An Integrated Approach towards Identification of the Barriers to Implementation of Rooftop Rainwater Harvesting Systems in Urban Residential Areas of Pakistan

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ABSTRACT

Water conservation in relation to rooftop Rainwater Harvesting Systems for urban residential areas is underdeveloped in Pakistan. Due to increased urbanisation, water availability in the domestic sector is stressed in terms of the quality and quantity of water resources. Rawalpindi the 4th largest city was selected as a case study for this research.

The purpose of this research was to assess the feasibility of implementing rooftop Rainwater Harvesting Systems for non-potable purposes in urban residential areas of Pakistan. The study included four focus areas; (i) A technical feasibility assessment of rooftop Rainwater Harvesting Systems in relation to annual/monthly rainfall data, current non-potable water demand and rooftop catchment., (ii) A questionnaire survey aimed at households in residential areas to identify socio-economic barriers/attitudes to rooftop Rainwater Harvesting Systems and (iii) Face to face interviews with policy-makers to identify the current policy implementation barriers regarding rooftop Rainwater Harvesting Systems.

In terms of data and results the study demonstrated that Rooftop Rainwater Harvesting Systems are technically feasible in urban residential areas of Rawalpindi in terms of roof catchment area and rainwater as a potential source of non-potable water. Household surveys showed that majority of the respondents were relatively unwilling to implement rooftop Rainwater Harvesting Systems. Major reasons for this included a lack of systems knowledge and awareness. In addition, concerns about water quality and maintenance presented significant barriers for respondents. Similarly, respondents reported that financial barriers were constraints to implementing rooftop Rainwater Harvesting Systems; large numbers of respondents were "very much willing" to install systems but only if local government provided incentives.

In terms of qualitative analysis, interviews with different stakeholders involved in policy formulation to policy implementation showed poor commitment and a lack of understanding and coordination. There were ambiguities in the process of policy formulation to the implementation of rooftop Rainwater Harvesting Systems; the policy process is complex and lacks a cohesive strategy. Last but not least poor monitoring and evaluation of the policy document were found to be barriers in the implementation of rooftop Rainwater Harvesting Systems.

DEDICATION

TO MY MOTHER (MAA- JEE)

-Thanks for being my first teacher-

"We never know the worth of water till the well is dry."

(Thomas Fuller)

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AJK	Azad Jammu Kashmir
ARV	Annual rental value
BCM	billion cubic meters
Cr	Coefficient of Runoff
DD	Dry day
DHA	Defence Housing Authority
DOI	Diffusion of Innovation
EGM	Expert group meeting
EMT	Ecological Modernization Theory
ERRA	Earthquake reconstruction and rehabilitation authority
GIS	Geographical information system
HHH	Household Head
HRDS	Human Resource Development Society
INGO	International Non-Government Organization
KPK	Khyber Pakhtoonkhaw
KWSB	Karachi water and sewerage board
LDA	Lahore Development Authority
MARLA	Traditional unit for area in Pakistan
MGD	Million gallons per day
Mm	Millimetre
MOE	Ministry of Environment
NGO	Non-Government Organization
NWP	National Water Policy
P & D	Planning and Development
PBS	Pakistan Bureau of Statistics
PCD	Per Capita Demand
PCRWR	Pakistan council of research and water resources
PKR	Pakistani Rupee
PMD	Pakistan Meteorological Department
PWOPs	Pakistan-Water operator’s partnerships
RDA	Rawalpindi Development Authority

RWHS	Rainwater Harvesting System
UCs	Union councils
UNEP	United Nations Environmental Program
UNICEF	United Nations International Children’s Emergency Funds
WASA	Water and sanitation Agency
WB	World Bank
WD	Wet day
WRRC	Water resource and research centre

Chapter 1 Introduction

1.1 Background

Water conservation, water rights and water pricing are underdeveloped in Pakistan. The country boasts several large cities which are growing in population and as a consequence, they are extremely vulnerable to water crises (Kamal, 2009). Pakistan lies in a semi-arid climatic region of south-east Asia with fluctuating precipitation throughout the seasons. The monsoon (rainy season) normally occurs from July to mid-September; when parts of the country are subject to rainfall of up to 1200 mm per month with approximately 70% of this rainfall flowing directly into the sea (Bukhari and Sayal, 2011). Pakistan has many large secondary water resources such as ground and surface water, from which water is used mainly for domestic, agriculture and industrial purposes (Ghafoor et al., 2002). Due to an increase in urbanisation, water consumption in these areas is stressed in terms of both quality and quantity. For these reasons, Pakistan is classified as one of the most vulnerable countries in the world in terms of water scarcity (WB, 2005, ADB, 2013).

According to the United Nations Development Program (UNDP), in Pakistan, the current domestic water availability is 1000 m^3 per capita per year. This is expected to decrease by 500 m^3 per year by 2025, due to a 40% increase in urban population (Kamal, 2009). In urban areas, the main source of domestic water is ground water; however these levels are falling rapidly due to excessive ground water pumping. According to the Pakistan urban population forecast, ground water resources will be worse by 2025 due to increases in the numbers of tube wells and boreholes (Majeed and Piracha, 2011). Moreover, according to a Water Aid Report (Pakistan Country Strategy 2010-2015), water availability has decreased per capita since the creation of the country. In 1951, this was approximately 5650 m^3per capita per year in and will be 885 m^3 per capita by 2020.

In addition to a domestic water supply crisis, Pakistan also faces and is still vulnerable to devastating floods (Islam and Sultan, 2009, Schilling et al., 2013). To deal with the water crisis and mitigate flood risk, a paradigm shift in water policy and implementation is required, otherwise Pakistan will face severe issues in the provision of domestic water (Afridi and Siddiqui, 2013, Bhandari, 2013).

Table 1.1 Per capita water availability and population of Pakistan (1951 to 2020)

Year	Population (million)	Per capita water availability (m^3)
1951	33.7	5650
1961	42.8	4000
1971	65.3	2800
1981	84.2	1900
1992	130	1700
2000	140	1400
2003	149	1200
2012	176	1000
2020	268	885

Source: (WaterAid, 2010)

Overall water conservation is not well developed in urban areas of Pakistan. As far as interventions taken to improve the current domestic water supply concerns different water supply projects have been initiated in Karachi, the largest and most densely populated city in the country (Moe and Rheingans, 2006, Westcoat JR, 2009). However, due to poor policy implementation and weak governance, these projects have failed to provide suitable domestic water as per need to the community (Khan, 2009). For example, three sewage treatment plants were launched by the Karachi Water and Sewage Board (KWSB) to mitigate the domestic water supply problem. These sewage treatment plants were launched to recycle the wastewater to overcome the burden on groundwater resource. Two were closed for rehabilitation more than a year ago, whereas the third has been non-functional since 2008 (Ilyas, 2015), suggesting no adequate practical developments in this area.

Policies formulated by the Ministry of the Environment and WASA (Water and Sanitation Agencies) regarding water conservation and the promotion of rainwater harvesting systems (RWHS) have been largely ignored in urban areas, however, a ground water recharge system is in operation in one of the large public buildings in the capital city, Islamabad. In some rural areas of Pakistan, rainwater collection systems are in operation via ponds and reservoirs, for example, in the Cholistan desert, the primary source of freshwater is rainwater which is collected in man-made or natural ponds called “Tobas”. However, in this district, 1000 out of 1500 Tobas are non-operative due to a lack of proper maintenance (Kahlown, 2009).

The Pakistan Council of Research in Water Resources (PCRWR) has initiated several projects developing ponds and reservoirs for water collection in the deserts of Pakistan. As in urban residential areas, water conservation strategies such as rooftop rainwater harvesting are still lacking in these areas. To identify the potential of rooftop RWHS for urban residential areas, a case study was carried out by the "Pakistan Water Operation Partnership (PWOP)". The partnership estimated the average annual rainfall and roof sizes in a particular housing scheme area of Lahore city. Their findings revealed that approximately 46,709,796 litres of water per annum could be harvested if rooftop RWHS were implemented in this particular housing area. (Hussain and Rehman, 2013). However, the study was limited to average annual rainfall and size of the catchment area. Hence, adequate investigation of rooftop RWHS implementation demands an integrated approach covering a technical assessment as well as politico-socio-economic barriers.

Therefore, the aim of this research was to assess the technical feasibility of rooftop RWHS in terms of its practical implementation in Pakistan societies and to consider its potential as a viable source of water. Moreover, the study aims to identify some of the socio-economic and policy barriers to implementation in urban residential areas of Pakistan.

1.2 The current water issues facing Pakistan

Summarising, it can be seen that Pakistan is one of the most vulnerable countries in the world facing water scarcity. In Pakistan, approximately 70% of rainfall flows into the sea leading to localised flooding (Bukhari and Sayal, 2011). To deal with this water crisis and mitigate flood risk, a paradigm shift in water policy and implementation is needed; otherwise Pakistan will face worsening water supply conditions. Different developed and developing countries are moving towards new paradigms in urban water management from centralised technologies to decentralised systems (Livingston, 2008).

Due to the increased risk of flood and domestic water supply problems, RWHS are receiving more recognition thanks to integrated approaches in developing new methodologies (Kern, 2008). Intensive physical analysis of local environments, including precipitation and local climate should be the primary objective in initial investigations. Similarly, a social willingness to engage and to overcome policy implementation barriers should also exist. This research aims to identify the policy barriers in the implementation of rooftop RWHS.

1.2 The Research Question (An integrated approach)

The purpose of this research was to apply the integrated approach in identification of the barriers towards implementation of rooftop rainwater harvesting system in urban residential areas of Pakistan. The idea behind to use the integrated approach was in-depth analysis of the barriers towards implementation. It was found during the initial proposal writing that in general there are different barriers such as technical, socio-economic and policy in the implementation. However, in the context of urban Pakistan these three barriers were not been studied comprehensively to get a clearer picture of the situation. Therefore, for this research all three barriers considered together to assess the feasibility of the system with regards to technical, social acceptability and policy implementation. Further to the barriers: in technical feasibility analysis the research will assess whether or not rooftop RWHS can offer potential solutions to water scarcity in urban areas of Pakistan with regards to annual/monthly rainfall, rooftop catchment area and water demand in the selected study area. Moreover, the research will ask if there is an awareness and social willingness in support of the implementation of rooftop RWHS. Lastly, the research will investigate the current gaps in policy implementation.

1.3 The Research Aims and Objectives

- To identify the current domestic water supply system and issues in major cities of the Pakistan
- To estimate the potential of rooftop rainwater harvesting system in major cities
- To estimate the annual/monthly rainfall distribution of the selected study area.
- To estimate the rooftop catchment area
- To assess the socio-economic willingness/acceptability in the implementation of rooftop RWHS.
- To identify policy barriers (if any) to rooftop the implementation of rooftop RWHS.

1.5 Research perspective and expected outcomes

Much of the previous literature on RHWS in Pakistan has been technical in terms of estimating the annual average rainfall of the area. The present research will contrast this work by presenting an integrated approach, representing all aspects of RWHS implementation, from technical perspectives, social acceptability and policy formulation and barriers to implementation.

This research will enrich the existing knowledge on the technical feasibility of rooftop RWHS. In addition, the research will enhance and contribute to the understanding of the social acceptance and policies aspect of the system in its promotion and future implementation.

1.6 Scope of the research

This research is limited to the urban residential areas of Pakistan. Rawalpindi the 4th largest city was selected as a study area. However the methodology and population selected for the study area can be generalised in similar settings of other parts of the country with regards socio-economic acceptability. The data collected for technical feasibility with regards to annual/monthly rainfall patterns, rooftop catchment area and water demand were mainly secondary data and it was specific to the study area. Therefore the generalizability of this data is limited. Moreover, the methodology, data collection and analysis of the policy implementation barriers can be generalize and reliable to similar research in other parts of the country.

1.7 Thesis structure

Chapter 1 introduces the research question along with the aims and objective of the research.

Chapter 2 presents a review of the major cities of Pakistan, current water supply systems, problems, water policies and historical development of rainwater harvesting system.

Chapter 3 focuses on the RHWS literature. Technical and politico-socioeconomic barriers in other parts of the world are also discussed.

Chapter 4 presents the research design and methodology/data collection tools. In addition to methodology data analysis techniques, sampling processes and limitations of the research are also discussed.

Chapter 5 outlines the technical feasibility of RWHS in urban residential areas.

Chapter 6 presents the results, data analysis and discussion on socio-economic acceptability towards RWHS.

Chapter 7 discusses the results, data and policy implementation barriers.

Chapter 8 presents a summary and future work/ recommendations.

Chapter 2 Literature review: rainwater harvesting systems

2.1 Introduction

Rain water harvesting (RWH) is a technique of collection and storage of rainwater into natural reservoirs or tanks, or the infiltration of surface water into subsurface aquifers One method of rainwater harvesting is rooftop harvesting (Vimont, 2017, Londra et al., 2017, Kinkade-Levario, 2007).

Solutions for effective water management in urban areas are usually preceded by the building of dams and the installation of costly water treatment systems, whereas policies play a central role in water demand and management, and have significant environmental, economic and social benefits. Social factors such as consumer behaviour and attitudes towards water are important components in water conservation strategies (Naidoo, 1999, T.M, 2000, Brar, 2013, Singh et al., 2013).

Many developing countries are water-stressed and vulnerable to water shortages due to the rapid increase in urban population (Amos et al., 2018, Falkenmark and Xia, 2013). Rainwater is becoming increasingly popular as an alternative source of water supply due to climate change and increases in water scarcity (Pandey et al., 2003). Water shortages are not limited to water scarce areas; different regions with proper water supply infrastructures also face these problems. The most important factors affecting secure and stable water supplies are the increase in urbanization and climate change (Mun and Han, 2012). Currently, in some developing countries, a rooftop rainwater harvesting system is mandatory for a residential building plan to get approval from local authorities; examples include Brazil, China and India (Aladenola and Adeboye, 2010). In city areas, roofs represent about half of the total surface and make a major contribution to storm water runoff flow. With RWH able to play a vital role in addressing these problems, (Farreny et al., 2011a, Farreny et al., 2011b, Singh et al., 2013) governments and public and private sectors should focus on their development as an alternative water supply system (Bulkeley and Castán Broto, 2013).

In the past, rainwater harvesting techniques did not attract as much attention as they have in the last few decades. This is because, in the twentieth century, countries were more focused on the construction of dams and a centralised water supply system. However, in the last few decades, rainwater harvesting techniques have gained increasing attention globally (Gould and Nissen-Petersen, 1999, Siddall, 2013). According to Mun and Han (2012) to cope with the current water crisis, a rainwater harvesting system offers a feasible option. Experiences from the implementation of rainwater harvesting systems in different urban areas around the world have shown a significant improvement in mitigating ongoing water supply problems (Morrow et al., 2010).

The review by Jung et al. (2015) and Magliano et al. (2015) has shown that even countries like South Korea, where rainwater harvesting is considered less acceptable due to seasonal variations, utilize rainwater as an integrated alternative source of water. In addition to this, some communities like those in the Chaco region of South America have shown the use of rainwater for a range of purposes including domestic, industrial and farming. However, in the implementation of rainwater harvesting systems, some socio-economic barriers also exist. For instance, sometimes people are not willing to adopt the system or cannot afford it. The utilization of rainwater is growing in both economic and environmental importance (Amos et al., 2018). Therefore, governments should nurture initiatives by supporting them financially, as found in a study from Tanzania, where the government has provided incentives to utilise rainwater harvesting for farming, and in Germany for domestic and industrial purposes (Herrmann and Schmida, 2000, Gowing et al., 2015). Similarly, the literature has shown that during times of drought, harvested rainwater can be useful to meet domestic water demand, for example, in the south-eastern United States and, China and India (Jones and Hunt, 2010). It is therefore believed that many lessons can be learned from these countries, particularly India, where the political, institutional and socio-economic factors are similar to Pakistan.

Literature also shows that for a sustainable urban drainage system, rainwater harvesting is recognised as a tool to restore the natural hydrologic cycle in urban areas (Palla et al., 2011). Rooftop rainwater harvesting systems are often seen to be given more importance in urban areas due to the growth in urbanization. For instance, in Mexico, use of rainwater harvesting is a common practice in cities (Fuentes-Galván et al., 2015). As noted previously, the use of rooftop RWH can mitigate storm water runoff in the cities. For example, in Japan, 50 per cent of the total impervious areas of the cities comprise roofs, and rainwater harvesting systems are being promoted on a large scale to cope with urban flooding (Ward et al., 2012, Cook et al., 2015).

2.3 Different categories of rainwater harvesting system

Rainwater harvesting is basically the collection and storage of rainwater from different catchment areas, either from man-made or from natural surface areas. However, a rainwater harvesting system can be categorized as small, medium and large scale (Che-Ani et al., 2009). The runoff mainly consists of rainwater sources and surface water sources. The rooftop rainwater harvesting system for domestic consumption falls in the small scale category. The figure 2.1 below shows rainwater harvesting system categories in detail.

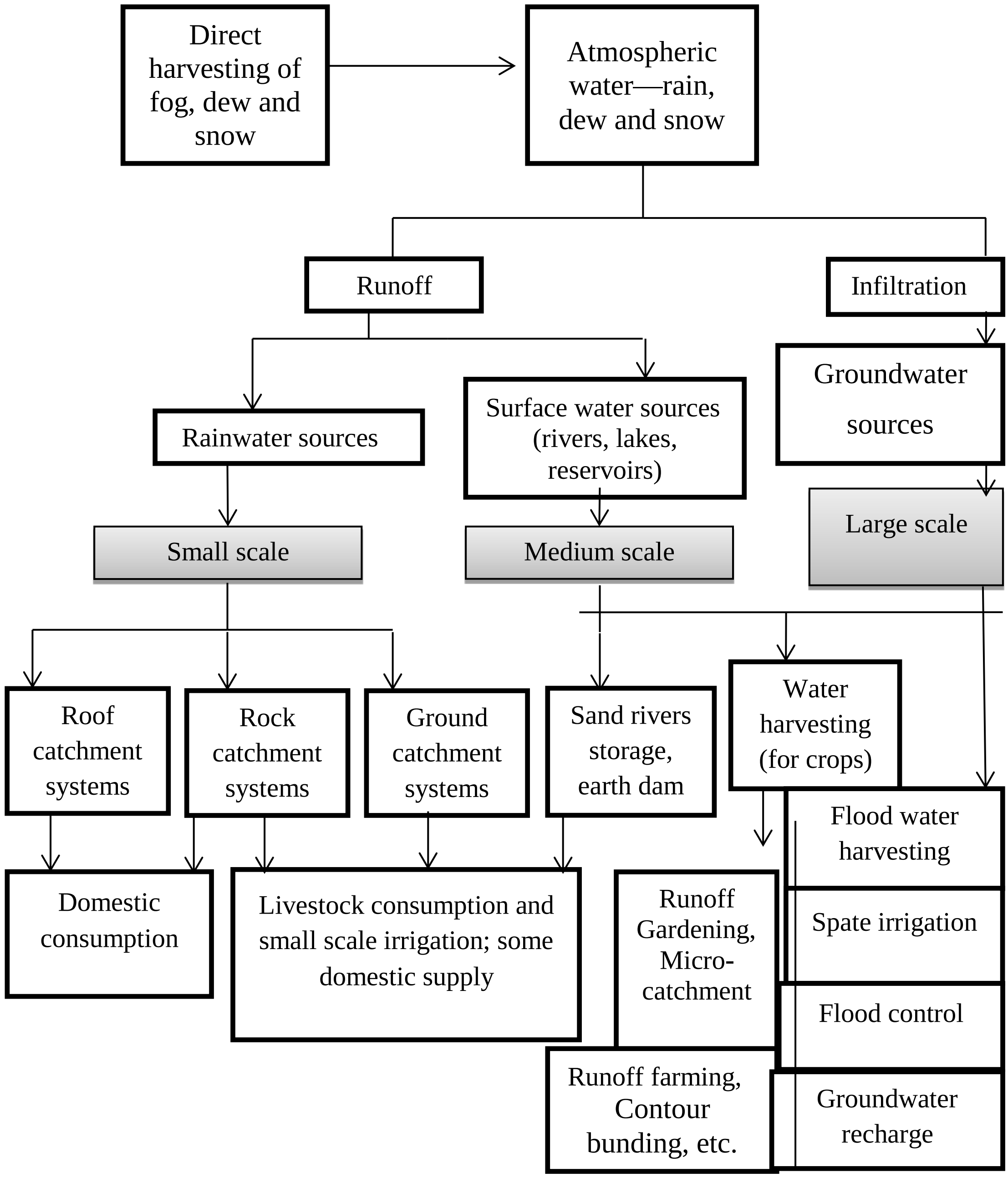


Figure 2. 1 Categories of rainwater harvesting

Source: (Jamaluddin and Huang, 2007, Che-Ani et al., 2009)

Different types of rainwater harvesting system for urban areas are also mentioned by the United Nations Environmental Protection Agency in its report ‘Rain water harvesting and utilization’. According to this report, the roof top is the best option for catchment and collection in urban areas (UNEP, 2002). Similarly, literature shows that the collection and catchment area is most important when identifying the potential of rainwater harvesting systems for urban areas (Malinowski et al., 2015).

2.3.1 Rainwater harvesting through ground water recharge system

In larger areas, such as stadiums, sports complexes, educational institutions and airports, the collection of roof and ground water is usually followed by storage in underground reservoirs and cisterns and then treated and used for non-potable purposes. Ground water recharge of aquifers is more economical than treated municipal wastewater and a new form of water supply for towns and cities (Dillon, 2005). For example in one case study in Australia, on a water sensitive urban development, it was shown that a ground water recharge system was able to retain up to 60 per cent of storm water runoff (Coombes et al., 2000). To cope with the current climate change situation and the growth of urban populations, both developing and developed nations are utilising alternative water sources such as the reuse of urban storm water and ground water recharge. As part of an overall sustainable urban water management plan, it has been shown that treated storm water could help urban areas meet the growing water supply demand (Mankad et al., 2015).

2.3.2 Collection of storm and surface water in ponds/reservoirs

The collection of surface and storm water in ponds/reservoirs is a relatively straightforward technique to harvest rainwater, but there is a chance of evaporation of surface water and of infiltration into the surrounding ground. In most cases, rain and storm water is collected as surface runoff, then treated and pumped to reuse for different domestic purposes (Kinkade-Levario, 2007). However, the treatment and maintenance costs for domestic reuse can be an obstacle in developing countries such as Pakistan. For urban residential areas, the rooftop catchment area is more appropriate in terms of cost and maintenance compared to the collection of storm and surface water in ponds. Sharma and Kansal (2013) also show that this type of system is of greater benefit to the agricultural water supply than for domestic use, because storm and surface water collection in urbanized catchments requires a high treatment cost.

2.3.3 A typical rooftop rainwater collection system for urban residential areas

The use of alternative water sources in urban residential areas is becoming more popular due to the increasing water demand placed on conventional urban water supplies. Rooftop RWH is more focused on coping with the growing urban domestic water demand in developed countries. (Chao et al., 2015). The collection of rainwater using rooftops in residential areas consists of different simple components, as presented below in Figure 2.2. For potable use, an additional treatment system is required prior to distribution.

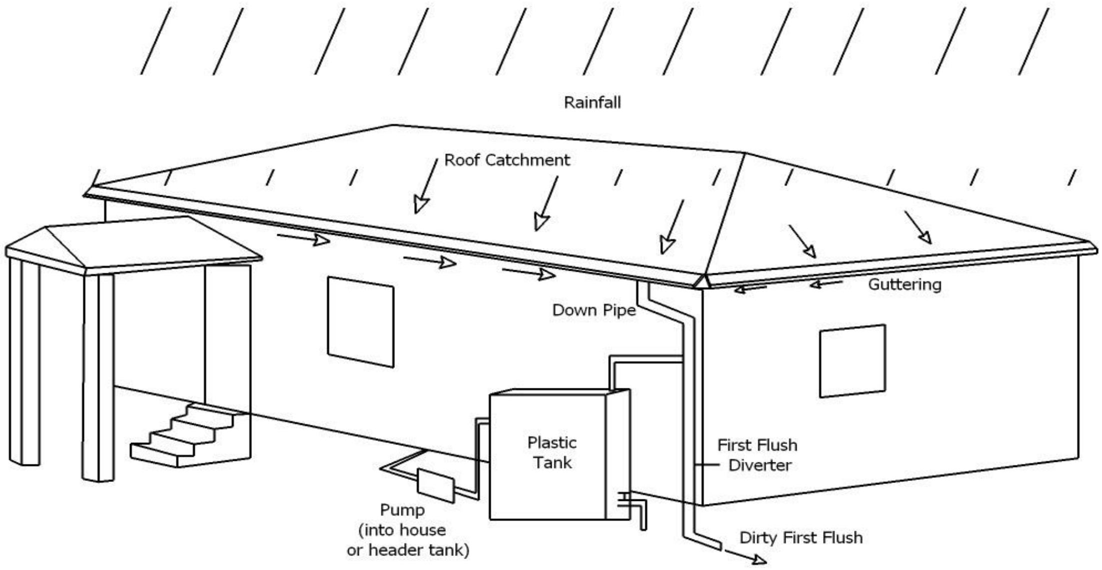


Figure 2. 2 A typical domestic rooftop rainwater harvesting system for non-potable purposes

Source: (Shende, 2015)

2.4 Potential of rooftop rainwater harvesting system in urban areas

Rooftop RWH is now gaining more attention in urban areas in the developed world due to the increase in water demand and storm water runoff (Jensen et al., 2010, Markowitz, 2010), However, it faces many challenges in implementation because of different urban characteristics, such as the overall water supply balance and storm water management (Karaca et al., 2015). In general, it is considered that rain and storm water is a surface runoff problem, but if rain water were to be collected, then benefits to the environment and urban infrastructure can be realised.

2.5 Technical feasibility of rooftop rainwater harvesting system

A feasibility analysis is an examination of the degree to which a rooftop rainwater harvesting system can be easily or conveniently used for domestic purposes at the household level. Knowledge of the amount of annual average rainfall is the fundamental component prior to implementation of a rooftop RWHS within the context of the urban residential area (Fuentes-Galván et al., 2015, Lade and Oloke, 2015). Similarly, a domestic rooftop rainwater harvesting system is most suitable in areas where the precipitation rate and rooftop areas are appropriate to the per capita water demand. However, where these criteria are not met, then it could form a partial or additional water supply. For instance, in Singapore, most of the urban residential areas comprise 12 to 13 storey blocks, where rooftop catchment areas are relatively small to be able to meet the domestic water demand (Thomas, 1998). Therefore, rooftop RWHS is used as an additional domestic water supply system.

According to Jakeman and Hornberger (1993) and Lade et al. (2013) the only means of representing and understanding the complex behaviour of a rainwater harvesting system is through the use of mathematical models. Similarly, there are numerous issues that require consideration when assessing the operational feasibility of a rooftop rainwater harvesting system—for example, the amount or percentage of the existing water demand that is likely to be met (Lade et al., 2013). This involves determining what the current domestic water demand per capita per day at the household level is and how it is distributed between potable and non-potable use. The amount of water that can be captured can be estimated using the annual or monthly average rainfall figures for the area. In addition, it is also important to estimate the catchment area and storage requirements to identify what amount of the existing water demand can be fulfilled by a rooftop RWHS, and whether it can provide for the full, or partial, water demand.

There are several technical aspects that require consideration when assessing the feasibility of a rooftop rainwater harvesting system for domestic use. Worm (2006) provides a general view of the technical aspects as follows:

- The rooftop material should be impermeable, such as cement, iron or slate.
- Domestic water demand needs to be ascertained, including the total number of users in a household and the types of use (e.g. washing, cooking, bathing, flushing toilets, etc.).
- Alternative water sources should be available in case the stored rainwater becomes depleted. The alternative water sources can be ground or surface water.

Furthermore, Worm (2006) describes the four types of rooftop rainwater harvesting management. He describes the different user regimes according to potential, water demand and catchment. The term "user regime" refers to how the system is administered as determined by system potential and by practical considerations.

1. An occasional user regime is where rainfall patterns are uniform and there are very few days without rain. Water is stored for a few days in a small storage tank. In addition to this, alternative water sources are available.
2. The intermittent user regime is for those areas where there is a long rainy (monsoon) season and all water demand or consumption is met by rainwater harvesting during that period. However, water is collected from alternative sources during the dry period.
3. Partial rainwater harvesting is the use of a rainwater harvesting system throughout the year, but not for all domestic needs. For instance, harvested rainwater may be used for washing and cooking only, while other domestic demands are fulfilled by alternative sources.
4. In a full user regime, all domestic demands are fulfilled by harvested rainwater. The rainwater is used throughout the year. Usually there are no alternative sources. In such cases, harvested rainwater should be stored and managed in a sophisticated way to cope with dry periods.

These user regimes are mainly dependent on rainfall patterns, the amount of water that can be stored and water consumption at the household level (Worm, 2006).

2.6 Potable and non-potable water supply by rooftop RWHS in different countries

Potable water means water which is safe for drinking; non-potable water is not suitable for drinking purposes (World Health Organization). In other words, water which is free from all kinds of microbiological and chemical contaminants is considered potable. In domestic water demands, both terms are used to allocate the use of water at the household level for different activities (Abdulla and Al-Shareef, 2009, Aladenola and Adeboye, 2010, Alam et al., 2012, Mehrabadi et al., 2013, Lade et al., 2013). For example, for cooking and drinking, potable water is used; for toilet flushing, car washing, laundry, floor cleaning, etc., non-potable water can be used. However, this varies from area to area. In some countries, like the United Kingdom, potable water is used for all household activities, whether for drinking or toilet flushing. Furthermore, when it comes to rooftop rainwater harvesting systems within the context of a household, it is very important to consider the water quality if it is to be used as a substitute for piped or mains potable water. This is because water captured from the rooftop contains a lot of impurities and contaminants that will require a proper cleaning and treatment mechanism, which will also increase the cost of the system. For non-potable use however, such as toilet flushing, laundry, car washing and floor cleaning, only primary treatment or screening is required. A review of literature has shown that many countries have identified the potential and feasibility of a system for non-potable use. For instance, Ghisi et al. (2006) has shown that there was sufficient rainfall to meet all the potable water demand over 62 cities of southern Brazil. Similarly, in some rural areas of India, rainwater is being used for potable purposes. However, issues related to the quality of water and its impact on the householders' health are still not being fully recognised (Desarda, 2001).

It is noted from literature that non-potable water demand is always high in comparison to potable water demand. In addition, potable water saving from rooftops also incurs high treatment and maintenance costs. The type of roof material also affects the water quality (Lye, 2009). The literature also shows that the use of a rooftop RWHS is mainly focused on non-potable water demand. For instance, in Denmark, it is estimated that 68 per cent of the demand for toilet flushing and washing of clothes can be fulfilled by means of a rainwater harvesting system from the roof catchment (Mikkelsen et al., 1999). Similarly, Appan (2000) studied the feasibility of a rooftop rainwater harvesting system for non-potable water use in urban areas of Singapore. Another example can be seen in Sweden, where Villarreal and Dixon (2005) identified that 45 per cent of the total non-potable water demand—which includes toilet flushing, laundry and car washing—can be fulfilled by rooftop RWH systems, while the potable water demand is mainly fulfilled by ground water sources without any treatment. Moreover, in Malaysia, Shaaban and Appan (2003) in their research "Utilising rainwater for non-potable domestic uses and reducing peak urban runoff in Malaysia" have shown the quality of rooftop rainwater to be very good, meeting World Health Organization (WHO) standards.

In developing countries such as Pakistan, the main source of potable water in urban areas is ground water, whether from a tube well or a borehole. In addition to this, it is also considered to be clean drinking water and so does not require any additional treatment. It can therefore be seen that, generally, the utilization of rooftop RWH systems is considered more appropriate for non-potable use.

2.6.1 Rooftop material and type

As mentioned above, a rooftop RWHS is mainly used for non-potable purposes in urban areas, though in some cases it is also found to be used for potable purposes. However, the quality of the rainwater collected is directly affected by the type of roof material. According to Nicholson et al. (2010), a more sustainable and ecological roof material is needed as an alternative to traditional materials for the provision of improved water quality for potable purposes. There may be severe health hazards if water is used for potable purposes without any treatment. It is very important to analyse the roof material before designing the system and considering potable and non-potable usage (Nicholson et al., 2009). Traditional roof materials include concrete and cement, and uncoated galvanized metal which contributes to the chemical contamination of water (Gould, 1999). Thus, it is suggested that the use of rooftop RWHS in urban areas is not suitable for the provision of drinking or potable water without treatment. Other factors to be considered include weather conditions, dry periods and storage time (Steffen et al., 2013).

2.6.2 Water quality of rooftop runoff

As noted above, rooftop rainwater is more suitable for non-potable purposes than for meeting potable water demand. In addition to this, Lye (2009) contends that most countries construct rooftop rainwater systems for non-potable use only—including laundry, toilet flushing, and other non-potable purposes—due to contamination. A leading role in the installation of rooftop RWH systems specifically for non-potable use is played by countries like Australia, Japan, India, Denmark and Germany. Furthermore, Albrechtsen (2002) asserts that most of these countries are also drafting legislation to promote rooftop RWH systems for non-potable uses. Appan (2000) also found microbiological and chemical contamination in rooftop rainwater, and suggested that water collected from rooftops is acceptable for only non-potable purposes. Similarly, Abdulla and Al-Shareef (2009) identified bacteriological contamination by faecal coliforms in rooftop water collected in Jordan's residential areas. Furthermore, the air quality of the area and the cleanliness of the roof area also affect the water quality of harvested rainwater.

2.6.3 Operation and maintenance of rooftop RWHS in urban areas

Operation and maintenance aspects are complex and important but necessary to ensure the successful implementation of rooftop RWHS. However, if correctly operated and maintained, then water collected can be used for potable purposes (White, 2009). Similarly, if the system is designed in an appropriate way and maintained on a regular basis, then good quality rainwater can be stored. The use of a rooftop RWHS is most common in urban areas because the rooftop area is considered less contaminated than other catchment areas such as roads, land and pavements (Li et al., 2010).

2.7 Socio-economic acceptance of rooftop rainwater harvesting system in global context

In relation to the socio-economic acceptance of a rooftop rainwater harvesting system, many researchers in developed and developing countries have a found positive response. According to Barthwal et al. (2014), rooftop RWH systems are acceptable to people in India. It is also very important to select an economically feasible supporting rainwater infrastructure using a lifecycle costing approach. For instance, it was found that in Spain, prior to implementation of rainwater harvesting systems, a cost-benefit analysis was brought into consideration in relation to socio-economic feasibility (Farreny et al., 2011a). In countries such as Sweden, Germany and New Zealand, the rooftop RWHS is much cheaper in energy and installation cost than deep bore hole ground water, where the water table is falling and in a vulnerable situation. In these countries RWHS are more socially acceptable due to their cost-effectiveness and onsite water collection and supply (Nolde, 2007, Gabe et al., 2012, Lawson, 2013). In Mexico, Fuentes-Galván et al. (2015) found in their research that the majority of households were willing to install a rainwater harvesting system as an alternative water supply system.

2.8 Policies and regulations for rooftop rainwater harvesting in the developing world

From different case studies from developing countries, it can be seen that, often, no progress is shown until and unless a RWHS is made mandatory in urban building design (Chakrabarti, 2001). In 2006, the Malaysian Prime Minister announced that a rainwater harvesting system would be made mandatory for large buildings, such as factories, sports complexes and stadiums (HO et al., 2009). Similarly in India, some provincial governments have stated that it is now compulsory to include a rooftop RWHS in new building plans in cities (Kumar et al., 2006). Institutional reform is a modern need in terms of integrated urban storm water management. The lack of technological awareness and policy planning is a major concern in coping with the current water crisis in terms of incorporating integrated urban storm water management (Brown, 2005). Water related legislation is not well developed in many developing countries—for instance, there is no clear water related legislation on the adaptation to rainwater harvesting in South Africa. Another barrier to the implementation of a RWHS is found to be the top-down approach rather than a bottom-up approach at the household level in Australia, as skilled engineers are required to undertake maintenance (White, 2009). It can hence be seen that the implementation of a rainwater harvesting system requires institutional innovation (Kahinda et al., 2010).

2.9 Advantages of rooftop rainwater harvesting system

From an environmental and socio-economic perspective, there are many advantages of a rooftop RWHS. It can be used for agricultural, domestic and industrial purposes. Rooftop rainwater harvesting systems also play an essential role in flood management and storm water runoff (Gould and Nissen-Petersen, 1999, Jia et al., 2013). Due to rapid growth in urbanization, it is one of the best alternative sources of water supply to all sectors. It can fulfil both potable and non-potable water demand. It is also more economical and socially acceptable to the community (Domènech and Saurí, 2011).

Chapter 3- Water supply problems and rainwater harvesting potential in major cities of Pakistan

3.1 Introduction

This chapter discusses the current domestic water supply systems and problems in four major cities of Pakistan; Karachi, Quetta, Lahore and Rawalpindi. In addition, the potential of RWHS will also be explained. The historical development of RHWS in Pakistan is also discussed.

3.2 The climate in Pakistan

Pakistan is located in a semi-arid climatic region of South East Asia. The country's average rainfall is less than 375 mm a year, however from southern to northern regions, the rainfall pattern varies across the seasons. Areas near the north-west region (Figure 3.1) receive an average rainfall of 950 to 1000 mm per month during the monsoon season (July to September). This includes major cities such as; Rawalpindi district and capital city Islamabad. On the other hand the climate is hot and dry near coastal areas such as Karachi city.

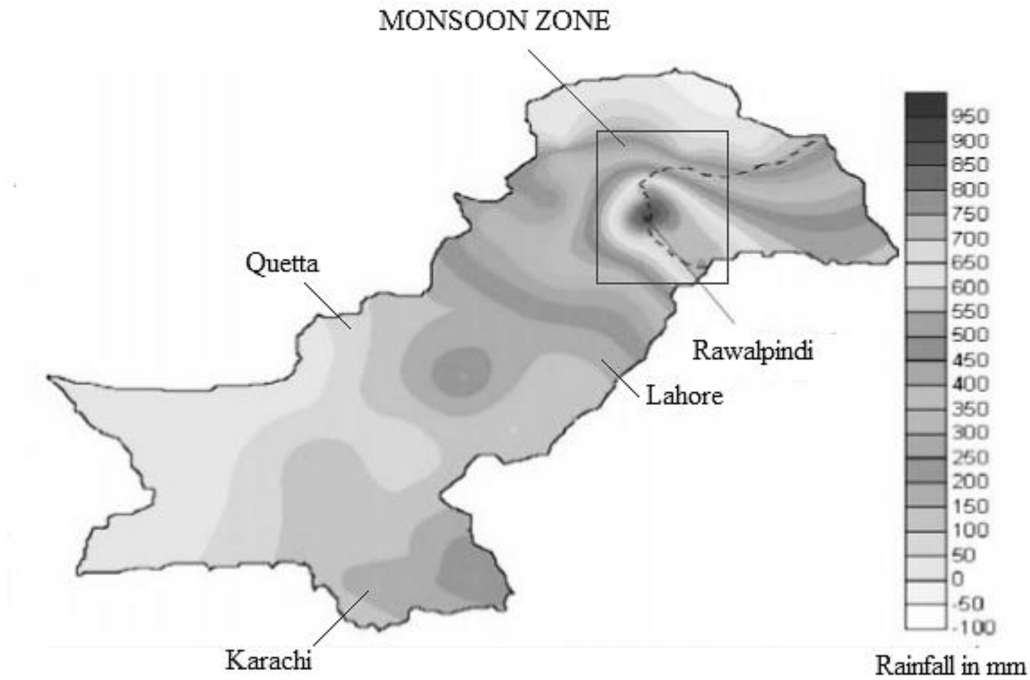


Figure 3. 1 Average annual rainfall distribution in Pakistan

Source: (Guimaraes, 2015)

3.3 Climate change and its effect on rainfall patterns in Pakistan

For any region, it is important to review the impact of climate change on rainfall patterns (Parry et al., 1998). As with most countries, the Pakistan climate is affected by global warming, resulting in increased temperature profiles. This has led to rainfall in coastal belts decreasing by up to 15%, however, in monsoon zones, a one third increase in rainfall has been observed (Farooqi et al., 2005), leading to flooding. This increase in rainfall in monsoon zones could be dealt with positively if climate change strategies were adopted in a more sustainable way. Increases in rainfall due to climate change demand sustainable solutions, therefore the implementation of RWHS could potentially contribute towards an improvement in the strategy of climate change adaptation. Overall however, a macro-strategy is required to develop or modify policies to deal with climate change (Farooqi et al., 2005).

3.4 Pakistan domestic water policy

In 1977, the first environmental protection policy was legislated for to safeguard environmental resources. To cope with water and sanitation problems in relation to climate change, the national environmental action plan was approved in 2001 by the EPC (Environmental Protection Council). Furthermore, a national environmental policy was established in 2005 under the national environmental plan, which clearly promoted appropriate technologies for rainwater harvesting in rural and urban areas. However, since the inception of this policy, full implementation of these technologies has not occurred, with only some minor implementation in rural areas, such as the development of pond reservoirs in the desert of Cholistan and rooftop RWHS in rural areas to the north of the country

In the case of domestic water supply, the national drinking water policy was established in 2009. However, this policy focussed primarily on drinking and agricultural water use. One aim of the policy was to provide safe drinking water to the entire Pakistani population by 2025, with the aim of launching 544 filtration plants throughout the country.

3.5 Urban water demand/supply management and planning

Urban water management encompasses the urban water cycle and addresses; storm water, groundwater, water supply and wastewater management, all with the aim of minimising environmental degradation through urban design (WBM, 2009, Lee et al., 2010, Searle, 2010, Baumann et al., 1997). Urban design in support of water conservation is not well developed in Pakistan, although some projects have been initiated in Karachi, the country's largest and most densely populated city (Westcoat JR, 2009). However, due to poor policy making and governance, these projects failed to provide a suitable water system supply to fulfil community water demands (Khan, 2009).

In general, urban design in support of water conservation should reflect the different hydro-climatic conditions of the locality, be it a city, town or village. For instance, the rainwater harvesting movement has expanded rapidly within a global context, from rooftop diversions to pond and reservoir storage, thereby underlining the significant potential of the hydrologic cycle. Cities such as Karachi, Lahore and Islamabad vary in their responses to water problems, responses that include innovations in water conserving design. Water shortages, floods and poor infrastructure are chronic features of some Pakistani cities, whilst their hydro climatic and infrastructures can differ. Therefore each city needs to adapt to and mitigate against urban water problems as per their hydro climatic and infrastructure (Westcoat JR, 2009).

3.6 Domestic water problems in the major cities of Pakistan

In the major cities of Pakistan, water supply and demand is unstable due to location, climate, urban infrastructure and socio-economic variables (Biemans et al., 2013) There are four provinces in Pakistan; Sindh, Punjab, Baluchistan and KPK (Figure 3.2). Karachi, Lahore, Quetta and Rawalpindi are the four major cities of Pakistan with the highest populations (Table 3.1). All major cities face urban water problems due to rapid growth in population and a falling ground-water table, with Lahore and Rawalpindi having the most severe urban water problems.

Figure 3. 2 Pakistan and its provinces

Source: Map courtesy of government of Pakistan (http://www.surveyofpakistan.gov.pk/)

Table 3. 1The major cities of Pakistan and their populations

Province	**Major Cities**	**Estimated population in 2013 (millions)**
Sindh	Karachi	13.205
Punjab	Lahore	7.130
Punjab	Rawalpindi	3.992
Baluchistan	Quetta	0.896

Source: (Planning and Development, 2014)

The major cities of Pakistan mainly rely on ground water resources for domestic purposes. However, ground water supplies are being over exploited; every year about ten thousand new tube wells are installed to supply water (Couton, 2009). In 2005, the

World Bank analysed the water sector problems in Pakistan in their report "Country Water Resources Assistance Strategy". The report found that domestic water sectors in urban areas were at risk and that policies were ineffective in tackling the issues. Furthermore, in practical terms, less attention was given to domestic water issues in urban areas when compared to rural settings (Westcoat JR, 2009).

In the following sections, the four major cities of Pakistan will be investigated to identify existing domestic water supply issues. This will provide information that will allow for a more focussed investigation on one city. Additionally, the annual rainfall of these major cities will also be investigated and will identify which city has most rainfall contributing to existing domestic water demand.

3.7 The Karachi domestic water supply system and its problems

Karachi is the largest city in the Sindh province and receives domestic water from a long distance water source through a bulk distribution system consisting of waterway channels, pipes, multi-stage pumping and filtration units. Karachi Water and Sewerage Board (KW&SB) is the main provider of domestic water to the city. Similarly, the Orangi Pilot Project (OPP) initiated in the 80s by three non-government organisations (NGOs) - Water Aid, the Asian Development Bank (ADB) and the United Nations Development Programme (UNDP), aimed to involve local communities in solving local sanitation problems. The OPP also collaborated with the KW&SB to enhance the implementation of projects and to develop sewerage systems and wastewater treatments According to the OPP and the KW&SB, there are two sources of water into Karachi (Rahman, 2008):

1) The river Indus which provides 650 million gallons per day (MGD)
2) The Hub dam which supplies on average 50 MGD. As the hub dam supply is rain fed, the supply ranges between 30 and 75 MGD.

Currently, water demand in Karachi is estimated at 1080 MGD with a current short-fall of approximately 430 MGD (KW&SB, 2013)

A town quota system organised by KW&SB provides domestic water to different cantonments and defence housing authority (DHA) areas in Karachi. The cantonment and DHA fall under the jurisdiction of military lands and cantonment departments (ML&CD). The DHA was originally built for army officers in the 1980s but later it was turned over to civilian use. While cantonment areas come under the jurisdiction of military lands, they do not meet the standard of DHAs with respect to amenities and quality of life. The population of cantonment areas is relatively small while 40% of the total landmass of Karachi is covered by cantonments.

There is a severe water shortage in DHA areas in Karachi, a shortage that in part, is being remedied by private water tankers (Shah, 2015). Currently, the available water for the city is 4.17 MGD; the remaining water being supplied by official and unofficial water tankers and the private tankers' association. There are more unofficial hydrants and filling points than official water tankers across Karachi. Most of these hydrants and filling points are near bulk distribution systems. According to the OPP-research training institute, there are 161unofficial hydrants in Karachi (Rahman, 2008).

3.7.1 The potential for rooftop RWHS in Karachi

There are two seasons in Karachi: summer and winter. Summers are long and dry. Karachi also experiences the monsoon (rainy) season from July to September. However, rainfall is low relative to other major cities.

The average annual rainfall is 200 mm with monthly average rainfall depths shown in Figure (Appendix D.1). Additionally, a decrease in current rainfall is also observed (Sadiq and Qureshi, 2010). As a result of low precipitation and high domestic water demand in urban areas of Karachi, RWH systems are unlikely to provide a suitable and appropriate solution to overcome domestic water problems.

3.8 The Quetta domestic water supply system

Quetta is the capital, and has the largest population, of Baluchistan. The main source of water for domestic and agricultural use is groundwater. However, across the past three decades, the ground water table has fallen in Quetta city (Khan et al., 2013). Interestingly, some distance from Quetta is a reliable surface water source, however it cannot be used as an alternative to ground water due to high treatment cost, and therefore WASA successfully drilled several wells locally. The agency is still in the process of investigating alternative groundwater sources (Khan et al., 2010).

According to the Baluchistan Times Report, Feb 14th 2013 “there remains a shortfall of 20 million gallons per day (MGD) in the water supply for Quetta, with a demand of 50 MGD”.

3.8.1 The potential for rooftop RWHS in Quetta

Groundwater source is almost the primary distribution of water for farming, agriculture and domestic purposes in Quetta. Currently, Quetta suffers from water shortages and with a growing population, the ground water sources cannot sustain the city’s needs (Birch et al., 1998).

Unlike other major cities, Quetta does not experience a monsoon season. Moreover, summer and winter provide much less precipitation than in other cities. In the last decade, due to global warming, temperatures have risen and mean precipitation has diminished (Khan et al., 2013). Average yearly precipitation in Quetta is very low when compared to other parts of Baluchistan. Most rainfall occurs in winter from December to March; while the summer is dry (see Appendix D.2).

3.9 The Lahore Domestic Water Supply system

WASA is the main water supplier in Lahore, operating as part of the Lahore Development Authority. According to the Lahore Development Authority (LDA), WASA is responsible for:

- the planning of the water supply system and,
- the planning, designing, maintenance and development of sewerage and domestic water supply system (Lahore Development Authority).

However, WASA does not supply private housing schemes or other informal unplanned settlements. Private housing schemes come into the planned category, and are approved by the LDA, but there are unplanned settlements which may be on either private land or mixed private and state land. Statistics show that 15% of the total Lahore population lives in these informal unplanned settlements; since 1970 around 254 housing schemes have been built in urban areas of Lahore and from that number only 14 were approved by the LDA, although some others were approved by private cooperative housing authorities (Baloch, 2011). As WASA (the Water and Sanitation Agency) only operates under the authority of the LDA, only a very small area of Lahore city is covered by WASA with provision of water and sanitation facilities. Thus there is a discrepancy between the private and government sectors in designing the water supply system.

3.9.1 A falling ground water table and pumping cost increases in Lahore

In Lahore, the water supply for potable and non-potable purposes relies mainly on fresh ground water resources through private, public tube well and hand pumps. Lahore is highly populated and is located near the River Ravi. However, ground water is not a reliable resource in the long term and is declining at a rate of 610 mm per year (Basharat and Rizvi, 2011). As urbanisation continues and populations increase, greater demands are placed on sourcing water, resulting in falling water tables. Accessing these sources is costly, therefore water pricing is the best option to overcome the demand (Rauf and Siddiqi, 2008)

Table 3. 2 Water tariff structures for domestic metered connections

Consumption (Gallons)	Rate (Rs per 1,000 GPM)	
	January 1998	May 2004
Up to 5,000	920	12.88
5,000 to 20,000	14.90	20.86
20,000 and above	19.50	27.30

Source: WASA, Lahore

Water is charged volumetrically where meter connections are provided, whereas for unmetered households, there is an annual rental value (ARV) charge. According to WASA, in Lahore, currently 30% connections are metered (Table 2.2).

3.9.2 The potential for rooftop RWHS in Lahore

Lahore city experiences two main seasons, summer and winter, which are mainly dry. The monsoon occurs during the July to September and it brings the highest rainfall of the year to Lahore city, causing flooding almost every year. It can be seen from (appendix D.3) that in the months of July, September and August, rainfall reaches up to 150mm, 130mm and 60mm respectively. Whereas in the rest of the months of the year, the average rainfall is 10 to 20 mm per month.

It was observed that rainfall in Lahore occurs primarily between July and September, whereas the remaining months experience very low rainfall over an average of five precipitation days (see appendix D.3). These data suggest that for Lahore, a city-wide rooftop RWHS scheme could be feasible; however, there remains the issue of consistent water supply as several months of the year experience dry weather.

However, in the past few years, a huge fluctuation has been observed by the PMD (Pakistan metrological department) in overall average annual rainfall as shown in (appendix D.4). In 2007 the average annual rainfall was 650mm, where this increases to 1585mm in 2011. This fluctuation could present an obstacle in designing the optimum storage capacity for rainwater harvesting.

If only considering the higher average annual rainfall figures for Lahore, it can be assumed that the city has considerable potential to harvest rainwater to mitigate the region's water crisis. However, as maximum rainfall occurs during the monsoon, it may not be possible to provide consistent water supplies throughout the year. Therefore more detailed research will be required to address the issues related to storage capacity over a longer period of time.

3.9.3 The LDA (Lahore Development Authority) plan for rooftop RWHS

The development authorities act as autonomous bodies for each district in Pakistan. The LDA is actively promoting RWHS in the Lahore district (Raza, 2014). The LDA has stated that the falling ground water table is 'catastrophic' and that the LDA has initiated RWHS at 39 different points within the city to recharge the underground aquifers. The LDA also conducted a land use survey using GIS (Geographical Information Systems), estimating the average annual rainfall and how much water could be captured by rooftops, including residential and commercial units in Lahore city. It was estimated that these could save sufficient water for domestic use (Hussain and Rehman, 2013). However this survey was limited in its scope with respect to the estimation of average monthly rainfall and average roof catchment areas. According to the officials of the

LDA, this plan is still to be discussed with technical and legal LDA personnel before implementation. (Raza, 2014).

3.10 Rawalpindi domestic water supply system

Similar to Lahore and other major cities of Pakistan, Rawalpindi relies mainly on ground water sources for domestic water supply. The system includes a large number of tube wells and private and municipal wells to fulfil domestic water needs. The Rawalpindi Development Authority (RDA) oversees WASA, the main water supply agency providing 260 tube wells (does not include private wells) and currently supplying all domestic water to the Rawalpindi region (Shabbir and Ahmad, 2015). However, to validate this claim of providing all domestic water to the community requires a proper household survey. Moreover, according to WASA and the RDA, the surface water is polluted but is being treated at its source before supply to the community (Islam-ul-haq and Shahid, 2008).

Similarly, ground water sources are also being treated with chlorine before supply to the consumer. According to WASA Rawalpindi, about 40 gallons per capita per day is being provided to the consumer through tube wells (Islam-ul-haq and Shahid, 2008). However, ground water in Rawalpindi is vulnerable due to excessive pumping. Therefore, practical solutions, particularly from researchers and policy makers, are required to address the vulnerability of water resources (Shabbir and Ahmad, 2015).

Domestic water supply problems and a falling ground water table in Rawalpindi are similar to the water problems experienced in Lahore. Both are large cities, both are under the management of WASA and both face severe water problems. However, the situation is particularly acute in Rawalpindi as its population is growing by up to 4 % per annum. (Ahmad et al., 2011)

3.10.1 The potential for rooftop RWHS in Rawalpindi

Rawalpindi requires a complete technical and sociological household survey to assess its potential for implementation of RWHS (Hussain and Rehman, 2013). Similarly, opportunities for RWHS have been explored in urban areas of Pakistan and suggest that rainwater harvesting can help overcome the water crisis and importantly, can be sustainable for big cities such as Rawalpindi (Shah et al., 2010). From the average monthly precipitation figures (see-appendix D.5), Rawalpindi shows a greater RWHS potential in terms of annual and monthly rainfall when compared to other major cities.

3.11 City comparisons in terms of urban growth, the falling groundwater table and rooftop RWHS potential.

As previously discussed, having annual average rainfall data is essential before the implementation of rooftop RWHS in any urban residential area can be considered. To this end, comparisons were made of water supply statistics in four major cities of Pakistan and will be used to select the study area for this research (Table 3.3).

Table 3. 3The major cities of Pakistan; facts and figures

Cities	Total estimated Population (millions)	Urban population growth rate (%)	Falling ground water table ft./year	Per capita consumption litre/day	Annual average precipitation (millimetres)
Karachi	13.205	3.5	-	165	200 to 210
Lahore	7.130	2.36	2 to 3	327	480 to 500
Rawalpindi	4.503	4	4 to 5	150	880 to 900
Quetta	0.896	2.75	7 to 8	59	225 to 235

Sources: (Brown, 2003, Basharat and Rizvi, 2011, PBS, 2012, Hussain and Rehman, 2013, Weatherbase, 2015)

3.12 The institutional structure of statutory bodies involved in planning and development of urban design and water supply systems

The administration structure of Pakistan flows from the central/federal government down to provincial level for policy formulation and implementation. The ministries of the four provinces function under federal ministries. The four provinces of Pakistan (Figure 3.3) are further divided into Divisions, then Districts, Tehsil/towns and union councils. In addition, the different ministries/divisions have 411 bodies, including attached departments, autonomous bodies, semi-autonomous bodies and organisational entities (Figure 3.3) (NCGR, 2016).

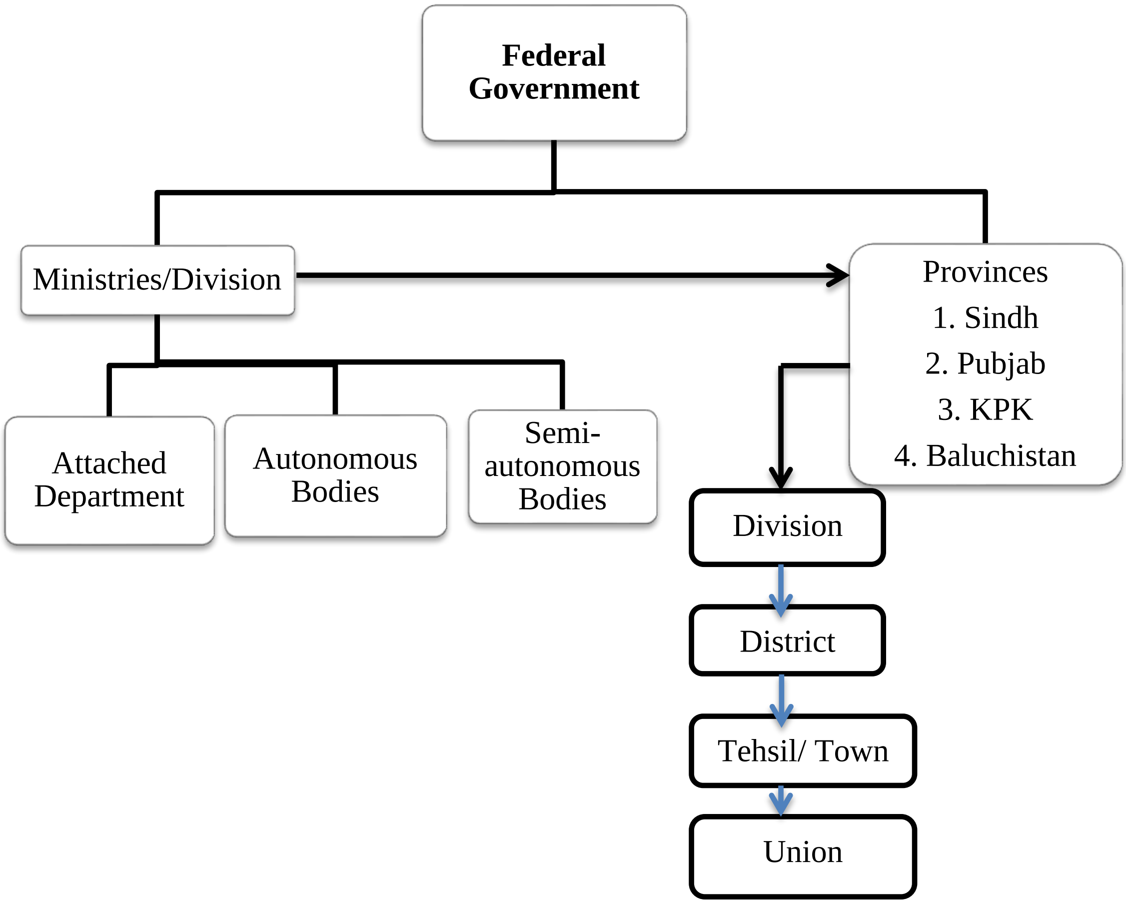


Figure 3. 3 The administration structure of Pakistan

Source: (NCGR, 2016)

The ministries and departments involved in the provision of water supply management and planning and other water related facilities are shown in Figure 3.4. The PCRWR (Pakistan Council of Research in Water Resources) was established to deal with water related issues in all sectors, including agricultural, domestic and industrial water use. The PCRWR is regulated by the Ministry of Science and Technology. Similarly, the Ministry of Climate Change uses the EPA (Environmental Protection Agency) to deal with all issues related to climate change, including urban water supply management and planning. WASA offices are distributed in the four major cities of Pakistan and are involved in the provision of water supply and sanitation facilities to urban communities. Responsibility for WASA falls to the Ministry of Housing Urban Development and

Public Health Engineering. The Water And Power Development Authority mainly focus on construction of dams and electricity generation.

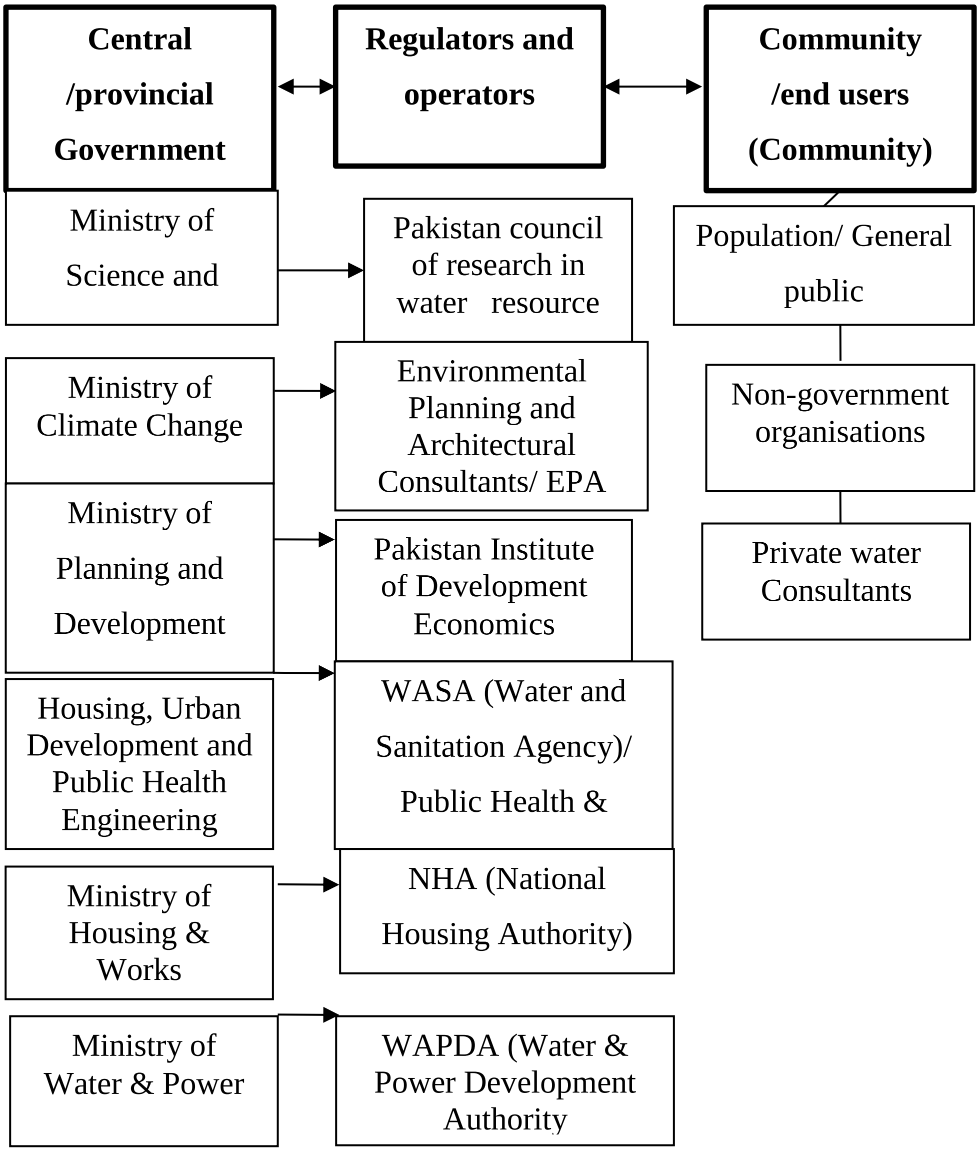


Figure 3. 4 The Government of Pakistan Stakeholder map. This identifies key statutory bodies and beneficiaries involved in the provision of water related facilities.

Sources: (Cardona, 2006)

3.13 The main agencies of water administration at central and provincial levels in Pakistan

The main agencies of water administration at central and provincial level in Pakistan are the PCRWR and WASA. The PCRWR was established to deal with research on water resource management and water quality in all sectors, including, agricultural, industrial and domestic whereas WASA was established to deal with water supply and sanitation facilities at the domestic level. All other departments, regulators and operators are also engaged in the provision of water supply facilities. However, these regulators are not directly involved in the water sector like PCRWR and WASA. For example, the EPA and WAPDA deal in the water sector, but domestic water supply is not the main objective of these operators. As mentioned previously, WAPDA is responsible for dam construction and electricity generation, while the EPA deals with environmental pollution.

3.14 The Pakistan Council of Research in Water Resources (PCRWR)

The PCRWR was established in 1964 under the then Ministry of Natural Resources and then in 1970, it was brought under the Ministry of Science and Technology. Initially, it was called the Irrigation, Drainage and Flood Control Research Council (IDFCRC) but in 1985 it was renamed the PCRWR. The council has played a vital role in providing and promoting applied and basic research in the water sector in Pakistan, in areas such as water quality assessment, groundwater recharge, desertification control and rainwater harvesting. The PCRWR has five regional centres with its headquarters based in Islamabad (Figure 3.5).

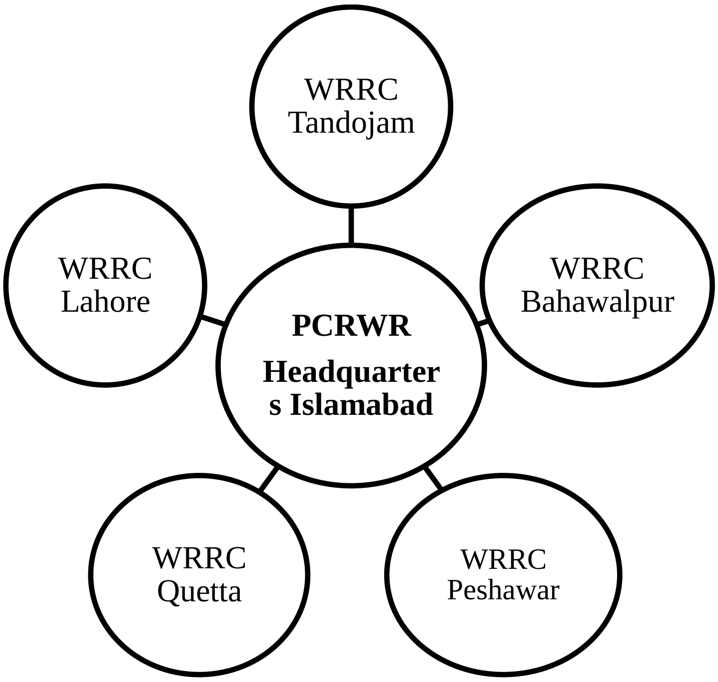


Figure 3. 5 The headquarters and regional centres of PCRWR

Source: (www.pcrwr.gov.pk)

3.14.1 Policies and statutory functions of PCRWR

Several policies underline the PCRWR mandate on water resource management. However, many of these policies focus on the monitoring and evaluation of drinking water quality and the irrigation sector. However, water conservation design is also included in its constitutional functions, i.e.;

- Design, develop and evaluate water conservation technologies.
- undertake contractual research and provide consultancy services to the private and public sector
- design, develop and evaluate water conservation technologies for irrigation, drinking and industrial water
- advise the government and submit policy recommendations regarding quality, development, management, conservation and utilisation of water resources

The PCRWR collaborates with different international governments and NGOs (Figure 3.6) on joint projects in water resources development and management.

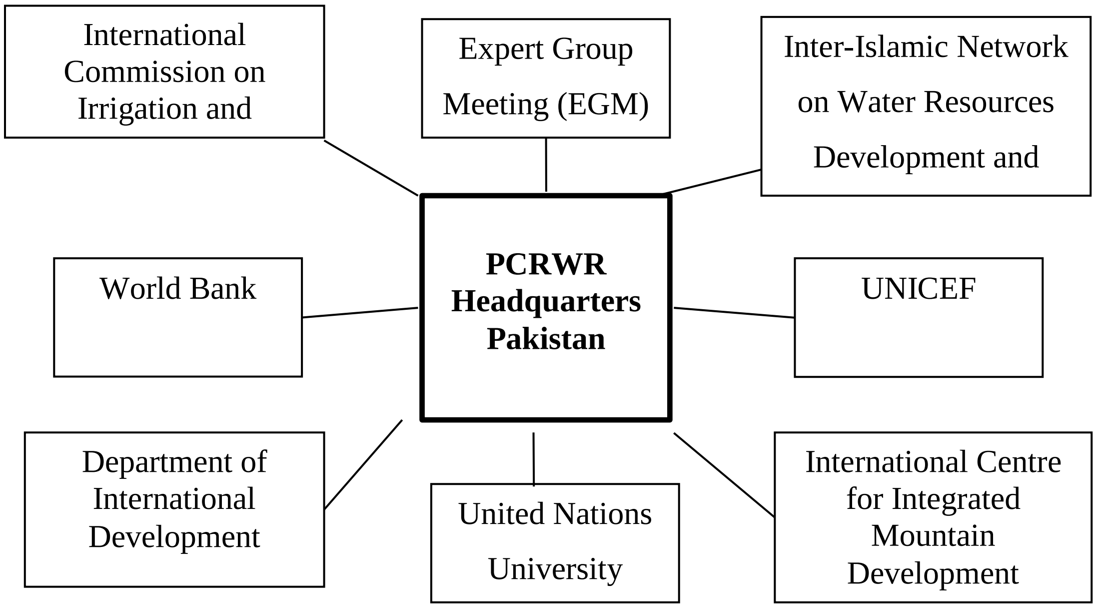


Figure 3. 6 The collaborative institutions of PCRWR

Source: (www.pcrwr.gov.pk)

The PCRWR also collaborates with different national/provincial organisations including academic centres and universities which are involved in research and the implementation of water management, desertification, irrigation, and water quality.

According to the PCRWR, several rainwater harvesting system projects have been completed; some are listed below;

- Urban rainwater harvesting (Ground Water Recharge) systems for domestic use in Islamabad (Completed)
- Rainwater harvesting (surface water collective ponds) systems and desertification control in Cholistan desert, Sindh province (Completed)
- Rainwater harvesting (surface water collective ponds) systems and desertification control in Baluchistan province (Ongoing) (source www. pcrwr.gov.pk)
- The first urban rainwater harvesting pilot project was launched in 2010; the project was a ground water recharge in Islamabad.

- Desertification control through the construction of ponds in the deserts of Cholistan Sindh province (Completed in the 1980s).

3.15 WASA (Water and Sanitation Agency) Pakistan

WASA (Water and Sanitation Agency) is the semi-autonomous body of the district government of seven cities in Pakistan. It was established by the LDA in 1976 for the development of sewerage and water supply systems for Lahore. The purpose was to develop, design and maintain the water supply and sewerage systems for the city. WASA was further expanded to include other major cities of Pakistan such as Faisalabad (1978), Quetta (1989) and Rawalpindi (1998) (Figure 3.7). Currently WASA is responsible for the water supply systems to households in these urban areas.

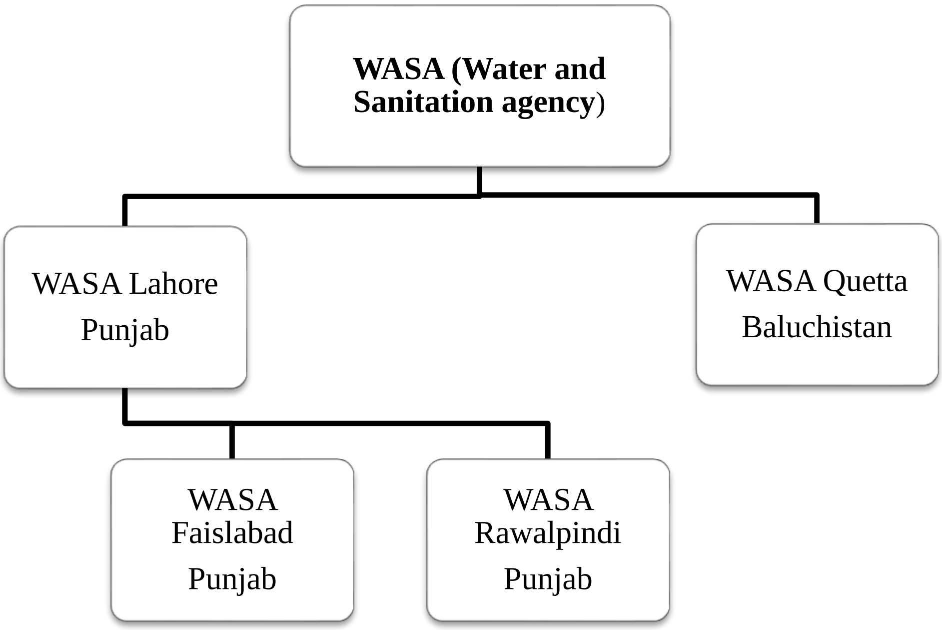


Figure 3. 7 The breakdown of Water and Sanitation Agencies (WASA) in Pakistan

Source: (www.wasa.punjab.gov.pk)

3.16 The historical development of RWHS in Pakistan

In general, RWH systems in rural Pakistan are more developed than in urban areas, thanks to the perception that rural communities are water-stressed and have less available water resource than their urban neighbours. RWH systems, employing different technical features such as; installation of gutters, storage tanks, cisterns for ground water recharge has recently been introduced into Pakistan. However, surface rainwater collection practices in ponds and reservoirs have been used in different areas of rural Pakistan for many years. For instance, the primary source of freshwater in the Cholistan desert is rainwater which is collected in natural depressions or man-made ponds (Tobas). There are more than 1500 Tobas in the desert, of which only 500 are in operation due to poor maintenance. (Kahlown, 2009). The PCRWR has initiated many projects developing ponds and reservoirs for water collection in desert areas thereby contributing to the well-being of the community. In urban areas however, RWH systems are not well-established and have not received much attention in the past.

In 2010, Pakistan installed the country's first urban RHWS in Islamabad (Faisal mosque location) as pilot rainwater harvesting (ground water recharge) project. The initiative was developed in collaboration with the UNDP and the PCRWR. In addition to ground water recharge, the project introduced a new invention through bio-sand filters to convert rain water into clean drinking water. At the Faisal Mosque in Islamabad, large water reservoirs were covered with metal lids. Sand-filter beds were put in place for the treatment of water. Around 3 million litres of water a day run through the Mosques drainage pipes (Figure 3.8). However, performance and evaluation of this system requires further research. Abdul Majeed from the PCRWR has reported, "*I installed this project rainwater harvesting through ground water recharge just a few weeks back. The salient feature of this project is that I have installed two bore holes. They are just acting like tube wells. We pump the water in the tube wells but in these bore holes we are letting the water flow through gravity. The immediate result that I noticed was a 14 feet rise in the local water table, after 3 days of rain. So that was a tremendous success.*"

Thus, the biggest mosque in Pakistan is no longer only an inspiration for believers; it has recently become a source of water supply by harvesting rainwater (Schwengsbier, 2010). As this project launched only recently, there is little or no data regarding performance available to academic researchers. However, the system performance needs to be evaluated, and if satisfactory and fit for purpose, more large scale RWHS projects will be launched in urban areas of Pakistan.

The Faisal Mosque

Drainage pipes to collect water

Drainage network under the mosque

Water reservoirs

Figure 3. 8 The rainwater harvesting (Ground water recharge) system at Faisal Mosque installed by CDA Islamabad, Pakistan

Sources: (Schwengsbier, 2010).

3.16.1 The Earthquake Reconstruction & Rehabilitation Authority (ERRA) in the promotion of rooftop RWHS in rural areas

Pakistan was affected by a devastating earthquake in 2005. According to ERRA (the Earthquake Reconstruction and Rehabilitation Authority), 4000 existing water supply schemes were affected, almost all water sources were disrupted and a 40% decrease in water yield was recorded in earthquake affected areas. During housing reconstruction, ERRA initiated rooftop RWHS installations as an alternative source of water and launched pilot projects of rooftop RWHS in the AJK region of Pakistan. However, important components were missing in the design of rooftop RWHS in this pilot project at Chitra Topi (a small village); these components were the first flush diverters, filter screens and chlorination for disinfection (Figure 3.9) (Aftab et al., 2012). Nonetheless, due to a higher precipitation rate, the system fulfilled the daily domestic demands of the community. This pilot project was deemed successful, therefore it was implemented in other parts of the AJK region (earthquake affected areas), where the first flush diverter, filter screens and chlorination were added. This project was also successful in terms of socio-economic and health benefits for the community. The PIED (Pakistan Institute of Development Economics) evaluated the project and stated that rooftop RWHS technology brought improvements to the health of water-fetching women, particularly in rural communities of earthquake affected areas, as they were responsible for water collection from sources distant to their residences (Ahmad et al., 2011).

Figure 3. 9 Rooftop rainwater harvesting system in AJK Pakistan installed by ERRA

Sources: (Aftab et al, 2011)

Figure 3. 10 Rooftop RWHS with the addition of first flush diverter

Source: Consolidated report on rooftop RWH Project ERRA, 2011

As outlined, both urban and rural RWHS were launched recently however, many research questions remain; how can RWHS performance and efficiency be fully evaluated and how can RWHS potential for optimum water conservation be realised in order to fulfil future water demands in residential areas.

3.17 Summary

Four major cities of Pakistan were assessed to identify current domestic water demands and issues related to the introduction of rooftop RWHS. This chapter has provided the background to the study and outlined the problems facing researchers and policy-makers.

The chapter identified that almost all major cities of Pakistan face water shortages in the domestic sector. As far as using rainwater as a potential source of water, both Rawalpindi and Lahore showed more potential for rainwater harvesting based on annual average rainfall. The potential of rainwater harvesting in Lahore has been studied previously and was found to experience large fluctuation in rainfall patterns. Rawalpindi has shown consistent and reliable rainfall patterns. Therefore Rawalpindi was selected for further study.

Chapter 4 Research methodology

4.1 Research philosophy

There are typically two types of research philosophy adopted in an investigation of this nature; positivism and interpretivism. The positivist research philosophy is based on observation of factual information or knowledge and depends on these observations being quantifiable, whereas interpretivist research is also based on observation but is more subjective in nature and involves interpretation of elements of the study through social constructs (Stopher, 2012). In this study, both a positivist and interpretivist research philosophies, as outlined below, have been adopted in order to capture the most relevant content and information.

4.2 Research Approach

There are generally two kinds of research approaches that fall under the positivist and interpretivist framework:

The deductive approach

The inductive approach

The positivist research phiolosophy is generally considered dedutive in approach, while the interpretisvist research philosophy is more inductive. This is because the deductive approach is aimed at testing an existing theory or hypothesis using observed data, while the inductive approach is concerned with observation, and theories are proposed towards the end of the research process as shown in the figure 4.1 below.

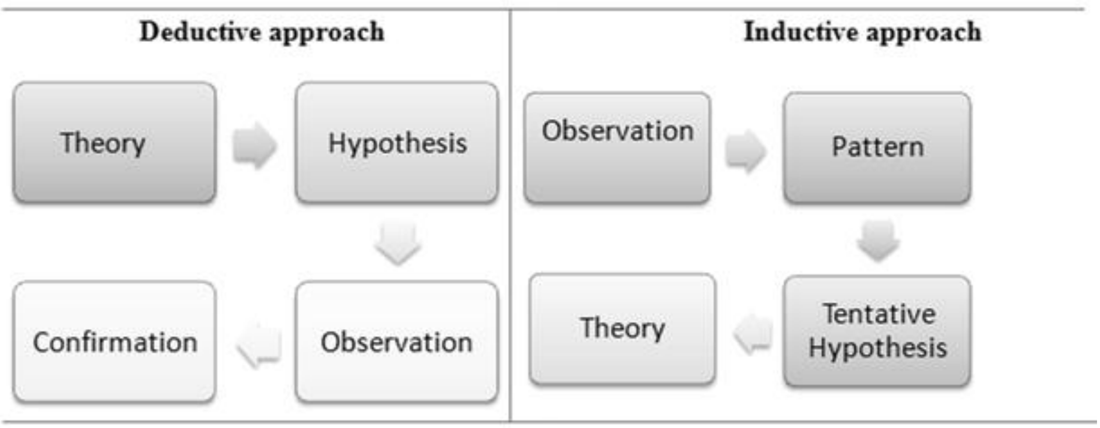


Figure 4.1 The Deductive and Inductive Approach

(Source: (Methods, 2006)

However, the boundaries of these methods are not necessarily fixed. Particularly, within the interpretive research philosophy, the deductive approach can also be used. For instance; exitising theories can be used to formulate a research question and explored inductively (Saunders and Lewis, 2012). To help undestand this, it is useful to describe the analystical methods used in deductive and inductive approaches.

4.3 Quantitative and qualitative methods

The qualitative and quantitative methods used depend on the type of data that is being analysed. The deductive research approach is most usually quantitative in nature. In social sciences generally, questionnaire surveys are used for quantitative analysis. The inductive approach is more qualitative and generally the data is gathered through interviews, personal observation, focus group discussions etc. (Hyde, 2000, Douglas, 2003, Bradley et al., 2007, Gabriel, 2013, Saunders and Lewis, 2012). Quantitave data analysis is quite typically straightforward and uses a deductive approach under the positivist research phiolosophy. In contrast, qualitative data collection and analysis is rather multifaceted. The inductive (qualitative) approach is generally used under the interpretivist research philosophy.

Overall; there are different inductive approaches used to analyse the qualitative data such as;

- Qualitative content analysis
- General inductive approach
- Grounded theory
- Discourse analysis
- Phenomenology

Table 4. 1 Comparison of different qualitative analysis approaches

	Qualitative content analysis	General inductive approach	Grounded theory	Discourse analysis	Phenomenology
Analytic strategies and question	In order to reveal or model people's information related to behaviors and thoughts.	What are the core meanings evident in the text, relevant to the research objectives	To generate or discover theory using open and axial coding and theoretical sampling	Concerned with talk and texts as social practices and their rhetorical or argumentative organisation	Seeks to uncover the meaning that lives within experience and to convey felt understanding in words
Outcome of analysis	Systematically organising and analysing segment of the text to identify patterns and themes in interviewee responses."	Themes and objectives most relevant to research objectives identified	A theory that includes themes or categories	Multiple meanings of language and text identified and described	A description of lived experiences
Presentation of the findings	Comparison of keywords or themes followed by the interpretation of the context	Description of the most important themes	Description of the theory that includes core themes	Descriptive account of multiple meanings in text	A coherent story or narrative about the experience

Source: (Neuendorf, 2002, Thomas, 2006, Krippendorff, 2012)

Furthermore, a qualitative deductive approach can also be used under the interpretivist research philosphy. Deductive qaulitative analysis is a technique in which pre-existing theories are used to formulate and explore the objective of the research. Unlike deductive quantitave analyses in which an initial hypothesis is proposed and tested using quantifiable or statistical data, in deductive qualitative analysis, interpretation of the results are concluded in relation to an existing theory. For the current research, a deductive quantitative approach was used to collect and analyse household surveys reviewing social acceptibility, whereas for the interviews, both deductive and inductive qualitative approaches were used. The questions underpinnng the interviews were forumualted around existing theories with regards to policy barriers and the interview responses analysed whilst using inductive reasoning as shown below:

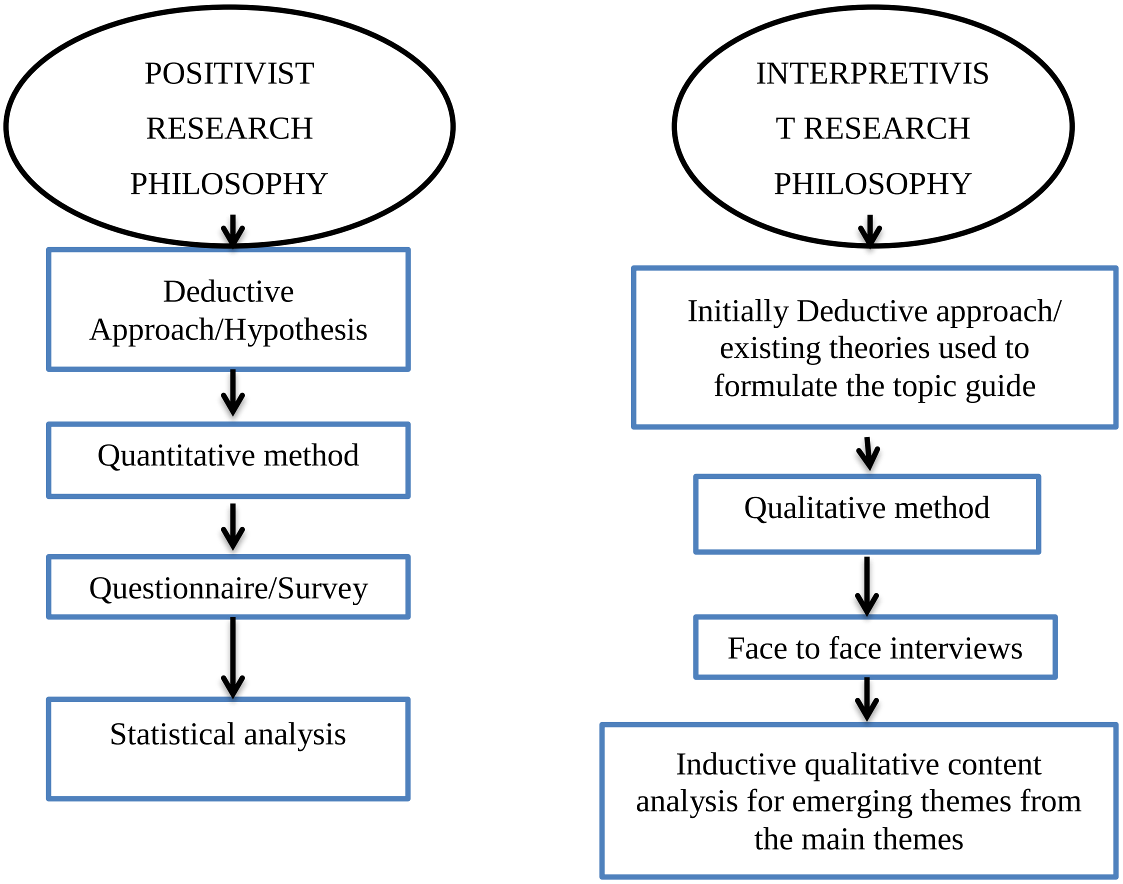


Figure 4.2 Methodological frameworks for the current research

Source (self-formulated)

4.4 Current Research Question

To what extent can rooftop rainwater harvesting systems provide a reliable source of domestic water supply in terms of technical feasibility, socio-economic acceptability, and whilst recognising any potential barriers introduced by policy issues.

4.5 Hypothesis proposed (Social acceptability of the system)

The following hypotheses were established prior to commencement of the field work and a quantitative research approach used to address the research objective.

- The system may not be attractive and acceptable to most of the urban residential population because it requires proper maintenance and time.

- The middle and lower classes might be more flexible in their acceptability and willingness as they are considered more vulnerable to water supply problems.

- The system is able to meet the daily demand for non-potable purposes to an average household as most of the houses in the study area are single or double storey.

- The system may not be a reliable source for potable water as this requires additional treatment which will increase cost and maintenance and which can lead to social unacceptability and unwillingness to adopt.

- If rooftop rainwater harvesting systems are made mandatory for new buildings then they can be promoted on a large scale with the help of social awareness programmes.

4.6 Research Method Adopted

As discussed previously, the current research is both quantitative and qualitative in nature. A 'mixed method' approach was used for the collection of primary and secondary data. Mixed method studies do not mean that research paradigms have been mixed; rather, they adopt different quantitative and qualitative techniques in sampling, data collection and analysis to be able to meet the research objective (Sandelowski, 2000, Creswell and Clark, 2007). Mixed methods research is also an appropriate means of using multiple approaches to address a given research question (Creswell, 2013).

This research focuses on water conservation through the implementation of rooftop rainwater harvesting systems. Policies regarding the promotion of rainwater harvesting systems at the household level have already been approved by the Ministry of the Environment in 2009. Therefore, the stakeholders involved in this policy formulation and implementation/management practices were identified and interviewed. In addition, quantitative research assessing the technical feasibility of rooftop RWHS as well as the socio-economic acceptability of such systems was undertaken.

The reason for the selection of a quantitative method for social-economic acceptability was to establish data on the number of people who are willing to implement RWHS based on an assessment of their existing water supply system, any issues and satisfaction level, their level of knowledge and on other demographic variables. In addition to this, questionnaires provide an appropriate quantitative technique to collect data for a large population size in that the random selection of respondents in quantitative methods also allows for a generalisation of representativeness of the larger population (Scott, 2012).

The qualitative data was collected through an analysis of the various policies and regulatory frameworks, and using face to face interviews to identify any policy implementation barriers. Policies play an essential role in the implementation of any technology or system. Within the context of this research, it is therefore essential to explore the scope of current policies regarding rainwater harvesting systems in Pakistan, as well as to understand how these policies are planned and managed. The interview itself was semi-structured, collected in audio recordings and short text notes. Interviews were based on a pre-determined topic guide (see appendices section) that was developed within the context of policy implementation barriers.

4.7 Study area and sampling

There are eight towns in the district of Rawalpindi comprising 175 Union councils (UCs) that make up the urban and rural population. Of these eight towns, Rawal town and Cantonment are completely urbanised, with 85 to 90% of the total urban population of the district residing therein (PBS, 2012).

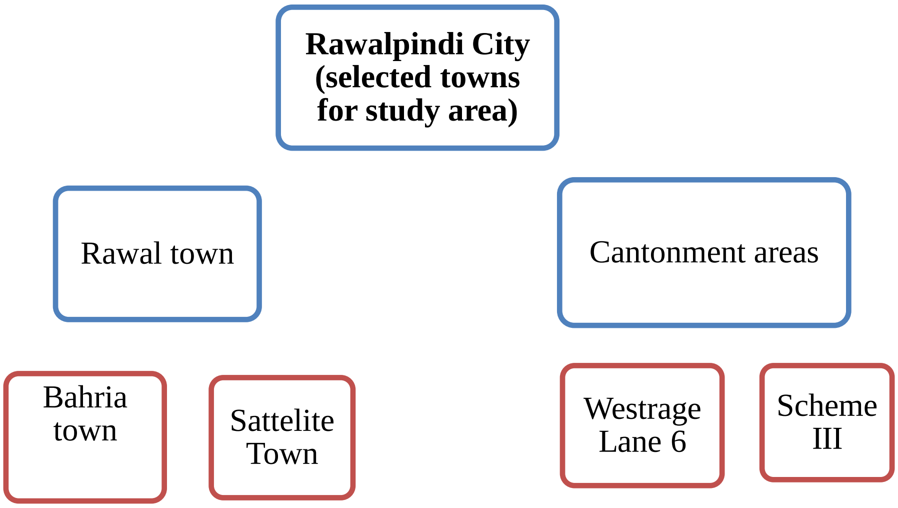


Figure 4.3 Selected towns for survey distribution

Rawal town falls under the Tehsil municipal administration while the Rawalpindi cantonment area falls under the military land and cantonments departments. It is a widely-held view in Pakistan that army-administered areas enjoy better policies and facilities. Military land and cantonments departments are permanent military stations, which are administered by cantonment boards. Therefore, the study area was further divided into the Tehsil Municipal administration area and cantonment area in order to identify any difference in responses.

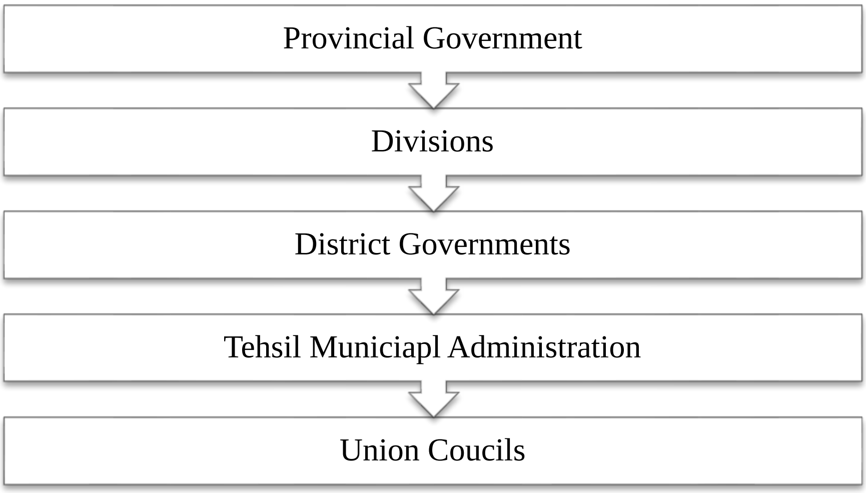


Figure 4.4 Political and administrative structure of the government of Pakistan

Source (self-formulated)

4.7.1 Sampling

Sampling is the statistical process of selecting a sample for observation and analysis from a population, as it is not feasible to study entire populations. It is particularly important to choose a sample that is truly representative of the population so that the conclusions derived from the sample can be generalized back to the population of interest (Bhattacherjee, 2012). Usually, a study of this kind seeks to establish as high a rate of response as possible, as a lower response rate can lead to a risk of unrepresentativeness (Blaikie, 2009).

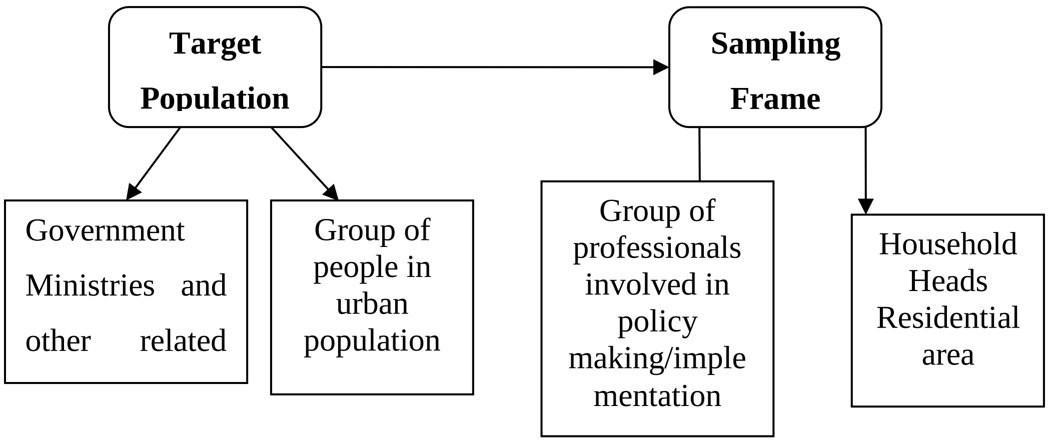


Figure 4. 5 Population and sampling frame

Source (self-formulated)

In the selection of sample size, it is important to select an appropriate proportion from the larger population. Stopher (2012) and Monette et al. (2013) discuss sampling on the basis of sample margin of error, confidence level, and population homogeneity. Baruch (1999) notes that on the basis of stringent conditions, a 3% sampling error and 95% confidence level can be used to help establish a good response rate from the population size. The estimation of the total population of the study area was based on a range of available sources. This is because the last poulation census was prepared eighteen years ago by the government.

In the current research, the total population size is assumed at around four million , meaning that for a 95% confidence level and 3.46 sampling error, the sample size was taken as 801, for which 345 responses are considered acceptable using a straightforward random sampling technique. Margin of error, confidence level and population proportion were estimated as follows:

Margin of error: Margin of error is the percentage that describes how closely the sample is to the "true value" within the total population. The smaller the margin of error the better. For the current study, a sample size, from the total population, of 3.46% was used.

Confidence level: confidence level is a measure of how certain the sample accurately reflects the population, within its margin of error. Common standards used by researchers are 90%, 95%, and 99%. For the current study, a 95% confidence level was used (Fowler Jr, 2013, Rea and Parker, 2014).

Population proportion: with the margin of error set at 3.46% and the confidence level at 95%, a population proportion of 0.5 was used. An estimation of population proportion, *p*, can be set at 0.5, 0.2 or 0.1. Where no prior information exists, then *p* = 0.5 should be used.

$$\textit{Sample Size} = \frac{\dfrac{z^2 \times p(1-p)}{e^2}}{1+\left(\dfrac{z^2 \times p(1-p)}{e^2 N}\right)}$$

Population Size = N

e- is percentage, and into decimal form it would be (3.46% = 0.0346)

Margin of error = e

P = population proportion (0.5)

Z-score = z

The z-score is the number of standard deviations a given proportion is away from the mean. The table below shows the z-score mapped to desired confidence level.

Table 4. 2 Confidence level and z-score

Desired confidence level	z-score
80%	1.28
85%	1.44
90%	1.65
95%	1.96
99%	2.58

Sources: (Rea and Parker, 2014)

An estimation of the sample size for the current study as per above formula

Sample size =

$$\frac{\frac{1.96^2 \times 0.5\,(1-0.5)}{0.0346^2} = 800}{1 + \frac{(1.96^2 \times 0.5\,(1-0.5)}{0.0346^2}} = 801$$

4.7.2 Stratified random sampling technique for the household survey

Stratified random sampling is a widely used technique in quantitative methods, particularly when seeking representativeness from a larger sample. In this technique, a large population is divided into smaller groups knows as strata. The division of the population is based on shared characteristics. After establishing the groups or strata from the sample population, the survey is then distributed randomly within the each group. Therefore, for the current research objective of assessing social acceptability and willingness to adopt rainwater harvesting systems, the study area population was divided into three smaller groups (strata). These strata were based on population characteristics and included lower class, middle class and upper-class groups.

Household heads were adopted as the unit of analysis for the survey as household heads play an important role in decision making for the adoption or rejection of household interventions. Questionnaires were distributed door-to-door with the help of local people. Furthermore, the mosque's imam also assisted with distribution, as many people gather five times a day in the local mosque for prayer, thereby providing a good opportunity to increase the response rate.

4.7.3 Purposive sampling technique for the policy-interviews

Purposive sampling is a technique in which a sample population is taken in a selective way. Unlike random sampling, purposive sampling is a type of non-probability sampling where the researcher selects which participants or members of the population chosen for the study. For the current research, when examining policy barriers, the stakeholders involved were chosen purposively. The chairperson, heads and directors of the department or organization involved in policy making and implementation hence formed the unit of analysis for these interviews.

Initially, seven policy makers and implementation managers were contacted and then interviewed using this purposive sampling technique. Due to the unavailability of further stakeholders, a snowball sampling technique was also applied. Snowball sampling - also known as chain referral - is a technique in which one member is chosen purposively and then he or she refers or recommends further interviewees. In this study, the chairperson of the HRDS (Human resource development society) Islamabad, Pakistan assisted in establishing an appropriate stakeholder interviewee list.

4.8 Data Collection

The household questionnaire was developed to collect data so as to understand the: socio-demographic profile, current water supply system, problems of water shortage, awareness and willingness to adopt rainwater harvesting systems, and information on whether this might be used for outdoor or indoor use. This allows a correlation with variables related to willingness to adopt the system, which included; level of education, income group, house size, current water supply, water shortage and awareness of rainwater harvesting systems.

4.8.1 Survey

Bearing in mind that the research question aims to identify the barriers to social acceptability of rooftop RWHS, it was hence important to know that what type of barriers exist within the social structure that influence peoples willingness and readiness towards acceptance of these systems. To achieve this requires knowledge of the current socio-demographic profile of the area based on the unit of analysis of households. Similarly, it was important to know what type of water supply system people currently rely upon and whether or not this also influences willingness or acceptance. The survey consisted of three sections. The first section comprised demographic questions; the second part assessed current water supply systems and problems e.g. water shortage, and the third part related to the household willingness and acceptability of rooftop RWHS (see Appendix A) in appendices section. This latter question was further divided into two categories addressing willingness to adopt rainwater harvesting systems for either indoor or outdoor water use. The reason for dividing this question was that the research objective focuses particularly on rooftop RWHS and not only rainwater reuse in general. For the purposes of data analysis and interpretation of the results, different variables were correlated with the help of statistical test techniques. The research questions were as follows:

- What is the current socio-demographic profile of the area?
    - *Class system, level of education, type of the house, ownership of the house and householder relation either with acceptance or rejection of rooftop RWHS*
- Current water supplies system and problems
    - *Does the type of current water supply system and householder level of satisfaction with it affect the acceptability of rooftop RWHS?*
- Willingness to adopt rooftop RWHS for outdoor water use
    - *If yes, then what are the reasons?*
- Willingness to adopt rooftop RWHS for indoor water use activities
    - *If yes, then what are the reasons?*
- Overall acceptance level of the householders for rooftop RWHS

In order to assess the validity of the hypothesis, different variables were taken into account in the translation of the research question. The research objective was to identify barriers to social acceptability and willingness to adopt rooftop RWHS. The following factors and variables were used to develop the householder questionnaire;

- *Gender*
- *Age*

- *Level of education*
- *Household size*
- *Level of income*
- *Level of knowledge*
- *Satisfaction with current water supply system*
- *Water shortage with current water supply system*
- *Availability of current water supply system*

A complete questionnaire is provided in the Appendix section at the end of the thesis.

4.8.2 Interviews

There are different methodological approaches available to identify policy implementation barriers. Analytical techniques such as content analysis, network analysis and social experimentation can all be used. However, interviews are the most common method of primary data collection (Develin, 2010). Moreover, in an interview the response rate is very high in comparison as people generally do not refuse a direct request for cooperation (Monette et al., 2013).

In this study, sixteen semi-structured interviews were conducted, of which thirteen were with government, regional and federal representatives, and three with non-government organisations. It was very difficult to determine the complete list of specific interviewees remotely i.e. from the UK, as there was no appropriate documentation or information sources to confirm the names of those involved in policy implementation. Therefore, a personal visit was enabled so as to identify appropriate stakeholders involved either directly or indirectly. Initially, some of the interviewees were identified from the official website of the ministry of climate change, Pakistan and include the Director of the EPA (Environmental Protection Agency).

Table 4. 3 List of the interviewees for policy implementation barriers

Designation	Department/ Organization
Managing Director	Water & Sanitation Agency Rawalpindi
Deputy Director Town Planning)	Rawalpindi Development Authority

Country Coordinator	Pakistan Water Partnership
Deputy Director (Water Supply)	Water and Sanitation Agency Rawalpindi
Designation	**Department/ Organization**
Project Coordinator	ERRA (Promotion of RWHS for earthquake affected areas
Project Director, Ex. chairperson	Pakistan Council of Research for Water Resources
Chief Environment Section	Planning and Development Ministry
Sr. Water and Sanitation Specialist	The world Bank office Islamabad
Dep. Chief Water Section	Planning and Development Ministry
Director Architecture & Building Control	Rawalpindi Development Authority
District Officer Planning	District Government Rawalpindi
Director EIA/ Monitoring	Pakistan-Environmental Protection agency Islamabad
Dep. Chief Executive Officer	Cantonment Board Rawalpindi
Director Water Management	Pakistan Council of Research for Water Resources
Director General	Pak-EPA
WSSCC representative	Pak Water Supply and Sanitation Collaborative Council

As discussed previously, a topic guide is an appropriate tool for use during such interviews (Bradley, 2007, Edwards and Holland, 2013). The topic guide for the current research is included in the appendices section (Appendix B).

The reason for opting for interviews with officials involved in policy planning and management practices was to obtain in-depth information and an understanding of the barriers presented by policy implementation. The topic guide was therefore designed to ask questions about the process of policy formulation and about mechanisms for implementation. The topic guide was used to structure and conduct the interviews, and the unit of analysis was the stakeholder/organisation involved in its implementation.

4.9 Different theoretical perspectives used to formulate the topic guide and main themes from the interviews

The theoretical perspectives of policy implementation are used to understand how government organisations interact with their external environment in the delivery of policies (Sanderson, 2000). The following perspectives and theories were used to formulate the topic guide and the main themes identified from the interviews throughout the process of data analysis.

4.9.1 Top down/Bottom up perspective

This approach focuses on how a single authoritative decision at a single or at multiple locations is implemented. Similarly, a bottom-up approach organises multiple factors that affect the problem and plan accordingly (Bressers, 2004, Rhodes, 2006).

4.9.2 Instrumentation theory

According to instrumentation theory, the process of policy implementation is not only about attaining the implementation, but also about addressing attempts to prevent implementation or to change the character of what is implemented. The theory also assumes that the factors which influence the implementation process do not operate in isolation from each other (Bressers and Klok, 1995, Bressers, 2004, Paudel, 2009).

4.9.3 Game-theoretic perspective

The game-theoretic perspective, which is also known as interactive decision theory, supports a vigilant analysis of interaction and collaborative processes between different actors involved in policy decision-making and implementation. Game theory also studies the behaviour of the actor towards policy implementation (Scharpf, 1997, Spratt, 2009). When dependent on the actions of several actors, *'Game theory can be a useful perspective to open the 'Black Box''* of the policy implementation process (Hermans et al., 2014)

4.9.4 Actor-centred Institutionalism

The basic argument of actor-centred institutionalism is that institutions are systems of rules that structure opportunities for actors (individual and corporate) to realise their preferences (Rhodes, 2006, Jackson, 2010).

4.9.5 Contextual Interaction Theory

The key assumptions of the contextual interaction theory are that the factors influencing the implementation process are interactive and collaborative. The influence of any factor, whether positive or negative, depends on the particular contextual circumstances. The theory distinguishes a set of "core circumstances" or constructs related to the actors involved, which jointly contribute to the implementation (Bressers, 2004, Paudel, 2009)

4.10 Methodological Approach for technical feasibility

The methodology for assessment of the technical feasibility of rooftop RWHS for urban residential areas followed three steps:

1. Determination of available rainfall
2. Estimation of how much available rainfall can be captured
3. Estimation of per capita non-potable water demand

4,10.1 Determination of available rainfall

To determine the available rainfall, the average monthly rainfall was considered. In general, annual average rainfall is taken into account when estimating the volume of rainwater available for rooftop harvesting. However, for the study area considered here, an annual rainfall figure cannot be considered due to significant seasonal variations (Martin, 2009). Monthly rainfall was estimated as follows:

- reference to available rainfall datasets, including an assessment of their reliability and validity
- determination of the number of dry days in each month (with no rainfall)
- use of these data to help determine the rainwater storage capacity and months during which the number of dry days mean the system may not be viable

4.10.2 Estimation of how much available rainfall can be captured

This was determined using figures for the available catchment area - estimated by taking into account the roof coverage of the residential properties, and in accordance with (Gould and Nissen-Petersen, 1999). Here:

- average sizes of houses within the study area were established using the questionnaire
- then a percentage of the total land size was assumed as a covered roof area. This assumption was based on protocols defined by the RDA (Rawalpindi development authority) for urban residential buildings.
- the runoff coefficient was determined based on the material and type of roof.

4.10.3 Estimation of per capita non-potable water demand

An estimation of the per capita water demand for non-potable purposes will be determined on the basis of previous studies. For example, Bhatti and Nasu (2010) conducted a detailed socio-economic household survey to identify the domestic per capita water demand of the two metropolitan cities of Pakistan including Rawalpindi. From these figures, the percentage of non-potable demand will then be allocated. It is worth noting that the per capita water demand for non-potable use is assumed constant throughout the year.

4.11 Data Analysis

4.11.1 Methods used in survey data analysis

The questionnaire data addressing social acceptibility and willingess were analysed statistically using SPSS software. Further details are discussed in chapter 6.

4.11.2 Methods used in interview data analysis

Policy implementation is defined as the step that follows policy formulation and is regarded as the process of carrying out a basic policy decision (Sabatier and Mazmanian, 1983, Ali, 2006).

In the structured interviews carried out, policy implementation barriers were analysed based on both existing policy approaches and inductive reasoning. For the interview data, firstly, the factors involved in the policy process were identified and secondly, the responses from the interviews were analysed using inductive-reasoning.

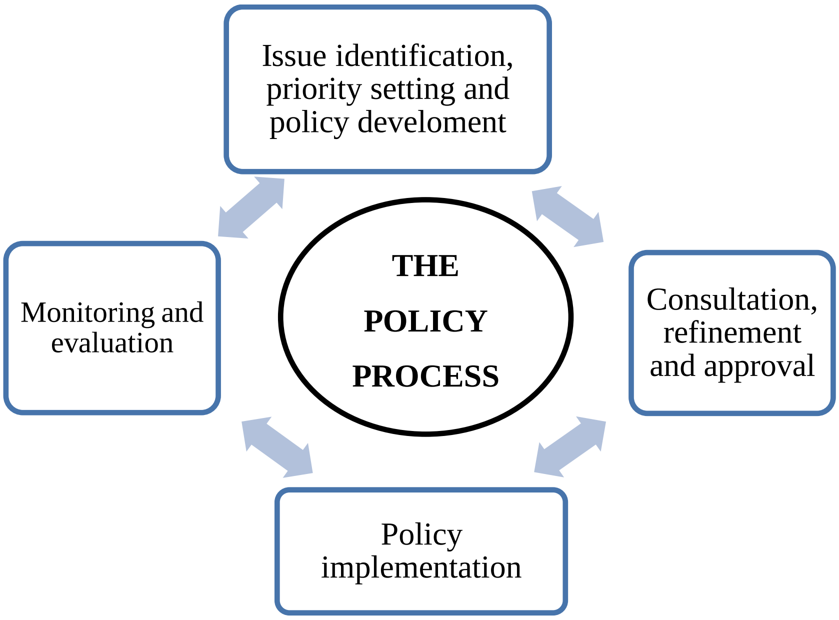


Figure 4.6 The policy process

Source: (Van Meter and Van Horn, 1975)

4.11.3 Steps involved in data analysis using deductive and inductive qualitative content analysis

- The first step towards analysis was to generate verbatim transcriptions of the raw data obtained from the audio recordings.
- The unit of analysis or the entity that was analysed were words, phrases, sentences and paragraphs as stated by the interviewees.
- Main themes were identified from all interview responses. The generation of main themes were basically the key response themes from each of the interviewees.
- From the main themes, sub-themes were generated using word search queries and word frequency counts with the help of Nvivo software. Nvivo software does not interpret or present analysis. Rather, it is used to arrange and organise the main themes and sub-themes from the transcript.

- In Nvivo software, the words ‘coding’ and ‘nodes’ are used for themes and sub-themes.
- Close coding was completed to narrow down the initial coding using an inductive qualitative content analysis approach. Close coding is basically an approach used to get to the core or essence of the interview or response whilst scrutinising themes.
- In addition, all the close coding was sorted into sub-themes or nodes to reflect the purpose of the research objective.
- The classification of the following themes were completed for further analysis
    - ➢ Ordinary themes
    - ➢ Unexpected themes
    - ➢ Major themes and sub-themes
- During the interviews, many themes, some unexpected, were generated. Therefore, during the analysis, it was important to identify the major themes and present all results specifically related to the research objective.

In general, both qualitative inductive and deductive approaches can be applied for initial coding schemes, such as:

- Using an inductive qualitative approach for developing the initial themes and categories. However, this is best suited for studies where no theories or previous related studies are available (Gabriel, 2013).
- Using a qualitative deductive approach to generate the categories and themes for data in relation to an existing theory.

In the current research, the interview data were transcribed and analysed using deductive qualitative coding methods to develop the main categories and themes of the data in relation to the existing theories. The subthemes/new categories which emerged from main categories and themes involved *“systematically organizing and analysing the segment of the text to identify patterns and themes in interviewee’s responses*” (Miles and Huberman, 1994, Schmidt, 2004, Wildemuth, 2009, Jantarasami et al., 2010, Marshall and Rossman, 2014) and were analysed using inductive qualitative content analysis. The figure below shows how different approaches were used at different levels of the analytical process.

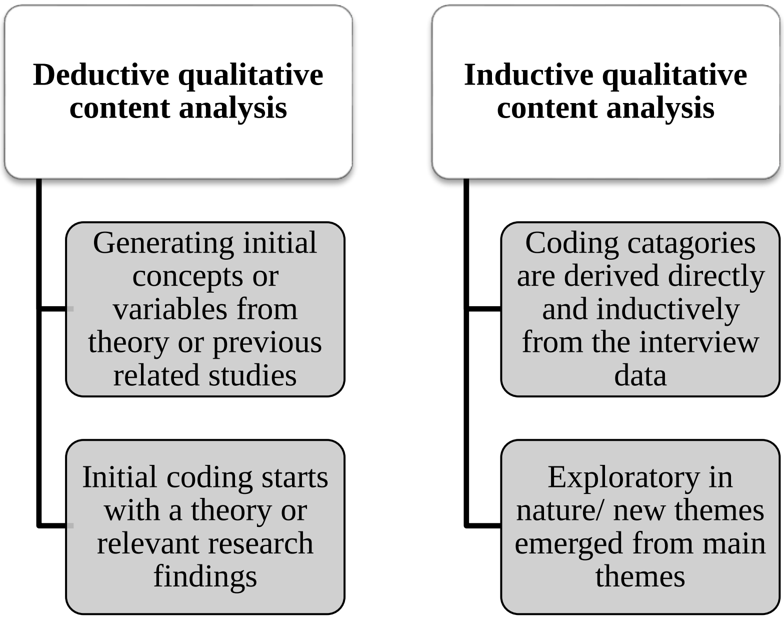


Figure 4.7 Different Approaches to Qualitative Analysis

Source: (Wildemuth, 2009, Hsieh and Shannon, 2005)

The above outlines the methods and approaches used for questionnaire and interviews data. The methodology for the technical feasibility is dealt with separately in chapter 5.

Chapter 5 Technical feasibility analysis of the rooftop RWHS

5.1 Introduction

This chapter discusses the analysis and assessment of technical feasibility of rooftop RWHS for urban residential areas in Rawalpindi. It addresses rainfall figures for the region, as well as examining the available catchment areas provided by rooftops within the study area. In addition, the per capita non-potable water demand is also discussed as well as the practicalities of RWHS installation for properties of different age and design.

5.2 Data gathering

5.2.1 Climate of study area

The highest and lowest temperatures for Rawalpindi along with the heaviest monthly rainfall in the past 85 years are represented in table 5.1. It was observed that the maximum or heaviest rainfalls occurred in July and August (743.3 mm and 641.4 mm respectively), demonstrating that the heaviest rainfall occurs during the monsoon season, whereas October and November experience minimum rainfall levels

Table 5. 1 Temperatures in Rawalpindi including rainfall data over the past 85 years

RAWALPINDI/ISLAMABAD (1931-2014)			
	Temperature (°C)		Monthly
Month	**Highest Maximum*(dd/yyyy)***	**Lowest Minimum*(dd/yyyy)***	**Heaviest Rainfall mm *(yyyy)***
January	**30.1 (30/1995)**	**-3.9 (17/1967)**	**166.9 (1954)**
February	30.0 (28/1985)	-2.0 (08/1978)	248.8 (1998)
March	34.4 (20/2002)	-0.3 (17/1967)	224.0 (1981)
April	40.6 (29/2006)	5.1 (07/1994)	264.9 (1983)
May	45.6 (31/1988)	10.5 (09/1997)	115.3 (1965)
June	46.6 (23/2005)	15.0 (02/1979)	255.0 (2008)
July	45.0 (03/2012)	17.8 (05/1966)	743.3 (1995)

August	42.0 (11/1987)	17.0 (03/1976)	641.4 (1982)
September	38.1 (05/1982)	13.3 (26/1994)	282.0 (2011)
October	37.8 (01/2009)	5.7 (31/1984)	95.8 (1997)
November	32.2 (02/1999)	-0.6 (28/1970)	91.2 (1959)
December	28.3 (07/1998)	-2.8 (25/1984)	177.9 (1990)
Annual	46.6 (23/06/2005)	-3.9 (17/01/1967)	1828.0(2007)

Source:(PMD, 2014)

5.2.2 Estimation of the average monthly rainfall in study are

A range of datasets are available that offer information on monthly average rainfall and the number of wet and dry days in each month. The Pakistan Bureau of Statistics (PBS) publishes monthly rainfall datasets, but without information on the number of dry and wet days. This is shown for the years 2013 and 2014 in figure (see-appendix D.6). This gives an indication of the variation in recorded rainfall patterns; for instance, 297.9 mm rainfall was recorded in February 2013 whereas for February 2014, the figure was only 50.4 mm. For this research, at least 10 years' worth of average monthly rainfall data is required for feasibility analyses. This is because, it is known that at least 10 years' rainfall data is required for a valid estimation, whether based on average annual or average monthly rainfall data (Hussain and Rehman, 2013). Different available datasets show average monthly rainfall data based on the previous 10 to 15 years, while some data sets show the last 50 to 60 years.

One of the sources for rainfall data is world weather online. World weather is an online database that generates datasets for different cities of the world based on their local meteorological reports and on forecasting reports of other world metrological organizations. For Rawalpindi, the average monthly rainfall and number of wet days is shown in Figure (appendix D.7) for 2000 to 2012.

Similarly, the Climatemps database also generates data showing an average monthly rainfall and number of rainfall days for Rawalpindi (See-appendix D.8) (Climatemps, 2015). Here, the average monthly rainfall was 267 mm for July and 309 mm for August.

However, the timescale over which this data was established could not be confirmed, thereby calling into question the reliability of this information.

The datasets (Appendices D.7 and D.8) revealed different average estimations of monthly rainfall for Rawalpindi. However, the most detailed and wide-ranging datasets were found at Weatherbase (Weatherbase, 2015). Here, all monthly mean rainfall data were presented in detail along with the average number of precipitation days each month. The overall estimation of average monthly rainfall was based on the past sixty years, and the average number of precipitation days on the past thirty years, (Appendix D.9). Weatherbase data resources revealed that data collection for average estimations are derived mainly from national climate centres and other authentic sources (Weatherbase, 2015).

5.2.3 Analysis of average monthly rainfall and number of precipitation days

Ideally, an estimation of rainwater potential for domestic purposes requires precise information as it directly affects storage capacity and daily water demand (Critchley and Siegert, 1991, Elgert et al., 2015).

In the study area, it was noted from the previous 60 years' datasets, that monsoons show stability in precipitation rates. This stability term refers only to the occurrence of rainfall from July to September. Unlike other months, monsoons always come with heavy rainfall, regardless of other variations in precipitation rates.

According to the Pakistan weather portal, the monsoons start in July and continue to mid- September. These months bring huge volumes of rain in Rawalpindi; higher than all other months put together. October to December are the driest months of the year with the lowest rainfall. The rainwater supply potential is usually calculated using annual mean precipitation except where there is a significant change in rainfall patterns, meaning that, here, monthly average rainfall patterns should be considered. However, these estimates do not provide information on average "consecutive" wet days in a month.

Annual rainfall estimations, catchment size and per capita water demand are widely-used indicators in assessing the potential and feasibility of rooftop RWHS (Chiu and

Liaw, 2007, Islam et al., 2011, Chiu et al., 2015). However, for this research, a dry-day assessment was also included on the basis of the amount of precipitation and maximum consecutive dry days to help identify how the system will work in practical terms. This is because the system is for the supply of water for domestic (residential) non-potable purposes and the higher the number of consecutive dry days, the higher the chance normal demand will not met. Additionally, if draw-off is low, then water quality issues may also be of concern.

5.2.4 Analysis of consecutive dry days

Daily rainfall data is generally used in identifying maximum consecutive dry days (Hernández et al., 2016). No standards were found in literature to specifically define the threshold value for the definition of a 'dry day' for rooftop RWHS in hot climatic conditions. However, the generally accepted threshold value for arid regions where RWHS are used for irrigation purposes is usually taken as 1 mm precipitation.

Abbas et al. (2014) present datasets from the last thirty years (1981 to 2010). These were obtained from the Pakistan Meteorological Department to analyse the average number of consecutive dry days for Rawalpindi. Any day experiencing < 1mm precipitation was considered a dry day. Abbas et al. (2014) found an average 44 maximum consecutive dry days for Rawalpindi. However, they did not mention which months of the year these occurred.

It was hence assumed on the basis of average monthly rainfall and number of precipitation days that the months of October and November have the maximum number of consecutive dry days. This is because the historical and statistical rainfall datasets covering the past 50 to 60 years show that October and November are the driest months of the year (Appendices D.7, D.8 and D.9). In addition to this it can also be seen from figure 5.1 that the months of October and November have the minimum number of precipitation days when compared to other months of the year. Only three days of precipitation occurred in each month (Appendix D.9). Therefore on average, a total of 44 maximum consecutive dry days were assumed across the months of October and November. All other months were considered as having no significant consecutive dry days. This is because, generally, less than 10 consecutive dry days in each month is considered satisfactory for the feasibility of rooftop RWHS for non-potable use (Yaziz et al., 1989, Kusre et al., 2017).

5.2.5 An estimation of storage requirements

The physical size of the water storage tank is an important factor in identifying the feasibility of rooftop RWHS in Rawalpindi. Rainfall data showing average seasonal variations helps design appropriately sized storage tanks for rainwater (Imteaz et al., 2013, Allen, 2012, Patel et al., 2014). In Rawalpindi, most rainfall occurs seasonally, meaning that monthly averages become more important than average annual yield.

As this research will focus mainly on the provision of non-potable water, the per capita (non-potable) demand was estimated at 50 litres per day based on previous findings (Bhatti and Nasu, 2010). This figure is corroborated in later sections of this chapter.

The monthly demand was then established as follows:

Demand = Water consumption/person/day x No. of people in household x 30 days = demand in litres/month

With the average number of people per household taken as six, this gives a monthly consumption of 9000 litres, thereby defining the indicative storage requirement for a household of six people. Data on household size (number of persons) was obtained from questionnaires during the collection of primary data, where it was found that the average number of members in a household was six. Similarly, Mahmood et al. (2013) observed that the average household size in Pakistan comprised six household members.

5.3 Potential rainwater supply from runoff

As noted above, a range of datasets were assessed in order to estimate the average monthly rainfall for Rawalpindi. On average, 60 mm rain falls in January, February and March, whereas for April, May June, July, August, September and December the estimated monthly rainfall is 40, 35, 50, 200, 230, 90 and 30mm respectively. The months of October with 10mm and November with just 8mm were found the driest months of the year.

The runoff coefficient (C_r) defines the actual volume of runoff relative to the total amount of rain falling on the surface, and is affected by the characteristics of the roof, e.g. vaporisation, infiltration, material, slope and if applicable, different soil types (Imteaz et al., 2011, Khosravi et al., 2013). Some web-based rainwater harvesting calculators use a runoff coefficient of 0.9, however 0.65 is better suited to tile and cement roof types (Gould and Nissen-Petersen, 1999). As the roof catchment for the study area is comprised primarily of cement roof types, the runoff coefficient was hence set as 0.65.

Catchment areas based on house sizes are discussed below, thereby allowing a determination of which months and size of the houses have potential to supply to rainwater to meet non-potable demand.

5.4 The size of the houses in residential areas of Rawalpindi

The catchment/rooftop area was determined based on different plot sizes and was based on standards for residential housing in Rawalpindi (RDA, 2007). Plot sizes (data) on which houses were built were also collected by questionnaire during the field work. A question regarding the plot size of the house was a part of demographic section of the questionnaire (Table 5.2). It was found that Rawal town and Rawalpindi cantonment areas consisted mainly of lower-middle and middle class areas with house sizes in the region of 4 to 5 Marla. The term “Marla” is a traditional unit used for land area in India and Pakistan. One Marla is equal to 25.29 square metres, therefore 5 Marla is equal to 126.46 square metres. In study area, 55.5 % of house sizes corresponded to 4 Marla and 45.6 % of respondents lived in 5 Marla houses.

Similarly, cantonment areas comprising lower-middle and middle classes also responded; 54.4 % were 4 Marla while 46.6 % were 5 Marla. Therefore, an average size catchment area was estimated as 101.17m^2 for 4 Marla houses and 124.46m^2 for 5 Marla. As a comparison, data from upper class areas such as Bahria town, Westrage and other satellite towns reported larger house sizes (almost double) when compared to Rawal town and Rawalpindi. The average size of the rooftop/catchment area for these upper class regions were estimated as 177.04 m^2 for 10 Marla houses and 265.7m^2 for 15 Marla houses (Table 5.5).

Table 5. 2 Rawalpindi residential areas distribution by house (Plot) size

House Size	Respondent local government area					Total
	Rawal Town	Bahria Town	Rawalpindi (Cantt)	Westrage Lane 7 & Scheme-III	Satellite Town	
5 Marla	83	1	26	0	0	110
6 Marla	7	0	7	0	1	15
7 Marla	0	8	2	0	2	12
8 Marla	0	14	0	3	1	18
10 Marla	0	16	1	24	4	45
15 Marla	0	1	0	31	4	36
1 Kanal	0	0	0	8	3	11

Source: Field work questionnaire survey (Sample population)

5.5 The rooftop catchment areas in residential areas in Rawalpindi

It was difficult to identify the exact rooftop catchment sizes due to the varying scale and differing designs of houses. As noted above, the typical land area on which houses within the study area are built is approximately 4 to 5 Marla in lower-middle areas, whereas this increases to 8 Marla to 1 Kanal in upper class areas. 1 Kanal equates to 20 Marla. Rooftop areas were estimated in-keeping with the RDA residential site requirements report “Rawalpindi Development Authority Building and Zoning Regulations, 2007” (RDA, 2007). This report gives mandatory open spaces and maximum ground coverage for different sizes of plot (Table 5.3).

Table 5. 3 Rawalpindi residential plot size and maximum ground coverage

Plot/Land size	Maximum ground coverage
5 to 10 Marlas	80%
10 Marla to 1 Kanal	70%
1 Kanal to 2 Kanals	65%
2 Kanals and above	60%

Source:(RDA, 2007)

From the maximum ground coverage of the average plot size it was estimated that a 4 to 5 Marla plot size generated an 80% rooftop catchment area. Similarly a 10 Marla to 1 Kanal plot generated a 70% rooftop size. This estimation method was followed for the calculation of all total rooftop catchment areas.

Table 5. 4 Estimated total rooftop catchment area of houses in Rawalpindi

Plot size	Total Land Area (m^2)	Total rooftop catchment area (m^2)
4 Marla	101.17	80.93
5 Marla	126.46	101.16
6 Marla	151.75	121.4
7 Marla	177.05	141.64
8 Marla	202.34	161.87
10 Marla	252.92	177.04
15 Marla	379.39	265.57
1 Kanal	505.85	354.09

Source: Calculated by current author

5.5.1 Roof type and material

Roof type was an important consideration in identifying the potential of rooftop RWHS, as this can affect the volume of runoff. 97.5% of the houses in the study area were flat, 1% tilted and 1.5% partially flat and tilted (Table 5.5). The lower-middle class houses were almost all flat roof type, while upper class areas such as Bahria town and scheme III, where houses are bigger and more complex, had tilted roofs. In all areas, the roofing material was cement; therefore the runoff coefficient was set as 0.65. The data for roof type and material was collected through field visits and the questionnaire.

Table 5. 5 Rawalpindi residential area distribution by roof type

Roof Type	Respondent local government area					Total
	Rawal Town	Bahria Town	Rawalpindi (Cantt)	Westrage Lane 7 & Scheme-III	Satellite Town	
Flat	175	40	98	67	16	396
Tilted	1	0	2	1	0	4
Partially flat/tilted	3	1	1	1	0	6
Total	179	41	101	69	16	406

Sources: Field work questionnaire survey (Sample population)

5.6 Estimation of per capita domestic water demand in study area

It is recognised that estimating water demand for households is challenging due to the different socio-economic and other characteristic factors that shape water requirements. Typically, regional demand varies from area to area due to changes in population and season (Parker and Wilby, 2013). Although reviewing metered systems is an option (Mujwahuzi, 2002, Gibbons, 2013), in some major cities of Pakistan, including Rawalpindi, domestic supplies of water to households are not metered properly.

The average daily water consumption was found to be between 135 to 150 litres per capita for urban residential areas of Rawalpindi (Hussain and Rehman, 2013). This figure was also adapted from the 2012 utilities directory, published by P-WOPs (Pakistan-Water Operator's Partnerships). Furthermore, Bhatti and Nasu (2010) conducted a detail socio-economic household survey to identify the domestic per capita water demand of two metropolitan areas, including Rawalpindi. For the purposes of water demand analyses, Bhatti and Nasu (2010) divided the population into three broad categories, based on income. They observed a high variation in each household's daily activity. For instance, shower and bath water demands ranged from 15 to 150 litres per person per day. The per capita demand of each domestic household in Rawalpindi was recorded in their findings "*Domestic Water Demand Forecasting and Management under Changing Socio-Economic Scenario"*, and summarised as;

- Drinking water; 2 litres/person/day
- Bath (showering); 15 to 150 litres/person/day
- Toilet flushing; 5 to 60 litres/person/day
- Kitchen; 5 to 45 litres/person/day

These values were the average demands as identified for major cities in Pakistan (Bhatti and Nasu, 2010). However, the authors also noted that the demands of high income groups were twice that of low income groups.

Bhatti and Nasu (2010) also analysed domestic water demand in relation to different socio-economic conditions. Their criteria were based on different income groups and residence areas, and they developed an urban water demand forecast model for a medium growth rate in population. Urban water demands were divided into three sub-groups comprising water demand for high, medium and low income groups. Three scenarios also addressed the future water demand forecast. These included;

- Constant water demand
- High water demand
- Low water demand

For constant water demand, it was assumed that current socio-economic trends would not change and water demand would stay more or less constant. For the 'high water demand' category, the assumption was that there would be changes in socio-economic conditions that would drive higher demand. Similarly, for the 'low water demand' category, an assumption was made that in the future there would be a greater awareness of water among the public and that better rules and policies and technological development would cause a lower domestic water demand. Therefore on the basis of previous findings as discussed above, the overall average water demand for the current study was estimated 135 litres per capita per day and taken in account for the study area.

5.7 Use of potable and non-potable water at household level in the study area

The household water use mainly comprised drinking water, kitchen, laundry, personal washing & bathing, toilet flushing, gardening and car washing. In some cases, with appropriate treatment, 'rooftop' rainwater can be used for potable consumption. However, this depends upon the climatic conditions of the area, the ambient temperature and the catchment surface. For this research, only non-potable water demand was considered. Figure 5.1 shows the percentage of water used in different daily household activities. Non-potable water makes up 37% of total household water demand, being used for various activities such as car washing, toilet flushing, house cleaning and laundry. This equates to approximately 50 litres of non-potable water demand per person per day.

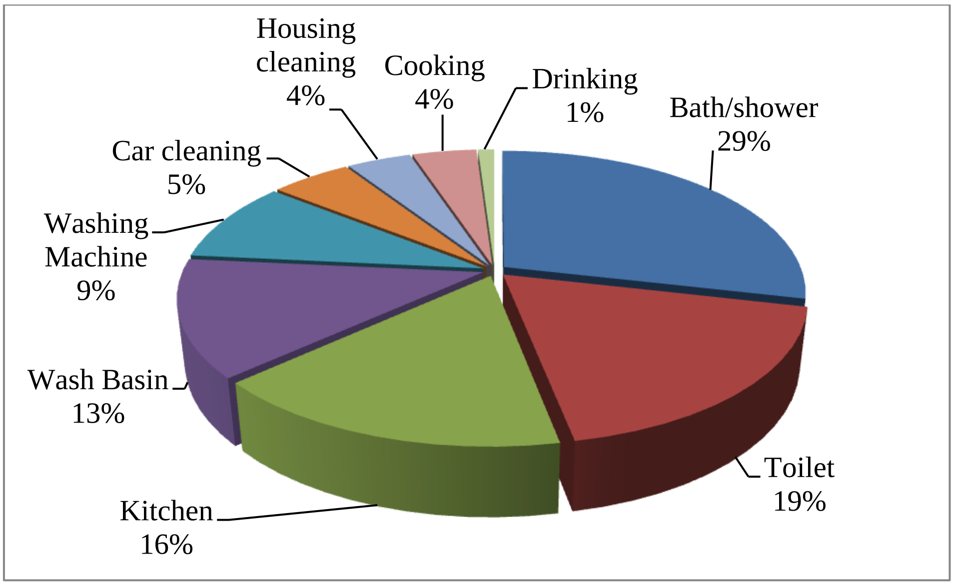


Figure 5. 1 Water use at household level for different activities)

Source: (Bhatti and Nasu, 2010)

Table 5. 6 Daily potable and non-potable water use at household level in urban residential areas

Potable water use	%	Non-potable water use	%	Total
Drinking	1	Car washing	5	6
Cooking	4	Toilet	19	23
Kitchen	16	-	-	16
Bath/showering	29	House cleaning	4	33
Wash basin	13	Laundry	9	22
Total water use	63 % Indoor	Total water use	37 % Outdoor	100%
Per capita per day	85 (litres)		50 (litres)	135 (litres)

Source: (Bhatti and Nasu, 2010)

5.8 Potential rainwater supply for 5 Marla house in study area

Using the figures discussed above, it was calculated that 5 Marla houses in residential areas of Rawalpindi could only provide 44% of their non-potable water requirements during the months of January, February and March (Table 5.7).While during the months of April, May and June, the rainwater could supply 29%, 25% and 36% respectively of the total non-potable water demand. On the other hand, in the months of July, August and September (the monsoon season), the potential rainwater supply can meet almost all of the required non-potable water demand. While, the months of October and November (driest months of the year) could only provide 7% and 5 % of non-potable water demand.

Table 5. 7 Potential rainwater supplies to size 5 Marla houses using average monthly rainfall data

Month	Average monthly rainfall (mm)	Potential rainwater supply (litres) (Rainfall x catchment area x	% of water demand that can be met

		0.65 (coefficient runoff)	
Jan	60	3945	44%
Feb	60	3945	44%
Month	**Average monthly rainfall (mm)**	**Potential rainwater supply (litres) (Rainfall x catchment area x 0.65 (coefficient runoff)**	**% of water demand that can be met**
March	60	3945	44%
Apr	40	2630	29%
May	35	2301	25%
Jun	50	3287	36%
Jul	200	13150	146%
Aug	230	15123	168%
Sep	90	5917	65%
Oct	10	657	7%
Nov	8	526	5%
Dec	30	1972	21%
12 months	920	57,398	

Source: Estimated by current author

The majority of houses within the urban areas of Rawalpindi are 5 Marla in size, and are situated in the lower-middle and middle class areas.

It can be seen from Table 5.7 that for 5 Marla houses, it is not feasible for rooftop RWHS to be used as a complete source of water supply to meet non- potable demand throughout the year. However, with an alternative water supply source, these systems are technically feasible and could provide an additional source of water. However, it should be noted that cleaning and maintenance are required, particularly during the maximum consecutive dry period in the months of October and November.

5.8.1 Suitability for old 5-Marla and new housing design

It was observed during field work in Rawal town that most houses were designed in an old fashioned manner; they were built in congested conditions and there was no open space for storage tanks. These conditions are prevalent in areas consisting of lower-middle and middle class income groups. Additionally, houses were two or three storeys high and rooftops were being used for, for example, store rooms and places for pets (Figure 5.2).

It was observed during the field work that an estimated 90% of existing old 5-marla houses are not suitable for rooftop RWHS where there a lack of adequate space for their installation.

Old Rawal town area; Rawalpindi **Bahria Town; Rawalpindi**

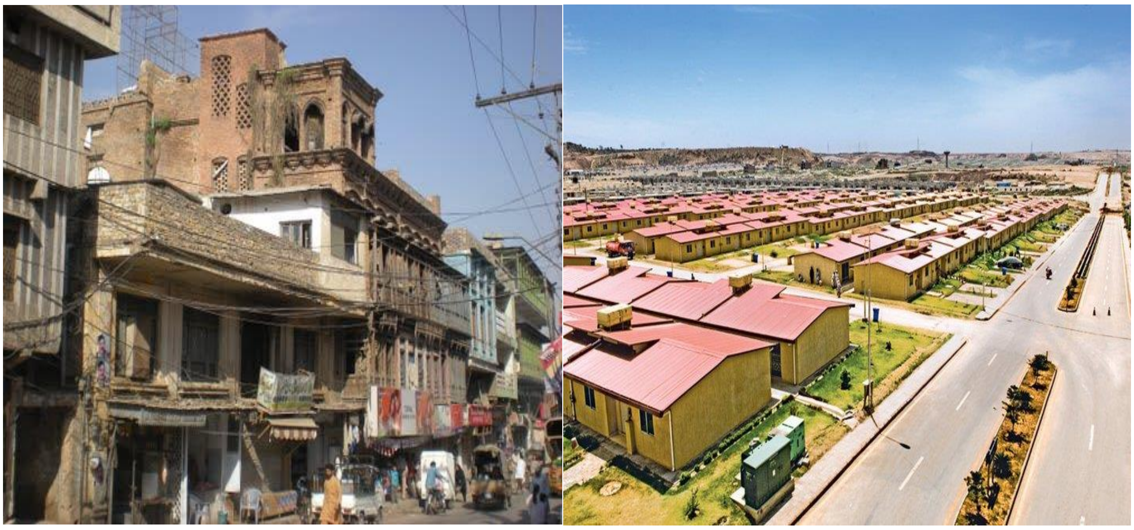


Figure 5. 2 Rooftops of old and newly constructed urban residences in Rawalpindi.

5.9 Potential rainwater supply for house sizes of 10 to 15 Marla in study area

Most upper class areas comprise 10 to 15 Marla houses; Bahria town, Westrage, scheme-III and Satellite town areas therefore had more potential for rainwater supply when compared to Rawal town.

It was calculated that 15 Marla houses in residential areas of Rawalpindi can provide up to 115% of their non-potable water requirements during the months of January, February and March (Table 5.9). While during the months of April, May and June, the rainwater can supply 76%, 67% and 96% respectively. On the other hand, in the months of July, August and September known as monsoon (rainy) season, the potential rainwater supply can provide, on average, almost three times more than the amount required, resulting in overflow from the storage tank. The months of October and November (the driest months of the year) can only provide 19% and 15 % of non-potable water demand (and December 57%).

Calculations for 10 Marla properties are shown in Table 5.8 while 15 Marla are presented in table 5.9.

Table 5. 8 Potential rainwater supplies to 10 Marla with rooftop area of (177.04 $m^{2)}$ houses based on average monthly rainfall data

Month	Average monthly rainfall (mm)	Potential rain water supply (litres) (Rainfall x catchment area x 0.65) (coefficient of runoff)	Percentage of total non-potable water demand
Jan	60	6904	76%
Feb	60	6904	76%
Mar	60	6904	76%
Apr	40	4603	51%
May	35	4027	44%
Jun	50	5753	63%
Jul	200	23015	255%
Aug	230	26467	294%
Sep	90	10356	115%
Oct	10	1150	12%
Nov	8	920	10%
Dec	30	3452	38%

Source: Calculated by current author

Table 5. 9 Potential rainwater supplies to 15 Marla with rooftop of (265.57 m^2) houses based on average monthly rainfall data

Month	Average monthly rainfall (mm)	Potential rain water supply (litres) (Rainfall x catchment area x 0.65) (coefficient of runoff)	Percentage of total non-potable water demand
Jan	60	10357	115%
Feb	60	10357	115%
Mar	60	10357	115%
Apr	40	6904	76%
May	35	6041	67%
Jun	50	8631	96%
Jul	200	34524	383%
Aug	230	39702	441%
Sep	90	15535	115%
Oct	10	1726	19%
Nov	8	1380	15%
Dec	30	5178	57%

Source: Calculated by current author

5.10 Summary

The purpose of this part of the study was to assess the technical feasibility of rooftop RWHS with regards to average monthly rainfall, rooftop catchment area and water demand. It can be seen from the results above that the monsoon (rainy) season (July to September) can provide two-three times more than the required non-potable water demand regardless of house size. The assumed 44 maximum consecutive dry days were considered during the months of October and November. Therefore, it is suggested that the higher the number of consecutive dry days, the higher the chance normal demand will not met. Additionally, if draw-off is low, then water quality issues may also be of concern. Moreover, 10 and 15 Marla houses were found more feasible due to increased rooftop catchment area.

It can also be seen that some houses in the lower-middle and middle class areas of Rawal town could have RWHS installed but only after proper investigations confirming the suitability of rooftop areas. This is because many older buildings do not support the installation of rooftop RWHS. In support of this, the RDA has improved residential building design in recent years, whereby mandatory open spaces and ground coverage limits have been included for new-builds. Areas such as Bahria town, Westrage, scheme-III and Satellite towns were previously designed to include open space, meaning they already have capacity for collection and storage.

Chapter 6 Social acceptability analysis: questionnaire results

In this chapter, the results of a questionnaire on social acceptability and willingness to adopt rooftop rainwater harvesting systems (RWHS) in urban residential areas in Pakistan are discussed. The urban residential population of the fourth largest city of Pakistan, Rawalpindi, was selected as a case study. Questionnaires were distributed in person. For this household survey, the residential population was divided into four class categories based on level of income, lifestyle and land value. This included upper and upper middle class and lower middle and middle class. The categories of class data were obtained from both primary and secondary sources. Identifying lifestyle and level of income formed part of the primary data collection. Secondary data on land value and distribution of the population according to different class systems were collected from local government officials, such as the Rawalpindi Development Authority (RDA).

6.1 Data collection and questionnaire distribution

Data was collected from two main areas, Rawal town and cantonment areas in the district of Rawalpindi. Selecting the urban population and dividing it into two areas was done to reflect the different amenity providers. In Rawal town, WASA, which falls under the RDA (Rawalpindi Development Authority), is responsible for the water supply to the community. In cantonment areas, the cantonment provides the water supply. Cantonment areas fall under the Military Land & Cantonment Department (ML&CD). There is a cantonment and civil government division in the provision of public facilities in almost every major city in Pakistan. Cantonment areas have superior facilities to civil government areas. This division will also help identify policy barriers and future strategies for rooftop RWHS among different providers. In investigating willingness to adopt rooftop RWHS, demographic profiles, current water supply system and related issues such as water availability are examined. The total number of questionnaires distributed and collected is presented in Tables 6.1 and 6.2. The population of cantonment areas was relatively small compared to that of Rawal town. Therefore, proportional with the total population of the urban areas of Rawalpindi, 65%

of the questionnaires were distributed in Rawal town and 35% were distributed in cantonment areas.

Table 6. 1 Questionnaire distribution and collection in different areas of Rawal town

Area/Colony	Questionnaires Distributed	Questionnaires Missing	Questionnaires Collected
Rawal town (Lower middle and middle class)	398	217	182
Bahria town (Upper class)	70	28	42
Satellite town (Upper middle and upper class)	45	26	19
Total	513	271	243

In Table 6.1, the numbers of questionnaires distributed in different areas of Rawal town are presented. Lower middle and middle class areas are included. Bahria falls into the upper class category. Satellite towns are upper middle or middle class.

Table 6. 2 Questionnaire distribution and collection from ML&CD areas in Rawalpindi

Area/Colony	Questionnaires Distributed	Questionnaires Missing	Questionnaires Collected
Cantonment areas (Lower middle)	185	82	103
West rage Lane No.7 & Scheme-III (Upper middle and upper class)	103	33	69

Total	288	115	172

The overall response rate was 52%: 415 of 801 questionnaires were returned. Six local people identified via personal references assisted in questionnaire distribution and collection. Household heads were asked to complete the questionnaires immediately, in order not to have to collect these later.

6.2 Data Analysis

The data was analysed using the Statistical Package for the Social Sciences (SPSS). According to (Bryman and Cramer, 2001), SPSS confers significant advantages, including the rapid and appropriate scoring and analysis of quantitative data.

6.2.1 Descriptive Statistics

Descriptive statistical analysis involves organising and summarising data, and provides the basis of any quantitative data analysis. It also helps reduce a large amount of data into a more condensed form (Mueller et al., 1977, Loether and McTavish, 1988) (Ryon, 2013). Univariate descriptive statistical analysis will be performed, consistent with questionnaire use. In univariate descriptive analysis, one variable is examined at a time across cases establishing frequency distribution (Siddall, 2013). In addition to frequency distribution, it is important to identify the measure of central tendency (Kerr et al., 2002, Lade and Oloke, 2015). In doing so, the mean, median and mode are the three most commonly-used calculations used (Mahbub, 2008). Generally, the data collected in this research involves nominal and ordinal measurement levels. The type of measurement is important in order to identify the type of statistical technique appropriate for analysis. For nominal levels of measurement, numbers are assigned to objects, where different numbers indicate different objects. Ordinal measurement is the same as nominal measurement in terms of assigning a number to the object; at this level, though, numbers also have meaningful order. For nominal and ordinal levels of measurement, non-parametric tests such as *t*-tests and chi-square are most appropriate.

6.2.2 Inferential Statistics

Inferential statistics are used to draw inferences from data or to generalise findings to a broader population (Loether and McTavish, 1988). Examples of inferential statistics include correlation analysis, chi-square and multivariate analysis using a general linear model. Similarly, a general logic of hypothesis testing is basically sample vs population, to draw conclusions on the population on the basis of the sample (England, 1991). A null hypothesis is adopted to carry out a test that has a particular pattern within the population. Although a significance level can be set as high as 0.1 or as low as 0.01, a typical significance level is 0.05 (Lade et al., 2013). The adjustment of the significance level is based on the tolerance of two types of errors. Type-I error is rejection of the null hypothesis when it is true while a type-II error is accepting a hypothesis that is false (Stevens, 2012, Vogt and Johnson, 2011, Lade and Oloke, 2015). There is higher probability of rejecting a true hypothesis if a significance level of 0.5 is adopted, and a higher probability of accepting a false hypothesis and lower probability of rejecting a true hypothesis if a significance level of 0.01 is adopted (Kerr et al., 2002, De Vaus, 2002, Lade et al., 2013). To minimise the probability of committing both types of errors, a significance level of 0.05 is usually adopted. Non-parametric tests such as chi-square and cross tabulations are performed to determine the relationship between the two variables (dependant and independent variables)

6.3 Analysis of social acceptability to rooftop rainwater harvesting system

Both descriptive and inferential statistical analyses were performed in order to analyse the questionnaire data. In entering the questionnaire data in SPSS, an "Expectation-Maximization" method was applied to replace missing values with predictive values in the SPSS data set. The missing values were those questions of the survey which were left blank. The "Expectation-Maximization" method in SPSS uses the predictive values as per the maximum response of the same question. The justification for replacing missing values with predictive values is based on enabling a more complete dataset and robust analysis (Peng et al., 2006, Larson-Hall, 2015). The frequency distribution of all variables was generated to establish an outline distribution before examining the relationship between each variable.

6.3.1 Descriptive statistical analysis of the survey

Firstly, a descriptive analysis of responses to section one of the questionnaire (socio-demographic profile) was presented in table form to establish different demographic variables. Secondly, cross-tabulation was then performed to examine the relationship between two variables, i.e. the willingness to adopt rooftop RWHS and each of the socio-economic variables, including class, level of education, house ownership, current water supply problems and level of satisfaction.

6.3.2 Inferential statistics of the survey

Here, Chi-square tests were performed in order to determine whether the differences in percentages across categories were due to sampling error or to real differences in the population. A null hypothesis (H_O) was proposed to obtain the standard significance level (confidence level 95%) from the results of the cross-tabulation and chi-square test. The null hypothesis H_O is as follows: The percentages of all categories of each variable are equal in the underlying population.

To test the null hypothesis, a threshold value, called the significance level of the test, is chosen. The standard level of significance, $p < 0.05$, is used here. If the results yield a p value of less than the 0.05, the null hypothesis is rejected and the finding effectively has a 95% chance of being true. Alternatively, if the probability of significance level is greater than 0.05 then the null hypotheses cannot be rejected.

6.4 Dependent and Independent Variables

The purpose of the study was to determine a relationship between independent variables and dependant variables. Independent variables are those that can be manipulated and controlled; dependant variables are outcome or measurement variables. The independent variables in the current study include income, level of education, house ownership, number of occupants; the dependant variables are level of satisfaction with RWHS, willingness and readiness to adopt rooftop RWHS, and level of knowledge and awareness about rooftop RWHS.

Both independent and dependant variables are either nominal or ordinal; therefore the chi-square test was used to identify a representative correlation between variables.

Furthermore, the descriptive statistics of the three sub sections of the questionnaire are provided: demographic socio-economic characteristics; current water supply system, problems and level of satisfaction; and awareness, willingness and readiness in relation to the above factors

6.6 Distribution of respondents by demographic variables

The following demographic information was gathered from respondents: gender, age group, level of education, level of income, house ownership, house type, house size, and roof type.

6.6.1 Gender

Table 6.3 below presents the gender distribution of respondents. There were 93.7% male and 6.3% female respondents. The disproportionately large number of male respondents is due to the cultural and traditional values of the study area, in which males are household heads and typically decide on matters. There were a few female respondents; mainly from Bahria town (upper class). This will enable a correlation between willingness towards adopting rooftop RWHS and gender.

Table 6. 3 Gender distribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	389	93.7	93.7	93.7
	Female	26	6.3	6.3	100.0
	Total	415	100.0	100.0	

6.6.2 Distribution of respondents by Age

Figure 6.1 illustrates the age of respondents. Most household heads fall within the age groups of 45 to 49 (30.6%) and 50 to 54 (24.6%).

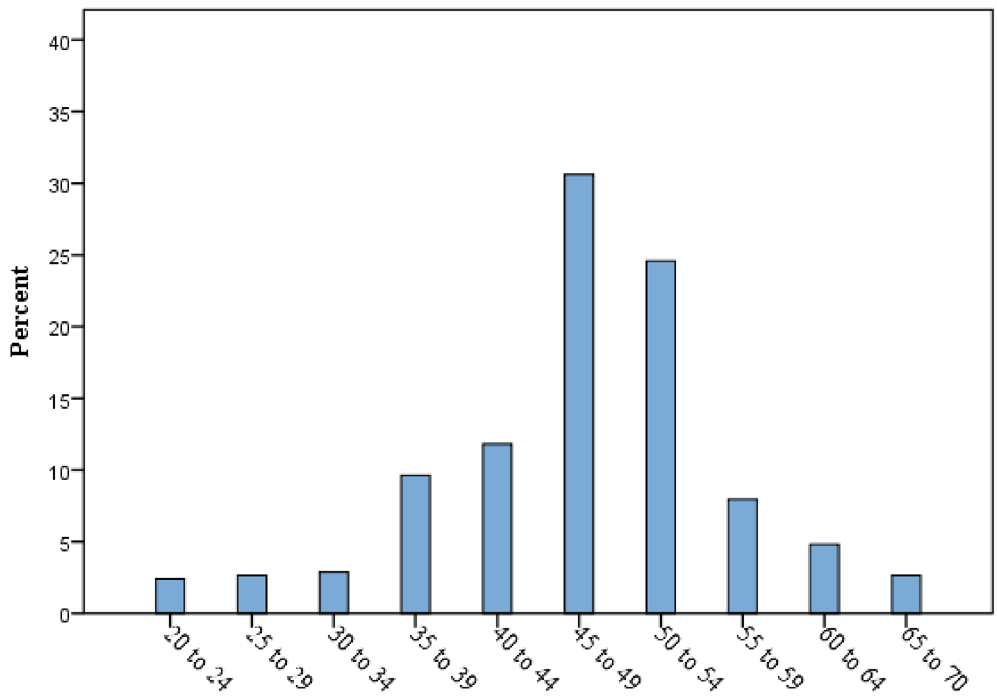


Figure 6. 1Age group distribution

6.6.3 Level of Education

Figure 6.2 below illustrates the level of education of the respondents. Level of education is an important factor which can be related to awareness and willingness to adopt rooftop RWHS. 34.2% of respondents have a high school education and 27.7% an undergraduate level of education. Approximately 15% of respondents had a primary school education and a further 15% a postgraduate level of education. The number of respondents with no education was minimal. The study was conducted in an urban area and, in Pakistan, education is much more common in urban than in rural areas. In the analysis, the level of education will be correlated with the level of knowledge of RWHS and willingness to adopt.

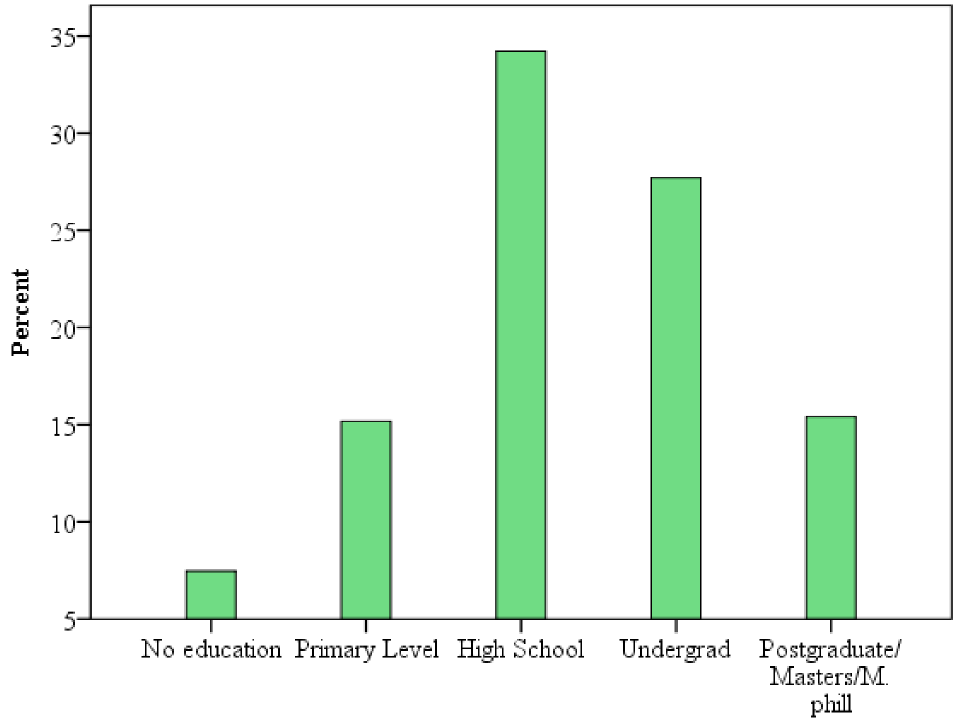


Figure 6. 2 Level of education distribution

6.6.4 Level of Income

The class system was divided according to income level:

- From 15001/PKR to 25000/PKR (Lower middle)
- From 25001/ PKR to 35000/- PKR (Middle)
- From 35001/PKR to 45000/-PKR (Upper middle)
- Over 45000/-PKR (Upper)

The Rawal town area and cantonment areas consist mainly of lower middle (28.9%) and middle class (23.1%) income households. However, some parts of cantonment areas such as Westrage lane and Scheme-III consist of upper middle class (16.4%). An income level of over 45000/PKR was recorded as 20% in Bahria Town and Satellite town. The purpose of collecting information with regards to income was to identify the different class system in the study area and how this affects willingness and readiness to adopt rooftop RWHS. As illustrated by Figure 6.3, a substantial proportion of respondents (11.6%) chose not to disclose their income.

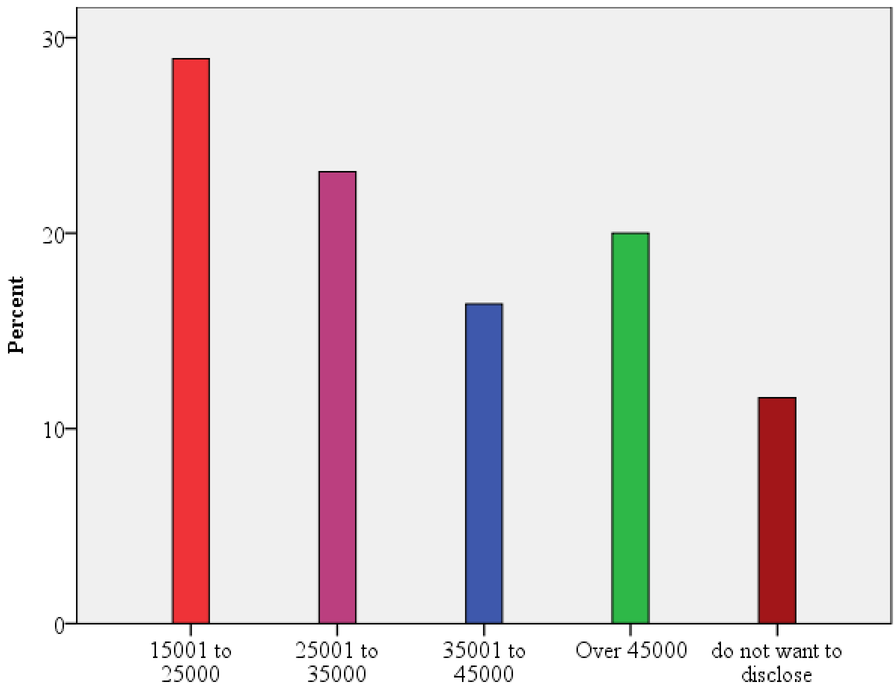


Figure 6. 3 Respondent distribution by level of income per month

6.6.5 House ownership

69.2% people responded that they owned the house in which they live; 30.8% that they were living in a rented house (Figure 6.4). The purpose of this question was to determine how house ownership reflects the decision to adopt rooftop RWHS.

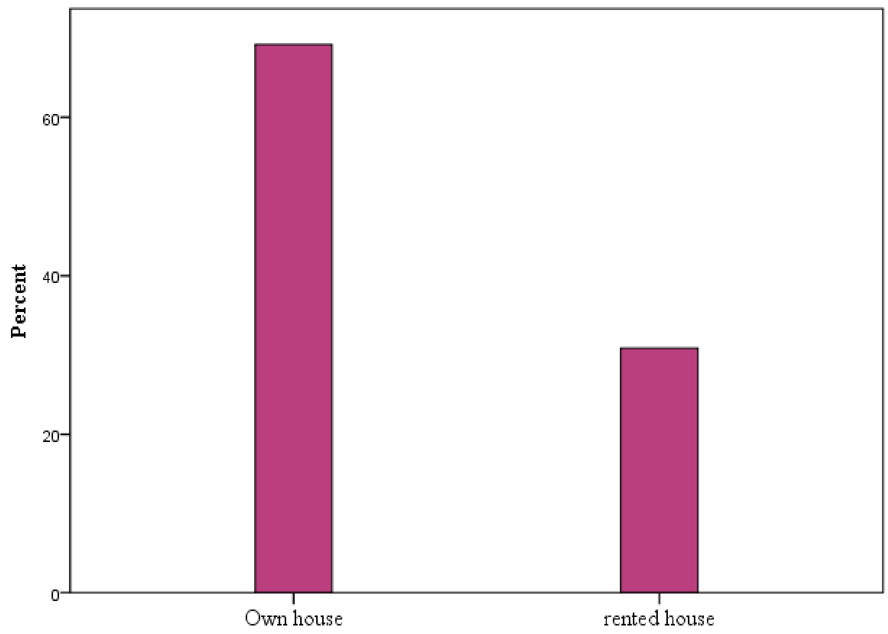


Figure 6. 4 Respondent distribution by house ownership

6.6.6 Distribution of respondents by house type

The purpose of including an item on house type in the survey was because house type should correlate with the technical feasibility of implementing rooftop RWHS. Single-storey houses are better suited as they typically have fewer occupants; triple- and four-storey houses increase demand on the rooftop RWHS whereas the catchment area for rainwater will remain same. Therefore, the relative proportions of different house types in the study area were determined. 76.4% of the houses in the study area were double storey, whereas single and triple storey properties were found to account for 12.3% and 10.4 % respectively. A further 1% was 4-storey (figure 6.5).

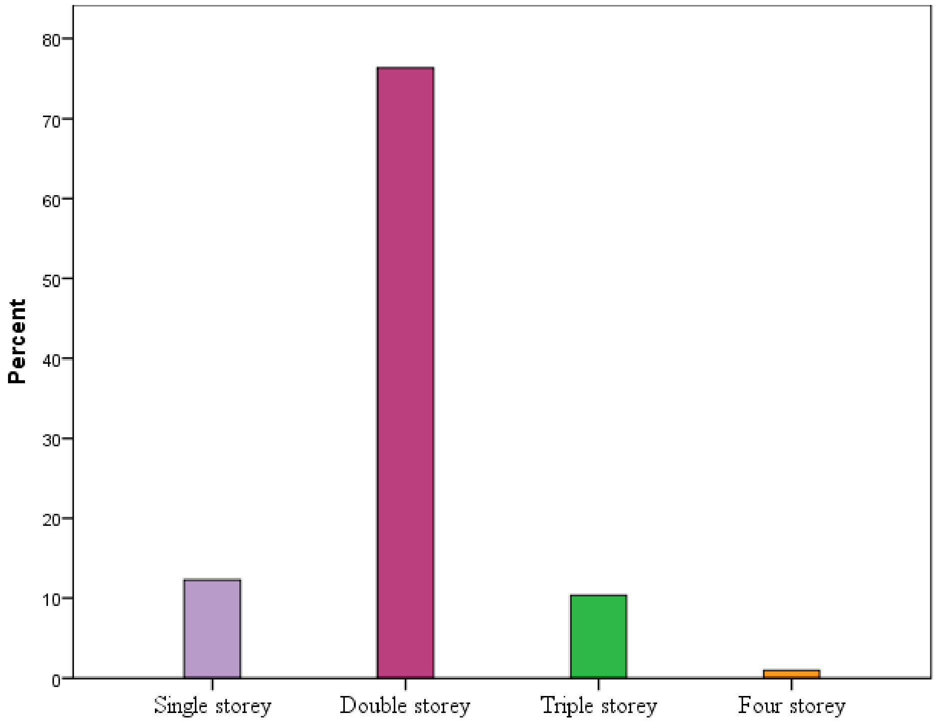


Figure 6. 5 House type distribution

6.6.7 Distribution of respondents House size

Figure 6.6 illustrates house sizes. Most houses are double-storey (76.4%), figure 6.5 and the average size of a house is 4 or 5 "Marla". A Marla is a traditional unit of area used locally. 1 Marla equals 225 square feet; 5 Marla equals 1124 square feet and 1 Kanal equates to 20 Marla. Rawal town and Rawalpindi cantonment areas mainly consist of lower middle and middle class areas with 4 to 5 Marla houses.

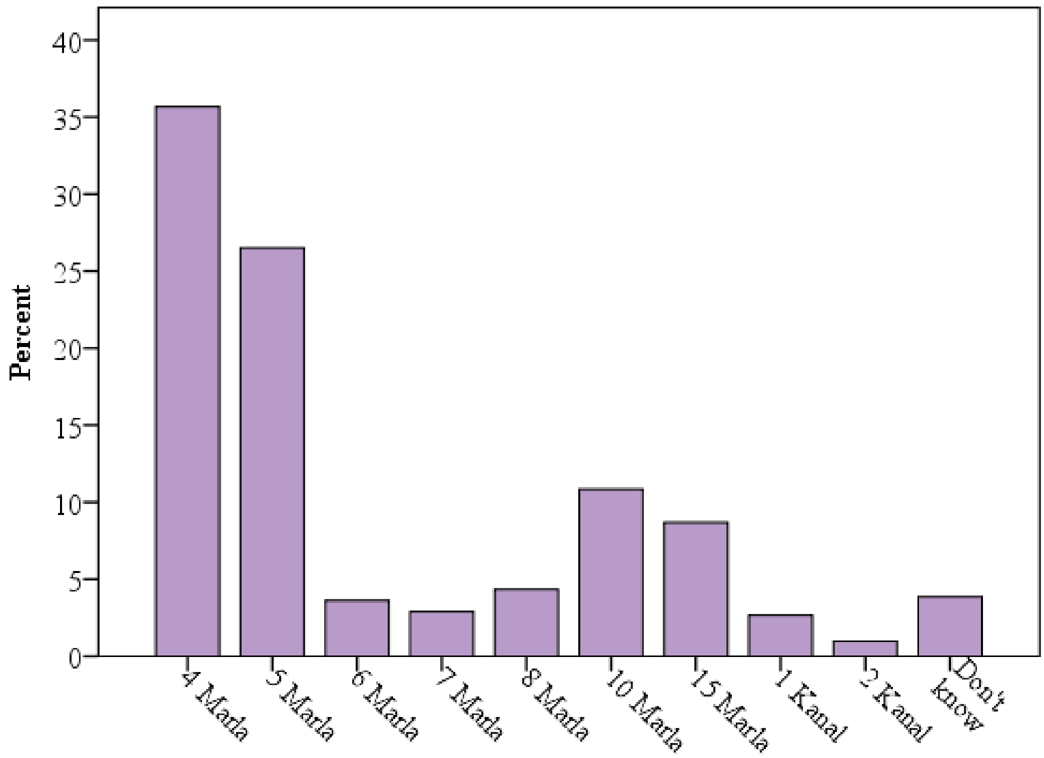


Figure 6. 6 Distribution of respondents by house size

In Rawal town, 55.5% responded with a house size of 4 Marla and 45.6% with 5 Marla. Similarly, cantonment areas of lower middle and middle class inhabitants responded similarly with 54.4% at 4 Marla and 25.2% at 5 Marla. The type and size of the house was included in the questionnaire to determine the potential of rooftop RHWS regardless of any socio-economic barrier. This will help determine how much water can be collected from the rooftop catchment area.

6.6.8 Respondent distribution by roof type of the house

The roof type is critical in terms of identifying the potential of rooftop RWHS. 97.5% of the houses in study area are flat and cemented, 1% tilted and 1.5% partially tilted (Figure 6.7).

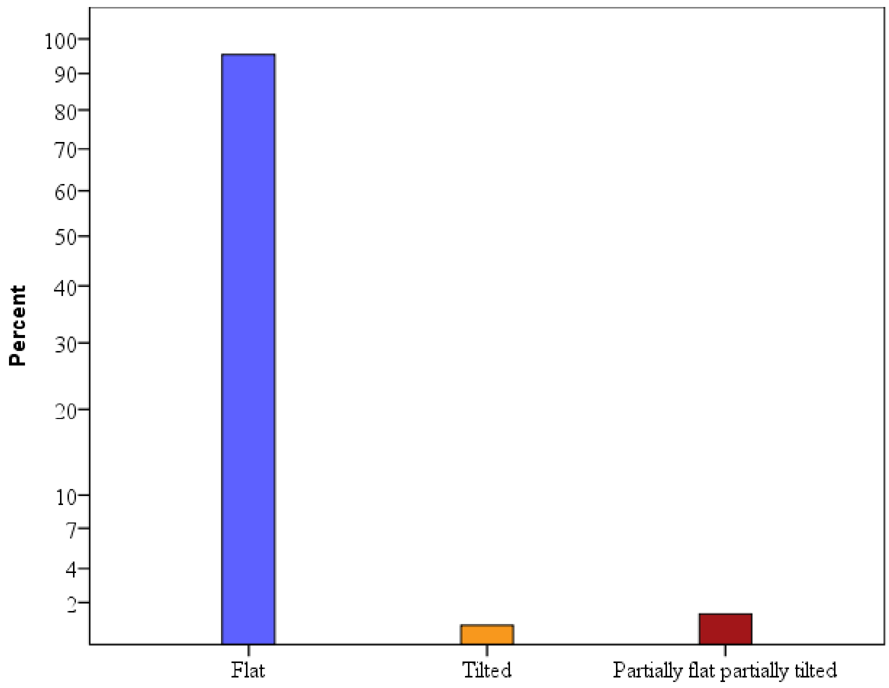


Figure 6. 7 Respondent distribution by roof type of the house

6.7 Current Water Supply System, Availability, Problems and Level of Satisfaction

This section of the questionnaire was developed to collect information on the current water supply system in the study area, the availability of water in hours per day, the extent to which the current water supply system meets demand and also levels of satisfaction. The aim was to identify factors that directly or indirectly represent willingness to adopt rooftop RWHS. In addition to frequency distribution, cross-tabulation will be performed.

6.7.1 Respondent distribution by current water supply system

As evident in Figure 6.8 below, 40% of the lower middle and middle income classes in Rawal town rely on the government water supply line; 41.7% have access both to a borehole and to the government water supply line. 7.7% have borehole access only. In contrast, 0.5% responded that they purchase water from private water tankers. Bahria town (10.1% of total responses) an upper class area, has its own water supply system. As it is a private housing scheme, it does not have any boreholes or government water supply.

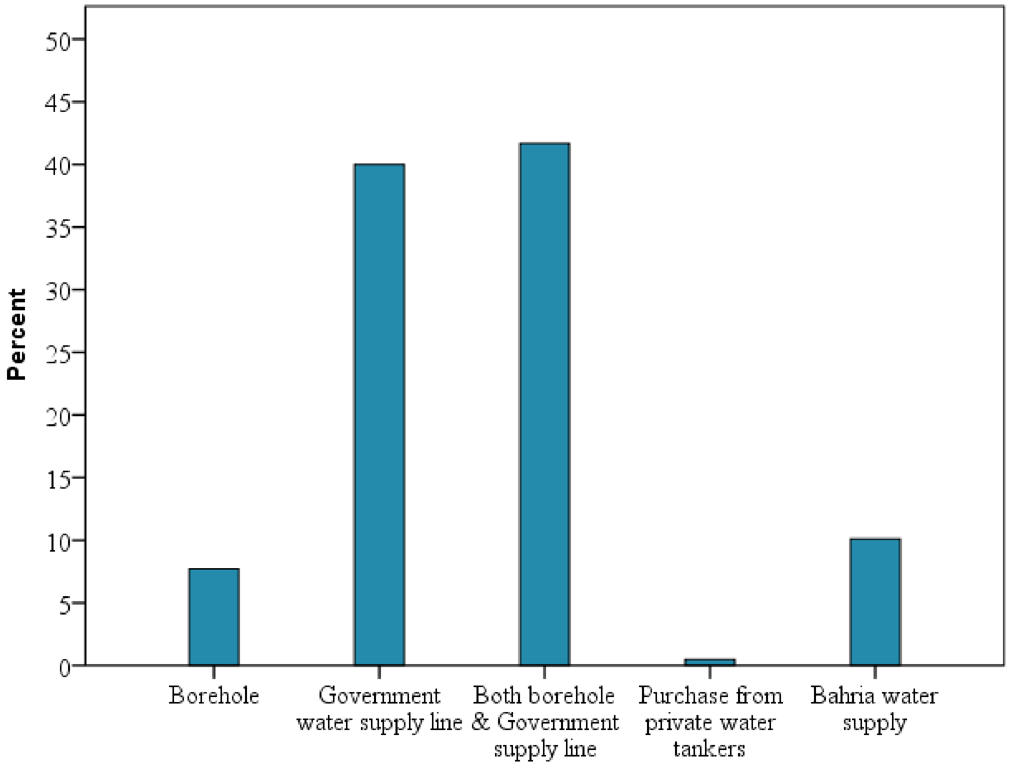


Figure 6. 8 Respondent distribution by current water supply system (Rawal town)

6.7.2 Respondent distribution by availability of water with the current water supply system

The availability of water varies with the water supply system. In Rawal town and cantonment (lower middle and middle class areas), 22.7% of the population who rely only on the government water supply have shown availability of water of 1 to 2 hours per day and 10.8% responded 4 to 7 hours per day. Similarly, 6.5% responded with an availability of water of less than an hour per day. The availability of water for those who rely only on the government supply was 3-6 hrs, 17-20 hrs and 8-12 hrs for 3.6%, 0.5 % and 0.7% of respondents respectively. 6.3% of respondents located in some areas of the cantonment (lower middle class) noted an availability of water of as little as 2 hours in 24. However, the majority of respondents (48.2%) have access to both the government water supply and a borehole, meaning they have 24-hour availability. Unlike in Rawal town and cantonment areas, Bahria town, which consists of upper class residents relies neither on borehole nor on a government water supply. It has its own water supply available 24 hours. Bahria town is a private housing scheme and considered the most expensive area of Rawalpindi. Similarly, Satellite town falls under the district government water supply and consists of upper class properties as per land value and living standards. It has shown an availability of water across 24 hours (Figure 6.9).

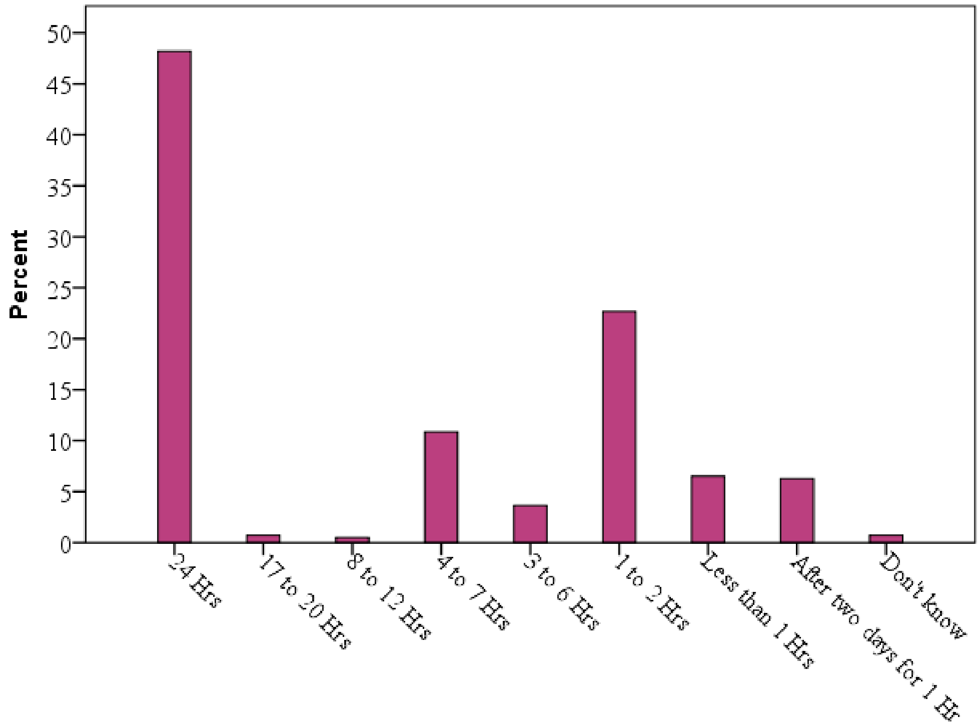


Figure 6. 9 Respondent distribution with availability of water per day

6.7.3 Respondent distribution by satisfaction with current water supply system

Figure 6.10 illustrates the level of satisfaction with current water supply systems. Overall, 52.2% of respondents are quite satisfied with their current water supply, regardless of local area; 16.1% are very satisfied. 16.3% are neither satisfied nor dissatisfied. Only 10.4% are quite dissatisfied, while 3.1% are very dissatisfied.

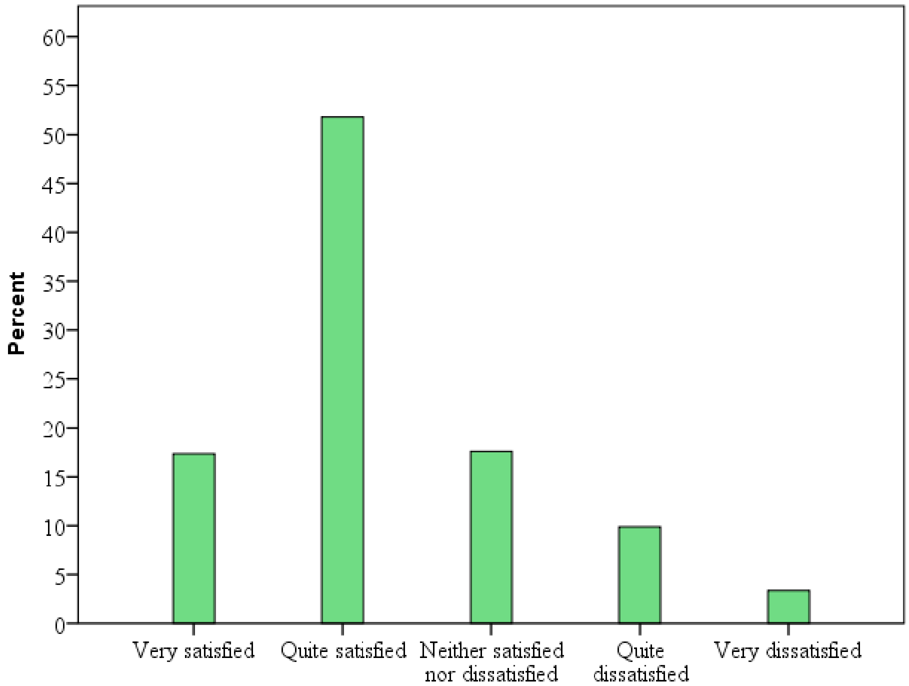


Figure 6. 10 Respondents level of satisfaction with their current water supply system

6.7.4 Demand met by current water supply system

The extent to which the current water supply system meets demand is presented in Table 6.4. This was a multi-response question (tick all that applies). It can be seen from this table that only 49.3% of respondents selected "YES" for drinking water. This shows the shortage of drinking water from the current water supply system, although this could be due to quality issues. Non-potable water demands are largely met by the current water supply system. The table below shows the descriptive statistics for which 'N' is the total number of respondents.

Table 6. 4 Demand met by current water supply system

Demand met by current WSS		N	Percent
Drinking	No	210	50.7
	Yes	205	49.3
	Total	415	100.0
Kitchen (Dish washing &	No	21	5.0

cooking purpose)	Yes	394	95.0
	Total	415	100.0
Bath (Showering)	No	22	5.3
	Yes	393	94.8
	Total	415	100.0
Faucet use (shave & brushing)	No	31	7.4
	Yes	384	92.6
	Total	415	100.0
Flushing toilets	No	27	6.4
	Yes	388	93.6
	Total	415	99.0
Laundry	No	36	8.6
	Yes	379	91.5
	Total	415	99.0
Floor cleaning	No	57	13.6
	Yes	358	86.4
	Total	415	99.0

6.8 Willingness to use rooftop RWHS for outdoor activities

This question was divided into two sections; willingness to use rainwater harvesting for indoor and for outdoor purposes. From the literature review, it is evident that opinions on rainwater harvesting, particularly rooftop rainwater harvesting, differ widely, owing to its method of collection and related concerns over quality.

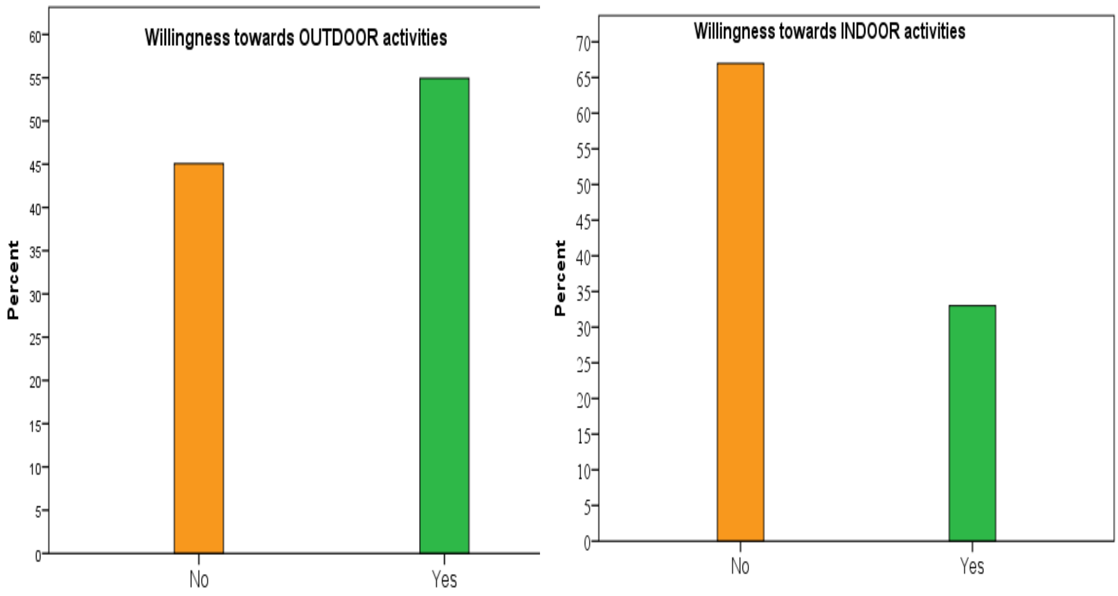


Figure 6. 11 Willingness to use rooftop rainwater indoors and outdoors

The majority of respondents, 54.9%, are willing to use rooftop RWHS for outdoor activities. While for indoor use, only 32.7 % are willing. Table 6.5 illustrates how willing respondents are to use rooftop RWHS for different outdoor activities:

Table 6. 5 Willingness to use rooftop rainwater for various outdoor activities

Willing to use for the following OUTDOOR activities		N	Percent
Laundry	No	162	39.0
	Yes	253	61.0
	Total	415	100.0
Flushing toilets	No	126	30.4
	Yes	289	69.6
	Total	415	100.0
Gardening	No	141	34.0

	Yes	274	66.0
	Total	415	100.0
Floor cleaning	No	284	68.4
	Yes	131	31.6
	Total	415	100.0
Car wash	No	294	70.8
	Yes	121	29.2
	Total	415	100.0

It can be seen from the table above that respondents showed more willingness towards laundry and flushing toilets when it came to using rooftop rainwater for outdoor activities. 61% and 69.6% responded ‘Yes’ to using rooftop rainwater for laundry and flushing toilet respectively. Almost equal proportions indicated being willing to use rainwater for gardening However, for floor cleaning and car washing, respondents were less willing. Laundry was included under both the outdoor and indoor question, as laundry can be done in either setting. Laundry, gardening and flushing toilets were considered the most acceptable uses for rooftop RWHS.

6.8.1 Reasons for using rooftop rainwater for outdoor activities

Of those who indicated they would use rooftop RWHS for outdoor activities, 33.1% are willing to use it because “it is cheap”, 30.4% think it is safe for outdoor activities, 26% consider it an alternative in the case of a water shortage and 10.5% a safeguard to reduce storm water runoff.

Table 6. 6 Reasons for using rainwater for outdoor activities

Reasons	**Responses Percentage**
It's cheap	33.1%
It is safe to use rooftop rainwater for outdoor activities	30.4%
In case of water shortage	26.0%
It can also reduce the storm water runoff	10.5%
Total	100.0%

6.9 Willingness to use rooftop rainwater for indoor activities

In contrast to outdoor activities, overall only 32.9% of respondents are willing to use rooftop rainwater for indoor activities; 67.1% are not. Of those who would, most indicate their willingness to use it for laundry (61%), 9.1% for bath (showering use), 4.3% for faucet use and 3.8% for the kitchen.

Table 6. 7 Willingness to use rooftop rainwater for various indoor activities

Willing to use for the following activities	IN-DOOR	N	Percent %
Drinking	No	409	98.6
	Yes	6	1.4
	Total	415	99.0
Kitchen	No	399	96.2
	Yes	16	3.8
	Total	415	99.0
Bath (showering)	No	381	91.9
	Yes	34	8.1
	Total	415	99.0
Faucet Use (Shave & Brushing)	No	397	95.7
	Yes	18	4.3
	Total	415	99.0
Laundry	No	162	39.0
	Yes	253	61.0
Total		415	100.0

The reasons respondents gave for their willingness towards indoor activities are presented in Table 6.8.

Table 6. 8 Reasons for using rainwater for indoor activities

Reasons	Responses Percentage
It's cheap	26.4%

It is safe to use rooftop rainwater for indoor activities	16.8%
In case of water shortage	17.7%
It is clean and natural source of water	12.3%
Rainwater should not be wasted	26.8%
Total	100.0%

It is evident from the above results that rainwater is considered a cheap and free water source for both indoor and outdoor activities. 26.8% responded that rainwater should not be wasted. 26.4% consider it cheap. 16.8% responded that it is safe to use rooftop rainwater for indoor activities and 17.7% indicated a willingness to use RWHS in the case of any water shortage. At the end of the survey, the overall perception of, and willingness to use, rooftop RWHS was evaluated. Reasons why people were not willing to use rooftop rainwater are presented in Table 6.9 below.

As illustrated by Figure 6.11, the majority of respondents are willing to use this system for outdoor activities particularly for laundry and toilet flushing. The reasons were mainly that "it is cheap and it is safe'. In contrast, the majority of respondents are unwilling to use rooftop rainwater for indoor activities. 39.2% justified this by concerns over water quality, 18.2% by the fact that such a system requires extensive maintenance and 16% that they have plenty of water and thus no need for rainwater harvesting. 14.3% responded that they had "not seen this system before" and 7.8% had concerns related to the cost of installing it (Table 6.9). The social factors that affected their decision are examined in the Chi-square test in the section on inferential statistics.

Table 6. 9 Reasons for unwillingness to use rooftop RWHS for both outdoor and indoor activities

Overall reasons to responses not willing for rooftop rainwater	Responses Percent
We have a plenty of water	16.0%
Concern about water quality	39.2%
Have not seen this system before	14.3%
Need much work to maintain	18.2%
Cost of installing	7.8%
Current supply line is cheap	4.6%

Total	100.0%

6.10 Overall readiness and acceptability to install rooftop RWHS

In the final part of the questionnaire, respondents were asked how willing they were to install rooftop RWHS in their house. This question was straightforward, in order to understand how reasons provided (for example, the cost of installation) affected willingness. Most respondents mentioned concerns over water quality, while only 7.8% mentioned the cost of installation. To obtain more accurate information, an additional question was examined, to determine how willing respondents would be if the government provided incentives for RWHS installation. Responses to this question differed significantly from responses about willingness to install the system personally.

6.10.1 Overall readiness and acceptability to install rooftop RWHS without government incentive provision

Prior to this question, respondents indicated their willingness to use RWHS outdoors and indoors. Those questions were related to the perception of rooftop rainwater use. However, as seen in Figures 6.12 and 6.13, perceptions of the system are directly related to the acceptability and readiness to install this system, independent of indoor versus outdoor use.

As can be seen in Figure 6.12 below, respondents are less willing to install the rooftop RWHS on their own: 33%, as opposed to 32% who are not willing at all. If the government were to provide incentives however, 30% of respondents are willing to install the system and only 18% unwilling (see Figure 6.13).

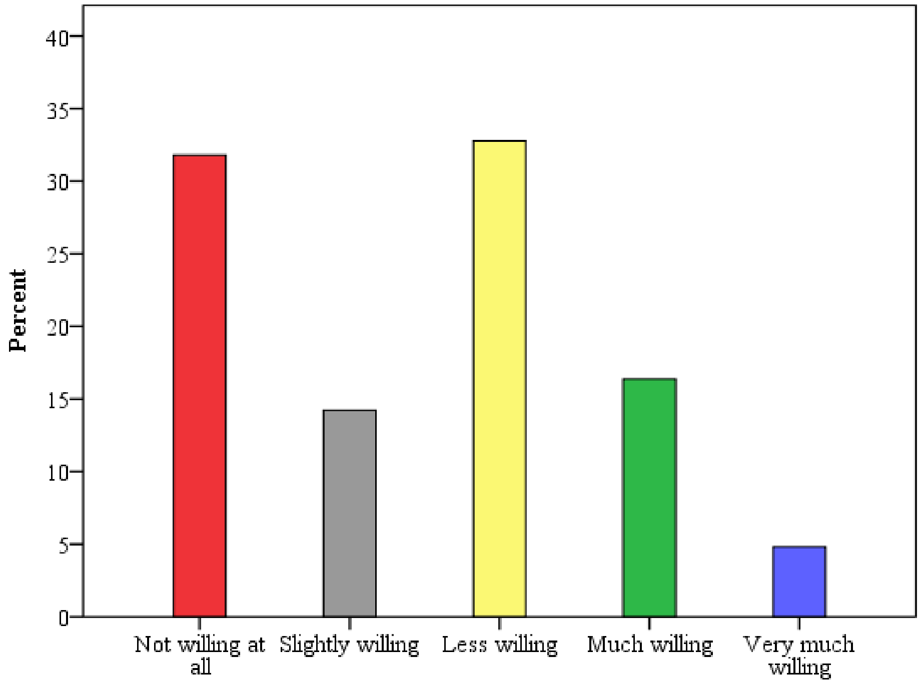


Figure 6. 12 Willingness to install rooftop RWHS without Government incentive provision

Furthermore, 28.4% of respondents are very much willing, provided that the government provide incentives.

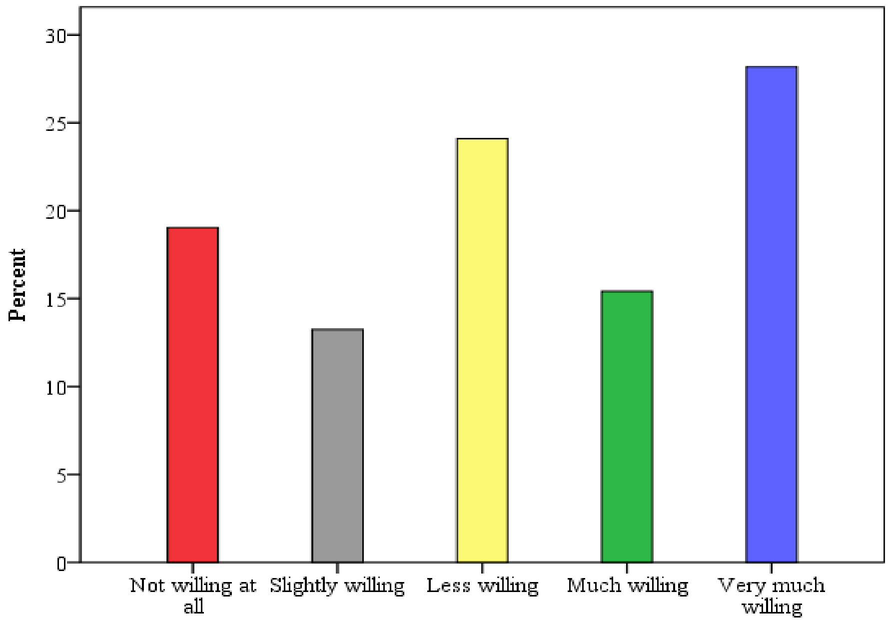


Figure 6. 13 Willingness to install rooftop RWHS with government incentive provision

6.11 Inferential Statics (Statistical significance correlation between the variables)

Descriptive statistics relating to frequencies and percentage of variables were presented in the previous section. In this section, the statistical significance correlations between different variables are presented using a different statistical test. This includes:

- Correlation/Chi-square test
- A multivariate model of key willingness-dependant variables using a range of independent variables.

A discussion on the correlation analysis results are also presented in this section, in order to determine which variables are significantly related. An important question is whether the indicated willingness to use rooftop rainwater for outdoor and indoor activities differs from the willingness to install such a system. Theoretically evaluating the usefulness of something and being practically willing to implement it, differ. Although the public might consider RWHS good in theory, they might be unlikely to adopt it themselves unless they witness its benefits.

6.12 Water shortages with current water supply system

Water shortages from the current water supply system are critical in influencing the willingness and readiness to adopt rooftop RWHS. It is reasonable to assume that people with shortages from the current water supply system might express a favourable attitude towards an alternative water system, such as rooftop RWHS. Therefore, data from this question will be cross-tabulated with the 'willingness' question in the next section. In this section, responses referring to water shortages in relation to different types of supply system are presented. Overall 48.3% reported water shortages; 50% reported no water shortages while 1.7% left no answer (Table 6.10). However, it can be observed from the separate responses (Figure 6.14) that households who rely only on the government water supply face significant water shortages (80%). The Chi-square test reveals a strong significant relationship between water shortage and type of current water supply system ($p < 0.05$), Table 6.10.

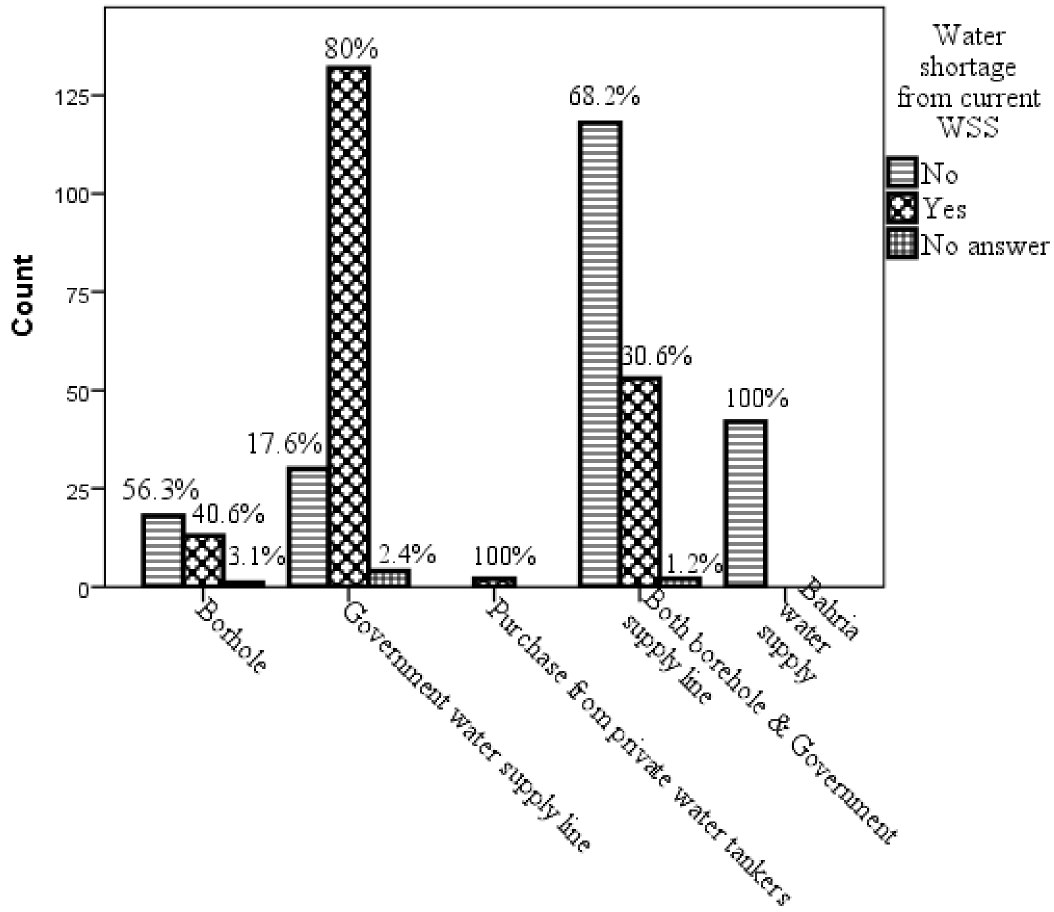


Figure 6. 14 Water shortages with current water supply system

Table 6. 10 Correlation of water shortage and current water supply system

Current water supply system	**Do you face any kind of water shortage (seasonal or other) from your current water supply system**			**Total**
	No	**Yes**	**No answer**	
Borehole	56.3%	40.6%	3.1%	100.0%
Government water supply line	17.6%	80.0%	2.4%	100.0%

Purchase from private water tankers		100.0%		100.0%
Both borehole & government supply line	68.2%	30.6%	1.2%	100.0%
Bahria water supply	100.0%			100.0%
Total	50.0%	48.3%	1.7%	100.0%

Chi-Square Test

	Value	***df***	**Asymp. Sig. (2-sided)**
Pearson Chi-Square	135.939[a]	8	.000
Likelihood Ratio	158.929	8	.000
Linear-by-Linear Association	94.055	1	.000
N of Valid Cases	415		

a. 7 cells (46.7%) have expected count less than 5. The minimum expected count is .03.

6.12.1 Coping with water shortage

The next question in the survey referred to how respondents cope with the water shortages. This was a multi-option question (i.e. tick all that applies) with many respondents choosing more than one option. The final column in Table 6.11 hence shows the total number of cases where this option was selected. To cope with water shortages, 42.4% of households would opt to reduce their water usage, 33.8% would purchase water from private water tankers, 12.2% would collect water from their neighbours and 7.6% would acquire more tank space. Unexpectedly, 4.0% of households would opt to store rainwater to overcome water shortages.

Table 6. 11 Means of coping with water shortages

How to manage the water shortage

	Percent
Purchase from private water tankers	33.8%
Collect from the neighbour's house	12.2%
Minimize the water use	42.4%
Increases the number of water tanks	7.6%
Storage of rainwater	4.0%
Total	100.0%

6.12.2 Level of knowledge about RWHS

Most respondents know little about and are relatively unaware of rainwater harvesting systems. 38.1% reported very little knowledge; 32.8% chose “Do not know at all”. 20.4% responded that they knew a little and 6%, not too much. Only 2.7% responded that they knew “A lot”:

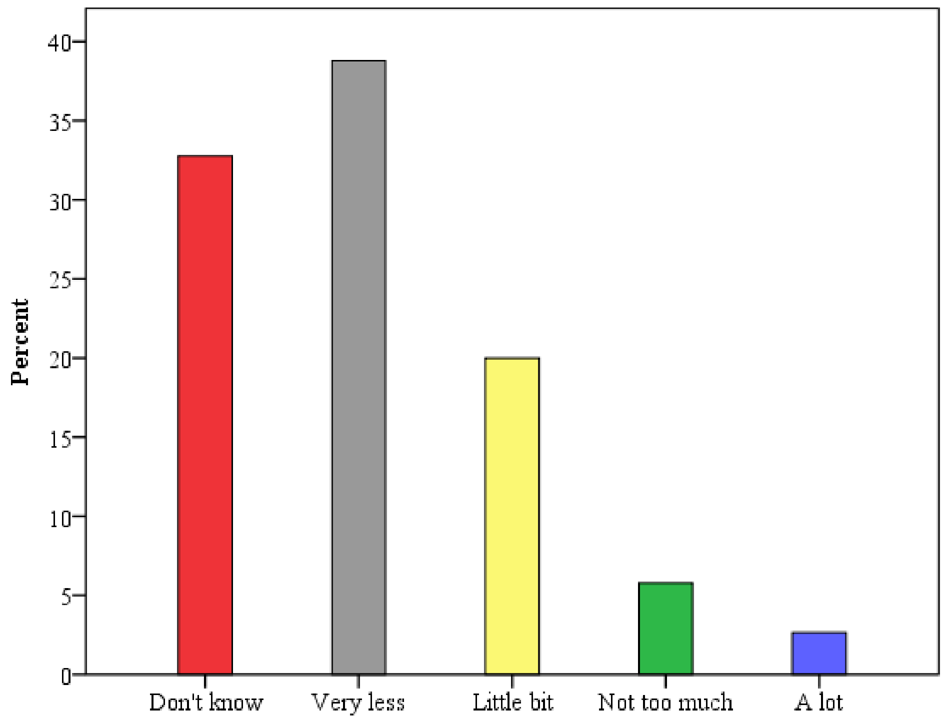


Figure 6. 15 Level of knowledge about RWHS

The cross-tabulation of level of knowledge about RWHS and level of education is presented in Table 6.12. Education level did not directly affect knowledge about RWHS in this sample.

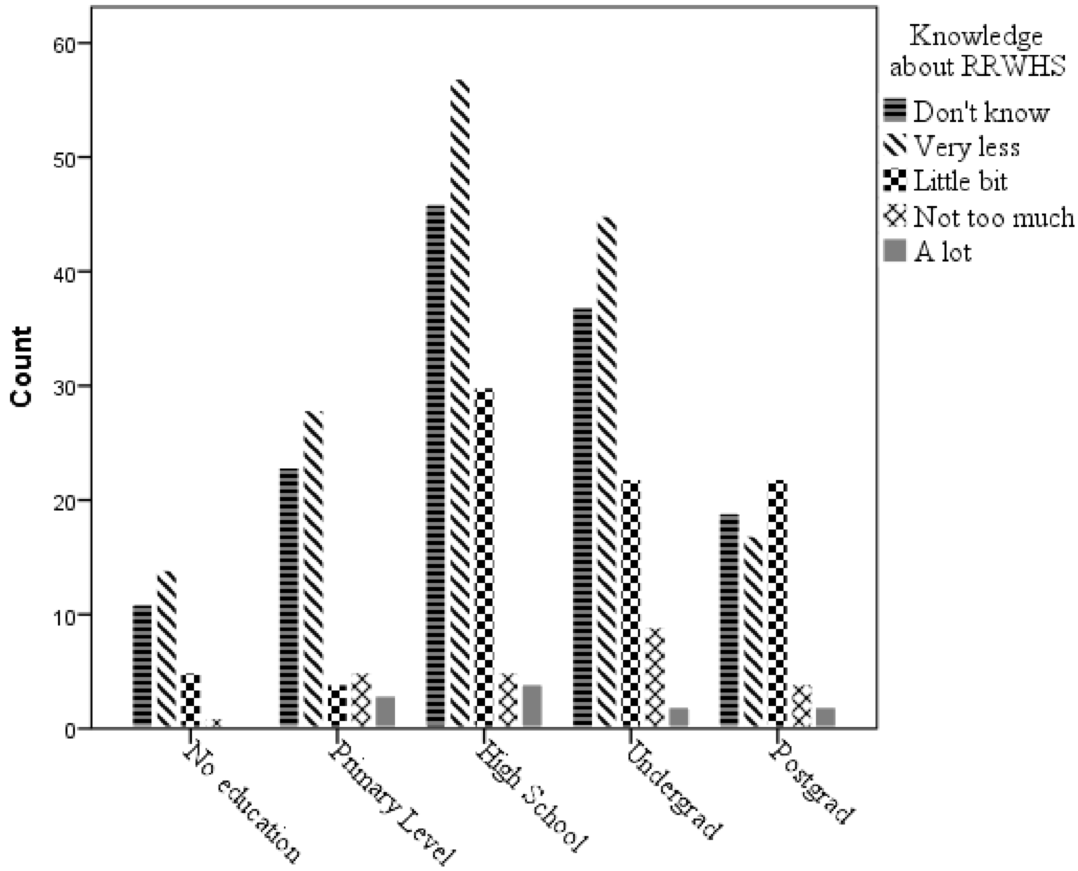


Figure 6. 16 Cross-tabulation of level of education and level of RWHS knowledge

Respondents with no education, with high school and with undergraduate education have responded similarly. This suggests that knowledge about RWHS and education level are not significantly related (Table 6.12).

Table 6. 12 Relationship between knowledge of RWHS and level of education

		Knowledge about RRWHS					**Total**
		Don't know	**Very less**	**Little bit**	**Not too much**	**A lot**	
Education	No education	11	14	5	1	0	31
	Primary Level	23	28	4	5	3	63

	High School	46	57	30	5	4	142
	Undergrad	37	45	22	9	2	115
	Postgraduate/ Masters/M.Phil.	19	17	22	4	2	64
Total		136	161	83	24	11	415

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	22.048[a]	16	.142
Likelihood Ratio	24.097	16	.087
Linear-by-Linear Association	3.548	1	.060
N of Valid Cases	415		

a. 8 cells (32.0%) have expected count less than 5. The minimum expected count is .82.

6.13 Willingness and acceptability of rooftop RWHS in different income class groups

Prior to initiating data collection, it was hypothesised that class might affect acceptance and willingness to adopt systems. This is because rainwater harvesting and its accessibility are both directly and indirectly linked to affordability. In the current study, findings indicate that class directly affects the willingness to use this system. However, those who are willing, still represent a relatively small proportion of the population. Table 6.13 shows that residents of the cantonment (lower middle and middle class) areas of Rawal town are willing to use this system, as they face water shortages and rely mainly on the government water supply line. The majority of respondents from lower middle and middle class areas pay private water tankers for water during shortages. Water availability in these areas is an hour or two daily. One of the reasons for their willingness could be paying substantial amounts to water tankers.

Table 6. 13 Correlation between willingness and Income class

Respondent's (Area)	Willingness to RRWHS					Total
	Not willing at all	Slightly willing	Less willing	Much willing	Very much willing	
Rawal Town (lower and middle class)	64	30	57	22	9	182
Bahria Town (upper class)	15	12	5	9	1	42
Rawalpindi Cantonment areas(lower middle and middle class)	28	6	39	22	8	103
Westrage Lane 7 & Scheme-III (upper middle class)	17	2	34	14	2	69
Satellite Town (Upper class)	8	9	1	1	0	19
Total	132	59	136	68	20	415

Chi-Square Tests	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	62.834[a]	16	.000
Likelihood Ratio	65.083	16	.000
Linear-by-Linear Association	2.016	1	.156
N of Valid Cases	415		

a. 6 cells (24.0%) have expected count less than 5. The minimum expected count is .92.

These findings are consistent with Kahinda et al. (2010) who reported that RWHS systems might benefit households financially, which is important to households with lower incomes. In Bahria and the satellite towns (upper class areas) that have access to borehole water, government water and a private water supply, residents are less willing to install rooftop RWHS as they do not face any water shortages. However, this is not the only reason discouraging installation. If the government provides incentives for people to install the rooftop RWHS, 28.4% were "very much willing", independent of class.

Table 6. 14 Correlation between overall willingness, respondent local areas and income group

		Respondent local government area	Income	Willingness to install RRWHS
Respondent local government area	Pearson Correlation	1	.146**	.070
	Sig. (2-tailed)		.003	.156
	N	415	415	415
Income	Pearson Correlation	.146**	1	-.123*
	Sig. (2-tailed)	.003		.012
	N	415	415	415
Willingness to install RRWHS	Pearson Correlation	.070	-.123*	1
	Sig. (2-tailed)	.156	.012	
	N	415	415	415

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

6.14 Level of education and willingness to adopt rooftop RWHS

This question was included in the questionnaire to determine whether there is a significant relationship between the level of education and respondents' willingness to adopt rooftop RWHS. The correlation was insignificant and weak. Respondents with no education were largely unwilling (45.2%), and those with primary education were generally less willing (30.6%). Those with high school education, undergraduate and postgraduate educations were slightly more willing than those with no education. Thus, level of education in the community does not significantly affect willingness to use this system. This system appears to be more need-based and independent of respondents' academic qualification.

Table 6. 15 Correlation of willingness and level of education

Level of Education	On a scale of 1 to 5 rate your level of willingness and readiness to install rooftop rainwater harvesting system for your house?					Total
	Not	Slightly	Less	Much	Very	

	willing at all	willing	willing	willing	much willing	
No education	14	4	7	5	1	31
	45.2 %	12.9%	22.6 %	16.1%	3.2%	100.0 %
imary level	16	7	19	14	6	62
	25.8 %	11.3%	30.6 %	22.6%	9.7%	100.0 %
High School	45	19	51	21	5	141
	31.9 %	13.5%	36.2 %	14.9%	3.5%	100.0 %
Undergraduate	41	17	39	13	5	115
	35.7 %	14.8%	33.9 %	11.3%	4.3%	100.0 %
Postgraduate/ Masters/M.Phil	16	12	19	14	3	64
	25.0 %	18.8%	29.7 %	21.9%	4.7%	100.0 %
Total	132	59	135	67	20	413
	32.0 %	14.3%	32.7 %	16.2 %	4.8%	100.0 %

Chi-Square Tests	Value	df	Asymp. *p* (2-sided)
Pearson Chi-Square	15.145[a]	16	.514
Likelihood Ratio	14.532	16	.559
Linear-by-Linear Association	.000	1	.996
N of Valid Cases	415		

a. 4 cells (16.0%) have expected count less than 5. The minimum expected count is 1.49.

6.15 House ownership and willingness to adopt rooftop RWHS

The purpose of this question was to identify whether house ownership significantly affects willingness to use this system. The rationale for this is that those living in rented houses might be unwilling to make the financial investment required. However, the results indicate that whether or not families owned the houses was not significantly related to their willingness to install rooftop RWHS ($p = 0.334$).

Table 6. 16 Correlation of willingness and house ownership

Willingness and readiness to install rooftop rainwater harvesting system for your house?	Ownership of house		Total
	Own house	Rent house	
Not willing at all	88	44	132

Slightly willing	39	20	59
Less willing	97	38	135
Much willing	50	17	67
Very much willing	13	7	20
Total	287	126	413

Chi-Square Tests	**Value**	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-Square	1.713[a]	4	.788
Likelihood Ratio	1.721	4	.787
Linear-by-Linear Association	.704	1	.402
N of Valid Cases	415		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.17.

6.16 Perceived benefits of rooftop RWHS for outdoor and indoor purposes

Although the proportion of respondents willing to adopt the system was not much higher than those who were not, the former indicated the following perceived benefits , providing useful data in the event of RWHS implementation.

6.16.1 Laundry and Toilet Flushing

Using RWHS for laundry was considered most beneficial. This was included under both the outdoor and indoor question, as laundry can be done indoor and outdoor. Use for flushing toilets was the second-most frequent response. Overall, people are willing to use harvested water for outdoor purposes particularly laundry and toilet flushing. In contrast, some of respondents would only consider using rooftop rainwater for showering under indoor activities. Few indicated kitchen and faucet use. Unexpectedly, 3% are willing to use it for drinking purposes. The results indicate that, with adequate awareness and education, RWHS could be implemented in urban residential areas and could reduce water shortages.

Table 6. 17 Willingness to use RWHS for Outdoor and Indoor purposes

Willingness for outdoor purposes	**Responses**
	%
Laundry	21.8%
Flushing toilets	20.9%
Gardening	20.5%
Floor cleaning	19.3%
Car wash	17.4%

Total	100.0%

Willingness for indoor purposes	Responses %
Drinking	3.0%
Kitchen (Dish washing & cooking purpose)	8.1%
Bathing & showering	17.2%
Faucet use (shaving & brushing)	9.1%
Laundry	62.6%
Total	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	229.161[a]	1	.000		
Continuity Correction[b]	225.970	1	.000		
Likelihood Ratio	257.302	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	228.609	1	.000		
N of Valid Cases	415				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 57.44.

b. Computed only for a 2x2 table

6.16.2 Economic and environmental benefits

As mentioned above, most respondents, notably those who are willing to use these systems, consider RWHS a cheap source of water. Some also consider rooftop RWHS environmentally friendly. 10.5% believe it reduces storm water runoff and 30.4% believe it is safe to use rooftop RWHS for outdoor activities, such as laundry, flushing toilets, gardening, cleaning floors, washing cars, etc. However, the proportion of those willing to use the system is only slightly higher than those who are unwilling. This limits the generality of the result.

6.16.3 In case of water shortage

A key benefit of rooftop RWHS is as an alternative in the case of water shortages. 26% of respondents, mainly from lower middle and middle class areas, consider this a good alternative. Respondents from areas that rely on the government water supply and that face water shortages consider RWHS a good alternative source. Respondents suggested that, if the government implemented rooftop RWHS as a pilot project, it would gain popularity. Currently, people know little about the system and the government does not prioritise it, either in policy-making or in awareness programs.

6.17 Perceived barriers to overall willingness to install rooftop RWHS

There are many perceived barriers, which render respondents unwilling or only slightly willing to install rooftop RWHS in their homes. Various reasons were provided for such unwillingness; mainly, "concern about water quality", as well as concerns over maintenance.

6.17.1 Concern about water quality and maintenance issues

The majority of respondents were concerned about water quality (see Table 6.18). The general perception is that rainwater collected from rooftops is unclean. 39.2% responded with concerns over water quality, and 18.2% with concerns over the extent of maintenance required. These perceptions are relatively typical, and common with the introduction of alternative technologies. However, with education and awareness, and once benefits begin to be realised, perceptions eventually change.

Table 6. 18 Reasons for unwillingness to use rooftop rainwater

Reasons	**Responses Percentage**
We have a plenty of water	16.0%
Concern about water quality	39.2%
Have not seen this system before	14.3%
Need much work to maintain	18.2%
Cost of installing	7.8%
Current supply line is cheap	4.6%
Total	100.0%

Chi-Square Tests	**Value**	**df**	**Asymp. Sig. (2-sided)**	**Exact Sig. (2-sided)**	**Exact Sig. (1-sided)**
Pearson Chi-Square	122.965[a]	1	.000		
Continuity	120.653	1	.000		

Correction[b]					
Likelihood Ratio	131.141	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	122.668	1	.000		
N of Valid Cases	415				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 63.05.
b. Computed only for a 2x2 table

There results indicate that there is strong significant association between willingness and concern about water quality and maintenance issues.

6.17.2 Lack of water conservation attitude

It is also noted from the results that respondents who do not face water shortages with their current water supply system lack a 'water conservation' attitude. 16% responded, "*We have plenty of water*". In contrast, those facing water shortages were very willing to install the new system (see Table 6.19). These results suggest that government incentive might encourage individuals to conserve water.

Table 6. 19 Correlation of willingness and water shortage with current water supply system

Level of willingness and readiness to install rooftop rainwater harvesting system for your house?	**Do you face any kind of water shortage (seasonal or other) from your current water supply system**			**Total**
	No	**Yes**	**No answer**	
Not willing at all	98	32	1	131
Slightly willing	27	30	2	59
Less willing	53	81	1	135
Much willing	23	41	3	67
Very much willing	4	16	0	20
Total	205	200	7	412

Chi-Square Tests	**Value**	***df***	**Asymp. Sig. (2-sided)**
Pearson Chi-Square	57.944[a]	8	.000
Likelihood Ratio	59.369	8	.000
Linear-by-Linear Association	44.172	1	.000

N of Valid Cases	412

a. 5 cells (33.3%) have expected count less than 5. The minimum expected count is .34.

The results indicate that experiencing water shortages with a current water supply system strongly and significantly affects willingness to install rooftop RWHS.

6.17.3 Responsibility of the government

When it came to the question of willingness to install rooftop RWHS if the government provides an incentive, the majority of the people responded that they were very much willing. Currently, the government is the service provider for water in urban residential areas regardless of the availability of water from boreholes. Therefore, people believe that the government should support the installation of RWHS. Table 6.21 below shows the results of cross tabulation of willingness with regards to water shortage with current water supply system if the government provides incentives. It is found that people facing water shortages are very much willing to install this system when it comes to the support of government. Moreover, it can also be observed from figure 6.17 that respondents from lower middle and middle class areas (Rawal town and cantonment) have shown that they are 'very much' willing' to adapt these systems should the government provide help. However, from table 6.20, it can be seen that people were less willing to install this system on their own regardless of water shortages and class. There could be another reason behind this willingness and readiness to install rooftop RWHS i.e. financial risk. Most people would not be able to take such a risk on their own. Therefore it can be suggested that until the government provides some sort of practical demonstration or support, then people will not be willing to use such systems.

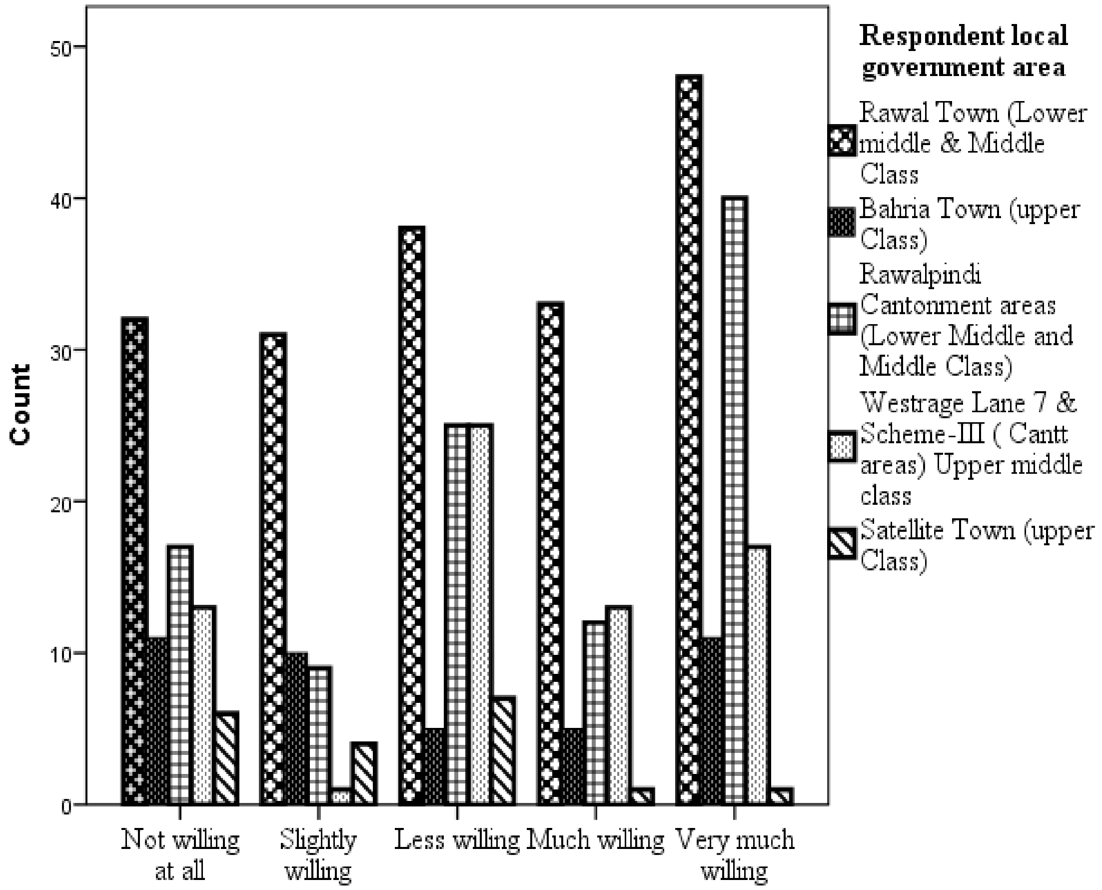


Figure 6. 17 Cross tabulation respondent areas (income class) with willingness if government provide incentives

Table 6. 20 Cross-tabulation of willingness should government provide incentive and water shortages with current water supply system

Willingness to RRWHS if Government provide incentives	**Water shortage from current water supply system**			**Total**
	No	**Yes**	**No answer**	
Not willing at all	62	17	0	79
Slightly willing	37	16	2	55
Less willing	54	46	0	100
Much willing	25	37	2	64
Very much willing	30	84	3	117
Total	208	200	7	415

Chi-square tests	**Value**	***df***	**Asymp. Sig. (2-sided)**

Pearson Chi-Square	68.539[a]	8	.000
Likelihood Ratio	73.929	8	.000
Linear-by-Linear Association	60.457	1	.000
N of Valid Cases	411		

a. 5 cells (33.3%) have expected count less than 5. The minimum expected count is .92.

6.18 Multivariate tests to summaries the key willingness variables

In multivariate analyses, one or more dependent variables are compared across two or more independent variables. The Multivariate test or MANOVA (multi analysis of variance) was performed here to compare key willingness (towards rooftop RWHS) dependent variables whilst using a range of independent variables. This multivariate analysis was performed using a general linear model to analyse and summarise the significance of the relationship as follows:

- Frequencies and descriptive statistics are given for mean and standard deviation of dependent variables.
- a correlation matrix for dependent variables as mean of multi-linearity between the dependent variables is obtained.
- a multivariate normality test (Kurtosis) is performed as well as a Skewness test to check the normality of the dependent variables
- Levene's test is performed to check the multivariate homogeneity of the variance between independent variables (Table 6.21).

Finally, to check the multivariate homogeneity of covariance between independent variables, Box's M. is shown in MANOVA. Box's M. tests the hypothesis that the covariance matrices of the dependent variables are significantly different across levels of the independent variable.

Therefore multivariate analysis was performed using a general linear model to analyse and summarise the significance of the relationship (Appendix C, C.1, and C.2) between key willingness dependant variables with a range of independent variables together as follows:

Key willingness dependant variables:

- Overall level of willingness and readiness to install rooftop rainwater harvesting system.
- Overall level of willingness and readiness to install rooftop rainwater harvesting system if the government provides this at no cost.

Independent variables:

- Level of education
- Ownership of the house
- Income
- Type of current water supply system
- Water shortage with current water supply system
- Satisfaction with current water supply system
- Level of knowledge about rooftop RWHS

Table 6. 21Willingness to install RWHS on own initiative *vs*. with government incentive

	General willingness	**Willingness with incentive**
Mean	2.48	3.20
N	415	415
Std. Deviation	1.227	1.463
Minimum	Not willing at all	Not willing at all
Maximum	Very much willing	Very much willing
Range	5	5

Box's Test of Equality of Covariance Matrices[a]

Box's M	71.977
F	.665
df1	75
df2	2759.537
p	.988

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

Levene's Test of Equality of Error Variances[a]

	F	**df1**	**df2**	***p***
Willingness to install RRWHS	1.394	264	150	.012
Willingness to install RRWHS if government provides incentives	1.808	264	150	.000

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

6.19 Results of Multivariate Analyses (General Linear Model)

Details of the multiple comparison and post-hoc tests are presented in the appendices owing to space limitations. Some variables have a strong significant relationship while some have only a weak relationship. For instance, the level of education and willingness to adopt rooftop RWHS were not significantly related. However, respondents who rely solely on the government water supply and purchase water from private water tankers are significantly more willing to adopt rooftop RWHS. These areas comprised lower middle and middle class households. It was hypothesised that lower middle and middle class respondents might be more willing to adopt rooftop RWHS, meaning the hypothesis holds true. In addition, if the government provides an incentive to install rooftop RWHS, the majority of people are willing to adopt this technology regardless of their current water supply system.

6.20 Summary

The analyses indicate that urban residents in Rawalpindi city are relatively willing to adopt rooftop RWHS but mainly for the purposes of laundry and toilet flushing. They are also ready to adopt this system for their own house but not at their own cost. Further, it was found that inadequate understanding of the system is a major barrier to wider adoption. People in residential urban areas are relatively unaware of rainwater harvesting technology. Concern about water quality and maintenance are perceived barriers among respondents. A further barrier is the lack of a 'water conservation' attitude, which is indirectly related to a lack of awareness, although a small number of respondents perceived economic and environmental benefits. Furthermore, this system is unfeasible for some existing residential houses owing to the small size of the catchment area and the double-storey build form. In summary, households facing water shortages as a result of their current water supply system are willing to use RWHS, but mainly for outdoor purposes. There is also a need to educate residents and practically demonstrate the importance of RWHS through pilot projects.

Chapter 7 – Policy implementation barriers for rooftop rainwater harvesting system in urban residential areas

This chapter explores what the policy barriers are to implementing rooftop RWHS in urban residential areas of Pakistan. Different stakeholders, mainly from government departments involved in policy formulation and implementation, were interviewed in order to evaluate these barriers. Stakeholders are those actors involved in policy formulation and implementation from different government and non-government organizations. In the first section the results are presented; mainly in terms of how the interviewees responded linked to which actors/departments were involved in this process. In the second section, the interpretive model along with the discussion is presented.

7.1 Analysis of interview transcripts

7.1.1 Major themes/initial concepts from interview data

The main themes were generated using Nvivo software before the auto coding process. All themes and initial concepts for data analysis were created according to the most commonly used top-down/bottom-up theoretical perspectives of policy implementation barriers. One interview with the executive of the cantonment department in Rawalpindi will be analysed separately, using the same themes, as the cantonment departments do not constitute part of the district government. The aim of interviewing the cantonment department separately was to determine their water supply policies and options for urban residential areas in comparison to civil government departments. All cantonment areas consist of urban settings.

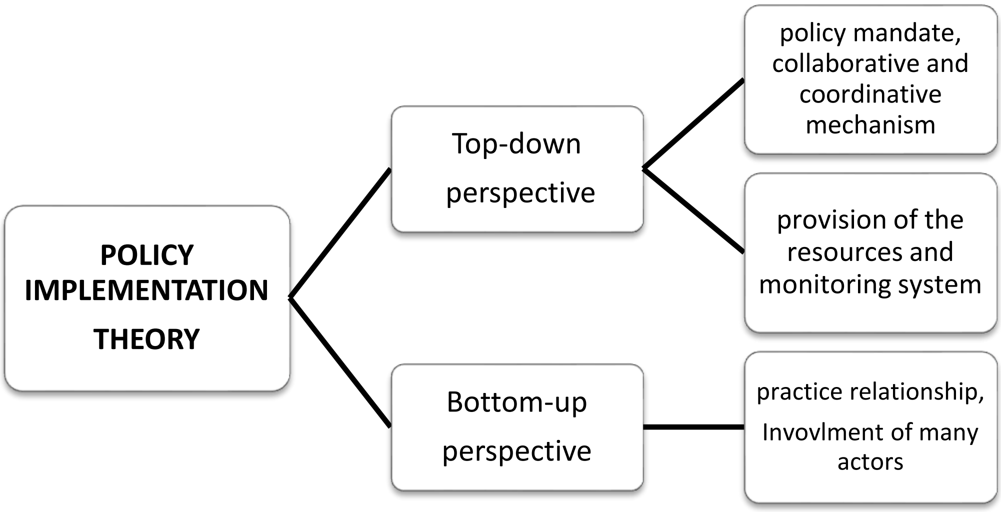


Figure 7. 1 Initial concepts/major themes of interview data organised deductively in relation to the top-down/bottom-up policy implementation theory

Source: (Rhodes, 2006)

7.1.2 Analysis of all major themes generated by initial and emerging codes in Nvivo

Firstly, all major themes were generated as shown in figure 7.2. Analysis of the interview data was done using these main themes. The terms ‘code’ and ‘node’ in Nvivo software were used to highlight a word or a sentence forming a theme or subtheme. All the questions and interview responses were used in Nvivo to identify the themes and subthemes via word frequency and word query.

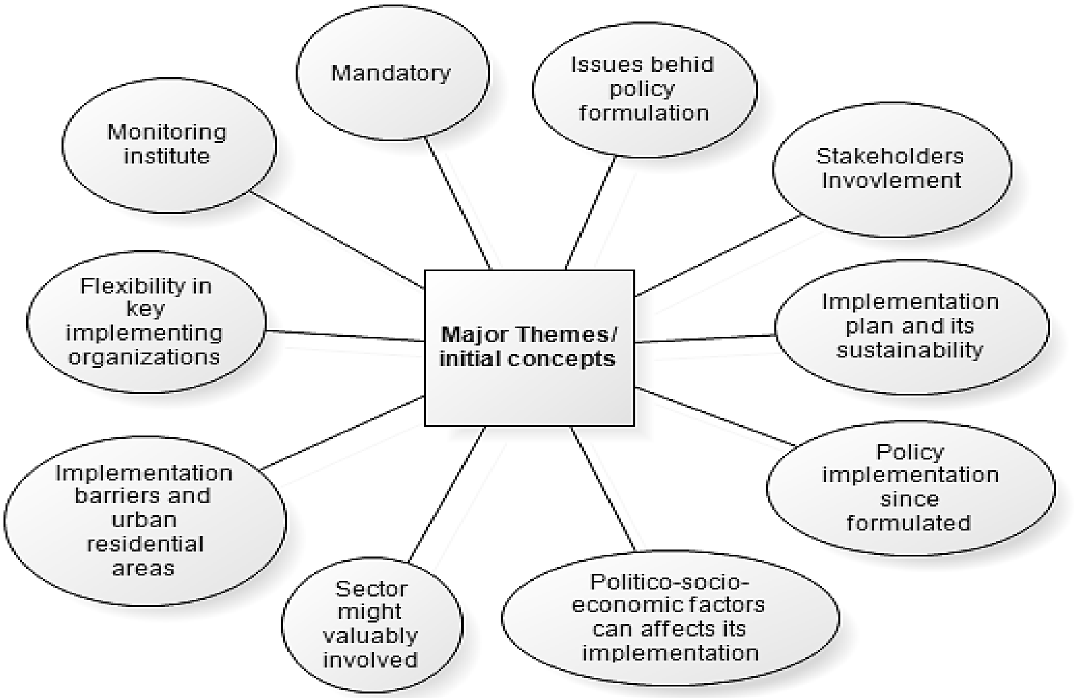


Figure 7. 2 Initial concepts/major themes analysed and coded from interview data

7.1.3 Subthemes coded from initial concepts/major themes

In qualitative data analysis, coding is the continuous emergence of subsequent themes. After initial coding of major themes, different subthemes that emerged from the main themes, and that enhance accuracy, were identified using Nvivo. Subthemes were coded on the basis of word frequency used by interviewees and number of references coded from each source.

7.2 Background on RWHS policy guidelines drafted by ministry of environment, Pakistan

The National Environment Policy (MOE, 2005) was first formulated by the Ministry of the Environment. One of the clauses of this policy focuses on *"design, development and evaluation of water conservation technologies"*. Furthermore, it was stated that the Ministry of the Environment in collaboration with provincial governments should coordinate the implementation and monitoring of this policy. Additionally, reports on progress in implementing these strategies and plans should be submitted to the Ministry of the Environment on a bi-annual basis. A National Environment Policy Implementation Committee was also established to monitor the implementation process

(Figure 7.4). In 2009, the Ministry of the Environment introduced rainwater harvesting within the National Drinking Water policy (MOE, 2009). However, this policy was not limited to rainwater harvesting; rather, it was set within the broader context of a "National Environment Plan". The current research aims to explore the barriers to implementation supported by clauses P1 and P2 shown below.

Table 7. 1Detail of the organization and policy formulation

Ministry of Environment/ Climate Change division	"Protection and conservation of water resources"	*Policy clause (P1)* *"Rainwater harvesting at household and local levels will be promoted to augment the municipal water supplies as well as for groundwater recharge, so as to promote sustainability of water sources"*	Date approved September, 2009
Ministry of the Environment	*National Environmental policy*	*Policy clause (P2)* *Design, develop and evaluate water conservation technologies.*	November 2005

Source: (MOE, 2005, MOE, 2009)

The list of stakeholders involved in policy clause P1 fall under the supervision of the Ministry of Environment/Climate Change Division as illustrated in Figure 7.3:

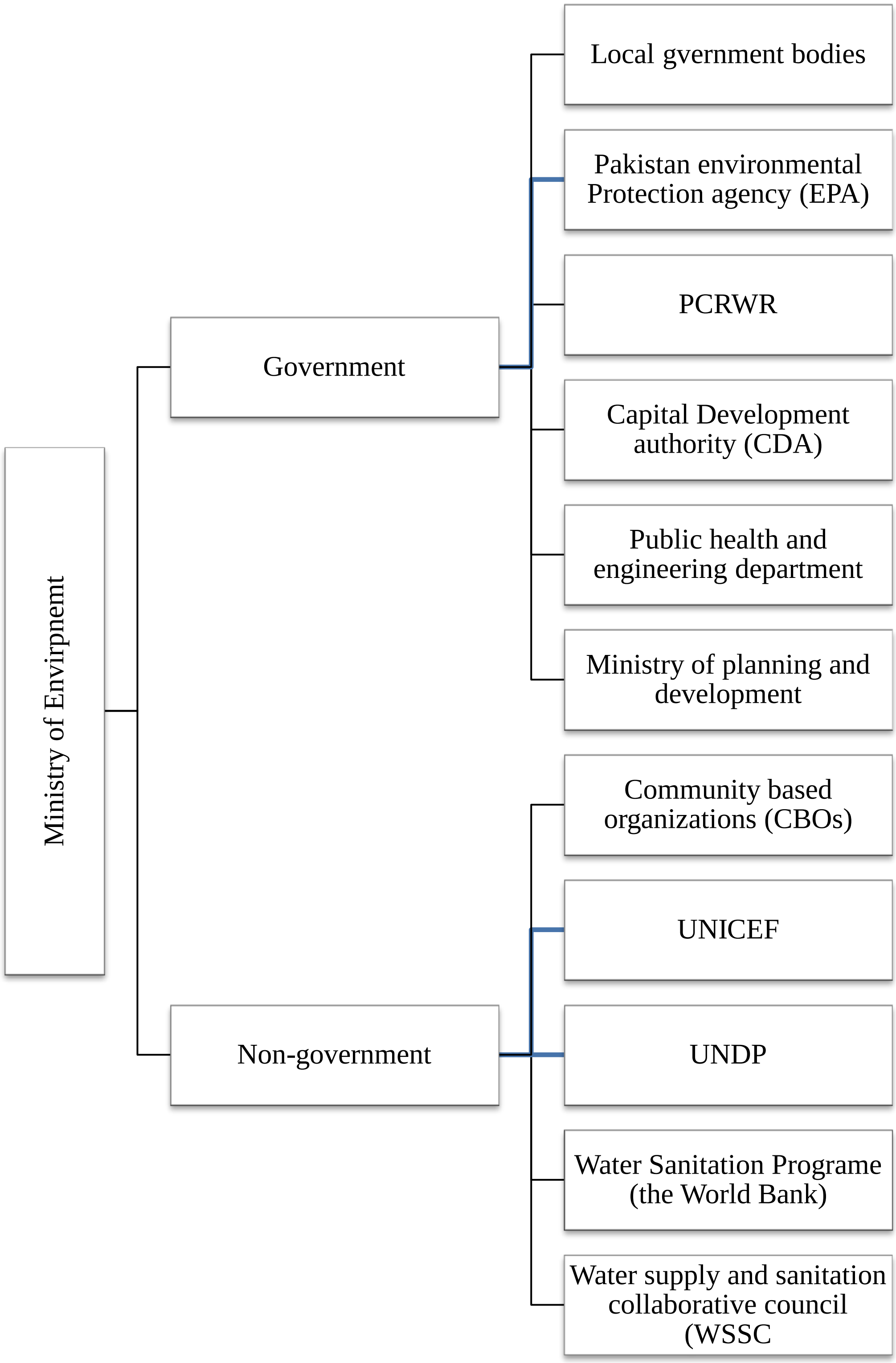


Figure 7. 3 Stakeholders involved in policy formulation Ministry of Environment/Climate Change division

Source: (PCRWR)

Organisations involved in policy implementation are show in figure 7.4 below

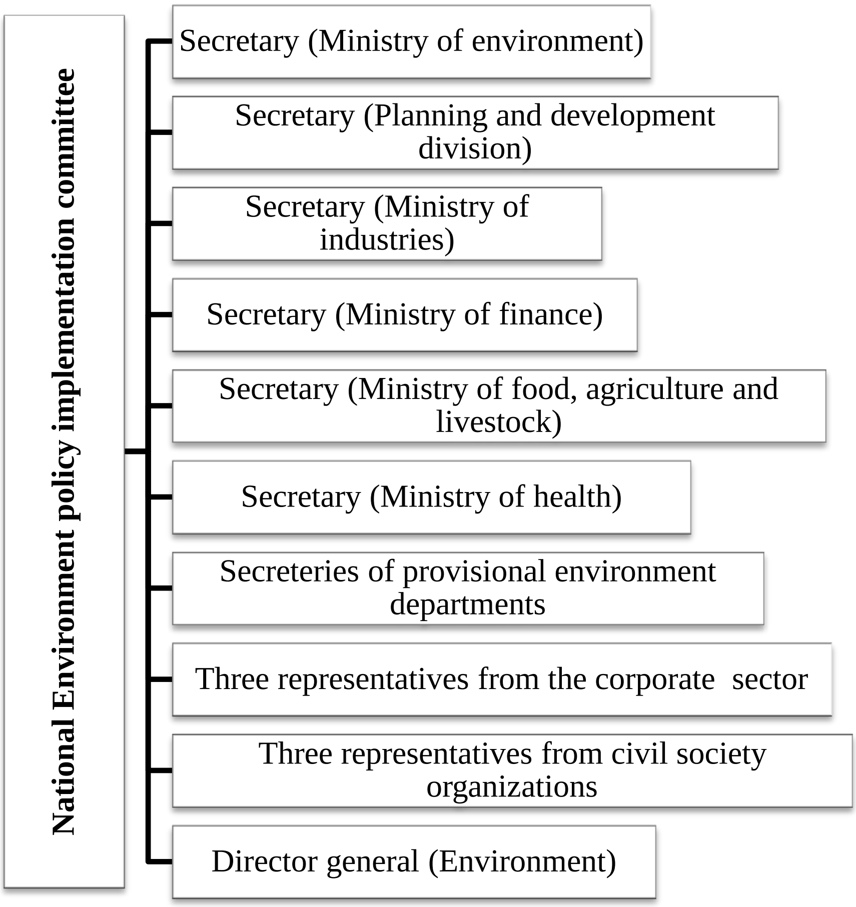


Figure 7. 4 National environment policy implementation committee

Source: (MOE, 2005)

Interviews conducted as part of this research focused on the policy clause P1. The objective was to establish what type of rainwater harvesting systems, at household level, are being promoted and what barriers there might be to implementation. The overall purpose of the assessment was to analyse to what extent rooftop RWHS are being considered for urban residential areas.

The policy clause referring to "*protection and conservation of water resources*" clearly mentions that rainwater harvesting at the household level should be promoted. Likewise, the policy formulated as part of the National Environment Plan also indicates that *'water conservation technologies should be designed and developed*'. Therefore, those departments closely involved with the Ministry of the Environment in policy formulation were asked how they perceive rooftop RWHS as a water conservation technology for urban residential areas.

7.3 Institutional structure of statutory bodies involved in the planning and development of urban design and provision of water supply system

Identifying the policy barriers to implementing rooftop RWHS requires an integrated methodological approach. The institutional structure of statutory bodies involved in urban design and provision of water supply system in Pakistan is illustrated below:

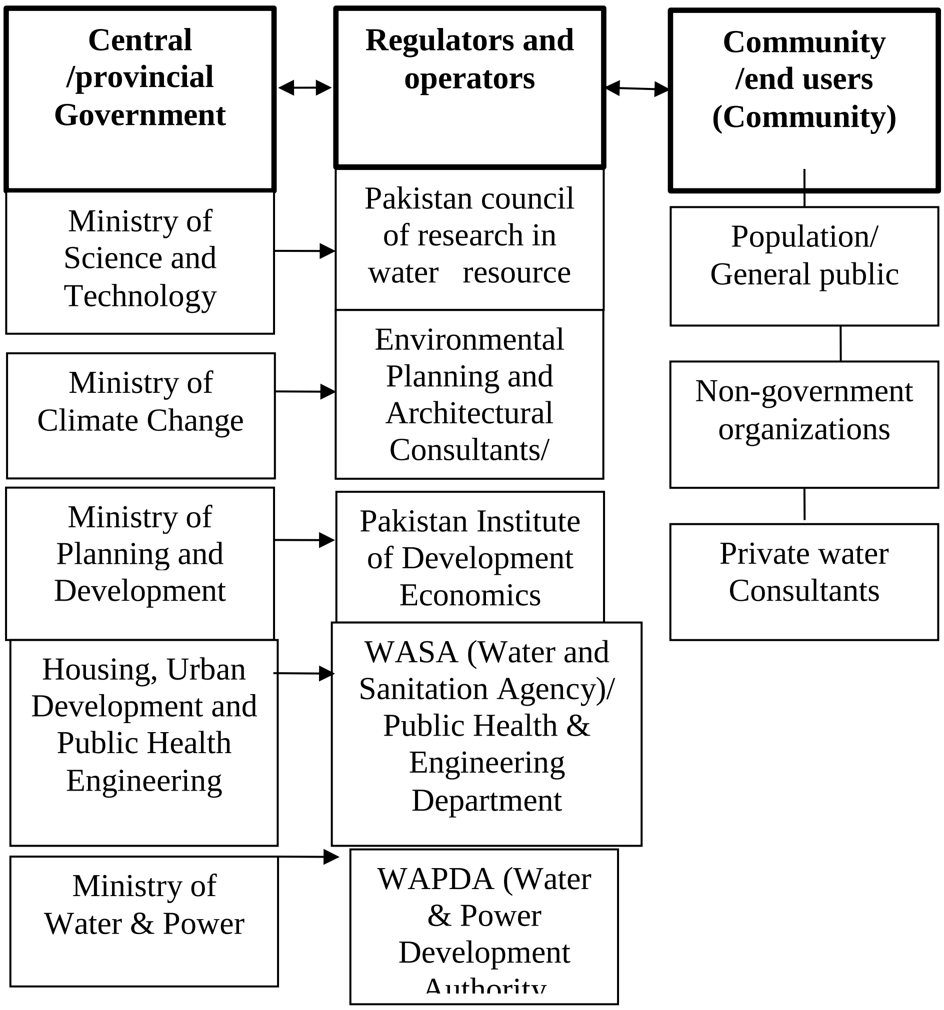


Figure 7. 5 Organizational map used to identify key statutory bodies and beneficiaries Source: (Cardona, 2006)

7.4 Results

In this section, the results from all transcripts are presented in relation to the main themes. The list of respondents and transcript numbers are presented in Table 7.2. The complete transcripts and topic guide for the interviews are provided in the appendix.

Table 7. 2 List of interviewees and transcript numbers mentioned in results and discussions

Department/ Organization	Respondent Number	Transcript Number
Water & Sanitation Agency Rawalpindi	R2	T2
Rawalpindi Development Authority	R3	T3
Pakistan Water Partnership	R13	T13
Water and Sanitation Agency Rawalpindi	R1	T1
ERRA (Promotion of RWHS for earthquake affected areas	R12	T12
Pakistan Council of Research for Water Resources	R10	T10
Planning and Development Ministry	R6	T6
The world Bank office Islamabad	R14	T14
Planning and Development Ministry	R7	T7
Rawalpindi Development Authority	R4	T4
District Government Rawalpindi	R5	T5
Pak-environmental protection agency Islamabad	R8	T8
Cantonment Board Rawalpindi	R16	T16
Pakistan Council of Research for Water Resources	R11	T11
Pak-EPA	R9	T9
Pak Water Supply and Sanitation Collaborative Council	R15	T15

*Please note that interviews were conducted in both English and Urdu. Quotations made within the body of the thesis have been subject to minor grammatical and presentational corrections, so as to ensure clarity. None of these corrections have altered the meaning or the essence of the interviewees' responses.

7.5 Issues underlying policy formulation and involvement of different stakeholders

Stakeholders involved in policy formulation were interviewed and were asked which issues informed policy formulation and which other stakeholders were involved. The main codes were set in Nvivo software with most responses as:

- Water scarcity
- Falling ground water table
- Merely to show that we have such a policy
- Policy was part of water management in general
- There was a need for water conservation at a national level

7.5.1 Water scarcity

Most interviewees cited *water scarcity* as a major issue underlying policy formulation. Some mentioned the falling *ground water table and water shortages*. All government and non-government department interviewees stated that policies are generally formulated at the national level, that there was no division between urban and rural areas and that this was part of a broader water management scheme, and included agriculture, industrial and domestic water management.

7.5.2 Formation of a water and sanitation agency due to the need for water conservation at a national level

According to *R-2, "In 1976, the Punjab City Development Act was approved by the Punjab assembly through which we, WASA, govern. It is called the 1976 Act. In that, it's been instructed who will pass building planning and who will cover water supply. So we (WASA) came into being as a result of that Act. It is obvious that Pakistan is water scarce. What you are talking about is the rainwater harvesting part of our Act". (T-2)*

7.5.3 Policy as a part of water management in general

Similarly, the *Ministry of the Environment*, which is now the Ministry of Climate Change, was the main actor according to all the respondents. Changing the name of the ministry from 'environment' to 'climate change' was done to emphasize the national and global issues of climate change. The Ministry of Climate Change invited all stakeholders related to the water sector and other administrative authorities to be involved in the consultation during the water management policy formulation in 2009. According to R-8*, "the national climate change policy was drafted in 2010. We started working on that policy in 2008 or 2009. It was in our agenda and the ministry of environment was really concerned about promoting the rooftop RWHS on a national level" (T- 8).*

R-9 mentioned, "*I was not in policy formulation, but I would like to tell you that the custodian of water, which is the Ministry of Water and Power, was not included. In fact, the subject of water, whether it is rainwater harvesting, irrigation or industrial wastewater, all included in the domain of water and power development, belongs to the water and power ministry. Actually, when they formulated the policy they didn't know what the objective of the policy is. The policy was copied from the Internet just to show that we have policy and we drafted it. So basically it was not for the division of urban and rural water conservation technologies" (T- 9).*

The policy formulated by the PCRWR does not clearly state which stakeholders were involved. R-10 stated, "*we work under the ministry of science and technology and we formulated the policies with the help of the ministry of science and technology" (T-10).* According to R-5, "*We didn't have any participation. We should make policies after research. However, we just made a policy and copied it from the Internet. We didn't have any involvement with this policy formulation" (T- 5).*

7.6 Implementation plan and its sustainability

As the focus of the interview was to identify the barriers to implementation, all interviewees were asked about implementation planning and its sustainability. Nine of

16 interviewees (including government and non-government) replied that implementation plans exist; however they also mentioned that they are unsustainable.
R-6 responded that "*The policy was well organised and policies are basically guidelines. Therefore we made guidelines on a national level."* On the question of sustainability of the implementation plan, he replied *"It was just a policy, not more than that". (T- 6)*
Similarly, R-3 stated that *"Yes, rooftop rainwater harvesting systems have been included in building plans but not here in the RDA yet. I have heard that recently, Lahore development authority has included rooftop RWHS in its new building plan"* whereas in response to the question on the sustainability of the implementation he stated "*I cannot say anything at the moment. Once it is shown practically then I can say something" (T- 3).*

Furthermore R-4 also mentioned that *"Yes, all our plans come from the urban unit development authority, Punjab. LDA (Lahore Development Authority) has granted approval, according to my informal information, that rooftop RWHS should be included in new building designs. All private schemes, such as infrastructure, require permission from us (RDA). So policy and plan both are there, but the issue is implementation" (T-4).*

R-11 responded, "*We provide implementation plans, but it is the government's responsibility to implement. My duty is to draft the policy and provide a plan, then it is the government's responsibility to implement this".* As for sustainability of the implementation plan, his response was *"It was well thought through at the time of formulation but this is not the final or the last document. We are always looking for improvement, where it is needed. If instructed, then we would try to improve the plan according to realities on the ground and taking account of what is feasible in terms of implementation for urban residential areas" (T- 11).*

According to R-9, *"If the policy is considered a dead document, then how could you expect the implementation and sustainability of the plan" (Transcript # 9).* In addition to that, R-8 also highlighted "*We are excellent in formulating policy but unfortunately we are very weak in policy implementation so the plan is sustainable in documents only" (T- 8).*

R-1, answered that "*We do have an implementation plan but it is not effective until and unless the building control department approves it. However we don't have any funding for this yet but again I would say there is an implementation plan that rainwater harvesting should be implemented" (T- 1).*

R-15 stated that "*I would say the plan is always sustainable but when it comes to its implementation then there is no sustainability and coordination" (T- 15).*

Furthermore the R-14 also mentioned that "*Fortunately with our technical assistance, Punjab government generated a Punjab municipal act. Once the act is approved by the cabinet and the provincial government of the provincial assembly, then an independent water commission will be established in Punjab, which will play the role of regulator on both public services as well as private. But at the moment, there is no regulator to look at the standards, to look at the policy clauses and to make sure service delivery is carried out in a sustainable manner" (T- 14).*

7.6.1 Policy implementation plan and the needs of urban residential areas

As mentioned above, all interviewees reported that policy formulation and implementation planning operates at national level. Furthermore, there is no differentiation of the policy for rural and urban areas. Therefore, all stakeholders were asked to what extent the policy implementation plan meets the needs of the urban residential areas. The responses were:

- Greater need in urban residential areas than in rural areas
- Government should demonstrate the system in urban residential areas
- There are some technical barriers, including seepage and seasonal variations
- There are some social barriers, including the unwillingness of the people to adapt to this technology
- Feasibility analysis required before implementation in urban residential areas
- Some respondents did not perceive any technical barriers to implementation in urban residential areas

According to R-6, "*there should be more focus due to flood and watershed problems in urban areas; for instance, if you go back in time, Islamabad was not fully paved. Now all Islamabad areas are paved and rain water directly flows to Rawalpindi and flood* *occurs".* In addition he said, "*social acceptability could be a barrier but it can be overcome by social awareness programmes. If you simply ask people to install this system, they will not be willing because they would say it's complex and needs maintained etc. However, if government offer demonstration projects in urban areas then it would be automatically implemented in future"(T- 6).*

R-3 stated that, "*I feel basically this rooftop rainwater harvesting is an urban need because urban areas are more vulnerable to water scarcity. Political will is very important to move actual needs-based policy to implementation" (T- 3).*

In response to the question relating to barriers to implementation in urban residential areas, R-5 stated, "*first there should be an awareness plan. If there is an awareness plan, then I can say if there are any barriers or not" (T- 5).* Similarly, R-7 responded that "*Quality of water is a real concern as a technical barrier; the catchment is another barrier as the rooftop areas at household level are very small in urban areas. Almost all houses are double storey here in Rawalpindi" (T- 7).* R-4 also mentioned, "*there could be a potential barrier, which is seasonal variation or maybe storage capacity. So barriers are there but it doesn't mean we leave it"* (*T- 4).*

R-8 responded, "*I can see practical, technical and social difficulties in implementation. In my thinking, they should go for public settings rather than for every single residential house"* (*T- 8).*

Similarly, R-12 responded, "*it's not an alternative. It will supplement, so you can take an advantage of this. Here, the role of planners to look at feasibility in urban areas comes into play*" (*T- 12).*

In contrast, R-10 responded, "*I don't see any barriers for urban residential areas except a few, such as seepage"* (*T- 10).* R-1 responded that, *"unpredictable rainfall patterns, I think, are a major technical barrier in implementation in urban areas. I can tell you it is not particularly feasible in urban areas but in scattered areas it could be feasible. Again, I would say you can include it in new building designs"* (*T- 1).* R-15 said that, "*In my opinion, I don't see any barriers to implementation in urban areas. It could be a supplement to the current water supply system"* (*T- 15).*

7.6.2 Policy implementation since formulated

How and where the policy has been implemented was a key question in understanding the current situation. Three codes were identified in response to this question, as per frequency and number of words coded:

- Not well implemented
- Implemented in some rural areas
- Implemented in a few public buildings of urban areas

R-6 responded, "*as explained earlier, when it comes to implementation, then we are weak. The policy has not been implemented despite a few initiatives taken by the ERRA and CDA but those were pilot projects and we cannot say that it represents the proper implementation of the policy at a national level."* (*T-6).* R-7 responded*, "As I said, it is well implemented in earthquake areas. As far as urban areas are concerned, the CDA (Capital Development Authority, Islamabad) took the initiative to implement in 2010*" (*T-7).*

According to R-9, *"The policy was generated here in the federal government so it has to be implemented by the provincial government, and the basic gap is here for not being implemented. Ideally, The CDA [Capital Development Authority] should have their own policy. Likewise, the RDA [Rawalpindi Development Authority] should have their own policy. I do not know why the Ministry of the Environment at federal level made this policy. All local departments should be responsible for formulating and implementing policies. The major gap in policy implementation is involvement of inappropriate stakeholders. I mean those who were involved in the policy formulation were not aware of how it is going to be implemented"* (*Transcript # 9).* According to R-8, "the *CDA has taken a number of initiatives in which they built inverted beds and collected rooftop water and recharge water in public buildings but they only showed enthusiasm in the beginning. Now everything is in front of you. I haven't seen this policy implemented in any residential areas of Pakistan. We say every household should have rooftop RWHS, but practically is it feasible? What will the cleaning mechanism be? We have to look to pilot projects to check the mechanism" (T-8).*

R-15 responded, *"It's been implemented in some rural areas. The policy is very good - that's what I am saying. In Pakistan, policy documents are presented in a good way but* *corruption is a barrier to implementing policies. Pakistan is not a poor country, it's a corrupt country. If we remove the corruption then implementation would work (T-15).* R-14 responded in a slightly different way saying, *"Policy is not the end of the game. It is just a guideline. After that, the focus should be on the strategy of how the government of Punjab through to Rawalpindi WASA will make sure that the citizens of Rawalpindi get enough water. Again, one of the reasons why policies are not being implemented is that we don't have a regulator. We need a regulator in a province whose responsibility it is to make sure whatever is written in the policy has been implemented by those who are responsible. For instance, PHED (the Public Health and Engineering Department) government of Punjab developed a policy. The sub-departments of PHED such as the TMAs (Tehsil Municipal Administration) and WASAa (Water and Sanitation Agencies) are going to implement it in their area. Now the problem is that there is no regulator between the main PHED and sub-departments. Who will check and ask why there is no implementation of the clause of policy?" (T- 14).*

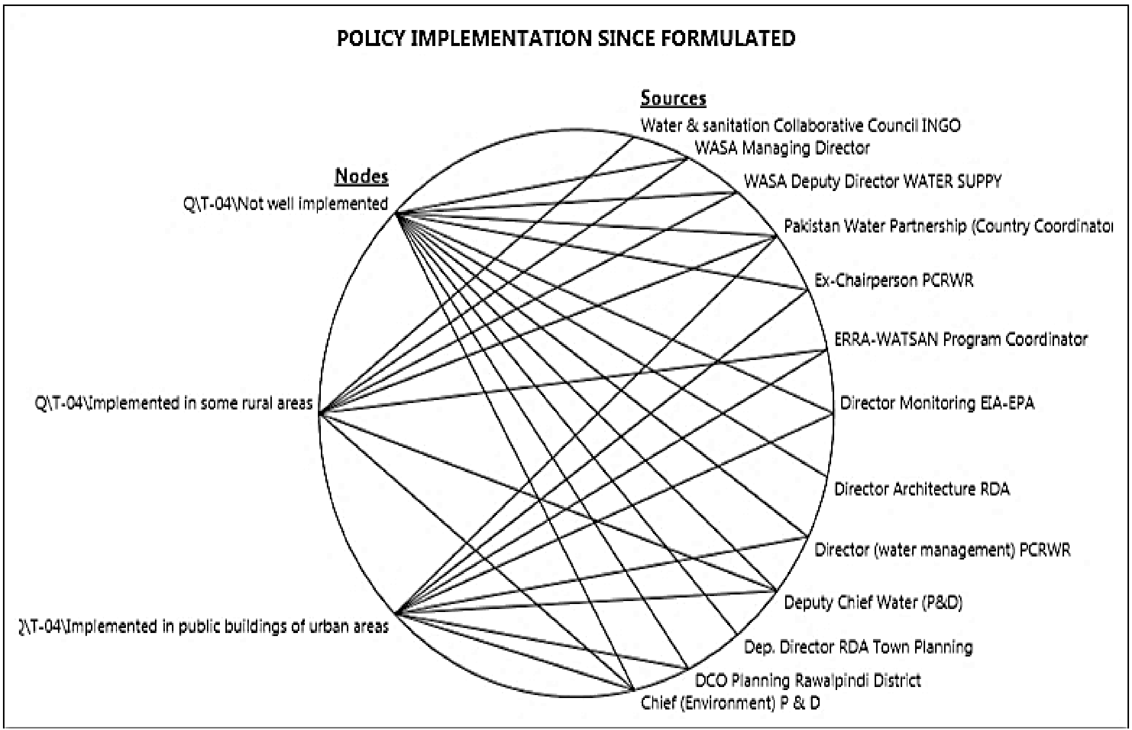


Figure 7. 6 Policy implementation since formulated

7.7 Flexibility in implementing organisations to adapt strategies and activities to respond to local needs

7.7.1 Change of authorities from federal to provincial level.

In Pakistan, there is one federal/central government and four provincial governments. Generally, the federal government is involved in policy dissemination and this is devolved to provincial governments for implementation. It was found during the interview process that this is now changing. In many areas, provincial governments are independent and can introduce their own polices and implement these without the involvement of the federal government. However, the financial distribution and allocation of budgets still sits with the federal government ministries. This is illustrated by R-6 who responded, "*as I explained, now all provinces are independent to formulate policies and implement them. So they have flexibility to adopt strategies and activities to respond to local needs"* (*T- 6).* In contrast, R-3 responded, "*No they don't have flexibility, as I said, there is a lack of coordination among different implementing organisations"* (*T-3).* Furthermore, R-4 stated that, *"the right person is not in the right position, I mean - not fully qualified. He or she doesn't have the relevant qualifications to suit the nature of their work. This is a dilemma you will find in many sectors, especially in the water sector. So how can they respond to local needs?"* (*T-4).* Similarly, R-9 responded that, *"they should give the role of implementation to the appropriate department"* (*T- 9).*

R-11 responded that, *"the key implementing organisations are doing nothing"* (*T- 11).* In addition, R-10 stated that, *"First, government need to define the key implementing authorities. Some departments are supposed to be autonomous but they are not working in an autonomous way*" (*T-10).* According to R-1, there is *'no flexibility and coordination between the departments and organizations'. According to* R-2, however, "*Yes they do have flexibility to adapt the strategies"* (*T- 2).*

R-15 responded that, "*there is serious overlap in local government and public health. In many places, PHED established different water schemes and they instructed the local government to manage them, so things become non-functional because local government make excuses that they don't have sufficient funds to manage those schemes. Also, we don't have the engagement from the community.*

So the point is - the schemes are just launched in response to politicians' order. So local government and PHED always have tussle and conflict about scheme ownership. Local *governments are supposed to cover schemes predominantly in the peri-urban areas while PHED predominantly looks after schemes for rural areas. However you run the schemes, you need to handover to the local government. The climate change division has had responsibility for coordinating water and sanitation over the last decade. But there have been efforts to make a water and sanitation council that push policy implementation to different stakeholders. So I would say PHEDs of all provinces, also needs to push and ask to implement this policy. So inter-departmental coordination is weak. They don't sit together and plan. So your action plan should be a joint plan. Even the policy says that institutional arrangements are critical and it is the responsibility of the each department that they should undertake joint planning"* (*T-15).* Similarly, R-14 responded that, *"No, I don't think so. As I explained you earlier, the strategies are not need-based"* (*T-14).* The details of the responses and sources are illustrated in the figure below:

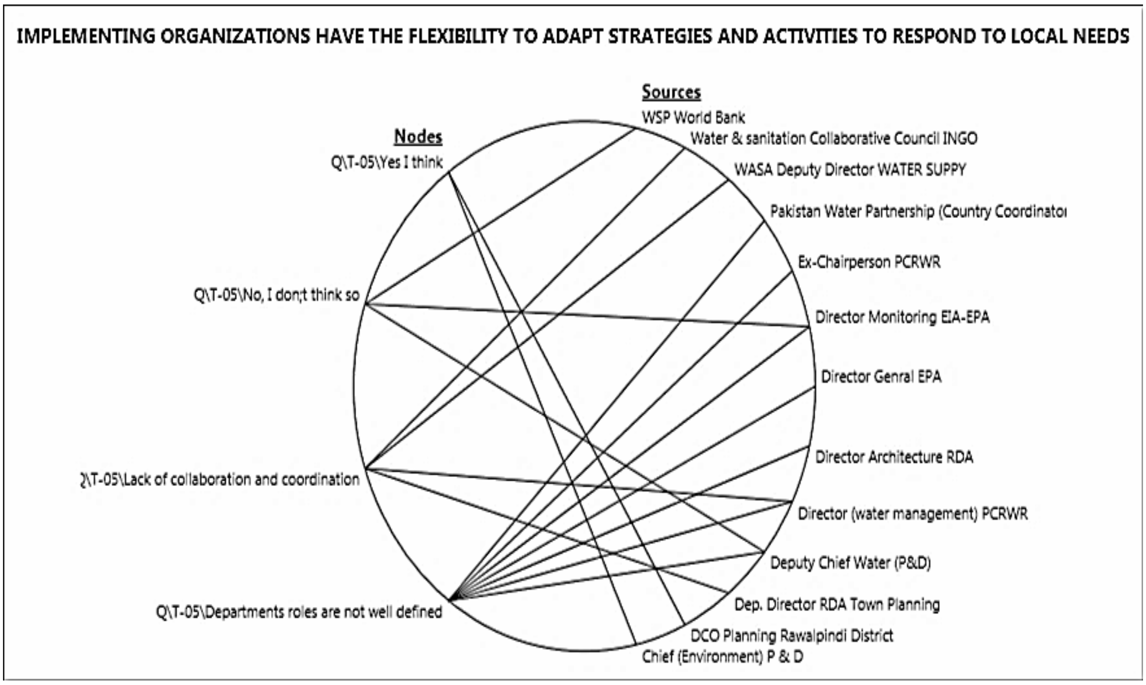


Figure 7. 7Implementing organisations to adapt strategies and activities to respond to local needs

7.7.2 Sector involved in its implementation

According to most respondents, the Ministry of Climate Change and Ministry of Planning and Development can play vital roles and might be valuably involved in implementing RWHS.

R-13 indicated "*WASA [Water and Sewerage Agency Rawalpindi] is the main actor in water supply provision. Instead of conserving water, they are exploiting the ground water table to provide water supply to the community through ground water resources. Similarly, the objective of the Pakistan agriculture research council is to deal with water harvesting in different areas. Different universities can also play an important role and might valuably be involved"* (*T-13)*. While R-15 responded, "*Finance and P&D should be active and efficient for implementation. Finance need to agree. Planning and Development needs to plan with aligned departments. Finance just needs to agree and say OK. Then again, its P&D's responsibility to divide finance among different departments. Local government elections are needed - then it will be further devolved and a bottom up approach will emerge"* (*T-15).*

7.8 Which politico-socio-economic factors can facilitate the implementation of rooftop RWHS

The most frequent response to this question was:

- Need for political will
- Need for more international agreements
- Devolution of governments (from central to provincial)
- Gender (females can play a vital role)
- Awareness and education
- Cost and energy efficiency

R-5 responded that "*the only thing nowadays in the corporate world is how things look. So politicians are only focused on the roads and bridges and other visible projects to get votes for the next elections. So different political persons can also play a vital role in implementation if they have some motivation about the importance of water and understand the environmental benefit. There are economic benefits but again I would say that first, government need to create social awareness" (T-5).* Similarly, R3 stated that, "*if there is personal benefit to the MNAs (Member of National Assembly) and MPSs (Member of Provincial Assembly) then they will be supportive. So they have a top-down approach - they don't have a bottom-up approach. Political people never look at the need of the people. They focus on what looks better and how to get votes for the* *next election. It is all about interest based policies. They implement those policies in which they have personal interest"* (*T-3).*

According to R-6, *"gender can play an important role, as females can see this technology in a better way. We accept new technology through a slow process, especially those things which are not our priorities"* (*T-6).* Similarly, R-9 said, "*we have to work on mind set and behavioural change when we talk about water conservation and sanitation, etc. Political factors alone can facilitate policy implementation. The reason is that people choose their political representatives and now it is the responsibility of that representative to provide basic needs and facilities to the community. Political will is really important to implement this system, otherwise it's not possible. However most of the political public representatives are not well-educated or aware of current environmental issues and the needs of our time" (T-9).*

Furthermore, R-12 said, *"I would say gender is important if you are looking for social factors in implementation. So female education regarding rooftop RWHS can play an important role"* (*T-12).*

According to R-15, *'government regulation needs to be introduced. The Punjab government has launched many water schemes but some of them are non-functional because there is no community participation. The chief minister, in his own way, is sort of supporting some components where they allocate funds for this massive filtration plant. So that is one initiative and that should be appreciated, but the whole objective is to meet the MDG (Millennium Development Goals) for Pakistan. They (the government) claim that they have met their target but that is not correct according to the current situation for water. Some people debate that. If you talk about Punjab (Rawalpindi), a large portion does not have piped water and they use boreholes at home, something that is happening illegally and that is causing the ground water table to fall. So they just drafted a policy document; which is not an achievement. However, we all supported it at that time, once the secretary of public health took the lead for this policy."* (*T-15)*

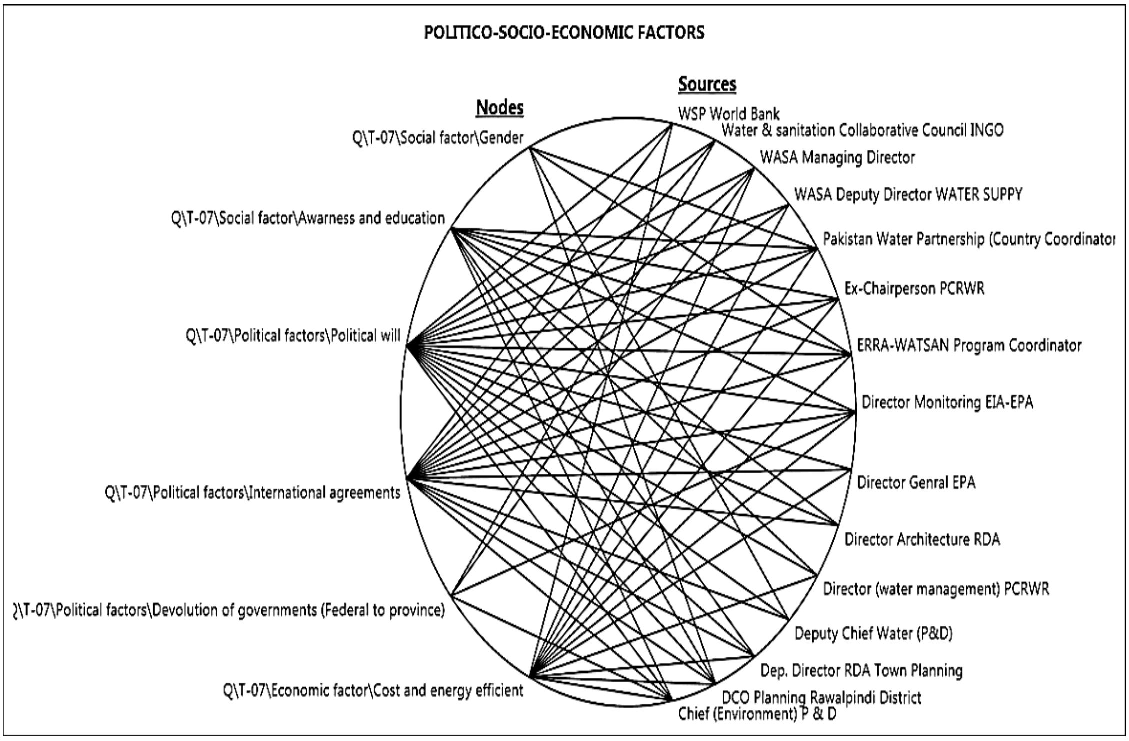


Figure 7. 8 Politico-socio-economic factors

7.9 Institutional monitoring of policy implementation

Most stakeholders responded that policy implementations are unmonitored. Four stated that the Ministry of the Environment is the key actor and should be the monitoring implementation. Local representatives of the Rawalpindi Development Authority (RDA) claim that the Ministry of Housing and Urban Development should be the monitoring institution.

R-6 responded that, *"District Government heads are responsible for monitoring the implementation of the policy. For example, WASA, RDA - they are autonomous organizations. Their heads in the Punjab province can monitor implementation and ask why policies have not been implemented"* (*T-6).* Similarly R-5 mentioned that '*the lack of policy implementation is due to a lack of feedback. There is no third party who monitors the policy success or failure. To be honest, there is no policy structure here in Pakistan - both policy formulation and implementation. Third parties should also look that how this is monitored"* (*T- 5).*

R-9 responded, "*as I said, a major barrier is that no institution is monitoring implementation and regulation. Honestly speaking, we couldn't do anything related to water conservation"* (*T-9).*

According to R-15, *"as such, no institute is monitoring implementation because the roles and responsibilities of all stakeholders need to be defined first. Water and sanitation do not fall in one department like education and health. Many departments are involved in the water sector - directly or indirectly. Water is addressed by local government; WASA is involved and PHEDs are also involved. The environmental departments, such as the EPA, are also involved, but they are more concerned with regulations rather than provision. First, they should introduce regulations and impose penalties if someone is not following the regulations"* (*T-15).*

7.10 Rooftop RWHS - should it be mandatory?

All interviewees responded, "Yes, it should be mandatory". Seven stakeholders, including government and non-government officials, believed it already to be in the building law but adhered to by no one.

R-3 responded: "*As I said, I have heard that it is included by law that rooftop RWHS should be included in new housing designs in Lahore, but we did not receive any such advice for our area, Rawalpindi"* (*T-3).*

Similarly, R-11 mentioned that "the *CDA have included this and made it mandatory for house plans, but I think that due to a lack of regulatory practice, no one is following the rules. The thing is - it is the responsibility of the government to evaluate this with some strict actions, not with written documents"* (*T-11).* According to R-10, "*the policy can only be implemented when you make it mandatory with strict regulations, such as enforcement of a fine or penalty. So I think it's not going to work until and unless you make it mandatory at national level"* (*T-10).*

R-14 responded that, *"Ideally, the government should provide incentives to the people to install rainwater harvesting system. In Pakistan, one aspect is practical and one is legal. Legally, all households have to have permission prior to digging a borehole for their house. But in reality, many people do not seek this as policy makers and so called* *regulating authorities do not bother to check. To cope with water scarcity and promotion of rainwater harvesting, I feel incentives should be provided to launch the pilot projects rather than putting in place a strict rule or making it mandatory"* (*T-14).*

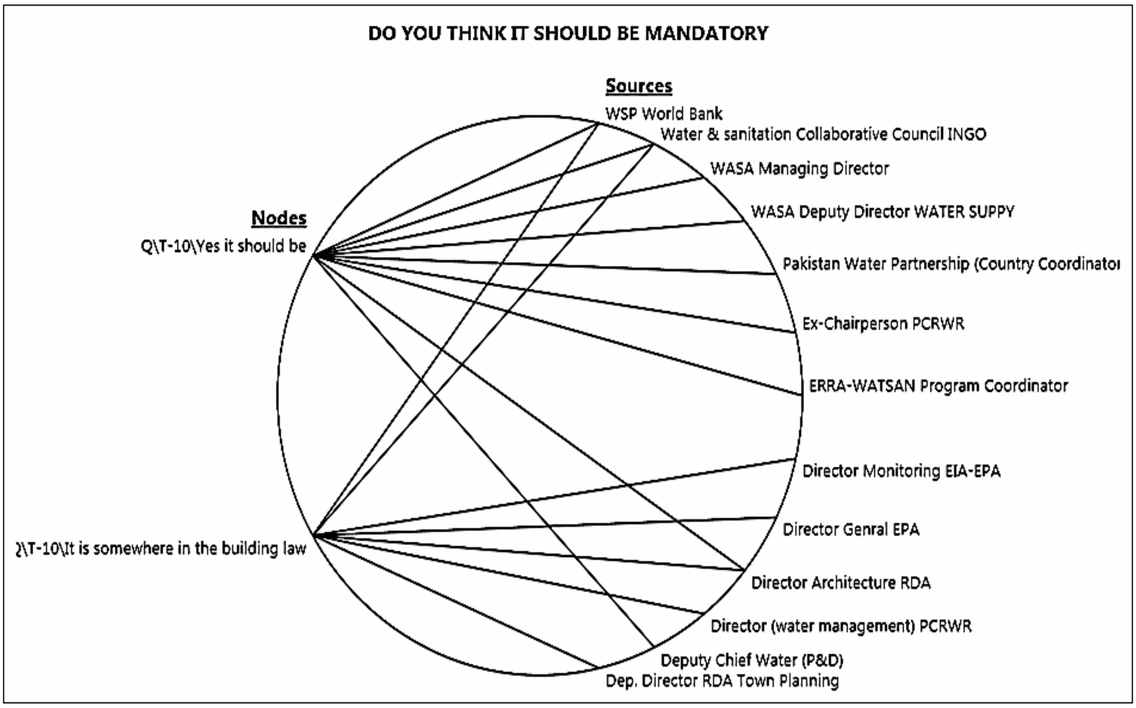


Figure 7. 9 should it be mandatory

7.11 Interview results from Cantonment Board Rawalpindi (R-16 and T16)

The results of the interview with the Cantonment Board in Rawalpindi are presented separately. It was the only interview conducted with the cantonment department due to a lack of accessibility and because of time constraints. Cantonment areas are not part of the district government. In almost every city (urban areas) of Pakistan, the cantonment boards provide services to the cantonment areas only. They have their own policies and services under the Ministry of Defence. The policies focused on during the previously reported interviews were unrelated to the cantonment boards. However, a third of the Rawalpindi population lives in cantonment areas. Therefore, it was important to explore their perspectives on rooftop RWHS and their policies on water conservation and water supply systems. The results from the interview with the Cantonment Board are as follows:

7.11.1 Would you like to comment on policies drafted by the Ministry of Environment and issues concerning their formulation?

"In Rawalpindi, water shortage is an issue. So we can say water shortage could be an issue behind formulation of this policy. We, the cantonment, do not fall within the Ministry of Environment and other district level departments. We have a separate department, which falls ultimately under the Ministry of Defence. However, in our schemes, installation of water meters is a top priority. The term rainwater harvesting has been used in our policies and we are thinking about it." (T-16).

7.11.2 Which stakeholders/departments are involved in formulating water-related policies?

"Cantonment departments are permanent military stations and administered by the Cantonment Board under the MLDC (Military Lands & Cantonment Departments) Ministry of Defence. We are completely independent in terms of policy formulation and implementation in our cantonment areas and municipal authorities. However, in the process of policy formulation we invite different stakeholders within the water area, (NGOs, Government and local authorities), to consult on the policy. (T-16)

7.11.3 Is there any implementation plan for a rooftop RWHS policy within your department?

"As I said, we are thinking about rainwater harvesting but we didn't include it in our policy yet
The policy formulation regarding rainwater harvesting is under review; as I said, we are thinking about it. Once it has been formulated, then I could say more about its implementation. However, installing water meters in our cantonment area (which is an urban area) is our top priority" (T-16).

7.11.4 Does your department have the flexibility to adapt strategies and activities in response to local needs?

"As far as our department is concerned, yes, we do have flexibility to adapt strategies and activities to respond to local needs." (T-16)

7.11.5 How do politico-socio-economic factors at either local or national levels facilitate policy implementation?

"These can play an important role through brain storming sessions, with regard to water conservation and systems such as rooftop rainwater harvesting." (T-16)

As noted above, the cantonment departments do not have a RWHS policy in their manifesto at the moment. However, during the interview with cantonment officials they acknowledge the district government policy guidelines and noted that if implemented then they would be very beneficial for the community and the environment. The cantonment department is also working on a better water supply system and on water conservation, and note that rainwater harvesting systems may be included in their future strategy.

7.12 Discussion

In this section, the results from the interview data are examined in relation to the interpretive model and in the context of the research objective. The purpose of this study was to explore perceived and actual barriers from the perspective of the stakeholder. Generally, policy implementation follows policy formulation and is regarded as the process of conducting a basic policy decision (Sabatier and Mazmanian, 1983, Ali, 2006). This study was conducted in order to identify and explore barriers to policy implementation. To do this, the background issues to policy formulation should be considered in order comprehensively analyse barriers to its implementation.

The discussion will focus on six main areas of interpretive model that emerged from the main themes during the coding process:

1. Ambiguity in policy formulation
2. Involvement of appropriate stakeholders
3. Implementation plan and its sustainability
4. Lack of political will

5. Technical and social feasibility for urban residential areas.
6. Lack of coordination and collaboration

7.13Ambiguity in policy formulation

From the process of policy formulation to implementation and monitoring, many factors are ambiguous. As for environmental issues, there were obvious and typical responses, such as water scarcity and a falling ground water table. However the statement from one respondent was highly controversial, as it noted: "*Actually, the policy was copied from the Internet just to show off that we have policy" (R-9).* R-5 also noted the lack of awareness of this policy, saying information was lacking. Another major response was that this policy was drafted at national level and that there was no division of urban and rural areas. However, when we look at the policy, it was drafted in the broader context of water conservation for all sectors, including agricultural, industrial and domestic, but clearly mentions that *"rainwater harvesting at* ***household*** *and local levels will be promoted to augment the municipal water supplies as well as for groundwater recharge, so as to promote sustainability of water sources".* The national water policy of Pakistan clearly identifies the problems associated with the over-use of ground water, while clarity for rainwater harvesting remains absent. This suggests a lack of adequate research and investigation before dissemination of the policy. According to R-14, "*policy is not the end of the game. It is just a guideline and it should be flexible".* Furthermore, the level of participation of NGOs was low.

7.13.1 Public involvement, policy and problem identification

In general, the public is considered to play a vital role in policy formulation (Gustama, 2013). In terms of water resource concerns, it was identified at the World Water Forum in Morocco (1997) that the public and politicians should be equally involved in water awareness. Furthermore, rainwater was included in the agenda at the 2000 World Water Forum in the Netherlands. There, it was recommended that new technologies are developed and promoted, in order to motivate concern in the general public. Recently, Stockholm Institute in Sweden organised an international symposium "unlocking the power of rainwater harvesting: a call to action" to bridge the gap between policy and implementation (Odera, 2015). As far as social acceptability is concerned, there is a need to create social awareness through media and other mediums (R-14). Similarly, but for the UK only, Ward (2010) highlighted the role of individuals in environmental management through government involvement and community participation.

7.13.2 Policy for urban and rural residential areas

The literature on policy analysis and implementation barriers to rooftop RWHS in Pakistan is scarce. However, some work has been done to address the potential of RWHS, regardless of policy implementation, technical feasibility and social acceptability in urban and rural residential areas. Aftab et al. (2012) have shown that, in rural residential areas of Pakistan, the rooftop RWHS program launched by the Earthquake Reconstruction and Rehabilitation Authority (ERRA) was successful from the policy draft through to its implementation, including social acceptability and technical feasibility. However, that policy and its implementation were limited to the ERRA project (R-12). The national policy under discussion here, remains unclear on rooftop RWHS. It only discusses rainwater harvesting systems as a whole. It is also noted from the literature that many countries have national water laws, while in Pakistan there is a national water policy but no water laws. Similarly, in India, there are no national laws regulating water use, though there is a national water policy (Kumar, et al., 2006).

7.13.3 Opportunities for RWHS policy reform in Pakistan

The policy clause *"Rainwater harvesting at household and local levels will be promoted to augment the municipal water supplies as well as for groundwater recharge, so as to promote sustainability of water sources* "was formulated at a federal/central level in 2009. Thereafter, there was a devolution of government in 2010 and all policy-making authorities, particularly the environmental-related policies, were transferred to each province (R-15). Currently, all provinces have their own Environmental Protection Agencies (EPAs) and they operate independently in terms of designing and implementing policies. The dilemma of this policy along with all other national polices is that now federal/central government claims that it is the responsibility of the provincial government to formulate and implement policies (R-6). Provinces are now required to formulate their own policies, thereby perhaps providing better opportunities for implementation in future. This would also seem to present an opportunity to differentiate between urban and rural residential areas and remove the dichotomy between approaches for roof water harvesting and rainwater harvesting systems.

7.14 Involvement of appropriate stakeholders

The EPA Islamabad, which falls under the federal ministry of the environment in Pakistan, was the leading stakeholder formulating the policy that states that *"Rainwater harvesting at* *__household__* *and local levels will be promoted to augment the municipal water supplies as well as for groundwater recharge, so as to promote sustainability of water sources* According to the top-most authoritative representative of the EPA, "*the policy was not supposed to be formulated by the ministry of the environment, the reason is that the subject of "water", whether it is rainwater harvesting or construction of dams, falls under the ministry of WAPDA (Water And Power Development Authority)"* (R-9). Many other interviewees simply put the responsibility on other organisations. Therefore, it can be seen that the majority of the interviewees were unaware of the involvement of appropriate stakeholders in policy formulation and implementation. It was also identified that the involvement of academics and researchers was limited.

7.14.1 Division of policy-making and implementation

The responses indicate that implementers place the responsibility on policy-makers, and vice versa. This provides a loophole for each stakeholder to escape responsibility. The typical responses were:

- *The key implementing organizations are doing nothing"* (*R- 11).*
- *Some departments are supposed to be autonomous but they are not working autonomously*" (*R-10).*
- *Political persons never look at the need of the people. They focus on what looks better to get votes for the next election. It is all about interest-based policies. They implement those policies in which they have personal interest"* (*R-3).*
- *We do have an implementation plan but it is not effective until and unless the building control department approve it. (R-1)*

According to Sutton (1999) "*the dichotomy and division between policy making and implementation is dangerous, because it separates the decision from the implementation".* This highlights one of the key barriers to the implementation of rainwater harvesting policies, suggesting that policy formulation and implementation should be conducted by the same department or organisation.

7.15 Implementation Plan and its Sustainability

Throughout the interview process, maladministration in coping with the policy and its implementation were observed. According to the majority of interviewees, the sustainability of the policy and any effectiveness will be observed only once there is a proper implementation plan. There is currently a chain of disorder, from policy inception through dissemination and on to implementation. Almost every interviewee responded that the policy is not as well implemented in urban residential areas as it should be, regardless of its implementation in some rural areas and public buildings in urban areas. R-8 mentioned that work is being done on its feasibility in urban residential areas, whereas R-12 responded that an initiative to launch a pilot project in rural areas was successful. R-12 also mentioned the limitation to earthquake areas, and the subsequent lack of awareness of how well systems had been implemented in urban residential areas. It was hence observed that an implementation plan might be suitable in theory but not in practice. Most, although not all, stakeholders were unsure of the implementation plan.

A further barrier is that there is no differentiation between urban and rural settings. R-12) mentioned his achievement towards the successful implementation of rooftop RWHS in rural areas (as a part of the reconstruction and rehabilitation of earthquake affected areas).

7.15.1 Commitment of WASA and RDA to implementing rooftop RWHS in Rawalpindi District

The role and responsibilities of the Water and Sewerage Agency (WASA) are inherent in its name. In principle and ideally, WASA should actively implement rooftop RWHS, as it supplies water to the urban residential areas of Rawalpindi. According to R-1 from WASA, the agency does "*have its implementation plan, but it is not effective until and unless the building control department approves it.*". In contrast, R-2 from WASA was unaware of the rooftop RWHS policy, responding as follows: "*This interview is a brain storming session, now we will think on its feasibility and try to implement it"*.

According to a social constructivist approach, it might be argued that organisations are fulfilling their roles and responsibilities. WASA currently relies upon ground water resources to provide water to Rawalpindi. With the aim of conserving water, WASA initiated the installation of a water metering system. However, alternatives to water conservation, such as urban rooftop RWHS, have not yet attracted the attention of stakeholders. According to R-3, "*recently, by law, rooftop RWHS should be included in new housing design in Lahore city. However, we did not receive any such thing for our area, Rawalpindi"*. In contrast, the neighbouring country, India, made rooftop RWHS mandatory for building design approval, as per plot sizes in 24 states out of 29. These states initiated financial assistance schemes, whereby they incentivised residents to install RWHS (Kumar, et al., 2006). These findings, together, indicate that the combination of government policy and incentives could positively affect uptake. Similarly, the Malaysian government has made RWHS mandatory, also adopting a social awareness program and incentives (Ho, et al., 2007). In Pakistan, RWHS are not well represented, whether the result of policy dissemination or implementation. Therefore, a lack of strong commitment, proper understanding and technical knowledge of systems is evident. Policy alone appears inadequate in implementing RWHS; social and technical feasibility must also be considered.

7.16 Lack of political will

A further barrier was how political factors facilitate implementation. *"Lack of political will"* was the barrier cited most often by interviewees. Policies are outlined by top management (Ministries) and top management comprises political representatives such as members of the national and provincial assembly. According to R-3, R-9 and R-15, most politicians focus on apparent developments, such as the construction of roads, bridges, metro services, etc., which guarantees their re-election. However, issues such as water supply and water conservation using RWHS require more motivated political representatives to think about the environment and its resources. This is consistent with Li et al. (2000) who emphasise the political factors inherent in the developing alternative policy instruments and social institutions to foster RHWS.

7.17 Technical and social unfeasibility for urban residential areas

The majority of interviewees cited a lack of technical and social feasibility, including factors such as the small size of the rooftop area, double- and triple-storey houses, seepage, water quality, unpredictability of rainfall patterns and social unacceptability. According to R-14, *"rooftop RWHS can supplement the current water supply system in the area. It cannot be expected to provide a complete water supply at household level."*. Kumar et al. (2006) in "*Rainwater harvesting in India: some critical issues for basin planning and research"*, argues that rooftop rainwater harvesting is one of many approaches to cope with the urban water crisis but that it is an incomplete solution and suggest that organisations should conduct feasibility analyses by practical demonstrations in their own buildings. Concerns related to social acceptability indicate the need for social awareness programs. HO et al. (2009) suggest that "*steps should be taken to incorporate rainwater harvesting system into the school education curriculum"*. Thus, thorough and appropriate research is required to analyse the feasibility of rooftop RWHS for urban residential areas.

7.18 Lack of Coordination and Collaboration

From the interviews, it emerged that all organisations unanimously perceive other departments, and not their own, as responsible for implementing RWHS. Departmental roles were unclear and fragmented; organisational commitment poor. Brown and Farrelly (2009) in the review, *Delivering sustainable urban water management*, also provided a comprehensive list of barriers relating to the provision of sustainable urban water management:

- Uncoordinated institutional framework
- Limited community engagement, empowerment and participation
- Limited regulatory framework
- Insufficient resources (capital and human)
- Unclear, fragmented roles and responsibilities
- Poor organisational commitment
- Lack of information, knowledge and understanding in applying integrated, adaptive forms of management
- Poor communication

- No long-term vision or strategy
- Technocratic path dependencies
- Little or no monitoring and evaluation
- Lack of political and public will

Likewise in the current research it was found that in addition to the lack of political will, the lack of coordination and collaboration also significantly hindered rooftop RWHS implementation in the study area. Barriers and gaps emerged clearly from the one-on-one interviews.

7.19 Summary of Interpretive Model and Discussions

The interpretation of the results indicates the poor commitment and lack of proper understanding of rooftop RWHS in the context of "sustainable urban water management". Organisational and institutional policies exist; however, these are inadequately understood. The process of policy formulation to implementation is unclear, and rife with complexity. The lack of monitoring and evaluation presents a further barrier to rooftop RWHS policy implementation. The majority of respondents reported that water conservation and environmental issues are not prioritised by politicians. Surprisingly, all respondents cited the social unacceptability and technical infeasibility of rooftop RWHS, using this question as an opportunity to demonstrate that it is not a feasible option for urban residential areas. This might be theoretically accurate, but practical investigation and appropriate feasibility analysis are required in order to understand this comprehensively.

CHAPTER 8- Conclusion and recommendations

8.1 Conclusion

The major cities of Pakistan rely largely on ground water resources for domestic purposes. However, ground water supplies are being over-exploited and every year, about ten thousand new tube wells are installed to help meet the demand for water. In particular, cities such as Karachi, the largest metropolitan area in Pakistan, have poor access to appropriate water supply systems. To help cope with this situation and to help mitigate against this increasingly- challenging water crisis, the research reported herein examines the extent to which rooftop RWHS can offer either a full or partial solution. Here, an integrated approach was applied to identify a number of different aspects related to rooftop RWHS when implemented in urban residential areas. The term 'integrated' refers to technical feasibility, social acceptability and the presence of any policy barriers to implementation. An early question focused on which cities suffer the most pressing domestic water problems, alongside an assessment of the potential of rooftop RWHS with regards to monthly/annual rainfall data. Although all major cities in Pakistan face huge water shortages, when considering the potential of rooftop RWHS for any area it is necessary to first look at the local rainfall data in order to help identify which regions exhibit the highest potential. It has been shown that Lahore and Rawalpindi are subject to a large number of wet spells and monsoon (rainy) season, with higher precipitation rates than other cities. However, Lahore city has also shown notable fluctuations in monthly rainfall patterns over the years in comparison to Rawalpindi, so it was assumed that Lahore city may not be an appropriate selection for this study. Rawalpindi was hence selected. Subsequently, a study of the technical feasibility of rooftop RWHS was undertaken. This included an assessment of;

- average annual/monthly rainfall
- rooftop catchment size
- consecutive dry days

This work showed that rooftop RWHS are technically feasible in terms of monthly average rainfall, catchment area and non-potable water demand in Rawalpindi.

However, systems cannot meet all of the non-potable demand throughout the year; this only happens during the months of July and August.

The research has also shown that rooftop RWHS offer a feasible solution in terms of the provision of additional water resource, when combined with an existing water supply system. However, it should be noted that these systems are not suited to older housing, such as 5 Marla double-storey properties in lower middle and middle class areas. This is due to a lack of relative catchment area and space for storage tanks. On the other hand, RWHS provide a good option for large catchment areas such as those provided in private housing schemes like Bahria town and scheme-III cantonment areas.

The second objective of the research was to identify the social acceptability of rooftop RWHS if implemented. The conclusion from this analysis is that urban residents in Rawalpindi are relatively unwilling to adopt rooftop RWHS. Inadequate understanding and awareness of the system is a major barrier. People in residential urban areas are relatively uninformed about the benefits of rainwater harvesting technology. Concerns about water quality and maintenance are perceived barriers among respondents. A further barrier to implementation is the lack of a 'water conservation attitude', which is indirectly related to a lack of awareness of economic and environmental benefits, although a small number of respondents were aware of these benefits. Households facing water shortages as a result of failings in their current water supply system are more willing to adopt rooftop RWHS, but for outdoor (non-potable) purposes only. However, when it came to the question of willingness to install rooftop RWHS if the government provides an incentive, a larger proportion, tending to a majority, were willing to adopt such systems. Currently, the government is the service provider for water in urban residential area regardless of any provision via borehole. Therefore, people believe that the government should support the installation of such systems. Another possible reason behind this approach to rooftop RWHS is that of financial risk. Most people are not be able to personally absorb the financial risk associated with the installation of this system.

The final objective of the research was to identify any policy implementation barriers. From the research undertaken and reported herein, it is concluded that the relatively poor level of commitment and a lack of understanding of rooftop RWHS in the context of "sustainable urban water management" were major concerns affecting the overall degree of implementation. Organisational and institutional policies exist; however, these are inadequately understood. The process of policy formulation to implementation is unclear, rife with complexity, and deficient in cohesion. A lack of monitoring and evaluation of implementation procedures is a further barrier. The majority of respondents reported that water conservation and environmental issues are not prioritised by politicians. Surprisingly, all respondents cited a lack of social acceptability and technical feasibility of rooftop RWHS.

In general the main purpose of the research is contribution at theoretical as well practical knowledge and this is how the research progress further. This research has contributed both theoretical and practical knowledge. It cannot be said that this research has been conducted first time to bring those barriers together. However, at smaller scale like Pakistan (Study area), it can contribute in practical knowledge prior to implementation of any future plan for RWHS. Usually; annual rainfall data is used to identify the potential of rainwater harvesting system. However this research discussed and argued that how estimation of monthly rainfall pattern can give more precise and robust results particularly when identifying the potential for residential water supply.

Similarly, it also gives the in-depth analysis of social acceptability, willingness and other perceived barriers and benefits involved in acceptability or unacceptability of the RWHS at household level. This can be generalized to other cities of the country. At large scale it can also be used to do the comparison of those countries that have similar culture and urban settings. Such as India, Bangladesh and Iran.

Moreover, the identification of the policy barriers is also a contribution in theoretical knowledge as well as practical knowledge. This research can help the future planers and government officials that how to cope and mitigate the policy process from dissemination to implementation.

8.2 Recommendations for future work

- Further research might be undertaken to better understand the dynamic response of rooftop RWH systems. This refers specifically to the variability of rainfall patterns, the number of consecutive dry days that arise, and the corresponding storage capacity of systems. This point is aimed specifically at geographical regions where rainfall variability, and monsoon seasons, are common.

- From the point of view of social acceptability, it is suggested that further work could be done on how best to raise awareness of such systems with residents. In addition, it is also recommended that a practical demonstration project might also be beneficial. Pilot schemes could be initiated in these areas which would showcase the benefits of rooftop RWHS to both the community and the environment.

- From the point of view of policy barriers. It is suggested that more comprehensive policy analysis can be conducted to analyze the broader picture of policy regarding the water sector. This research was aimed and limited to identify the policy implementation barriers particularly for the rainwater harvesting system.

APPENDICES

Appendix A. Household questionnaires survey

Case No____

Demographic characteristics of the Household

AREA

- ☐ Rawal Town
- ☐ Bahria Town
- ☐ Rawalpindi Cantt areas
- ☐ Westrage lane 7 & Scheme-III
- ☐ Sattelite Town

1. Gender

- ☐☐Male
- ☐ Female

2. Age:

- ☐ 20 to 24
- ☐ 25 to 29
- ☐ 30 to 34
- ☐ 35 to 39
- ☐ 40 to 44
- ☐ 45 to 49
- ☐ 50 to 54
- ☐ 55 to 59
- ☐ 60 to 64
- ☐ 65 to 70

3. What is your monthly income?

- ☐ **Under 15,000 PKR**
- ☐ 15,001 to 25,000 PKR
- ☐ 25,001 to 35,000 PKR
- ☐ 35,001 to 45,000 PKR
- ☐ **Over 45,000 PKR**
- ☐ Other ____________
- ☐ Do not want to disclose

4. Level of education (Completed)

- ☐ Primary level
- ☐ High school
- ☐ Undergrad Degree
- ☐ Postgraduate Degree

5. Are you the

- ☐ Living in a house you own
- ☐ Living in rented house

6. Type of your house

- ☐ Single Storey
- ☐ Double Storey
- ☐ Tipple storey

7. What is the size of land on which your house is built?

- ☐ 4 Marla
- ☐ 5 Marla

☐ 6 Marla

☐ 7 Marla

☐ 8 Marla

☐ 10 Marla

☐ 15 Marla

☐ 1 Kanal

☐ 2 Kanal

☐ Don't Know

8. Total Number of household members in your house

- Number of Adults (above 18) __________
- Number of children or youth (under 18) ________

9. How many other members of your family are employed excluding you?

☐ No one

☐ One member

☐ Two members

☐ Three members

☐ Four members

10. Type of the roof of your house

☐ Flat roof

☐ Tilted

☐ Partially flat and partially tilted

☐ Mansard roof

Structured questionnaires **Section B**

This section seeks to gather information regarding the type of current domestic water supply system, cost of the system, problems and satisfaction level of the population.

11. What type of current water supply system you have in your house (Please **TICK** all that apply)

- ☐ Borehole
- ☐ Government water supply line
- ☐ Purchase from private water tankers
- ☐ Rainwater harvesting system
- ☐ Both (Government supply line and Borehole)
- ☐ Bahria Water Supply

12. How much do you pay for your water supply system?

- ☐ Cost if government water supply line ________________ PKR/Month
- ☐ It's free
- ☐ Do not know the cost

13. What is the availability of your current water supply system per day?

- ☐ 24 Hours
- ☐ 17 to 20 Hours
- ☐ 8 to 12 Hours
- ☐ 4 to 7 Hours
- ☐ 3 to 6 Hours
- ☐ 1 to 2 Hours
- ☐ Less than 1 Hour
- ☐ After two days for 1 Hours
- ☐ Don't Know

14. Which of the following water demand is fulfilled by your current water supply system? (Please **TICK** all that apply)

- ☐ Drinking
- ☐ Kitchen (Dishwashing & cooking purpose)

☐ Bath (Showering)

☐ Faucet use (shave and brushing)

☐ Flushing toilets

☐ Laundry

☐ Floor cleaning

15. Which of the following water demand is NOT fulfilled by your current water supply system? (Please **TICK** all that apply)

☐ Drinking

☐ Kitchen (Dishwashing & cooking purpose)

☐ Bath (Showering)

☐ Faucet use (shave and brushing)

☐ Flushing toilets

☐ Laundry

☐ Floor cleaning

16. Do you face any kind of water shortage (Seasonal or other) from your current water supply system?

☐ **Yes** →

☐ **No**

If yes then how do you manage the shortage (Please TICK all that apply)

☐ Purchase from private water tankers
☐ Collect from the neighbour's house
☐ Minimize the water use
☐ Increase the number of storage tanks
☐ Storage of rainwater in cisterns

17. Do you use tap water for drinking purposes?

☐ **Yes**

☐ **No**

> ***If No then how do you fulfil your daily drinking water demand (Please TICK all that apply)***
>
> ☐ Collect from the neighbour's house
> ☐ Use mineral water
> ☐ Collect from tube wells
> ☐ Boil the tap water
> ☐ Filter the tap water

18. On what scale you would choose your satisfaction level with your current water supply system?

☐ Very satisfied
☐ Quite satisfied
☐ Neither satisfied nor dissatisfied
☐ Quite dissatisfied
☐ Very dissatisfied

<u>Section C</u>

This section seeks to gather information regarding awareness and willingness of rooftop rainwater harvesting system among different groups of people if implemented.

19. On a scale of 1 to 5 rate your level of knowledge about roof top rainwater harvesting system?

1	**2**	**3**	**4**	**5**
Don't know	very less	little bit	not too much	a lot

20. Would you consider using rainwater harvesting system from the rooftops and store water for <u>OUTDOOR</u> household activities?

☐ **Yes**

☐ **No** *(If No then go to Q. No 22)*

If yes Please TICK all activities you would be willing to use rainwater for

- ☐ Laundry
- ☐ Flushing toilets
- ☐ Gardening
- ☐ Floor cleaning
- ☐ Car wash

21. Why you <u>WOULD BE</u> willing to use rainwater for OUTDOOR activities: (Please **TICK** all that apply)

☐ It's cheap

☐ It's safe to use rainwater for outdoor activities

☐ Due to water shortage

☐ It can also reduce the storm water runoff from the roof area

☐ Other___________________

22. Would you consider using rainwater harvesting system from the rooftops and store water for <u>INDOOR</u> household activities?

☐ **Yes**

☐ **No** *(If No then go to Q. No 24)*

If yes Please TICK all activities you would be willing to use rainwater for

- ☐ Drinking
- ☐ Kitchen (Dishwashing & cooking purpose)
- ☐ Bath (Showering)
- ☐ Faucet use (shave and brushing)
- ☐ Laundry

23. Why you <u>WOULD BE</u> willing to use rainwater for INDOOR activities: (Please **TICK** all that apply)

☐ It’s cheap

☐ It’s safe to use rainwater for indoor activities

☐ Due to water shortage

☐ It’s clean and natural source of water

☐ Rainwater should not be wasted

☐ Other______________________

24. What are the reasons from options above that you indicated in Q.20 OR Q.22 you <u>would NOT</u> be willing to use rainwater for: (Please **TICK** all that apply)

☐ Have not seen this system before

☐ We have a plenty of water (Don’t need of rainwater harvesting)

☐ Concern about water quality

☐ Cost of installing

☐ Current water supply is cheap

☐ Other______________________________

25. On a scale of 1 to 5 rate your level of willingness and readiness to install rooftop rainwater harvesting system for your house?

1 **2** **3** **4** **5**

Not willing at all slightly willing less willing much willing Very much

26. On a scale of 1 to 5 rate your willingness to install rooftop rainwater harvesting system if government provide this with no cost to you?

1 **2** **3** **4** **5**

Not willing at all slightly willing less willing much willing Very much

****************************Thank you********************************

Appendix B. Interview Topic guide

The following basic information about the interviewee was completed before interview starts for our record that which person is going to be interviewed from different department or organization.

Basic information about the interviewee before the interview

Name of interviewee:

____

Official title:

____

Sex: F: ______ M: ______

Department/organization:

____

Length of employment at Department/organization:

____

Office address:

____

Email and contact numbers:

____

Date of interview:

____

Print of this section along with consent form on a separate sheet had given to the respondent to give an idea about focus of assessment before to start the interview.

Policy issuing body/institution	**Detail of the policy that is the focus of the assessment**	**Date officially approved**
Ministry of Environment Pakistan	***Rainwater harvesting*** *at* ***household*** *and local levels will be promoted to augment the* ***municipal water supplies*** *as well as for groundwater recharge, so as to promote sustainability of water sources.*	September, 2009
Ministry of Environment	*Design, develop and evaluate water conservation technologies.*	April 14, 2007

Introduction

My name is _________ and I am interviewing the officials (involved in policy implementation) regarding the barriers in implementation of the ***rooftop rainwater harvesting system in residential urban areas of Pakistan****. This interview is being conducted as a partial fulfilment of PhD research at ______________.* ***Your answers will be kept strictly confidential.*** *Your responses will be combined with answers from other respondents involved in policy implementation.*

By policy implementation, I mean the activities and operations of various stakeholders toward achieving the goals and objectives articulated in an authorized policy—in this case, the ***implementation of rooftop rainwater harvesting system for urban residential areas.***

The purpose of this assessment is to analyse how well ***rooftop rainwater harvesting system*** is being considered for urban residential areas during policy implementation. The results of the interviews can be used by policymakers and stakeholders to clarify guidelines and directives, address barriers to implementation, improve resource mobilization, update implementation plans, or advocate for policy reform.

I anticipate the interview will last about 45 to 50 minutes.

CONSENT

Please be assured that all your responses will be held in strict confidence; findings will be presented in aggregate, and no statements used in the report will be attributed directly to you. Your participation is voluntary, and you may decline to answer any question or end the interview at any point. Do you agree to continue?

___Yes ___No ____________Interviewee's signature

The topic guide is formulated under different sections to get precise response in different context and factors involved in the policy implementation process.

SECTION 1

1. THE POLICY, ITS FORMULATION, AND DISSEMINATION

1.1 Referring to the goals and objectives of this policy, what were the issues behind its development?

- Who was included
- Government, NGOs etc.
- What did you think at that time?
- What do you think about it now?

1.2 What was the involvement of various stakeholders during the process of formulating the policy?

(Involvement means stakeholders, as appropriate based on the policy text analysis: NGOs, women's groups, the private or commercial sector, different ministries [e.g., Finance, Planning, groups representing the poor, and others)

1.3 In your opinion how has this degree of involvement in policy formulation affected implementation?

--

1.4 In your opinion, how well was the policy and how well has it been implemented?

- Who has benefited and
- Who has not

SECTION 2

2. SOCIAL, POLITICAL, AND ECONOMIC CONTEXT

2.1 From your perspective, how do social factors—at either local or national levels—facilitate the policy implementation? Like

- gender
- Level of education
- Social status etc.

2.2 Similarly how do political factors at either local or national levels facilitate the policy implementation? Like:

- Changes in Government,
- Decentralization or divergent priorities at national and local levels
- Policy environment including alignment or conflict with other policies
- International agreements (e.g., United Nations declarations, Millennium Development Goals).

2.3 In your opinion how do economic factors at either local or national levels facilitate the policy implementation? Like

Unemployment Global assistance mechanisms, donor priorities

Migration

Poverty

SECTION 3

3. LEADERSHIP FOR POLICY IMPLEMENTATION

3.1 Currently, which stakeholders support the policy?

- Who and why

3.2 Does any stakeholders oppose in implementing the policy? Who and why?

SECTION 4

4. STAKEHOLDER INVOLVEMENT IN POLICY IMPLEMENTATION

4.1 In what ways different sectors involved in implementing the policy? Such as

- Finance sector
- Planning, NGOs etc.

4.3 Do you think that any other agency or sector might valuably be involved? Who and why?

SECTION 5

5. IMPLEMENTATION PLANNING AND RESOURCE MOBILIZATION

5.1 Is there any implementation plan for the policy at national level?

- How effective it is?
- How well funded is the plan?
- How sustainable it is in the long time?

5.2 How well does the policy implementation plan offer for the needs of urban residential areas?

- Its advocacy in urban as compare to rural areas?
- Coordination among different stakeholders to achieve the policy's goal?

SECTION 6

6. OPERATIONS AND SERVICES

6.1 Are you aware of any barriers to providing services under the policy in urban residential areas?

6.2 In your opinion, do the key implementing organizations have the flexibility to adapt strategies and activities to respond to local needs?

- Can you give me any example

SECTION 7

7. FEEDBACK ON PROGRESS AND RESULTS

7.2 What institution(s) is monitoring the implementation of this policy?

7.2 How is it being monitored? *Such as*

Regular meetings, periodic reports, site visits, service statistics, and client).

SECTION 8

8. OVERALL ASSESSMENT

8.1 Overall, how well do you think the policy is being implemented in urban residential areas?

8.2 What if implementing this policy in urban residential areas? Or if it is implementing then what

- Positive outcomes, negative outcomes, environmental issue, social etc.

8.3 I understand that scheme must be provided by law, like in India, Malaysia and some other developing countries it is mandatory to have rooftop RWHS for new building design?

- What do you think it is not here in Pakistan?
- Do you think it should be here or not? Why

8.4 How any lessons been learned since the policy was first implemented? Like

- Things that doesn't work
- Things that does work etc.

8.5 Is there anything that you think I should have asked or that you would like to add to what already been said

- Suggestions that would improve implementation of this policy? Please describe.

Thanks end of interview

Appendix C. Multivariate analysis between subject factors

Between-Subjects Factors

		Value Label	N
Level of Education	0	No education	31
	1	Primary Level	63
	2	High School	142
	3	Undergrad	115
	4	Postgraduate/ Masters/MPhil	64
Income	1	Under 15,000	22
	2	15001 to 25000	51
	3	25001 to 35000	96
	4	35001 to 45000	68
	5	Over 45000	83
	6	do not want to disclose	95
Ownership of the house	1	Own house	287
	2	rented house	128
Current water supply system	1	Borehole	32
	2	Government water supply line	166
	3	Purchase from private water tankers	2
	5	Both borehole & Government supply line	173
	6	Bahria water supply	42
Do you face any kind of water shortage (seasonal or other) from your current water supply system	0	No	208
	1	Yes	200
	2	No answer	7

Appendix C. 1 Results of Key independent variable with dependent variables

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Education	Willingness to install RRWHS	15.196	4	3.799	.015	.042	12.597	.817
	Willingness to install RRWHS. If gov provide incentives	11.719	4	2.930	.154	.023	6.737	.514
Income	Willingness to install RRWHS	6.557	5	1.311	.368	.019	5.436	.386
	Willingness to install RRWHS. If gov provide incentives	4.562	5	.912	.758	.009	2.622	.194
Current WSS	Willingness to install RRWHS	10.508	4	2.627	.072	.029	8.711	.639
	Willingness to install RRWHS. If gov provide incentives	6.769	4	1.692	.423	.013	3.891	.307
Shortage from WSS	Willingness to install RRWHS	8.119	2	4.060	.036	.023	6.731	.632

	Willingness to install RRWHS. If gov provide incentives	20.154	2	10.077	.003	.039	11.585	.868
WSS and Shortage from WSS	Willingness to install RRWHS	3.159	3	1.053	.455	.009	2.619	.240
	Willingness to install RRWHS. If gov provide incentives	10.840	3	3.613	.103	.021	6.231	.529
Education * Income * WSS	Willingness to install RRWHS	13.898	17	.818	.824	.038	11.521	.480
	Willingness to install RRWHS. If gov provide incentives	17.969	17	1.057	.886	.035	10.329	.427
Education * Income * Shortage from WSS	Willingness to install RRWHS	6.032	7	.862	.660	.017	5.001	.307
	Willingness to install RRWHS. If gov provide incentives	8.571	7	1.224	.669	.017	4.927	.302
Education * WSS * Shortage from WSS	Willingness to install RRWHS	5.894	5	1.179	.432	.017	4.886	.348
	Willingness to install RRWHS. If gov provide incentives	6.031	5	1.206	.629	.012	3.467	.250
Income * WSS * Shortage from WSS	Willingness to install RRWHS	11.829	6	1.972	.137	.033	9.806	.622

	Willingness to install RRWHS. If gov provide incentives	20.669	6	3.445	.068	.040	11.882	.722
Education * Income * WSS * Shortage from WSS	Willingness to install RRWHS	7.305	4	1.826	.198	.021	6.056	.467
	Willingness to install RRWHS. If gov provide incentives	6.336	4	1.584	.458	.012	3.642	.288

a. R Squared = .443 (Adjusted R Squared = .199)
b. R Squared = .434 (Adjusted R Squared = .187)
c. Computed using alpha = .05

Correlations

		Income	Edu	Ownership of the house	Current WSS	water shortage from your current WSS	Knowledge about RRWHS
Willingness to install RRWHS	Pearson Correlation	-.123*	.000	-.041	-.158**	.324**	.415**
	Sig. (2-tailed)	.012	.996	.402	.001	.000	.000
	N	415	415	415	415	415	415
Willingness to install RRWHS. If gov provide incentives	Pearson Correlation	-.136**	-.034	-.033	-.203**	.382**	.373**
	Sig. (2-tailed)	.005	.490	.504	.000	.000	.000
	N	415	415	415	415	415	415

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Appendix C. 2 Multivariate normality- Kurtosis and Skewness

		Willingness to install RRWHS	Willingness to install RRWHS. If gov provide incentives
N	Valid	415	415
	Missing	0	0
Mean		2.48	3.20
Median		3.00	3.00
Mode		3	5
Skewness		.184	-.182

Std. Error of Skewness	.120	.120
Kurtosis	-1.062	-1.295
Std. Error of Kurtosis	.239	.239

Frequencies

Willingness to install RRWHS for your house

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not willing at all	132	31.8	31.8	31.8
	Slightly willing	59	14.2	14.2	46.0
	Less willing	136	32.8	32.8	78.8
	Much willing	68	16.4	16.4	95.2
	Very much willing	20	4.8	4.8	100.0
	Total	415	100.0	100.0	

Willingness to install RRWHS. If government provide incentives

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not willing at all	79	19.0	19.0	19.0
	Slightly willing	55	13.3	13.3	32.3
	Less willing	100	24.1	24.1	56.4
	Much willing	64	15.4	15.4	71.8
	Very much willing	117	28.2	28.2	100.0
	Total	415	100.0	100.0	

Correlations

		Level of willingness to install rooftop rainwater harvesting system for your house?	Level of willingness to install rooftop rainwater harvesting system for your house? If government provide this with no cost to you
On a scale of 1 to 5 rate your level of willingness and readiness to install rooftop rainwater	Pearson Correlation	1	.786**
	Sig. (2-tailed)		.000

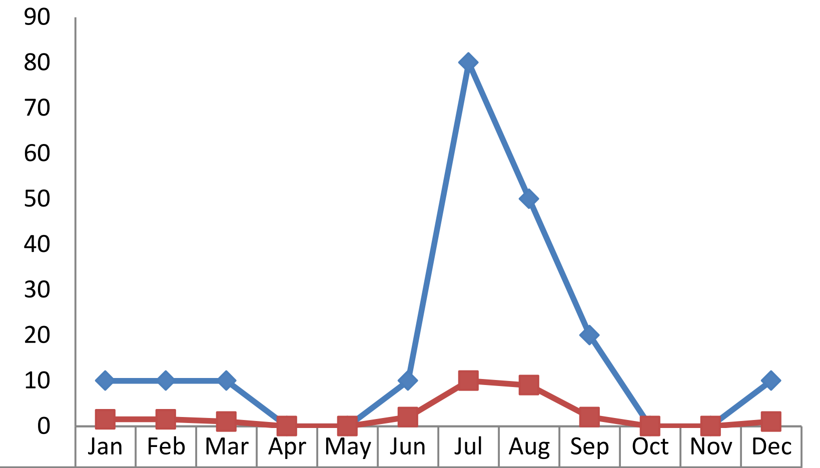
harvesting system for your house?	N	415	415
On a scale of 1 to 5 rate your level of willingness and readiness to install rooftop rainwater harvesting system for your house? If government provide this with no cost to you	Pearson Correlation	.786**	1
	Sig. (2-tailed)	.000	
	N	415	415

**. Correlation is significant at the 0.01 level (2-tailed).

Descriptive Statistics

	Mean	**Std. Deviation**	**N**
On a scale of 1 to 5 rate your level of willingness and readiness to install rooftop rainwater harvesting system for your house?	2.48	1.227	415
On a scale of 1 to 5 rate your level of willingness and readiness to install rooftop rainwater harvesting system for your house? If government provide this with no cost to you	3.20	1.463	415

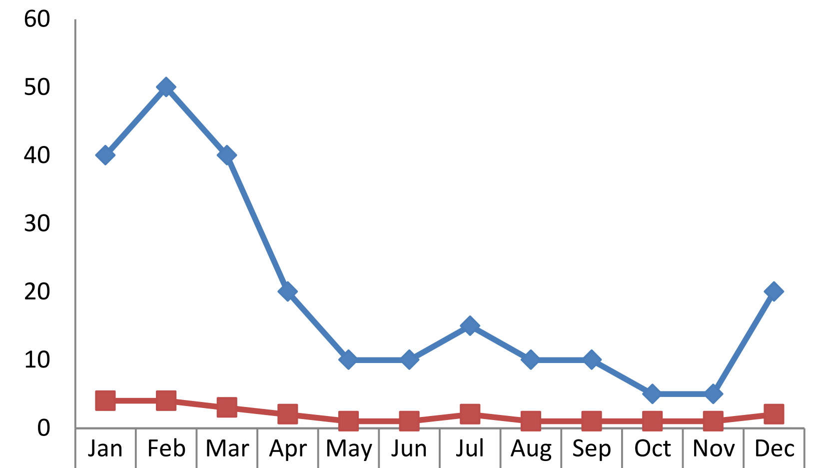
Appendix D. 1 The estimated average monthly rainfall (mm) in Karachi (1971 to 2015)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	10	10	10	0	0	10	80	50	20	0	0	10
No of precipitation days	1.5	1.5	1	0	0	2	10	9	2	0	0	1

Source: (WeatherbaseKarachi, 2015)

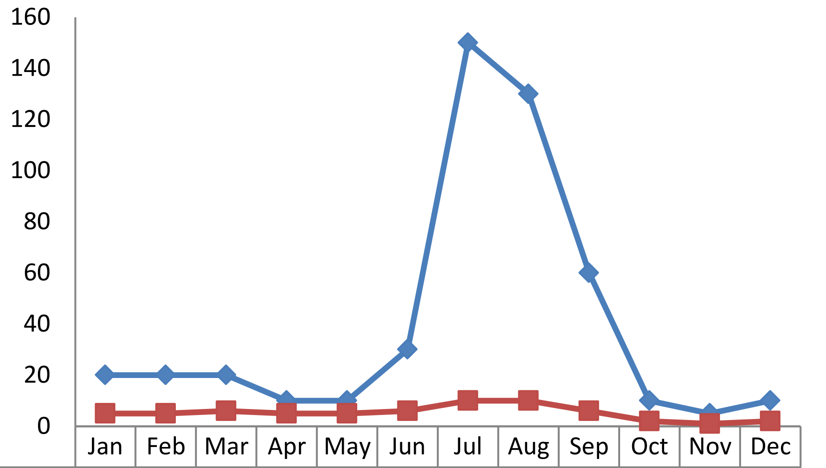
Appendix D. 2 The estimated average monthly rainfall (mm) in Quetta (1955 to 2015)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	40	50	40	20	10	10	15	10	10	5	5	20
No of precipitation days	4	4	3	2	1	1	2	1	1	1	1	2

Source: (WeatherbaseQuetta, 2015)

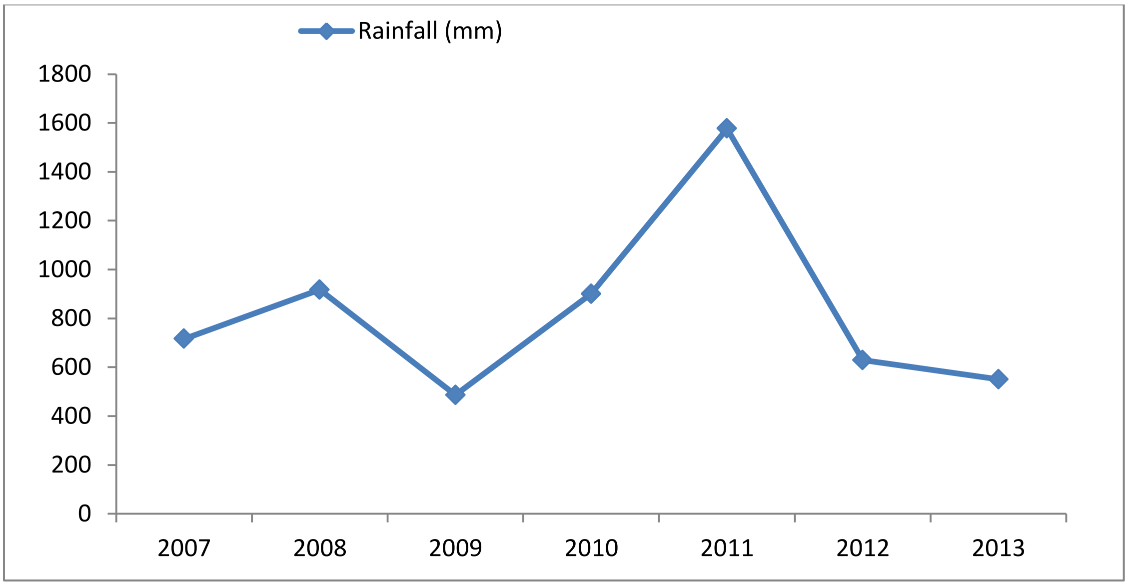
Appendix D. 3 Estimated average monthly rainfall (mm) in Lahore (1905 to 2015)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	20	20	20	10	10	30	150	130	60	10	5	10
No of precipitation days	5	5	6	5	5	6	10	10	6	2	1	2

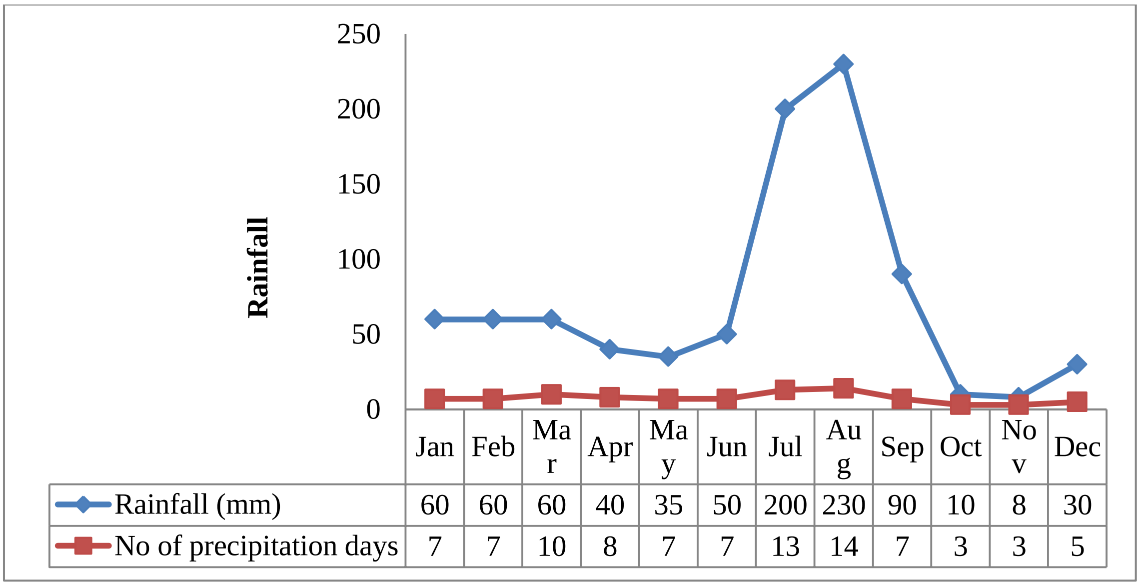
Source: (weatherbaseLahore, 2015)

Appendix D. 4 Annual rainfall patterns due to climate change in Lahore



Source: (PMD, 2013)

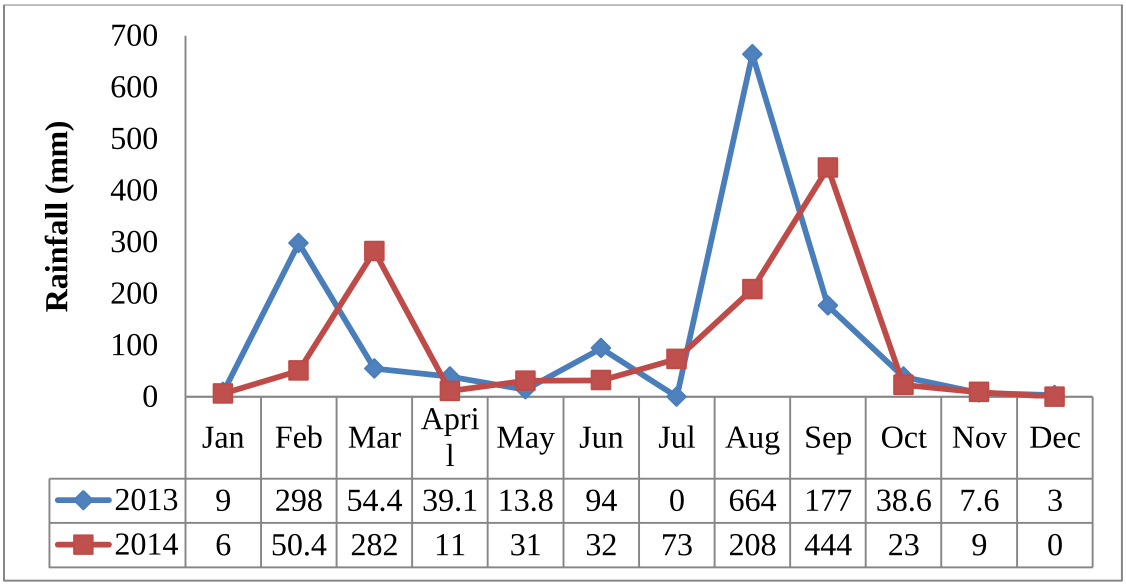
Appendix D. 5 Estimated average monthly rainfall in Rawalpindi (1955 to 2015)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	60	60	60	40	35	50	200	230	90	10	8	30
No of precipitation days	7	7	10	8	7	7	13	14	7	3	3	5

Source:(Weatherbase, 2015)

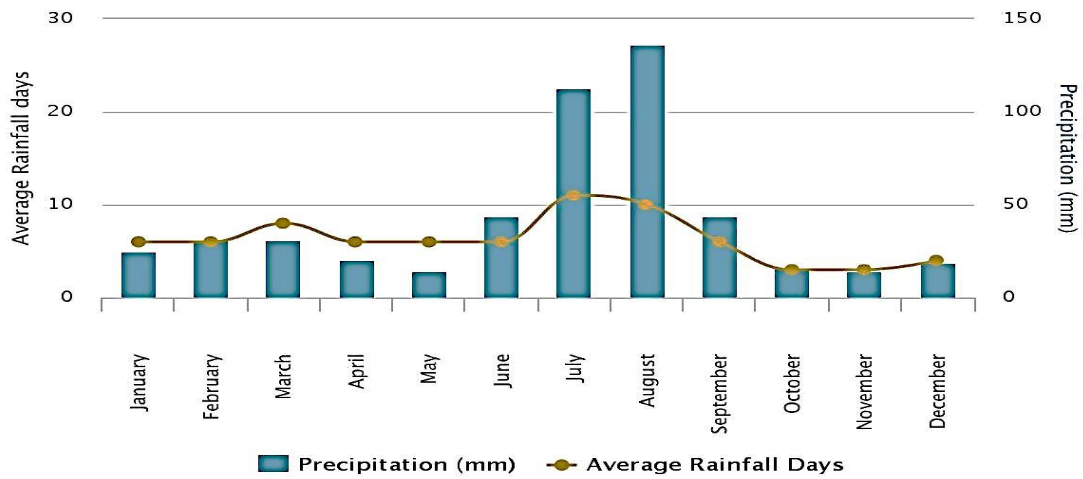
Appendix D. 6 Monthly rainfall (mm) in Rawalpindi for 2013 and 2014



	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	9	298	54.4	39.1	13.8	94	0	664	177	38.6	7.6	3
2014	6	50.4	282	11	31	32	73	208	444	23	9	0

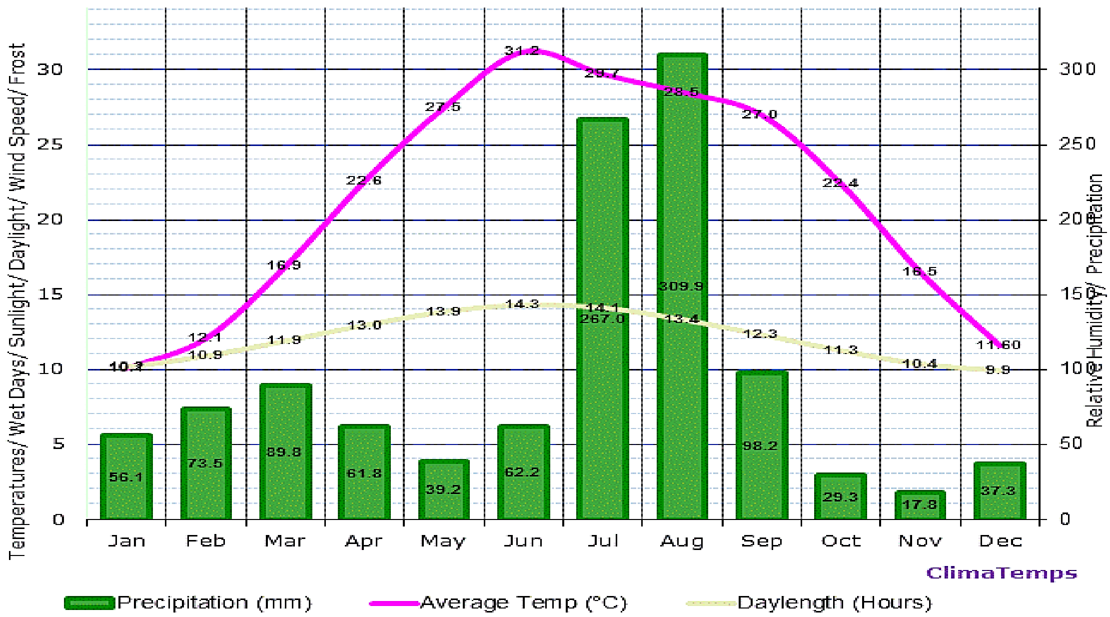
Sources: (PBS, 2015)

Appendix D. 7 Rawalpindi average monthly rainfall and average rainfall days (2000 to 2012)



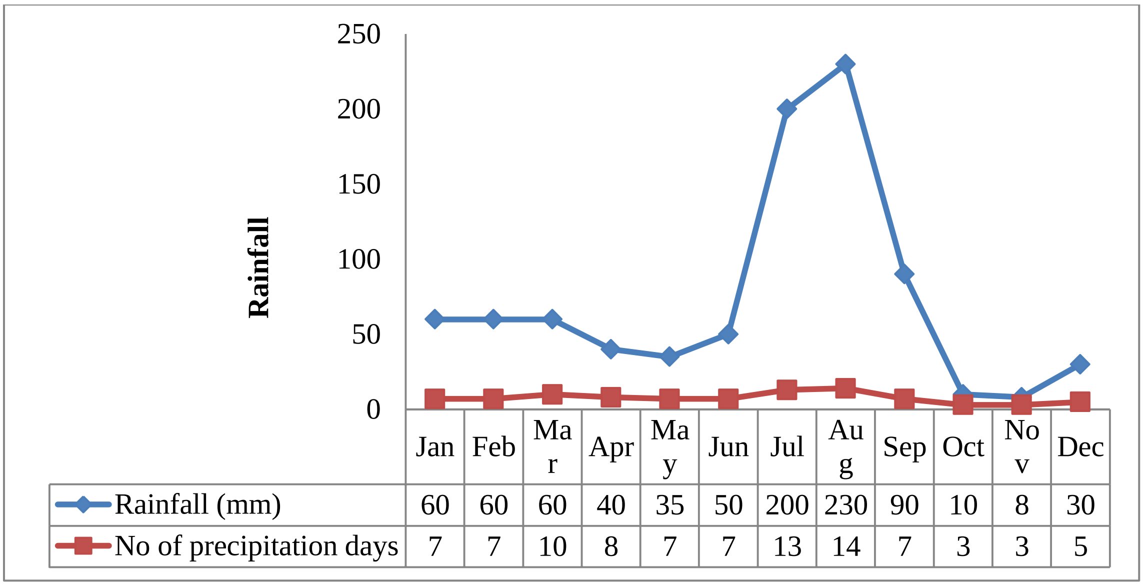
Sources: (Worldweather, 2012)

Appendix D. 8 Average monthly rainfall (mm) in Rawalpindi



source: (Climatemps, 2015)

Appendix D. 9 Estimated average monthly rainfall in Rawalpindi (1955 to 2015) and average number of precipitation days (1985 to 2015)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	60	60	60	40	35	50	200	230	90	10	8	30
No of precipitation days	7	7	10	8	7	7	13	14	7	3	3	5

Source: (Weatherbase, 2015)

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