.

WDM in mosques not only introduces practical engineering solutions in promoting sustainable living, but it is also in line with Islamic principles of using natural resources in a prudent manner.

The author of this study decided to carry out an interview with the Assistant to the Grand Mufti of the Sultanate of Oman during this research to obtain clear responses on the matters of water recycling in Oman, the ‘Fatwa‘ and other issues related to filling the knowledge gap in this area. The **Assistant to the Grand Mufti of Oman** gave his permission for any disclosure of identification in this respect**.**

The ‘fatwa‘ from Oman was very clear and different of other ‘fatwas‘ mentioned in the literature from other countries regarding recycling ablution water for ablution purposes; that is, recycled ablution water but can be reused for agricultural uses or for other uses, **except for religious uses,** like ablution and washing up. This is not because it’s recycled; there is another reason that it cannot be used for ablution. They do add water in the process of purifying. They add materials and originally also most of this used water is not mainly pure water. So, recycled ablution water is a used water and used water cannot be used again for ablution. There is some disagreement between scholars on this opinion, but there are authentic narrations where it was found Prophet Muhammed ρ: **”نهى عن الوضوء من فضل الماء”** ”**prevents use of used water** (فضل الماء). So, although this water is originally pure water, once it has been used for ablution, then it cannot be reused for ablution. However, it can be used for other purposes.

Chapter 8 : Conclusion

8.1 Introduction

This research aimed to **achieve appropriate water demand management (WDM) in mosques,** as highlighted in Chapters 1, 2 and 3. This chapter makes conclusions based on the findings in Chapters 3, 4 and 5 and the discussion Chapter 7.

The conclusion is structured around a review of the primary research objectives by following the order of the three research objectives as listed in section 1.5 in Chapter 1. The conclusion chapter also outlines the suggestions of the research findings, their contribution to the knowledge in this area, the limitations of the research. This chapter closes with suggestions for further research.

- **Conclusion about objective 1**

This section addressing the first objective: **Investigating water consumption in mosques, policies, regulation, saving practices, appliances, techniques applied in mosques and water**, which was achieved through answering three research sub-questions, as listed in section 1.5 in Chapter 1.

This research, through investigation and gathering of data and analysis, found that there is a relation between the type of tap or appliance and techniques applied and between the total consumption of water for ablution with different people's behaviours which cannot be separated to measure consumption.

This research studied all the different appliances and techniques available and that were applied in mosques, as well as adding some other appliances and another technique which is not practiced any more in mosques in Oman, i.e. carrying out ablution using a pot. This research contributes to knowing the exact and main reasons for high water consumption, which will in turn help and would lead to water demand management if the reasons can be avoided or worked on.

The study founded technical reasons to be the main factors for wasting water in ablution, rather than in users' behaviour; this is different to what management, policymakers, and engineers think. The study found that advanced devices such as sensor and push taps controlled by a timer and techniques used currently in Oman are consuming more water than regular taps which can be controlled in opening and closing by users. From this research investigation, it was found that welfare and lack of awareness of the need to save were also among the causes of wasting water. This was proved by asking users to carry out the ablution ritual in two different ways, by using a normal tap and by using a pot, and then measuring water consumption. The result, for example, for one user was around 4L using the normal tap and around 0.7L by the same user using a pot.

The study used a precise method of employing a device normally used to measure water consumption in agriculture; here, for the first time, it was used to calculate the quantity of ablution water accurately for each user for around 120 experiments. Overall, the study provides details of the exact amount of water used for ablution by users, depending on the type of faucet or tap, for any necessary calculations of the amount of water that can be used in recycling, and to decide what it could be used for.

The study shows that the total fixed timing for advanced devices like push and sensor taps, although reduced in some mosques, is still excessive for the purpose of ablution. The users collect a small quantity of water in the hand for the first wash and take an amount of water in the second, while the water continues to flow; when he returns for the second time again to take water, he finds that the water has stopped. Then he needs to touch the sensor or to push the tap again to take another handful of water, to continue with his wash, and again the water continues to flow. So, on that basis, the need of the person is only the around one second and not the 7-10 seconds it takes for one click or touch of the sensor or push taps.

The measured consumption for ablution per capita with advanced appliances such as sensor or push taps controlled by a timer is **4.5L**; this figure for normal taps controlled by users is **3.1L**. The annual consumption of water for mosques in Muscat is **894,631,837L** and the cost is **697,145 OMR** (**£1,394,291)**. This is the cost of consumption with support of around **50%** from the government. By comparison, the cost of water production without government support reaches **1,391,649 OMR** (**£2,783,299)**.

Correspondingly, the study noted that although mosques are under the management of the same ministry, there is no systematic system to have uniform timing for sensor or push taps which are controlled by a timer or pressure. Even in terms of the flush in the toilets, every mosque differs completely from the others. Moreover, in a single mosque there may be different measurements from one tap to another and from one toilet to another. This is evidence of the absence of specific laws or ways of thinking in following such laws.

Another contribution from this study through observation and analysing, is that the decision-makers in the ministry use the sensor devices and push taps controlled by a timer as they are interested in rationalization and they wish to reduce the consumption of water. Yet, the results of the study show otherwise – the new technologies actually increase water consumption. At the same time, the decision-makers in the ministry that use normal faucets confirmed that they wished to have the capacity to change the current faucets (normal taps) and to put in a law forcing builders to install sensor and push taps to reduce the consumption of water. Again, the study proves that normal taps such as those currently available in small mosques, consume less water compared to the sensor and push taps controlled by a timer.

In conclusion of the study investigation, it could be said that there is a gap between the donor who is the builder of mosques and who has chosen the appliances and the organization or ministry that is responsible for paying the bills. There are exonerations and every organization foot the responsibility in the tasks of rationalization in water to another organization. Moreover, there is no policy or standard or regulation for plumbing or for greywater standards.

- **Conclusion about objective 2**

After finishing this investigation and observation covering the first objective in this research, the next section provides effective solutions in water demand management to cover the second objective, which is:

Identify effective water demand management policies and measures and techniques that are compatible with the needs of water consumers in mosques.

This intention, addressing the second objective of the thesis, has been achieved by answering again the three research sub-questions listed in section 1.5 in Chapter 1.

These research findings come out through the 120 measurements of water consumption, as explained before, by analysis of interviews with policymakers, engineers and mosque management, and with focus groups interviews with users.

Through observations and investigations, it was found that, water could be easily managed, avoiding the causes of water wastage, if the reasons for this wastage were known. Adjustments in the fixed timing of touch in sensor and push taps can handle the problem by letting sensors of the tap work properly and the water to flow when it is touched and to stop immediately when the user moves away to wash/scrub while performing his or her ablution. This is what the most advanced and effective devices and techniques available in markets can do. Instead, current practices involve the use of sensor taps but, from research observation, it has been found that such appliances are dependent on fixed timing to stop. Such advanced appliances, devices and techniques are used in different ways and this has not been studied in depth; however, the technique currently being used in Oman has led to increased consumption more than non-advanced devices, as proved in the consumption analysis chapter (Chapter 4).

As this study has proved through experiments, welfare and lack of awareness of the need to save water is one of the main causes of water wastage. Such experiments were carried out by asking the same users to do their ablution using two methods: with a normal tap and using a pot (capacity 1L, which they could refill at any time). The experiment results show that all of the users consumed much more water using taps. The users' maximum consumption was 0.73L with the pot and all others were between 0.5L and 0.65L; by comparison, users reached between 4L and 5L with normal taps and went up to 7L of water when carrying out their ablution using a sensor tap controlled by a timer. The experiments found that changing the method from tap to pots itself let users feel there was a need for conservation. The same thing was observed while doing the experiments with sensor taps controlled by a timer. The high pressure, high water flow and taps still running after the end of the ablution sent a message to users that there was no need to think about conservation.

There were differences in opinion (agreement and disagreement) across the groups of users in opinions of some statements like if the people in Oman were not interested enough in saving water and if the government needed to implement water restrictions for water management in mosque section.

In conclusion of this section, it is possible to apply the Prophetic Sunnah and virtue of the ideal ablution with the same quantity of water that the Prophet used (0.6L), by using a pot for ablution to save water and preserve the environment. There is an urgent need for policies and procedures to establish systematic ways and methods in techniques, water pressure, timing and amounts to be followed in all mosques in Oman. It is also necessary to start working on and implementing policies for reusing greywater (ablution water) in mosques, with these to be made a part of the construction contract before a mosque is built.

- **Conclusion about objective 3**

The next section in this research is a continuation of the first objective of investigation, but particularly addressing the feasibility of reusing ablution water to cover the third and last research objective, which is:

Investigate acceptability of reusing water in mosques.

This objective addresses the third objective of the thesis, which has been achieved by answering the two research sub-questions listed in section 1.5 in Chapter 1.

These research findings emerged through 170 measurements to estimate total water consumption per capita to get an exact total consumption from ablution only, without mixing it with a total for blackwater, as all other studies have done before. Nor have other studies specified the consumption for ablution method in an accurate way as is done in the present research. Estimating a figure for water consumption for ablution from the total water bill has prevented studies from discovering the effects of appliances and techniques on water demand management (as discovered and explained in the present study). As has also been discovered in this research, no one estimation for water consumption for a single ablution could work for different mosques, which have different appliances and different techniques and pressures. Inaccurate estimations lead to inaccurate totals for water consumption for recycling.

There is a gap in the knowledge on the opinion of religion in Oman, in terms of the possibility of using greywater for ablution and for mosques in general. The religious opinion on reusing greywater in Oman for ablution after treatment differs from the religious opinion in the Islamic countries and other Gulf countries. This study addressed this knowledge gap by interviewing the Assistant to the Grand Mufti of Oman to obtain clear responses on matters of water recycling, the suggested ‘fatwa’, and other issues relating to the knowledge gap in this area.

The research also studied people’s opinions, along with their openness to recycling. Users, policymakers, engineers, and mosque management welcomed the idea of reusing greywater. Yet available waste or treated waters are still not being reused to their full potential in mosques in Oman. The sewage pipe and ablution water both go to one single pipe to the main sewage pipe. This makes the purification of ablution water more complex and means it has to go through stages that it does not need, which increases the cost of treatment and impacts the environment more. Separating greywater from blackwater, recycling it and using it in toilet flushing could save 25 to 35% of total water bills.

The present research also proves that current advanced devices in Oman are consuming more water than normal water taps. Yet, both are in need of management, as both consume more water compared to the ideal ablution (Prophetic Sunnah) quantity that the Prophet used (0.6L) by using a pot for ablution. At the same time, there is an urgent need to enforce and act on the laws on greywater for best water management in mosques.

To sum this section up, there is an urgent need for appliances and techniques management to enable the reuse of ablution water for flushing and irrigation. In working to manage demand by fixing the problem with appliances and techniques, the government would save 40 to 50% of total water consumption, as has been observed while taking the measurements and also when compared with the research findings using a pot. These show that half services as currently provided and the amount of water and flow are more than enough as these amount to more than maximum total consumption for ablution using a pot. If the government were also to save and manage demand by recycling greywater in mosques, it would save 25% to 35% of water bills while at the same time having extra green areas around mosques. There would be **effective water demand management** if the government applied both solutions to save more than 70%, by using sensor and push taps, and more than 80% by using a pot when carrying out ritual ablution.

- **Conclusion about research problem**

This research used different methods as qualitative research may have weak points, be unscientific or only exploratory; however, this research included working on measurements and tests which enhanced the validity of the results.

This research applied a mixed method of qualitative and quantitative research. It consisted of measuring water consumption per capita in parallel with carrying out interviews with policymakers, mosque management, engineers, and water users in mosques, analysis of water bills for two years across all the mosques in Muscat, and archival analysis – as it is shown in Table 3.6. Measuring total water consumption per capita was carried out in mosques and in houses.

The data was collected for the three research objectives using different methods. Research was carried out via interviews and measuring water consumption to **investigate water consumption in mosques, as well as policies, regulations, saving practices, appliances and techniques applied in mosques.** A review of the literature looked at the policies available with results of consumption and interview investigations by talking to policymakers, engineers and mosque management to **identify effective water demand management policies and measures and techniques that are compatible with the needs of water consumers in mosques**. Other interviews conducted were with ‘Iftaa’ and group interviews with users of water in mosques to **investigate the acceptability of reusing water in mosques** and to identify WDM practices that would be compatible with the needs of water users in the mosques. This all helped the researcher to address the research problem and to come out with recommendations.

Following on from the measurements, an investigation was conducted to confirm the interviews with policymakers and management of the mosques that there were no policies in term of in plumbing. Because the measurements were different from mosque to mosque because of different flow, pressure and controlled timing in taps, this approved and validated information from the literature from the study done in Oman by Prathapar et al. (2005) and from the research study interviews with policymakers and mosque management. Additionally, measuring consumption per capita gave information on consumption and potential savings, in what area these might be, potential investment or recycling and how these might be carried out. It also let the researcher observe the relationship between appliance type and total consumption, which led the research to go on to a detailed investigation of sensor and other types of taps in Chapter 5, and as discussed in Chapter 7. Interviewing engineers, ‘Iftaa’ and water users analysing resulted in this research study needed to recommend and shade light in the important of considering on consumer needs to **achieve**

appropriate water demand management (WDM) in mosques. This study carried out the work necessary to calculate savings and cover knowledge gap in what is not allowed in Oman based on the opinion of religion in recycling, which is that recycled ablution water can be used for any purpose, but not for ablution to prevent working in inappropriate WDM in mosque.

Finally, despite minimal limitations, the research aim was achieved.

8.2 Recommendations

When the issues that currently constrain the potential for reusing greywater are studied, most of them can be considered surmountable. In areas where low quantities of greywater are being **produced, or when the separation of greywater and blackwater requires major plumbing** conversions, it may be less economically beneficial to invest in such systems. However, the benefits to individual residents, as well as the entire country, should not be ignored when water conservation is such a significant issue. Greywater reuse can be a very cost-efficient alternative to supplying freshwater, particularly in arid and semi-arid countries such as Oman. It can contribute to the development of sustainable resource conservation. Despite the many measurable benefits, the use of treated greywater is not widely seen in Oman at this point. Generating greater public interest will help this alternative become a reality. Should the Oman government, or other promoters, properly extol the benefits of reusing greywater, using facts and statistics, proper greywater reuse may contribute to the overall fiscal health of the country. The separation of greywater and blackwater, treatment of greywater, and reuse on-site will help to alleviate the high pressure currently placed on urban sewer systems and the cost of making and maintaining them.

Water recycling policies for greywater and plumbing policies for appliances are needed in mosques for WDM. It is necessary to start working and implementing policies of reusing greywater (ablution water) in mosques to be a part of construction contracts. Correspondingly, the study noted that although mosques are under the management of the same ministry, there is no systematic system to implement uniform timing for sensor or push taps that are controlled by a timer or for water pressure and flow. Mosques even differ in terms of amount of water used to flush a toilet; a single mosque may have different measurements from one tap to another and from one toilet to another. The study recommends that the government intervene by having an agreement in law specializing in plumbing in terms of tap flow, quantities of water per minute and fixed timing in sensor taps which are controlled with timing.

Yet, both normal and more advanced devices are in need of management A systematic procedure in terms of techniques, water pressure and flow needs to be the same in all the mosques in Oman or for all mosques under the same organization.

The present research also recommends fixing sensor timing in ablution so that it is better suited to user needs.

The saving in demand benefits from reusing greywater can be used to increase the distribution system to the areas that are not as yet being served by the government distribution system. Practical education on WDM would also be well suited to mosque public buildings as these include different ages and generations in one place, five times in a day. Thereafter, such education would be much easier to transfer to home.

To sum this section up, there is an urgent need for appliances and techniques management to enable the reuse of ablution water for flushing and irrigation.

8.3 Limitations of the work

The sites of masjids and Jame's in this research study were the only ones that were permitted and approved by the Ministry of Endowments and Religious Affairs and the Royal Diwan Court to carry out the research. The permitted and approved masjids and Jame's were within the research specifications.

The research findings in WDM and investigations and implementations in mosques could not be generalised to all Muslim countries and all mosques, as the work was only carried out in Oman.

The research could not get experts in the faucet industry in Oman to discuss appliances that would be efficient for ablution at the manufacturing stage.

One of the research methods used in this study was observation while taking water consumption measurements, which could have had an effect on user behaviour while carrying out their ablution.

8.4 Future work

The findings from this research could lead to numerous possible future avenues and questions that could be studied to broaden WDM investigations and implementations. Some of these include:

- What is a suitable standard for treating ablution water of the greywater type, as ablution water is cleaner compared to other types of greywater from showers or washing machines?
- In terms of cost implications, it would help to know, ‘What is the cost of implementing a recycling system to reuse ablution water for flushing toilets? And, ‘What is the cost of implementing a recycling system to reuse ablution water for irrigation?’
- Is separation of greywater and blackwater in mosques economically beneficial in terms of plumbing conversions?
- Could recycling ablution water in mosques be harmful to human health? Could it cause any harm to public health or the environment? Is there evidence of this?
- What is the ideal ablution tap timing?
- Finally, the findings from this research could lead to broadening WDM investigations and implementations by future work of similar methodology to this study but in other Muslims countries, so to be able to generalise the research findings to all Muslims countries and all mosques.

8.5 Contribution to knowledge

Consequently, important contributions have been added by this research to the body of knowledge on the subject. The contributions were on the investigation of current WDM in terms of policy, appliances, and recycling, efficient appliances, and on the feasibility of reusing water in mosques. This thesis has contributed a new and novel method and data position through which to further consider WDM policies and practices in the mosques across the world. These research contributions in more detail were as follows:

8.5.1 Investigation of current WDM in terms of policy, appliances, and recycling

The most modern advanced designs of the appliances are sensor and push taps controlled by a timer. Normal appliances are taps which are controlled by users in opening and closing and in controlling the amount of flow. The investigation found that the government aims to install the most modern advanced designs for appliances, such as sensor and push taps, in order to save water; in fact they hope these appliances to be included for small mosques in future.

The contribution in this thesis shows that ideas and the facts are totally different, as the measurements show that modern advanced designs for appliances such as these actually consume more water than normal taps.

This research contributes through investigation by showing water users that there is a need to save water, and this could be through changing their method of carrying out ablution to using a pot.

8.5.2 Efficient appliances

The study used a precise method of employing a device normally used to measure water consumption in agriculture; here, for the first time, it was used to calculate the quantity of ablution water accurately.

Providing explicit water consumption measurements for ablution is another research contribution and clearly shows the effect of appliance types on consumption. This thesis could provide the government with information on which appliances are most efficient in terms of WDM.

Another contribution in terms of efficient appliances in this thesis is that illustration of important elements in the efficient appliances in terms of WDM which could work in a reverse way if it had not been considered in a proper way like (pressure, timing, flow, etc).

The thesis also contributes to knowing the exact and main reasons for high water consumption, which will help and lead to water demand management if the given reasons can be avoided or worked on. The study found technical reasons to be the main reasons for wastage of water in ablution, rather than in users' behaviours.

The study shows that the total fixed timing for advanced devices like push and sensor taps, although reduced in some mosques, is still excessive for the purpose of ablution (see discussion earlier in this chapter). The needs of the person performing ablution is only around one second and not the 7-10 seconds it takes for one click or touch of the sensor or push taps.

The study contributes in that the fixed timing that is most often used in sensor and push taps normally wastes a lot of water if it is being used in ablution.

8.5.3 Acceptability of reusing water in mosques

The study contributes in giving the amount water consumed for ablution exactly, depending on the type of faucet used, then going on to calculate the amount of water that can be used in recycling and deciding what it could be used for. Therefore, this study contributes towards providing an accurate estimation leading to accurate total consumption for recycling.

The study contributes by proving through measurements that the ablution water is enough to be reused for flushing toilets.

It also contributes in a way to protect the environment and to soften the hot air in Oman by increasing the green spaces around mosques by reusing ablution water for landscape irrigation and without demanding more freshwater.

Finally, the study contributes to filling a knowledge gap on religious opinion in Oman in terms of the possibility of using greywater for ablution and for mosques in general. The religious opinion – from an interview with the Assistant to the Grand Mufti of Oman that it is not possible to reuse greywater for ablutions after treatment – differs from the religious opinion in Islamic and other Gulf countries.

8.6 Significance, originality and impact of the study

According to statistical data conducted in 2015, the number of Muslims will increase. Praying five times a day and performing ritual ablution (wudu) using water is an obligation for all the Muslims before praying. At the same time, there are 1.1 billion people in the world who do not have access to a drinking water source (UN.org, viewed on 19/03/2019). Therefore, to contribute to the global knowledge of water conservation, studies from these parts of the world are significant and should also be considered to work in water demand management.

According to the present research study, the maximum consumption of water would 45.9 billion litres in ablution if we assume Muslims all over the world use the most advanced devices for flushing toilets and sensor and push taps controlled by a timer to preforming their ritual ablution five times in a day. On another hand, this figure would be 31.62 billion litres of water if we assume Muslims all over the world use the normal flush range between 3 and 6L per flush in toilets and normal taps controlled by the user in opening and closing to perform their ritual ablution five times in a day.

However, although normal taps consume less than most advanced devices like sensor and push taps, this does not mean that there is no wastage of water in normal taps, nor does it mean they are efficient in saving water. Work still needs to be carried out on the features of high water pressure and high water flow with maximum and minimum opening of the tap.

This study sheds light on the amount of water used in mosques, including when performing ablution, and the savings that could be achieved, to introduce possible suitable techniques to conserve water, as well as to look at the feasibility of reusing water in mosques. It indicates the savings that could be achieved through efficient appliances and water reuse by recommending a number of policies that can promote the application of suitable tools and techniques in mosques. However, changing the method for ablution, which was examined by using a pot to perform the ritual, found that this method saves more than 80% of water consumption for ablution.

Maximum: 2.04 billion x 5 x18L = 183.6 billion L per ablution and toilet use (flush and taps)
Maximum in ablution only: 2.04 billion x 5 x 4.5 = 45.9 billion L
Minimum: 2.04 billion x 5 x 9L = 91 Billion L per ablution and toilet use (flush and tap)
Maximum in ablution only: 2.04 billion x 5 x 3.1 = 31.62 billion L

References

References

Abdel-Dayem, S. (2000). Sustainability of low quality water use in agriculture. *GRID-Magazine of the IPTRID Network (FAO/United Kingdom)*.

Abdul Rahman (2005). Water in the GCC- Towards on Integrated Water Resources In: *The 7th Gulf Water Conference, 19-23 November 2005*, State of Kuwait.

Abu-Rizaiza, O. S. (2002). Ablution water: prospects for reuse in flushing of toilets at mosques, schools, and offices in Saudi Arabia. *Engineering Sciences*, *14*(2).

Al-Mashaqbeh, O. A., Ghrair, A. M., & Megdal, S. B. (2012). Grey water reuse for agricultural purposes in the Jordan Valley: Household survey results in Deir Alla. *Water*, *4*(3), 580-596.

Al-Maskati, H. (2011). *Water demand management: a case study of the kingdom of Bahrain* (Doctoral dissertation, © Hana Husain Al-Maskati).

Al-Otaibi, G. (2015). By the numbers: Facts about water crisis in the Arab world. *The World Bank*: Voices and.

Al-Shueili, A. A. M. (2014). *Financial sustainability of the water sector in the Sultanate of Oman* (Doctoral dissertation, © Al Shueili, AAM 2014).

Ambituuni, A. (2016). *A risk management framework for downstream petroleum product transportation and distribution in Nigeria* (Doctoral dissertation, Newcastle University).

Arnell, N. W. (2004). Climate change and global water resources: SRES emissions and socio-economic scenarios. *Global environmental change*, *14*(1), 31-52.

Australian Standards (2000). Australian Standards, *Sydney*. http://www.standards.org.au.

Australian Standards (2003). Australian Standards, *Sydney*. http://www.standards.org.au.

Bacchi, C. (2000). Policy as discourse: What does it mean? Where does it get us?. *Discourse: studies in the cultural politics of education*, *21*(1), 45-57.

Baker, T. L. (1988). Doing social research. *McGraw-Hill College*.

Balbin, M., Tansel, B., & Lee, M. (2010). Effectiveness of Miami-Dade water use efficiency program senior retrofit project: comparative analysis of water consumption rates and savings. *The Florida Water Resources Journal*, 62(8), 14-15.

Baskerville, R. (1991). Risk analysis as a source of professional knowledge. *Computers & Security*, *10*(8), 749-764.

Baumann, D. D. (1998). Urban water demand management and planning. *McGraw-Hill Professional Publishing*.

Beal, C., Stewart, R., Huang, T., & Rey, E. (2011). *South East Queensland residential end use study*. Brisbane, Australia: Urban Water Security Research Alliance.

Berlin, I. (1953). *The Hedgehog and the Fox*: *An Essay on Tolstoy's View of History*. By George L. Kline.

Bryman, A. (2008). *Social Research Methods* (3rd edn.) Oxford University Press.

Bryman, A. & Bell, E. (2007). *Business Research Methods*. Oxford University Press.

Bryman, A. & Bell, E. (2011). *Business Research Methods*. Oxford University Press.

Casanova, L. M., Little, V., Frye, R. J., & Gerba, C. P. (2001). A SURVEY OF THE MICROBIAL QUALITY OF RECYCLED HOUSEHOLD GRAYWATER 1. *JAWRA Journal of the American Water Resources Association*, *37*(5), 1313-1319.

Cavana, R. Y., Delahaye, B. L., & Sekaran, U. (2001). *Applied business research: Qualitative and quantitative methods*. John Wiley & Sons Inc.

Cheng, C. L., & Hong, Y. T. (2004). Evaluating water utilization in primary schools. *Building and Environment*, *39*(7), 837-845.

Chen, Y., Zhang, D., Sun, Y., Liu, X., Wang, N., & Savenije, H. H. (2005). Water demand management: a case study of the Heihe River Basin in China. *Physics and Chemistry of the Earth, Parts A/B/C, 30*(6-7), 408-419.

Clarke, A., Grant, N., Thornton, J., & Solutions, E. (2009). Quantifying the energy and carbon effects of water saving. *Environment Agency*.

Cooley, H., Christian-Smith, J., Gleick, P. H., Cohen, M. J., Heberger, M., Ross, N., & Luu, P. (2010). California’s next million acre-feet: saving water, energy, and money. *Pacific Institute, Oakland, September*.

Corr, K., Adams I. and Boynton D. (2009). *Water use and sustainable commercial buildings, Your Building*, Australia.

Creswell, J. W., & Creswell, J. D. (2017). Research design: Qualitative, quantitative, and mixed methods approaches. *Sage publications*.

Dainty, A. (2008). Methodological pluralism in construction management research. *Advanced research methods in the built environment*, *1*, 1-13.

Davidová, M., & Horváthová, P. (2015). *15th International Multidisciplinary Scientific Geoconference and EXPO, SGEM 2015*; Albena; Bulgaria; 18 June 2015.

Darwish, M. (2014). Qatar water problem and solar desalination. *Desalination and Water Treatment*, *52*(7-9), 1250-1262.

Dawson, T. (2002). Practical research methods: *New Delhi*: UBS. Publishers Distributors, India.

Denzin, N. K., & Lincoln, Y. S. (2008). *Collecting and interpreting qualitative materials (Vol. 3)*. Sage.

Department of the Environment & Heritage (2006c). Water efficiency labelling and standards (_WELS) scheme. Discourse: *Studies in the Cultural Politics of Education*, 21(1), 45-57.

Dixon, A., Butler, D., Fewkes, A., & Robinson, M. (2000). Measurement and modelling of quality changes in stored untreated grey water. *Urban Water*, 1(4), 293-306.

Dolnicar, S., Hurlimann, A., & Grün, B. (2012). Water conservation behavior in Australia. *Journal of environmental management*, 105, 44-52.

Droogers, P., Immerzeel, W. W., Terink, W., Hoogeveen, J., Bierkens, M. F. P., Van Beek, L. P. H., & Debele, B. (2012). Water resources trends in Middle East and North Africa towards 2050. *Hydrology and Earth System Sciences*, *16*(9), 3101-3114.

Easterby-Smith, M., Thorpe, R. & Lowe, A. (2002). *Management Research: An Introduction. 2nd ed*. Sage Publications. London.

Edwards, K., & Martin, L. (1995). A methodology for surveying domestic water consumption. *Water and Environment journal, 9*(5), 477-488.

E'haqi, N., & Al-Khaddar, R. (2015). Water Sustainability Needs a Sustainable Community: Water Knowledge and Awareness Assessment in the Kingdom of Bahrain. *School of Built Environment,* Liverpool John Moores University (LJMU).

EPA (2017). Washington, DC. *Drinking Water Contaminants* – Standards and Regulations.

Eriksson, E., Auffarth, K., Eilersen, A. M., Henze, M., & Ledin, A. (2003). Household chemicals and personal care products as sources for xenobiotic organic compounds in grey wastewater. *Water Sa*, *29*(2), 135-146.

EU's, (2017). *Drinking water standards*. Council Directive 98/83/EC on the quality of water intended for human consumption. Off J Eur Commun L, 330. Adopted by the Council, on 3 November 1998:

Farina, M., Maglionico, M., Pollastri, M., & Stojkov, I. (2011). Water consumptions in public schools. *Procedia Engineering*, 21, 929-938.

Fellows, R. F., & Liu, A. M. (2016). *Research methods for construction*. John Wiley & Sons.

Fidar, A., Memon, F. A., & Butler, D. (2010). Environmental implications of water efficient microcomponents in residential buildings. *Science of the total environment*, *408*(23), 5828-5835.

Fidar, A. M., Memon, F. A., & Butler, D. (2016). Performance evaluation of conventional and water saving taps. *Science of The Total Environment*, 541, 815-824.

Fidar, A. M., Memon, F. A., & Butler, D. (2017a). Economic implications of water efficiency measures I: assessment methodology and cost-effectiveness of micro-components. *Urban Water Journal*, *14*(5), 522-530.

Fidar, A. M., Memon, F. A., & Butler, D. (2017b). Economic implications of water efficiency measures II: cost-effectiveness of composite strategies. *Urban Water Journal*, *14*(5), 531-538.

Franklin, M. I. (2012). *Understanding research: Coping with the quantitative-qualitative divide.* Routledge.

Galliers, R. D. (1991). Choosing appropriate information systems research methods. *Information systems research*: contemporary approaches and emergent traditions.

Garcia, X., & Pargament, D. (2015). Reusing wastewater to cope with water scarcity: Economic, social and environmental considerations for decision-making. *Resources, Conservation and Recycling*, 101, 154-166.

Given, L. M. (Ed.). (2008). *The Sage encyclopedia of qualitative research methods*. Sage publications.

Glazer, R. (1991). Marketing in an information-intensive environment: strategic implications of knowledge as an asset. *Journal of marketing, 55*(4), 1-19.

Grant, N., & Howarth, D. (2003). *The economics of water efficient products in the household*. In Advances in Water Supply Management (pp. 592-601). CRC Press.

Guba, E. G. (1984). The Effect of Definitions of" Policy" on the Nature and Outcomes of Policy Analysis. *Educational leadership, 42*(2), 63-70.

Hartman, R. S. (2011). *The structure of value: Foundations of scientific axiology*. Wipf and Stock Publishers.

Hinkelmann & Witschel (nd). *Presentation slides on research methodology*. University of applied sciences North Western Switzerland. School of Business.

Hodges, D. (1998). Safe use of household greywater. *Water & Environment Manager, 3*(6), 15-17.

Horne, J. (2016). Policy issues confronting Australian urban water reuse. *International Journal of Water Resources Development, 32*(4), 573-589.

Howard, G., Bartram, J., Water, S., & World Health Organization. (2003). *Domestic water quantity, service level and health (No. WHO/SDE/WSH/03.02)*. Geneva: World Health Organization.

Hyder Consulting (2005). *Alternative urban water supplies: regulatory review technical summary report, Report prepared by Hyder Consulting, Melbourne*: Victorian Government.

Jagerskog, A., Granit, J., Lofgren, R., Weyler, E., Ullock, A., Gooijer, G. & Pettigrew, S. (2009). *Water resources in the Middle East*. Water and Energy Linkages in the Middle East.

Jamrah, A., Al-Futaisi, A., Prathapar, S., & Al Harrasi, A. (2008). Evaluating greywater reuse potential for sustainable water resources management in Oman. *Environmental monitoring and assessment, 137*(1-3), 315.

Jamrah, A., Futaisi, A., Harrasi, A., & Al-Qasem, L. (2004). *Assessment of Grey Water Characteristics and Potential for Reuse in Agriculture*. In Proceedings of the International Conference on Water Management.

Jamrah, A., Al-Omari, A., Al-Qasem, L., & Ghani, N. A. (2006). Assessment of availability and characteristics of greywater in Amman. *Water international, 31*(2), 210-220.

Jasim, S. Y., Saththasivam, J., Loganathan, K., Ogunbiyi, O. O., & Sarp, S. (2016). Reuse of treated sewage effluent (TSE) in Qatar. *Journal of Water Process Engineering, 11*, 174-182.

Jenkins, B. (1997). *Policy analysis: Models and approaches*. The policy process: A reader, 2.

Jeppesen, B. (1996). Domestic greywater re-use: Australia's challenge for the future. *Desalination, 106*(1-3), 311-315.

Kayaga, S., & Smout, I. (2007). *Water demand management: A key building block for integrated resource planning for the city of the future*. In First SWITCH Scientific Meeting, Univ. of Birmingham, UK.

Kayaga, S., & Smout, I. (2011). Water demand management in the city of the future: selected tools and instruments for practitioners. *Water demand management in the city of the future: selected tools and instruments for practitioners.*

Kayaga, S., & Smout, I. K. (2014). Tariff structures and incentives for water demand management.

Kenney, D. S., Goemans, C., Klein, R., Lowrey, J., & Reidy, K. (2008). Residential water demand management: lessons from Aurora, Colorado 1. JAWRA. *Journal of the American Water Resources Association, 44*(1), 192-207.

Kimwaga, R. J. (2014). Characterization of greywater and its implication for reuse: a case study of peri-urban and unplanned areas. *International Journal of Ecology and Development, 28*(2), 79-86.

Knight, M. J., Tomlin, J. S., Paffard, A. R., & Nicol, R. A. (2000). *Potential of greywater reuse for irrigating household land in Sydney and Brisbane*. In 10th World Water Congress: Water, the Worlds Most Important Resource (p. 921). International Water Resources Association.

Lee, M., Tansel, B., & Balbin, M. (2011). Influence of residential water use efficiency measures on household water demand: A four year longitudinal study. *Resources, Conservation and Recycling, 56*(1), 1-6.

Lee, M., Tansel, B., & Balbin, M. (2011). Goal based water conservation projections based on historical water use data and trends in Miami-Dade County. *Sustainable Cities and Society, 1*(2), 97-103.

Levin, M. H., Olson, B. R. U. C. E., Nathan, C., Kabins, S. A., & Weinstein, R. A. (1984). Pseudomonas in the sinks in an intensive care unit: relation to patients. *Journal of clinical pathology*, *37*(4), 424-427.

Li, F., Wichmann, K., & Otterpohl, R. (2009). Review of the technological approaches for grey water treatment and reuses. *Science of the total environment*, *407*(11), 3439-3449.

Lodge, B. N., Seager, T., Stephenson, T., English, P. H., & Ford, R. (2000). A water recycling plant at the Millennium Dome. In *Proceedings of the Institution of Civil Engineers-Civil Engineering* (Vol. 138, No. 5, pp. 58-64). Thomas Telford Ltd.

Mayer, P. W., DeOreo, W. B., Opitz, E. M., Kiefer, J. C., Davis, W. Y., Dziegielewski, B., & Nelson, J. O. (1999). Residential end uses of water.

McConville, J. R., Kvarnström, E., Jönsson, H., Kärrman, E., & Johansson, M. (2017). Source separation: challenges & opportunities for transition in the Swedish wastewater sector. *Resources, Conservation and Recycling*, *120*, 144-156.

Melnychuk, N., Jatel, N., & Warwick Sears, A. L. (2017). Integrated water resource management and British Columbia’s Okanagan Basin Water Board. *International Journal of water resources development*, *33*(3), 408-425.

Millock, K., & Nauges, C. (2010). Household adoption of water-efficient equipment: the role of socio-economic factors, environmental attitudes and policy. *Environmental and Resource Economics*, *46*(4), 539-565.

Mimi, Z. A. (1999). *Water resources and water demand management for arid and semi-arid areas: West Bank as a case study* (Doctoral dissertation, © Ziad A. Mimi).

Mitchell, C., & White, S. (2003). Sustainable Urban Water Service Systems. In Innovations in Water: *Ozwater Convention & Exhibition*, Perth (pp. 6-10).

Moosa, A. (2005). Muscat area. September 15, 2005, *accessed through web site: http://www.moneoman.gov.om/mone/ generalinfo.htm*

Nolde, E. (2000). Greywater reuse systems for toilet flushing in multi-storey buildings–over ten years experience in Berlin. *Urban water*, *1*(4), 275-284.

NSW Health (2000). *Greywater re-use in sewered single domestic premises*, Sydney: NSW Health.

OECD. (2002). The Measurement of Scientific and Technological Activities Frascati Manual 2002: *Proposed Standard Practice for Surveys on Research and Experimental*

Development. Cambridge University Press.

OFWAT (2011). *Your Water and Sewerage Bill*.

Olmstead, S. M., & Stavins, R. N. (2009). Comparing price and nonprice approaches to urban water conservation. *Water Resources Research, 45*(4).

Otterpohl, R. (2002). Options for alternative types of sewerage and treatment systems directed to improvement of the overall performance. *Water science and technology, 45*(3), 149-158.

Patton, M. Q. (1990). *Qualitative evaluation and research methods*. SAGE Publications, inc.

Postel, S. L., Daily, G. C., & Ehrlich, P. R. (1996). Human appropriation of renewable fresh water. *Science, 271*(5250), 785-788.

Prathapar, S. A., Ahmed, M., Al Adawi, S., & Al Sidiari, S. (2004). *Variation in quality and quantity of greywater produced at two mosques in Oman*. In Proceedings of the International Wastewater Conference, Salalah, Oman.

Prathapar, S. A., Jamrah, A., Ahmed, M., Al Adawi, S., Al Sidairi, S., & Al Harassi, A. (2005). Overcoming constraints in treated greywater reuse in Oman. *Desalination, 186*(1-3), 177-186.

Presentation slides on research methodology by Manchester University, UK *http://www.methods.manchester.ac.uk/events/whatis/archival.pdf*

PAEW (2015). *Public Authority of electricity and water*. Annual Report Sultanate of Oman.

PAEW (2016). *Public Authority of electricity and water*. Annual Report Sultanate of Oman.

PAEW (2018). *Public Authority of electricity and water*. Annual Report Sultanate of Oman.

Qing, L., Chen, Z., Yang, X., Zhang, Z., & Zou, Y. (2015). Change of water sources reduces health risks from heavy metals via ingestion of water, soil, and rice in a riverine area, South China. *Science of the Total Environment, 530*(531), 163-170.

Rahman, A., Muneer, M., Kaamin, M., Mohamad, M. A. H., Omar, M., & Hanif, M. (2016). ReWudhuk: A Sustainable Device to Reuse Musta'mal Water for Ablution Purpose. *Advanced Science Letters, 22*(9), 2170-2173.

Randolph, B., & Troy, P. (2008). Attitudes to conservation and water consumption. *Environmental science & policy, 11*(5), 441-455.

Reidy, K., Tejral, J., Aurora (2008). Water conservation annual report. City of Aurora Government; 2011. *https://www.auroragov.org/stellent/groups/public/documents/articlepublication/035857*

Robson, C. (2002). *Real World Research A Resource for Social Scientists and Practitioners-Researchers*. 2nd ed. Blackwell Publishers. Oxford, UK.

Sapsford, R. (2007). Survey research. 2nd ed. London: Sage Available as an e-book via the Library catalogue: *http://prism.talis.com/derby-ac/*

Saunders, M., Lewis, P. & Thornhill, A. (2012). *Research Methods for Business Students.*

Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research methods for business students. Essex*. Financial Times/Prentice Hall.

Savewater (2006). Water conservation in the home. *http://savewater.com.au*.

Savić, D., Vamvakeridou-Lyroudia, L., & Kapelan, Z. (2014). Smart meters, smart water, smart societies: The iWIDGET project. *Procedia Engineering*, *89*, 1105-1112.

Schneider, A., & Ingram, H. (1993). Social construction of target populations: Implications for politics and policy. *American political science review*, *87*(2), 334-347.

Scott, P., Tayler, B., & Walters, D. (2017). Lessons from implementing integrated water resource management: a case study of the North Bay-Mattawa Conservation Authority, Ontario. *International journal of water resources development*, *33*(3), 393-407.

Sekaran, U., & Bougie, R. (2016). *Research methods for business: A skill building approach*. John Wiley & Sons.

Sheikh, B. (1993). The city of Los Angeles gray water pilot project shows safe use of gray water is possible. *In Water Management in the'90s*: A Time for Innovation (pp. 678-681). ASCE.

Shields, P. M., & Rangarajan, N. (2013). *A playbook for research methods: Integrating conceptual frameworks and project management*. New Forums Press.

Shields, P. M., & Tajalli, H. (2006). Intermediate theory: The missing link in successful student scholarship. *Journal of public affairs education, 12*(3), 313-334.

Smout, I. K. (2013). Strategic planning for water security in developing countries.

Smout, I., Kayaga, S., & Muñoz-Trochez, C. (2008, November). Financial and economic aspects of water demand management in the context of integrated urban water management. In *3rd SWITCH Scientific Meeting*.

Sountharajah, D. P., Kus, B., Kandasamy, J., & Vigneswaran, S. (2017). Quantifying the reduction in water demand due to rainwater tank installations at residential properties in sydney. *Journal of Sustainable Development of Energy, Water and Environment Systems, 5*(2), 202-218.

Suratkon, A., Chan, C. M., & Ab Rahman, T. S. T. (2014). SmartWUDHU': Recycling Ablution Water for Sustainable Living in Malaysia. *Journal of Sustainable Development, 7*(6), 150.

Surendran, S., & Wheatley, A. D. (1998). Grey-water reclamation for non-potable re-use. *Water and Environment Journal, 12*(6), 406-413.

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research techniques*. Thousand Oaks, CA: Sage publications.

Tam, V. W. Y., Shen, L. Y., & Tam, C. M. (2000). The practices of implementing governmental control in managing construction wastes in Hong Kong. *Proceedings of CIBW107*, 11-13.

Tate, D. M. (1990). Water Demand Management in Canada: A State of the Art Review. *Social Science Series No. 23. Inland Waters Directorate*. Technical Advisory Committee (TAC) (2000). Global Water Partnership: GWP Secretariat, concerned with the management of water demand.

Tim, D., Reuben, I., Nikhil, A., & Mark, R. (2007). Recycling: Cost Benefit Analysis. *Covec Ltd*, 1-74.

Trochim, W. M., Marcus, S. E., Mâsse, L. C., Moser, R. P., & Weld, P. C. (2008). The evaluation of large research initiatives: a participatory integrative mixed-methods approach. *American Journal of Evaluation, 29*(1), 8-28.

Tsai, Y., Cohen, S., & Vogel, R. M. (2011). The Impacts of Water Conservation Strategies on Water Use: Four Case Studies 1. JAWRA. *Journal of the American Water Resources Association, 47*(4), 687-701.

Turner, A., White, S., Beatty, K., & Gregory, A. (2005). Results of the largest residential demand management program in Australia. *Water Science and Technology: Water Supply, 5*(3-4), 249-256.

United Nations (2015). Sustainable Development Goals: 17 Goals to Transform Our World. *United Nations Sustainable development knowledge platform.* The Sustainable Development Goals Report, July 29, 2015.

UN-Water (2011). *A Water Toolbox or Best Practice Guide of Actions*. A Contribution from UN-Water Conference on ' Water in the Green Economy in Practice towards Rio + 20' Compiled by the UN-Water Decades Program Advocacy and Communication (UNW-DPAC).

UNEP (2003). United Nations Environment Programme – Division of Technology, Industry and Economics International Environmental Technology Centre (UNEP – DTIE – IETC*).* *http://www.unep.or.jp/*

US Environment Protection Agency (1999). Water efficiency technology fact sheets: composting toilets, Washington DC: US EPA.

Veale, B., & Cooke, S. (2017). Implementing integrated water management: illustrations from the Grand River watershed. *International journal of water resources development*, *33*(3), 375-392.

Venkatesh, T., & Senthilmurugan, S. (2017). Grey water treatment and simultaneous surfactant recovery using UF and RO process. *Separation Science and Technology*, *52*(14), 2262-2273.

WAWA (1993). *What is in wastewater? Wastewater 2040*. Perth, Australia: Water Authority of Western Australia.

Wertz, F. J. (2011). A phenomenological psychological approach to trauma and resilience. *Five ways of doing qualitative analysis: Phenomenological psychology, grounded theory, discourse analysis, narrative research, and intuitive inquiry*, 124-164.

White, S. (2001). Demand management and integrated resource planning in Australia. *Efficient Use and Management of Water for Urban Supply*, *20018*.

Wood, W. W., & Alsharhan, A. S. (Eds.). (2003). *Water resources perspectives: evaluation, management and policy* (Vol. 50). Elsevier.

World Health Organization (2006). *Guidelines for Drinking-water Quality*. First Addendum to Third Edition.
http://www.who.int/water_sanitation_health/dwq/gdwq0506.pdf.

Willis, R. M., Stewart, R. A., Panuwatwanich, K., Jones, S., & Kyriakides, A. (2010). Alarming visual display monitors affecting shower end use water and energy conservation in Australian residential households. *Resources, Conservation and Recycling, 54*(12), 1117-1127.

Willis, R. M., Stewart, R. A., Giurco, D. P., Talebpour, M. R., & Mousavinejad, A. (2013). End use water consumption in households: impact of socio-demographic factors and efficient devices. *Journal of Cleaner Production, 60*, 107-115.

Yin, R. (2003). K. (2003). *Case study research: Design and methods*. Sage Publications, Inc, 5, 11.

Yin, R. K. (2014). Case study research: Design and methods.

Young, R. E., & Holiman, T. R. (1990). *Reclaimed water in high rise office buildings*. Proc. of Conservation of Water, 90.

Zehnder, A. J., Yang, H., & Schertenleib, R. (2003). Water issues: the need for action at different levels. *Aquatic sciences, 65*(1), 1-20.

Zikmund, W. G., Babin, B. J., Carr, J. C., & Griffin, M. (2010). Business Research Methods, Eight Edition. *Canada, South Western Cengage Learning*.

Zubari, W. (2004a). GCC Water Resources Perspective: Evaluation, Management, Policies, and Cooperation. In: *Proceedings of Water Middle East 2nd International Exhibition and Conference for water Technology*: Manama, Kingdom of Bahrain 13 - 15 September.

Appendices

Appendix A: Draft of research instruments

A1. Focus group interview with users

Introduction

Good morning/afternoon and welcome to our session. Thanks for taking the time to join us in a talk about water demand management in mosques in our country. My name is Aliya Ali Al-Alawi Ph.D. student from Loughborough University. The aim of this research is to identify ways to manage water demand in mosques in GCC by knowing what your needs are, what practices you follow, and what your opinions are with regard to water demand management and recycling or reusing. We are having discussions like this with several groups around the county in different mosques. You were invited because you are using the mosque which has been taken as the case study site, so you're familiar with what saving practices, appliances, techniques are applied in the mosque, and you all live in this section of the county. There are no wrong answers but rather different points of view. Please feel free to share your point of view even if it differs from what others have said. Keep in mind that we're just as interested in negative comments as positive comments, and at times the negative comments are the most helpful. You've probably noticed the microphone. We are recording the session because we don't want to miss any of your comments. People often say very helpful things in these discussions, and we can't write fast enough to get them all down. We will be on a first-name basis today, and we won't use any names in our reports study. I can assure you that everything you say will be treated in the strictest confidence; you will not be individually identified, and your responses will only be used for research purposes. Well, let's begin. We've placed name cards on the table in front of you to help us remember each other's names. Let's find out some more about each other by going around the table. Tell us your name, age, education level and type of profession. To what extent do you think, water demand management is important? **(Sub-question 1.1)**

Do you think water demand in Oman needs improvement in management? **(Sub-question 1.1)**

If yes;

What kind of improvement do you suggest? **(Sub-question 1.1)**

Which of the following most describes water in mosques? **(Sub-question 3.2)**

a. Not at all environmentally friendly
b. Not very environmentally friendly
c. Environmentally friendly in some ways
d. Fairly environmentally friendly
e. Very environmentally friendly
f. Don't know

What comes to your mind when you hear the term ‘water demand management in mosques‘? **(Sub-question 1.1)**

What are the consumers water needs when performing ablution in mosques? **(Sub-question 2.1)**

What are consumer’s water behaviours when performing ablution in mosques? **(Sub-question 2.2)**

How to achieve efficient use of water? **(Sub-question 1.1)**

Do you think there are roles that could be played with users of water in the mosque to increase the chance of water demand management in mosques? What are those roles?

Do you accept reusing (same water without treatment) or recycling (doing some treatment) ablution water in mosques for flushing toilets and irrigation**? (Sub-question 3.2)**

How would you describe yourself regarding water use? Example? **(Sub-question 2.2)**

To what extent do you agree or disagree with each of the following statements?

a. It is difficult to reduce the amount of water used in the mosque **(Sub-question 3.2)**
b. I have never thought much about the amount of water I use in mosques **(Sub-question 2.2)**
c. I think people use more water than they need to do ablution (wudu) in the mosque (**Sub-question 2.1)**
d. I try to save on my water bill by using water outside the home, for example, by showering at work or at the gym, or taking the car to a car wash or doing ablution in mosques. **(Sub-question 2.2)**
e. I am satisfied with the facilities I received from mosques. **(Sub-question 2.1)**

I’m now going to read out a list of behaviours and I’d like you to tell me how often you personally do each of these to save water. Please be as accurate in your answers as possible and remember that this is confidential. **(Sub-question 2.2)**

a. Turn off and on the tap when doing ablution.
b. Limit the amount of time spent in the ablution.
c. Leave the toilet unflushed.
d. Close the tap after finishing

From what you know, would you say that others in the mosques do these things more or less often than you do yourself? **(Sub-question 2.2)**

a. Open the tap continuously without turning it off and on when performing ablution.

b. Do not limit the amount of time spent in the ablution.
c. Leave the toilet unflushed.
d. Leave the tap open.

Thinking about how you spend water during ablution or how you use water, would you say that you use water more or less in comparison to when you were younger? Why? **(Sub-question 2.2)**

To what extent do you agree or disagree with each of the following statements? **(Sub-question 3.2)**

a. In Oman, we are not interested enough in saving water.
b. The government needs to implement water restrictions for water management in mosques.
c. It is important to protect our natural environment.
d. Using less water is good for the environment.
e. I live in an area that is likely to drought.
f. There is wastage of water in mosques.
g. The water companies should work more on water recycling in the mosque.

Of all the things we discussed, what to you think is the most important?

As I mentioned at the beginning, the aim of this research is to identify ways to manage water demand in mosques in GCC by knowing what your needs are, what are your practices, and what are your opinions in regard of water reusing or recycling and your opinions in regard of water demand management in general.
Final question
Have we missed anything?

Thanks for taking the time to join us to talk about water demand management in mosques.

A2. Interview questions: with policymakers and mosque management

Introduction
Good morning/afternoon. My name is Aliya Ali Al-Alawi, Ph.D. student from Loughborough University. I'm carrying out a 20-minute survey today on Water Demand Management in mosques. Could you spare the time to answer a few questions? I can assure you that everything you say will be treated in the strictest confidence; you will not be individually identified, and your responses will only be used for research purposes.
Work title:
Educational level:
Work experience:

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1. What are the current water-saving practices, rules and policies applied by the government of Oman? **(Sub-question 1.1)**

2. What are policies on water demand management, measures, and techniques in Oman? **(Sub-question 1.1)**
In plumbing:
In appliances:
In recycling for irrigation and flushing toilet:
In reusing for irrigation and flushing toilet:

3. What are the current tools, appliances, and techniques applied in mosques? **(Sub-question 1.2)**
Specification of the appliances (tap, WC, irrigation system)
Techniques applied in mosques:

4. Do you have any information or test result on total water consumption in ablution per capita? **(Sub-question 1.3)**

5. Do you have any information or test results of total water consumption for landscape irrigation and for WC toilet flushing? **(Sub-question 1.4)**

6. What are effective WDM techniques, tools, and behaviours that are compatible with the needs of water consumers in mosques? **(Sub-question 2.3)**
Effective WDM techniques:
Effective WDM tools:
Effective WDM behaviours:

7. What are effective water demand management policies and measures and techniques? **(Sub-question 2.3)**

8. What are the policies of recycling water for irrigation? **(Sub-question 3.1)**

9. What are the policies of reusing water for irrigation? **(Sub-question 3.1)**

10. What are the policies of recycling water for flushing toilets? **(Sub-question 3.1)**

11. What are the policies of reusing water for flushing toilets? **(Sub-question 3.1)**

12. Do water policies makers accept recycling water in mosques for landscape? If no, why? **(Sub-question 3.2)**

13. Do water policies makers accept reusing water in mosques for landscape? If no, why? **(Sub-question 3.2)**

14. Do water policies makers accept recycling water in mosques for flushing toilet? If no, why? **(Sub-question 3.2)**

15. Do water policies makers accept reusing water in mosques for flushing toilet? If no, why? **(Sub-question 3.2)**

16. What is a number of users of water in mosques every day? **(Sub-question 3.3)**

17. Is there water meter in all mosques in Oman? **(Sub-question 3.3)**

18. Who pays the mosques' water bills? **(Sub-question 3.3)**

19. Who is responsible for mosques management in Oman? **(Sub-question 3.3)**

A3. Interview questions with Engineers

Introduction
Good morning/afternoon. My name is Aliya Ali Al-Alawi Ph.D. student from Loughborough University. I'm carrying out a 20-minute survey today on Water Demand Management in mosques. Could you spare the time to answer a few questions? I can assure you that everything you say will be treated in the strictest confidence; you will not be individually identified, and your responses will only be used for research purposes.

Work title:
Educational level:
Work experience in the water field:

What are the current water-saving practices applied by the government of Oman? **(Sub-question 1.1)**

What are the current tools, appliances, techniques and policies applied in mosques? **(Sub-question 1.2)**

Tools	techniques	Appliances specification (WC, tap, irrigation system)	Policies
1.			
2.			
3.			
4.			

What are the appropriate water-saving tools, appliances, techniques, and policies? **(Sub-question 2.3)**

Tools	techniques	Appliances specification (WC, tap, irrigation system)	Policies

What are effective water demand management policies? **(Sub-question 2.3)**

What is your opinion on the idea of recycling water in mosques for flushing toilet and landscape? **(Sub-question 3.2)**

What is your opinion on the idea of reusing water in mosques for flushing toilet and landscape? **(Sub-question 3.2)**

Do you have any information if the water quality of reusing ablution water is suitable for flushing toilet and landscape? **(Sub-question 3.1)**

I need to recycle ablution water in the mosque. What is the suitable treatment required? **(Sub-question 3.1)**

Do you think reusing or recycling ablution water in mosques for flushing toilet and landscape will reduce water demand in the mosque? Why? **(Sub-question 3.2 and 3.3)**

Appendix B: Tables of consumption data collection

B1. First mosque

Table 1.1 Water consumption in ablution with users in first Jama

Users code in Al-Ameen mosque	Minutes	Litres for ablution	Litres of water from last tach of tap	Number of pushes
1	00:49.77	3.5	3.5	2
2	00:54.34	4.1	5.2	3
3	00:48.85	3.8	4.9	3
4	1:00.89	4.9	5.2	3
5	00:42.92	3.1	3.5	2
6	1:12.26	5.2	5.5	4
7	00:50.12	3.5	3.5	2
8	00:45.34	3.4	3.8	2
9	1:01.12	4.5	4.5	3
10	00:53.61	4.1	4.8	3
1	00:49.00	3.5	3.8	3
2	00:58.33	4.3	5.2	3
3	00:48.85	3.8	4.9	3
4	1:00.89	4.9	5.2	3
5	00:47.92	3.5	3.8	3
6	1:13.20	5.4	5.5	4

7	00:50.10	3.5	3.5	2
8	00:43.33	3.3	3.8	2
9	00:60.60	4.5	4.5	3
10	00:52.59	4.1	4.8	3

Table 1.2 Flow per litres and time taken for one push of ablution tap in first Jama

Time	Flow per one push
00:17.54	1.2
00:16.47	1.1
00:13.27	0.9
00:17.16	1.2
00:16.92	1.2

Table 1.3 Four reading were taking in 47:00 seconds in first Jame

00:47.00 seconds	Litres	Number of pushes
	3.8	3
	3.8	3
	3.7	2
	3.8	3

Table 1.4 Reading for time per one flush in first mosques

Time per one flush	Litres per one flush
00:07.02	8L
00:07.15	8L
00:07.00	8L

Table 1.5 Reading for time taking to reach half (0.7L) and full (1.4L) of the bottle in first mosque from toilet tap

Toilet tap	Time	Litres
Half	00:08.02	0.7
Half	00:08.20	0.7
Full	00:10.50	1.4
Full	00:11.60	1.4

Note: (High Pressure) half of it is more than enough

B2. Second mosque

Table 2.1 Water consumption in ablution with users in second Jame

Users code in first mosque	Minutes	Litres	Litres of water from last touch of tap	number of touches
1	1:31.00	7.2	7.7	7
2	1:19.00	5.8	6.5	5
3	1:15.00	5.5	5.5	4
4	1:00.17	4.9	5.2	3
5	1:28.01	6.3	6.5	5
6	1:20.18	5.8	6.5	5
7	1:10.00	5.1	5.2	3
8	00:59:20	4.2	5.2	3
9	00:59.16	4.2	5.2	3
10	1:25.02	6.0	6.5	5
1	1:10.00	5.1	5.2	3
2	1:00.12	4.3	5.2	3
3	1:20.06	5.9	6.4	5
4	1:00.20	4.9	5.2	3
5	00:59.12	4.2	5.3	3
6	1:18.00	5.7	6.4	5
7	1:10.02	5.1	5.5	4
8	1:00.14	4.2	5.2	3
9	00:59.14	4.2	5.2	3
10	1:18.12	5.9	6.5	5

Table 2.2 Flow per litres and time taken for one push of ablution tap in second Jame

Time	Flow per L for one sensor touch
00:12.60	0.6
00:10.74	0.6
00:10.82	0.6
00:11.00	0.6
00:11.00	0.6

Table 2.3 Four reading were taking in 47:00 seconds in second Jame from ablution tap with number of touches in tap no.1

00:47.00 seconds	Litres	Number of touches
	2.4	4
	2.7	4
	2.8	4
	2.6	4

Table 2.4 Four reading were taking in 47:00 seconds in second Jame from ablution tap with number of touches in tap no.2

00:47.00 seconds	Litres	Number of touches
	3.9	2
	3.6	2
	3.6	2
	3.5	2

Table 2.5 Reading for time taken per one flush in second Jame

Time per one flush	Litres per one flush
00:10.30	8L
00:09.60	8L
00:09.40	8L

Table 2.6 Reading for time taking to reach half (0.7) and full (1.4) of the bottle in second Jame from toilet tap

Toilet tap	Time	Litres
Half	00:06.82	0.7
Half	00:06.90	0.7
Full	00:10.50	1.4
Full	00:11.69	1.4

Note: (High Pressure) half of it enough

B3. Third mosque

Table 3.1 Water consumption in ablution with users in third Jame

Users code in third mosque	Minutes	Litres for ablution	Litres of water from last touch of tap
1	0:56.42	1.9	2.5
2	1:15.32	2.6	3.1
3	1:29.32	3.0	3.2
4	1:45.50	3.6	4.0
5	1:13.00	2.7	2.7
6	1:26.16	3.3	3.3
7	1:26.02	3.3	3.3
8	1:37.87	3.8	4.0
9	1:28.37	3.6	3.6
10	1:28.77	3.6	3.7
1	0:59.20	2.3	2.5
2	1:20.22	2.9	3.1
3	1:33.00	3.2	3.2
4	1:50.00	3.8	4.0
5	1:13.05	2.7	2.7
6	1:26.06	3.3	3.3

7	1:26.04	3.3	3.3
8	1:50.08	3.8	4.0
9	1:28.30	3.6	3.6
10	1:28.25	3.6	3.6

Table 3.2 Flow per litres and time taken for one push of ablution tap in third Jame

Time	Flow per one sensor touch
00:17.40	0.6
00:15.54	0.6
00:15.10	0.6
00:15.63	0.6
00:15.76	0.6
00:15.76	0.6

Table 3.3 Reading for time per one flush in third Jame

Time per one flush	Litres per one flush
00:09.00	20L
00:09.10	20L
00:09.00	20L

Note: stay for very long time with very high pressure

Table 3.4 Reading for time taking to reach half (0.7) and full (1.4) of the bottle in third Jame from toilet tap

Toilet tap	Time	Litres
Half	00:06.72	0.7
Half	00:06.80	0.7
Full	00:09.15	1.4
Full	00:09.20	1.4

Note: (High Pressure) half of it is enough

B4. Fourth mosque

Table 4.1 Water consumption in ablution with users in fourth Jame

Users code in	Minutes	Litres for ablution	Way
1	0:58.02	2.8	Continuous
2	0:31.36	1.3	Continuous
3	0:38.22	3.7	Continuous
4	1:11.50	4.9	Continuous
5	01:07.41	2.7	Continuous
6	01:05.26	2.6	Continuous
7	0:36.17	1.5	Continuous
8	0:35.60	1.5	Continuous
9	1:00.90	3.4	Continuous
10	1:06.56	3.9	Continuous
1	0:50.20	2.00	Continuous
2	0:32.30	1.3	Continuous
3	0:40.22	4.0	Continuous
4	1:10.50	4.0	Continuous
5	01:05.20	2.6	Continuous
6	01:06.25	2.6	Continuous
7	0:35.15	1.3	Continuous

8	0:35.40	1.5	Continuous
9	1:20.90	3.4	Continuous
10	1:20.50	3.9	Continuous

Table 4.2 Four reading in 47:00 seconds in fourth Jame from ablution tap with number of ways of opening

00:47 seconds	Litres	Way of opening tap
	4.8	more than half
	3.4	Less than half
	1.9	Quarter
	3.4	Less than half

Table 4.3 Reading for time per one flush in fourth Jame

Time per one flush	Litres per one flush
00:04.60	5L
00:05.02	5L
00:05.47	5L

Table 4.4 Reading for time taking to reach half (0.7) and full (1.4) of the bottle in fourth Jame from toilet tap

Toilet tap	Time	Litres
Half	00:08.43	0.7
Half	00:08.97	0.7
Half	00:10.10	0.7
Half	00:05.47 tap opened for more than half in high pressure	0.7
Full	00:15.50	1.4
Full	00:11.50	1.4

Note: (High Pressure) half of it is enough

B5. Fifth mosque

Table 5.1. Water consumption in ablution with users in fifth masjid

Users code in	Minutes	Litres for ablution	Way
1	1:03.82	8.4	Continuous
2	0:50.34	3.4	Continuous
3	1:17.08	3.0	Continuous
4	1:18.52	3.4	Continuous
5	1:27.12	2.2	Continuous
6	0:43.27	2.6	Continuous
7	1:16.55	6.6	Continuous
8	1:16.27	7.3	Continuous
9	0:43.93	2.4	Continuous
10	0:53.16	2.5	Continuous
1	1:12.93	0.5	Open and closing
2	0:55.30	3.5	Continuous
3	1:25.08	3.2	Continuous
4	1:11.50	3.0	Continuous
5	1:28.11	2.1	Continuous
6	0:48.22	2.8	Continuous
7	1:16.05	3.5	Continuous

8	1:12.27	3.2	Continuous
9	0:50.33	2.5	Continuous
10	0:53.19	2.5	Continuous

Note: Colour shading is about values been discussed in analysing chapter.

Table 5.2 Four reading in 47:00 seconds in fifth mosque from ablution tap with number of ways of opening

00:47.00 seconds	Litres	Way of opening tap
	5.8	more than half
	4.3	Less than half
	2.4	Quarter
	4.2	Less than half

Table 5.3 Reading for time per one flush in fifth masjid mosques

Time per one flush	Litres per one flush
00:03.82	3L
00:03.40	3L
00:04.00	3L

Note: the flushing tank takes around 01:25.18 to refill again. (Reasonable time)

Table 5.4 Reading for time taking to reach half (0.7) and full (1.4) of the bottle in fifth mosque from toilet tap

Toilet tap	Time	Litres
Half	00:20.27	0.7
Half	00:20.30	0.7
Full	00:33.50	1.4
Full	00:33.65	1.4

Note: satisfied with pressure

B6. Sixth mosque

Table 6.1 Water consumption in ablution with users in sixth masjid

Users code in	Minutes	Litres for ablution	Way
1	1:08.03	4.4	Continuous
2	1:01.02	4.6	Continuous
3	1:10.08	3.4	Continuous
4	1:20.15	3.1	Continuous
5	1:20.10	3.4	Continuous
6	1:16.27	3.1	Continuous
7	1:16.25	3.2	Continuous
8	1:16.29	5.0	Continuous
9	0:44.90	2.6	Continuous
10	0:55.16	2.5	Continuous
1	1:12.90	3.5	Continuous
2	0:55.30	3.5	Continuous
3	1:25.08	2.8	Continuous
4	1:21.50	3.0	Continuous
5	1:30.12	2.5	Continuous
6	1:45.22	3.0	Continuous
7	1:17.04	4.0	Continuous

8	0:55.17	2.5	Continuous
9	1:13.02	3.6	Continuous
10	0:54.29	2.5	Continuous

Table 6.2 Four reading in 47:00 seconds in sixth mosque from ablution tap with number of ways of opening

47:00 seconds	Litres	Way of opening tap
	5.0	more than half
	4.2	Less than half
	2.5	Quarter
	4.2	Less than half

Table 6.3 Reading for time per one flush in sixth masjid mosques

Time per one flush	Litres per one flush
00:04.13	5L
00:04.08	5L
00:04.15	5L

Table 6.4 Reading for time taking to reach half (0.7) and full (1.4) of the bottle in sixth mosque from toilet tap

Toilet tap	Time	Litres
Half	00:15.26	0.7
Half	00:15.20	0.7
Full	00:30.50	1.4
Full	00:30.44	1.4

Note: satisfy with pressure

B7. Seventh measurement in house

Table 7.1 Water consumption in ablution with users in house using modern normal tap

Users cods in house measurement	Minutes	Litres for ablution/modern normal tap
1	01:00.20	1.6
2	00:54.19	2.5
3	01:07.43	3.9
4	01:45.77	1.2
5	00:55.20	2

B8. Eighth measurements using put

Table 8.1 Water consumption in ablution with users in house using pot

Users cods in house measurement	Litres for ablution/pot
1	0.5
2	0.7
3	0.73
4	0.6
5	0.65

Appendix C: Tables of interviews

Table 1.1 Interview question no. 2 to policymakers for answering sub-research question 1.1

Research question no. 1	What is water consumption in mosques, policies, regulation, saving practices, appliances, techniques applied in mosques and water?
Sub-research question 1.1	What is the water saving policies and regulation that applies in mosque to achieve efficient use of water?
Interview question no.2	What are policies on water demand management, measures and techniques in Oman?

Table 1.2 Interviewees answers of question no.2 of policymakers interview from different organizations

Organizations	Interviewees	Answers
Organization responsible of masjids and Jame's.	E.1 E.2 E.3 E.4	no policies no policies no policies no policies
Organization responsible of supplying water in Oman.	W.1 W.2 W.3 W.4 W.5 W.6	no policies no policies no policies no policies no policies no policies
Organization responsible of Royal mosques (Jame's).	R.1 R.2 R.3	no policies no policies no policies
Mosque managements.	M.1 M.2 M.3	no policies no policies no policies

Table 1.3 Interview question no. 7 of policymakers for answering sub-research question 1.1

Research question no. 1	What is water consumption in mosques, policies, regulation, saving practices, appliances, techniques applied in mosques and water?
Sub-research question 1.1	What are the water saving policies and regulation applies in mosque to achieve efficient use of water?

Interview question no.7	What are effective water demand management policies?

Table 1.4 Interviewees answers of question no.7 of policymakers interview from different organizations

Organizations	Interviewees	Answers
Organization responsible of masjids and Jame's.	E.1 E.2 E.3 E.4	need for database. policies for appliances. limit amount of water. water bill paid by the users.
Organization responsible of supplying water in Oman.	W.1 W.2 W.3 W.4 W.5 W.6	force using sensor tap. policies for appliances. efficient appliances sensor. recycling greywater. water bill paid by the users. cost effective.
Organization responsible of Royal mosques (Jame's).	R.1 R.2 R.3	policies in recycling. policies for appliances. policies for appliances.
Mosque managements.	M.1 M.2 M.3	limit of using water. rules to be implemented. no answer.

Table 1.5 Interview question no. 11 of policymakers for answering sub-research question 1.1

Research question no. 1	What is water consumption in mosques, policies, regulation, saving practices, appliances, techniques applied in mosques and water?
Sub-research question 1.1	What are the water saving policies and regulation applies in mosque to achieve efficient use of water?
Interview question no.7	What are policies and standards of recycling greywater not blackwater?

Table 1.6 Interviewees answers of question no.11 of policymakers interview from different organizations

Organizations	Interviewees	Answers
Organization responsible of masjids and Jame's.	E.1 E.2 E.3 E.4	no policies and standards no policies and standards no policies and standards no policies and standards

Organization responsible of supplying water in Oman.	W.1 W.2 W.3 W.4 W.5 W.6	no policies and standards no idea no policies and standards no idea no idea no idea
Organization responsible of Royal mosques (Jame's).	R.1 R.2 R.3	no policies and standards no policies and standards no policies and standards
Mosque managements.	M.1 M.2 M.3	no policies and standards no policies and standards no policies and standards

Table 1.7 Interview question no. 3 of policymakers and mosque management for answering sub-research question 1.2

Research question no. 1	What is water consumption in mosques, policies, regulation, saving practices, appliances, techniques applied in mosques and water?
Sub-research question 1.2	What are the water practices and appliances applied in mosques?
Interview question no.3	What are the current tool, appliances and techniques applied in mosques? Specification of the appliances (tap, WC): Techniques applied in mosques:

Table 1.8 Interviewees answers of question no.3 of policymakers and mosque management interviews from different organizations

Organizations	Interviewees	Answers
Organization responsible of masjids and Jame's.	PE.1 PE.2 PE.3 PE.4	no specification-good quality no specification-sensor tap no specific system no specification
Organization responsible of supplying water in Oman.	PW.1 PW.2 PW.3 PW.4 PW.5 PW.6	no specification-sensor tap no specification no specification no specification no specification-sensor tap no specification

Organization responsible of Royal mosques (Jame's).	PR.1 PR.2 PR.3	Push and sensor taps, small tank of WC or direct flush valve Push and sensor taps maintenance and price
Mosque managements.	M.1 M.2 M.3	Normal taps- no specification sensor and push taps Normal taps- no specification

Table 1.9 Interview question no. 5 of policymakers and mosque management for answering sub-research question 1.2

Research question no. 1	What is water consumption in mosques, policies, regulation, saving practices, appliances, techniques applied in mosques and water?
Sub-research question 1.2	What are the water practices and appliances applied in mosques?
Interview question no.5	Do you have any information or test results of total water consumption for landscape irrigation and for WC toilet flushing?

Table 1.10 Interviewees answers of question no.5 of policymakers interviews from different organizations

Organizations	Interviewees	Answers
Organization responsible of masjids and Jame's.	PE.1 PE.2 PE.3 PE.4	No No No No
Organization responsible of supplying water in Oman.	PW.1 PW.2 PW.3 PW.4 PW.5 PW.6	No No No No No No
Organization responsible of Royal mosques (Jame's).	PR.1 PR.2 PR.3	Treated effluent water (STP) for irrigation 7 to 10L per flush 3L per flush
Mosque managements.	M.1 M.2 M.3	5L per flush 8L per flush 3L per flush

Table 1.11 Interview question no. 1 of Engineers for answering sub-research question 1.2

Research question no. 1	What is water consumption in mosques, policies, regulation, saving practices, appliances, techniques applied in mosques and water?
Sub-research question 1.2	What are the water practices and appliances applied in mosques?
Interview question no.1	What are the current water saving practices applied by the government of Oman?

Table 1.12 Interviewees answers of question no.1 of Engineers interview from different organizations

Organizations	Interviewees	Answers
Organization responsible of masjids and Jame's.	EE.1 EE.2 EE.3	Self-close tap. TV advertisement. TV advertisement.
Organization responsible of supplying water in Oman.	EW.1 EW.2	Awareness through public gathering and school. Awareness through media.
Organization responsible of Royal mosques (Jame's).	ER.1 ER.2 ER.3 ER.4 ER.5	Store storm water in Dams. Not giving attention on saving. Sensor taps. Sensor taps, WC-Two bottoms. Sensor taps.
Government company responsible of treating water	EH.1 EH.2 EH.3 EH.4	Treating wastewater and reusing. Treating wastewater and reusing. Treating wastewater and reusing. Leak detection system.
International company for designing water piping	E.P.1 E.P.2	Treated effluent networks. No idea.
University college in engineering department	EU.1 EU.2 EU.3 EU.4 EU.5 EU.6	Advices users. No or very limited. No idea. Treating wastewater and reusing. No or very limit.

	EU.7 EU.8 EU.9 EU.10	Wastewater treated and reusing. Not aware. Water Cost scheme and reusing wastewater. Wastewater treatment and reusing. Sensor tap- automated water taps.

Table 1.13 Interview question no. 3 of Engineers for answering sub-research question 1.2

Research question no. 1	What is water consumption in mosques, policies, regulation, saving practices, appliances, techniques applied in mosques and water?
Sub-research question 1.2	What are the water practices and appliances applied in mosques?
Interview question no.3	Do you have any information or test results of total water consumption for landscape irrigation and for WC toilet flushing?

Table 1.14 Interviewees answers of question no.3 of Engineers interview from different organizations

Organizations	Interviewees	Answers
Organization responsible of masjids and Jame's.	EE.1 EE.2 EE.3	No No No
Organization responsible of supplying water in Oman.	EW.1 EW.2	No No
Organization responsible of Royal mosques (Jame's).	ER.1 ER.2 ER.3 ER.4 ER.5	No No No No No
Government company responsible of treating water	EH.1 EH.2 EH.3 EH.4	No No No No
International company for designing water piping	E.P.1 E.P.2	No No

University college in engineering department	EU.1 EU.2 EU.3 EU.4 EU.5 EU.6 EU.7 EU.8 EU.9 EU.10	No No No No No No No No No No

Table 1.15 Interview question no. 4 of Engineers for answering sub-research question 1.2

Research question no. 1	What is water consumption in mosques, policies, regulation, saving practices, appliances, techniques applied in mosques and water?
Sub-research question 1.2	What are the water practices and appliances applied in mosques?
Interview question no.4	What is the current tool, appliances, techniques and policies applied in mosques?

Table 1.16 Interviewees answers of question no.4 of Engineers interview from different organizations

Organizations	Interviewees	Answers
Organization responsible of masjids and Jame's.	EE.1 EE.2 EE.3	Normal tap-flush tank-no policy Normal tap-flush tank-no policy Normal tap-flush tank-no policy
Organization responsible of supplying water in Oman.	EW.1 EW.2	Normal tap-flush tank-no policy Normal tap-flush tank-no policy
Organization responsible of Royal mosques (Jame's).	ER.1 ER.2 ER.3 ER.4 ER.5	Sensor and push taps-flush valve- no policy No idea – not Muslim No idea – not Muslim Sensor tap- double flush-no policy Sensor and push taps-flush valve- no policy

Government company responsible of treating water	EH.1 EH.2 EH.3 EH.4	No idea – Female No idea – Female Sensor tap- no policy Sensor tap- double flush- no policy
International company for designing water piping	E.P.1 E.P.2	No idea – Female No idea – not Muslim
University college in engineering department	EU.1 EU.2 EU.3 EU.4 EU.5 EU.6 EU.7 EU.8 EU.9 EU.10	Sensor tap- no policy Sensor tap- no policy Normal and sensor taps- no policy Normal tap and flush- no policy Normal tap and flush- no policy Sensor detect the hand- no policy Sensor tap – no policy Sensor tap – no policy Sensor tap – no policy Sensor and normal taps – no policy

Table 1.17 Interview question no. 4 of policymakers and mosque management for answering sub-research question 1.3

Research question no. 1	What is water consumption in mosques, policies, regulation, saving practices, appliances, techniques applied in mosques and water?
Sub-research question 1.3	What is estimated water consumption in ablution and toilet flushing per capita?
Interview question no.4	Do you have any information or test result on total water consumption in ablution per capita?

Table 1.18 Interviewees answers of question no.4 of policymakers and mosque management interviews from different organizations

Organizations	Interviewees	Answers
Organization responsible of masjids and Jame's.	PE.1 PE.2 PE.3 PE.4	No No No No
Organization responsible of supplying water in Oman.	PW.1 PW.2 PW.3	No No No

	PW.4 PW.5 PW.6	No No No
Organization responsible of Royal mosques (Jame's).	PR.1 PR.2 PR.3	No – 250L/ day / capita (ablution + toilet) No – 15 to 20 approximately No
Mosque managements.	M.1 M.2 M.3	No No No

Table 1.19 Interview question no. 2 of Engineers for answering sub-research question 1.3

Research question no. 1	What is water consumption in mosques, policies, regulation, saving practices, appliances, techniques applied in mosques and water?
Sub-research question 1.3	What is estimated water consumption in ablution and toilet flushing per capita?
Interview question no.2	Do you have any information or test result on total water consumption in ablution per capita?

Table 1.20 Interviewees answers of question no.2 of Engineers interview from different organizations

Organizations	Interviewees	Answers
Organization responsible of masjids and Jame's.	EE.1 EE.2 EE.3	No No No
Organization responsible of supplying water in Oman.	EW.1 EW.2	No No
Organization responsible of Royal mosques (Jame's).	ER.1 ER.2 ER.3 ER.4 ER.5	No No – approximately 220L/ day No No No
Government company responsible of treating water	EH.1 EH.2 EH.3 EH.4	No – 245L/ capita from company master plan estimation No - 245L/ capita from company master plan estimation No

		No
International company for designing water piping	E.P.1 E.P.2	No No
University college in engineering department	EU.1 EU.2 EU.3 EU.4 EU.5 EU.6 EU.7 EU.8 EU.9 EU.10	No No No No No No No No No No

Table 1.21 Interview question no. 6 of focus group with users for answering sub-research question 2.1

Research question no. 2	What is effective water demand management policies, measures and techniques that are compatible with the needs of water consumers in mosques?
Sub-research question 2.1	What are consumers' needs and behaviours when making ablution in mosques?
Interview question no.6	What is consumers water needs when making ablution in mosques?

Table 1.22 Groups interview with users answers to question no.6

group 1 responds:
Clean water Enough amount of water
group 2 responds:
Clean water Enough amount of water Type of valve Continuous water for washing legs Less pressure
group 3 responds:
Clean water Enough amount of water Suitable pressure The valves To reduce timing in the sensor and push taps To reduce the amount of water

Table 1.23 Interview question no. 7 of focus group with users for answering sub-research question 2.1

Research question no. 2	What is effective water demand management policies, measures and techniques that are compatible with the needs of water consumers in mosques?
Sub-research question 2.1	What are consumers' needs and behaviours when making ablution in mosques?
Interview question no.7	What are consumer's water behaviours when making ablution in mosques?

Table 1.24 Groups interview with users answers to question no.7

group 1 responds:
Opening water when they are not ready for doing ablution yet. Taking long time to do ablution. Some of them did not understand what ablution is. They don't close water while doing ablution.
group 2 responds:
Wasting a lot of water. Different ages and different thinking. Opening tap 3 times more than what they need it. They don't understand what ablution is, and they are not doing it like how Prophet Mohamad was doing.
group 3 responds:
Wasting a lot of water. Opening water and doing something else. The behaviours depend of users thinking of water. Not care of the water bill. Some kids thought sensor tap is for playing.

Table 1.25 Interview question no. 11 of focus group with users for answering sub-research question 2.1

Research question no. 2	What is effective water demand management policies, measures and techniques that are compatible with the needs of water consumers in mosques?
Sub-research question 2.1	What are consumers' needs and behaviours when making ablution in mosques?
Interview question no.11	How would you describe yourself regarding water use? Example?

Table 1.26 Groups interviews with users answers of question no.11

Focus group 1 responds:
Depends on the mosque appliances. Normal and not wasting water. At home very normal not wasting water but in public like in mosques depend of the appliances.
Focus group 2 responds:
Normal in medium level. Depend with mosque appliances.
Focus group 3 responds:
Normal in medium level. Depend of the mosque appliances and pressure.

Table 1.27 Interview question no. 12 of focus group with users for answering sub-research question 2.1

Research question no. 2	What is effective water demand management policies, measures and techniques that are compatible with the needs of water consumers in mosques?
Sub-research question 2.1	What are consumers' needs and behaviours when making ablution in mosques?
Interview question no.12	To what extent do you agree or disagree with each of the following statements? It is difficult to reduce the amount of water used in the mosque. I have never thought much about the amount of water I use in mosques. I think people use more water than they need to do ablution (WUDU) in mosque. I try to save on my water bill by using water outside the home, for example, by showering at work or at the gym, or taking the car to a car wash or doing ablution in mosques. I am satisfied with the facilities I received from mosques.

Table 1.28 Groups interviews with users answers of question no.12

Statements:	Group 1	Group 2	Group3
It is difficult to reduce the amount of water used in the mosque.	All Disagree	All Disagree	All Disagree

I have never thought much about the amount of water I use in mosques.	All Disagree	3 Agee 3 Disagree	2 Agee 4 Disagree
I think people use more water than they need to do ablution (WUDU) in mosque.	All Agree	All Agree	All Agree
I try to save on my water bill by using water outside the home, for example, by showering at work or at the gym, or taking the car to a car wash or doing ablution in mosques.	All Disagree	All Disagree	All Disagree
I am satisfied with the facilities I received from mosques.	All agree	All Agree	Depend with mosque

Table 1.29 Interview question no. 13 of focus group with users for answering sub-research question 2.1

Research question no. 2	What is effective water demand management policies, measures and techniques that are compatible with the needs of water consumers in mosques?
Sub-research question 2.1	What are consumers' needs and behaviours when making ablution in mosques?
Interview question no.13	I'm now going to read out a list of behaviours and I'd like you to tell me how often you personally do each of these to save water. Please be as accurate in your answers as possible and remember that this is confidential. Turn off and on the tap when doing ablution. Limit the amount of time spent in the ablution. Leave the toilet unflushed Close the tap after finishing

Table 1.30 Groups interviews with users answers of question no.13

Statements:	Group 1	Group 2	Group3
Turn off and on the tap when doing ablution.	Sometimes	Sometimes	No
Limit the amount of time spent in the ablution.	No	No	No

Leave the toilet unflushed.	No	No	No
Close the tap after finishing.	Yes	Yes	Yes

Table 1.31 Interview question no. 14 of focus group with users for answering sub-research question 2.1

Research question no. 2	What is effective water demand management policies, measures and techniques that are compatible with the needs of water consumers in mosques?
Sub-research question 2.1	What are consumers' needs and behaviours when making ablution in mosques?
Interview question no.14	From what you know, would you say that others in the mosques do these things often than you do yourself? Open the tap continuously without turning it off and on when doing ablution. Do not limit the amount of time spent in the ablution. Leave the toilet unflushed. Leave the tap open.

Table 1.32 Groups interviews with users answers of question no.14

Statements:	Group 1	Group 2	Group3
Open the tap continuously without turning it off and on when doing ablution.	Yes	Yes	Yes
Do not limit the amount of time spent in the ablution.	Yes	Yes	Yes
Leave the toilet unflushed.	Sometimes	Sometimes	Sometimes
Leave the tap open.	Sometimes	Sometimes	Sometimes

Table 1.33 Interview question no. 16 of focus group with users for answering sub-research question 2.1

Research question no. 2	What is effective water demand management policies, measures and techniques that are compatible with the needs of water consumers in mosques?

Sub-research question 2.1	What are consumers' needs and behaviours when making ablution in mosques?
Interview question no.16	Q16. To what extent do you agree or disagree with each of the following statements? In Oman we are not interested enough in saving water. The government needs to implement water restrictions in water management in mosques. It is important to protect our natural environment. Using less water is good for the environment. I live in an area that is likely to drought. There is wastage of water in mosques. The water companies should work more in water recycling in mosque.

Table 1. 34 Groups interviews with users answers of question no.16

Statements:	Group 1	Group 2	Group3
In Oman we are not interested enough in saving water.	All Disagree	All Agee	All Agree
The government needs to implement water restrictions in water management in mosques.	All Disagree	All Agee	All Disagree and Agree
It is important to protect our natural environment.	All Agree	All Agree	All Agree
Using less water is good for the environment.	All Agree	All Agree	All Agree
I live in an area that is likely to drought.	All agree	Disagree and Agree	Disagree and Agree
There is wastage of water in mosques.	All Agree	All Agree	All Agree
The water companies should work more in water recycling in mosque.	All Agree	All Agree	All Agree

Table 1.35 Interview question no. 15 of focus group with users for answering sub-research question 2.1

Research question no. 2	What is effective water demand management policies, measures and

	techniques that are compatible with the needs of water consumers in mosques?
Sub-research question 2.1	What are consumers' needs and behaviours when making ablution in mosques?
Interview question no.15	Think about how you spend in doing ablution or how you use water, would you say that you use water more or less in comparison to when you were younger? Why?

Table 1.36 Interviews question no. 1 of policymakers for answering sub-research question 2.1

Research question no. 2	What is effective water demand management policies, measures and techniques that are compatible with the needs of water consumers in mosques?
Sub-research question 2.1	What are consumers' needs and behaviours when making ablution in mosques?
Interview question no.1	What is the current water **saving practices**, rules and polices applied by the government of Oman?

Table 1.37 Interviewees answers of question no.1 of policymakers and mosque management interviews from different organizations

Organizations	Interviewees	Answers
Organization responsible of masjids and Jame's.	PE.1 PE.2 PE.3 PE.4	Very few use practicing- no rule No saving – no rules No saving – no rules No saving – no rules
Organization responsible of supplying water in Oman.	PW.1 PW.2 PW.3 PW.4 PW.5 PW.6	Tariff structure Tariff structure Tariff structure Tariff structure Tariff structure Tariff structure
Organization responsible of Royal mosques (Jame's).	PR.1 PR.2 PR.3	Sensor and push taps- no rules Sensor and push taps- no rules Sensor and push taps- no rules

Mosque managements.	M.1 M.2 M.3	No saving – no rules No saving – no rules No saving – no rules

Table 1.38 Interview question no. 5 of Engineers for answering sub-research question 2.2

Research question no. 2	What is effective water demand management policies, measures and techniques that are compatible with the needs of water consumers in mosques?
Sub-research question 2.2	What are effective water demand management policies and measures and techniques and what are saving tools and appliances available on market?
Interview question no.5	What is the appropriate water saving tools, appliances, techniques and policies?

Table 1.39 Interviewees answers of question no.5 of Engineers interview from different organizations

Organizations	Interviewees	Answers
Organization responsible of masjids and Jame's.	EE.1 EE.2 EE.3	Using sensor taps Sensor taps Sensor tap
Organization responsible of supplying water in Oman.	EW.1 EW.2	Sensor taps Sensor taps
Organization responsible of Royal mosques (Jame's).	ER.1 ER.2 ER.3 ER.4 ER.5	No idea Sensor taps with timer No idea No idea Sensor tap operated for 5 seconds
Government company responsible of treating water	EH.1 EH.2 EH.3 EH.4	Sensor taps Not applicable to us Not applicable to us Filter tap produce bobbles
International company for designing water piping	E.P.1 E.P.2	Sensor taps No idea – not Muslim
University college in engineering department	EU.1 EU.2 EU.3 EU.4 EU.5	Water tap aerators Sensor taps No idea Sensor taps Sensor taps

	EU.6 EU.7 EU.8 EU.9 EU.10	Sensor taps Sensor taps Sensor taps Sensor taps Sensor taps

Table 1.40 Interview question no. 8 of Engineers for answering sub-research question 2.2

Research question no. 2	What is effective water demand management policies, measures and techniques that are compatible with the needs of water consumers in mosques?
Sub-research question 2.2	What are effective water demand management policies and measures and techniques and what are saving tools and appliances available on market?
Interview question no. 8	How do you think wastage water can be invested by the government?

Table 1.41 Interviewees answers of question no.8 of Engineers interview from different organizations

Organizations	Interviewees	Answers
Organization responsible of masjids and Jame's.	EE.1 EE.2 EE.3	Using in industries Using it for irrigation Using in industries
Organization responsible of supplying water in Oman.	EW.1 EW.2	Separating pipes grey and blackwater Recycling
Organization responsible of Royal mosques (Jame's).	ER.1 ER.2 ER.3 ER.4 ER.5	Separating pipes grey and black recycling recycling irrigation recycling
Government company responsible of treating water	EH.1 EH.2 EH.3 EH.4	Recycling recycling selling ablution water for recycling in irrigation recycling
International company for designing water piping	E.P.1 E.P.2	Recycling Recycling

University college in engineering department	EU.1 EU.2 EU.3 EU.4 EU.5 EU.6 EU.7 EU.8 EU.9 EU.10	By introducing market for trading recycling Separating pipes grey and black recycling recycling recycling recycling using latest technology in water saving recycling irrigation

Table 1.42 Interviews question no. 6 of policymakers for answering sub-research question 2.2

Research question no. 2	What is effective water demand management policies, measures and techniques that are compatible with the needs of water consumers in mosques?
Sub-research question 2.2	What are effective water demand management policies and measures and techniques and what are saving tools and appliances available on market?
Interview question no. 6	What are effective water demand management techniques, tools and behaviours that are compatible with the needs of water consumers in mosques?

Table 1.43 Interviewees answers of question no.6 of policymakers and mosque management interviews from different organizations

Organizations	Interviewees	Answers
Organization responsible of masjids and Jame's.	PE.1 PE.2 PE.3 PE.4	education - new technology sensor tap – awareness sensor tap – awareness sensor tap – awareness
Organization responsible of supplying water in Oman.	PW.1 PW.2 PW.3 PW.4 PW.5 PW.6	Not related to our organization Not related to our organization Not related to our organization Not related to our organization new technology

		policy and standards-education
Organization responsible of Royal mosques (Jame's).	PR.1 PR.2 PR.3	Sensor and push taps – proper pressure Using bobbles – reducing pressure – education Bobbles- education and awareness by using religion
Mosque managements.	M.1 M.2 M.3	Normal tap – less pressure- awareness Normal tap – less pressure- recycling – education Normal tap – less pressure- education-recycling

Table 1.44 Interview question no. 8 of focus group with users for answering sub-research question 2.2

Research question no. 2	What is effective water demand management policies, measures and techniques that are compatible with the needs of water consumers in mosques?
Sub-research question 2.2	What are effective water demand management policies and measures and techniques and what are saving tools and appliances available on market?
Interview question no.8	How to achieve efficient use of water?

Table 1.45 Groups interviews with users answers of question no.8

group 1 responds:
Limit water in bottle. Sensor taps with screens. Recycling.
group 2 responds:
Awareness is important of water. Awareness in amount, way and time needed. Open tap less. Signs in ablution areas.
group 3 responds:
Normal tap. Recycling. Education.

Table 1.46 Interview question no. 9 of group with users for answering sub-research question 2.2

Research question no. 2	What is effective water demand management policies, measures and techniques that are compatible with the needs of water consumers in mosques?
Sub-research question 2.2	What are effective water demand management policies and measures and techniques and what are saving tools and appliances available on market?
Interview question no.9	Do you think there are roles that could be played with users of water in mosque to increase the chance of water demand management in mosques? What are those roles?

Table 1.47 Groups interviews with users answers of question no.9

group 1 responds:
To put limited bottles instead of policies. Not suitable. Control in amount of water and pressure better than policies. Signs and awareness better.
group 2 responds:
Difficult. Better Awareness. Policies will make people avoid coming to pray in mosque.
group 3 responds:
Limit water and extra to be paid is better than policies. To put someone body to monitor them is better than policies. Difficult to put rules and policies.

Table 1.48 Interviews question no. 14 of Engineers for answering sub-research question 3.1

Research question no. 3	How to investigate feasibility of reusing water in mosques?
Sub-research question 3.1	Is the water quality of ablution water suitable for reuse in toilet flushing and/or landscape irrigation? If so, what type of treatment is required?

Interview question no. 14	If need to treat recycled greywater from ablution water in mosque, what is the suitable treatment required?

Table 1.49 Interviewees answers of question no.14 of Engineers interview from different organizations

Organizations	Interviewees	Answers
Organization responsible of masjids and Jame's.	EE.1 EE.2 EE.3	No idea No idea No idea
Organization responsible of supplying water in Oman.	EW.1 EW.2	No idea Filter by activated carbon filter
Organization responsible of Royal mosques (Jame's).	ER.1 ER.2 ER.3 ER.4 ER.5	No idea No idea No idea No idea No idea
Government company responsible of treating water	EH.1 EH.2 EH.3 EH.4	Simple treatment Depend on the quality needed Simple treatment Simple treatment
International company for designing water piping	E.P.1 E.P.2	Simple treatment No idea
University college engineering department	EU.1 EU.2 EU.3 EU.4 EU.5 EU.6 EU.7 EU.8 EU.9 EU.10	Disinfection Simple treatment and disinfection No idea Sand filtration Simple treatment Primary treatment using STP Only primary treatment No idea Not recommended for religious reason Simple treatment

Table 1.50 Interviews questions no. 9, 10, 11, 12, 15, 16, 17, 18 of Engineers for answering sub-research question 3.2

Research question no. 3	How to investigate acceptability of reusing water in mosques?

Sub-research question 3.2	Is water reuse or recycling acceptable to the mosque users and relevant policymakers?
Interview question no. 9, 10, 11, 12, 15, 16, 17 and 18	Q9. What is your opinion on idea of recycling (treated water) greywater in mosques for flushing toilet and landscape? Why? Landscape: Flushing toilet: Q10. What is your opinion on idea of reusing (not treated) greywater in mosques for flushing toilet and landscape? Why? Landscape: Flushing toilet: Q11. What is your opinions in using treated greywater that is compatible to the standard of drinking water? For drinking? Why? For washing cars. Why? For ablution? Why? Q12. What is your opinion in separating the pipes and drainage of greywater from blackwater? Why? Q15. Do you think reusing (without treating) or recycling (with treating) ablution water in mosques for flushing toilet and landscape will reduce water demand in mosque? Why? Q16. Do you think reusing or recycling ablution water in mosques for flushing toilet and landscape would be financially beneficial? How? Q17. Do you think reusing or recycling ablution water in mosques for flushing toilet and landscape will lead to environmental degradation? How? Q18. Do you think reusing or recycling ablution water in mosques for flushing toilet and landscape would be harmful to human? why?

Table 1.51 Interviewees answers of question no. 9, 10, 11, 12, 15, 16, 17 and 18 of Engineers interview from different organizations

Organizations	Interviewees	Q9	Q10	Q11	Q12	Q15	Q16	Q17	Q18
Organization responsible of masjids and Jame's.	EE.1	✓ ✓	✗ ✗	✗ ✓ ✓	✓	✓	maybe	maybe	✓
	EE.2	✓ ✓	✗ ✗	✓ ✓ F	✓	No idea	✓	✗	✗
	EE.3	✓ ✓	✗ ✗	✗ ✓ ✓	✓	✓	✓	✗	✗
Organization responsible of supplying water in Oman.	EW.1	✓ ✓	✗ ✗	✓ ✓ ✓	✓	✓	✓	✗	✗
	EW.2	✓ ✓	✗ ✗	✓ ✓ ✓	✓	✓	✓	✗	✗
Organization responsible of Royal mosques (Jame's).	ER.1	✓ ✓	✗ ✗	✓ ✓ ✓	✓	✓	✓	✗	✗
	ER.2	✓ ✓	✓ ✓	✗ ✓ ✗	✓	✓	✓	✗	✗
	ER.3	✓ ✓	✓ ✗	✓ ✓ ✓	✓	✓	✓	✗	maybe
	ER.4	✓ ✓	✓ ✓	✗ ✓ ✗	✓	✓	✓	✗	✗
	ER.5	✓ ✓	✗ ✗	✗ ✓ ✓	✓	✓	✓	✗	Maybe

Government company responsible of treating water	EH.1	✓ ✓	✗ ✗	✓ ✓ ✓	✓	✓	✓	maybe	maybe
	EH.2	✓ ✓	✓ ✓	✓ ✓ F	✓	✓	✓	✗	✗
	EH.3	✓ ✓	✓ ✓	✓ ✓ F	✓	✓	✓	✗	✗
	EH.4	✓ ✓	✓ ✓	✗ ✓ F	✓	✓	✓	✗	✗
International company for designing water piping	E.P.1	✓ ✓	✓ ✓	✗ ✓	✓	✓	✓	✗	✗
	E.P.2	✓ ✓	✓ ✓	✗ ✓ ✗	✓	✓	✓	✗	✗
University college in engineering department	EU.1	✓ ✓	✓ ✓	✗ ✓ ✓	✓	✓	✓	Maybe	maybe
	EU.2	✓ ✓	✓ ✓	✗ ✓ ✓	✓	✓	✓	✗	✗
	EU.3	✓ ✓	✓ ✓	✓ ✓ ✓	✓	✓	✓	✗	✗
	EU.4	✓ ✓	✗ ✗	✗ ✓ ✗	✓	✓	✓	✗	✗
	EU.5	✓ ✓	✓ ✓	✓ ✓ F	✓	✓	✗	✗	✗
	EU.6	✓ ✓	✗ ✗	✓ ✓ ✓	✓	✓	✓	✗	✗

	EU.7	✓ ✓	✗ ✓	✗ ✓ ✗	✓	✓	✓	✗	✗
	EU.8	✓ ✗	✗ ✗	✗ ✓ ✗	✓	No idea	✗	✗	✓
	EU.9	✓ ✗	✗ ✗	✗ ✓ ✗	✓	✓	✓	✗	✗
	EU.10	✓ ✓	✗ ✗	✓ ✓ ✓	✓	✓	✓	✗	✗

Note: Ticks is representing responses of who agreed of different statements, crosses is representing responses of who not agreed of different statements and F means need answer from 'Iftaa' who have thoughts in religious of Islam

Table 1.52 Interviews questions no. 8, 9, 10, 11, 15, 16, 17, 18, 19 and 20 of policymakers and mosques management for answering sub-research question 3.2

Research question no. 3	How to investigate feasibility of reusing water in mosques?
Sub-research question 3.2	Is water reuse or recycling acceptable to the mosque users and relevant policymakers?
Interview question no. 8, 9, 10, 15, 16, 17, 18, 19 and 20	Q8. What is your opinion on idea of recycling (treated water) greywater in mosques for flushing toilet and landscape? Landscape: Flushing toilet: Q9. What is your opinion on idea of reusing (not treated) greywater in mosques for flushing toilet and landscape? Landscape: Flushing toilet: Q10. What is your opinions in using treated greywater that is compatible to the standard of drinking water? For drinking?

	For washing cars? Why? For ablution? Why? Q15. Do you accept the idea of unlimited use of treated greywater? Why? Q16. What is your opinion in separating the pipes and drainage of greywater from blackwater? Why? Q17. Do you think reusing (without treating) or recycling (with treating) ablution water in mosques for flushing toilet and landscape will reduce water demand in mosque? Why? Q18. Do you think reusing or recycling ablution water in mosques for flushing toilet and landscape would be financially beneficial? How? Q19. Do you think reusing or recycling ablution water in mosques for flushing toilet and landscape will lead to environmental degradation? How? Q20. Do you think reusing or recycling ablution water in mosques for flushing toilet and landscape will would be harmful to human? Why?

Table 1.53 Interviewees answers of question no. 8, 9, 10, 15, 16, 17, 18 and 20 of policymakers and mosque management interview from different organizations

Organizations	Interviewees	Q8	Q9	Q10	Q15	Q16	Q17	Q18	Q19	Q20
Organization responsible of masjids and Jame's.	PE.1	✓ ✓	✓ ✓	✓ ✓ ✓	✗	✓	✓	✓	✗	✗
	PE.2	✓ ✓	✓ ✓	✗ ✓ F	✗	✓	✓	✓	✗	✗
	PE.3	✓ ✓	✗ ✗	✗ ✓ F	✗	✓	✓	✓	✗	✗

	PE4	✓ ✓	✗ ✗	✗ ✓ F	✗	✓	✓	✓	✗	✗
Organization responsible of supplying water in Oman.	PW1	✓ ✓	✓	✓ ✓ F	✓	✓	✓	✓	✗	✗
	PW.2	✓ ✓	✓ ✓	✗ ✓ ✗	✗	✓	✓	✓	✗	✗
	PW.3	✓ ✓	✗ ✗	✗ ✓ ✗	✗	✓	✓	✓	✗	✗
	PW.4	✓ ✓	✗ ✗	✗ ✓ ✗	✗	✓	✓	✓	✗	✗
	PW.5	✓ ✓	✗ ✗	✗ ✓ ✓	✗	✓	✓	✓	✗	✗
	PW.6	✓ ✓	✓ ✗	✗ ✓ ✗	✗	✓	✓	✓	✗	✗
Organization responsible of Royal mosques (Jame's).	ER.1	✓ ✓	✗ ✗	✗ ✓ ✓	✓	✓	✓	✓	✗	✗
	ER.2	✓ ✓	✓ ✓	✓ ✓ ✓	✗	✓	✓	✓	✗	✗
	ER.3	✓ ✓	✓ ✓	✓ ✓ ✗	✓	✓	✓	✓	✗	✗
Mosque management	M.1	✓ ✓	✗ ✗	✗ ✗ ✗	✗	✓	✓	✓	✗	✗

	M.2	✓ ✓	✓ ✓	✗ ✓ ✗	✗	✓	✓	✓	✗	✗
	M.3	✓ ✓	✓ ✓	✗ ✓ ✗	✗	New mosq .	✓	✓	✗	✗

Note: Ticks is representing responses of who agreed of different statements, crosses is representing responses of who not agreed of different statements and F means need answer from 'Iftaa' who have thoughts in religious of Islam.

Table 1.54 Interview question no. 10, 17 and 18 of focus group with users for answering sub-research question 3.2

Research question no. 3	How to investigate feasibility of reusing water in mosques?
Sub-research question 3.2	Is water reuse or recycling acceptable to the mosque users and relevant policymakers?
Interview question no. 10, 17 and 18	Q10. Do you accept reusing (same water without treatment) or recycling (doing some treatment) ablution water in mosques for flushing toilets and irrigation**?** Q17. Do you accept the idea of unlimited use of treated greywater? Why? Q18. Do you support the idea of separating greywater from blackwater? Why?

Table 1.55 Groups interviews with users answers of question no.10 17 and 18 from each group.

group 1 responds:
Q10. Need simple treatment for flushing toilets and irrigation.

Q17. No Q18. Yes
group 2 responds:
Q10. Yes, for flushing toilets and irrigation and need simple treatment. Q17. No Q18. Yes
group 3 responds:
Q10. Yes, for flushing toilets and irrigation. Other answers were only for irrigation. Q17. No Q18. Yes

Appendix D: Potential for Publication

There potential for publication by end of December 2019 targeting RESOURCES, CONSERVATION AND RECYCLING journal. The journal contributions from research, which consider sustainable management and conservation of resources. The journal impact factor: 2017: 5.120 © Clarivate Analytics Journal Citation Reports 2018.

The titles and Authors name for publications:

1. Ablution water consumption and demand management in mosques
   Aliya Al-Alawi, M. Sohail, Sam Kayaga

2. Acceptability of reusing ablution water in mosques regarding religious opinions in Oman
   Aliya Al-Alawi, M Sohail, Sam Kayaga

Appendix E: Training attended

E1. Record of Courses Attended

Course	Dates
Marketing Your Research Skills	14:00, 24th February 2016 15:30, 24th February 2016
Writing your Doctoral Thesis	14:00, 4th March 2016 16:00, 4th March 2016
Managing Your Research as a Project	13:00, 10th March 2016 16:00, 10th March 2016
Open access – Why is it important to me?	14:00, 16th March 2016 15:30, 16th March 2016
Postgraduate Induction Day	09:40, 19th April 2016 13:00, 19th April 2016
Collaboration: tools to help you share and communicate your research	10:00, 10th May 2016 12:00, 10th May 2016
Demystifying systematic reviews	10:00, 11th May 2016 11:30, 11th May 2016
Essential Teaching Skills C2 - Planning Classroom Teaching	14:00, 11th May 2016 16:00, 11th May 2016
Academic writing	12:00, October 2016 14:00, October 2016
Questionnaire Design	14:00, 2nd November 2016 16:00, 2nd November 2016
Finding information for your literature review theory	9:30, 3rd November 2016 11:00, 3rd November 2016
Introduction to SPSS	9:00, 8th November 2016 11:00, 8th November 2016
Introduction to Data analysis using SPSS	14:00, 14th November 2016 16:00, 14th November 2016
Introduction to statistical methodology	15:00, 21st November 2016 17:00, 21st November 2016
Fundamental of Nvivo part 1	10:00, 19th March 2018 16:00, 19th March 2018
Fundamental of Nvivo part 2	10:00, 29th May 2018 16:00, 29th May 2018

E2. Record of Conferences Attended

Conferences	Dates
2016 East Midlands University Association (EMUN) Postgraduate Research Student Conference	9.00, 1st September 2016 15.30, 1st September 2016
Loughborough University Annual Research Conference 2016	9.00, 31st October 2016 16.30, 31st October 2016
40th WEDC International Conference	Wed 26th of July 2017 Monday 31st of July 2017