Research Paper on

Water Harvesting System

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Research Officer (WaSH Project)

Acronyms	
BBS	Bangladesh Bureau of Statistics
BUET	Bangladesh University of Engineering and Technology
BMD	Bangladesh Meteorological Department
CBO	Community Based Organization
CI	Corrugated Iron
CIDA	Canadian International Development Agency
DANIDA	Danish International Development Agency
DPHE	Department of Public Health Engineering
FGD	Focus Group Discussion
GIS	Geographical Information System
HFHI-B	Habitat for Humanity International
MS Rod	Mild Steel Rod
NGOs	Non-government Organizations
PNGO	Partner Non Government Organization
PVC	Poly Vinyl Chloride
RCC	Reinforced Cement Concrete
RWH	Rain water harvesting
RWHS	Rain Water Harvesting System
UNICEF	United Nations Children's Fund
WaSH	Water Sanitation and Hygiene
WHO	World Health Organization
WPP	Water Partnership Program

Glossary	
Cement/ Mortar Jar	Cement or Mortar Jar is the type of rain water harvesting system. In this system using the cement Mortar the reservoir is build. The Cement/ Mortar Jar can be constructed in different size/ capacities such as 1,000 liters, 2,000 liters, 2,500 liters and 3,000 liters.
Do-it-yourself model (Motka)	This is an indigenous process of RWHS, which has been practicing in different parts of Bangladesh. It is one kind of bigger earthen pot which is used for water collection store rice in village. In Bangladesh it is locally called "Motka".
Ferro – Cement Tank	Ferro-cement tank is a system of rainwater from roofs. Tanks made of ferro-cement and it is fairly cheap, simple to make and easy to repair.
Garo Community	The Garos are a tribal people in Mymenisngh, India and who call themselves A·chik Mande (literally "hill people," from a·chik "hill" +

	mande "people") or simply A·chik or Mande. They are the second-largest tribe in Bangladesh.
Rainwater Harvesting (RWH)	Rainwater harvesting is the accumulating and storing, of rainwater for reuse, before it reaches the aquifer. It has been used to provide drinking water, water for livestock, water for irrigation, as well as other typical uses given to water.
Rainwater Harvesting Systems (RWHSs)	Rainwater Harvesting System (RWHS) is an option, which has been adopted in many areas of the world where conventional water supply systems are not available or adequately meets requirement of the people.
Underground RWHS	Underground rain water harvesting system is the rain water harvesting system where water is collected from roof top to the underground storage by using gutter and supply pipe. Then it is withdrawn from the underground using tubewell.
Union	Union Parishad is the smallest but most important unit of local government in Bangladesh which is formed in the village level of the country where more than 70 per cent of the populace lives.
Upazila	The districts of Bangladesh are divided into sub districts called Upazila Parishad (UZP), or Thana.
Gutter	Gutter is the water conveyance system from catchments to storage reservoir. Gutter may be made with different type of materials such as GI sheet, PVC pipe, split bamboo etc. It is also an important component of RWHS.
Catchments	For Rainwater Harvesting System (RWHS) normally clean rooftop is being used as catchments. Catchments are an important component of RWHS.
Flushing System	Flushing system is also an important component of RWHS. It is applied to discharge first foul rainwater outside the tank easily. To maintain the quality of harvested water easy flushing system is very essential.
Dry Season	In Bangla Months Falgun, Chaitra, Baishak, Jaistha (November -March)) is the dry season where rainfall is rarely occurs.

Abstract

In Bangladesh, the most of the irrigation and drinking water is supplied from underground sources due to the limitation of protected surface water. Under this circumstances arsenic and iron concentration in ground water has emerged as a fresh blow in Bangladesh (Rahman et al. 2003). Further, scarcity of water during the dry season (November-March) is a major problem. Being a part of developing country the study area has many poverty impacted families who cannot install deep tubewell by their own financial support. Considering all the problems this paper gives an overview about the opportunity of promoting RWHS in Mymensingh, Madhupur and Durgapur area. People in above mentioned areas lack safe water for drinking as well as bathing, cooking, washing. As the household use unprotected surface water, the water related disease is also high. Our study reveals that about 19.9% of the disease among the total diseases events is skin diseases and the household mostly suffered who are using the unprotected water for drinking, bathing, washing and other daily activities. Further iron, arsenic, concentrations of fecal coliform and bacterial components are found in drinking water. In this context rainwater harvesting provides a logical solution to the problem. Based on climatic data provided by Bangladesh Meteorological Department and our survey data; justification, affordability and social acceptability have been analyzed. The study also examines various water harvesting technologies for implementation.

Chapter l: Introduction and Background of the study

1.1 Introduction

Water and life represents the same value therefore inadequate access to safe water makes life worse. The condition is more than worse in developing country where the demand of ground water is high for agriculture. In Bangladesh access to safe water becomes a question in areas where physiography, environment and other anthropogenic activities are complex. It is known to all that Water supply and sanitation in Bangladesh is characterized by a number of achievements and challenges. In 1993 contamination of arsenic is discovered in groundwater which is the only source of drinking water for the rural communities of Bangladesh. It gradually emerged that 70 million people drank water and leading to chronic arsenic poisoning (UN-HABITAT, 2005). On the other hand, surface water is usually polluted and requires treatment. Taking arsenic contamination into account, it was estimated that in 2004 still 74% of the population had access to arsenic-free drinking water although many more remains drinking contaminated water of pond, lake of their nearby areas. The government of Bangladesh has adopted a number of policies to remedy the challenges in the sector, including National Policies for Safe Water Supply and Sanitation, both of 1998, a National Water Policy of 1999, a National Water Management Plan, and a National Policy for Arsenic Mitigation 2004.

1.2 Background of the study area

In Mymensingh, Madhupur, and Durgapur water harvesting system is rear to be found as it is not familiar to the community. But the composition of the basic three components of water harvesting systems like collection of rain water, store in big pot can be found in different format. So the potentiality of water harvesting system exist compositing the basic three components and it can yields several benefits. According to Krishna, Hari J., 2003, the most important benefit of rainwater harvesting is that the water is totally free; the only cost is for collection and use. It has some other benefits especially use of rain water reduces the pressure on ground water and increase the efficiency of recharging of ground water. The impacts of rooftop rainwater are greatest where it is implemented as part of wider strategies that considers people's overall livelihood strategies. Rain Water can be seen as a key productive as well as domestic resource and it can involve men and women. The overall benefit to households and communities will be doubled by taking such an approach, covering health related issues. The most important impact in terms of women and the poor is, the reduction in time spent collecting water, a vital issue (Ariyabandu, 1991). This time then becomes available for other purposes like education, socializing with children and friends. (Smet & Moriarty, 2001). The main benefit of water harvesting system is, it will make the water safe and will help to reduce water born diseases events.

Rain water harvesting as well as water harvesting system technologies is familiar to the rural and remote part of Bangladesh but not in Mymensingh, Madhupur and Durgapur area. So Water harvesting technologies, infrastructures and option requires to be made according to the community required. Further, The potential advantages of using water harvesting systems in new developments require an understanding of the relationships between a wide variety of factors, namely social, environmental, technological, and operational.

1.3 Study area

The study has been conducted in the project area therefore the data has been assessed covering the project area. The study area is also determined giving the urgency of problems found from the base line survey. The study area covers:

1. Mymensingh: Mymensingh Sadar, Aqua, Gohailkadi, Dhapunia and Khagdohor.
2. Madhupur: Aronkhola, Aushnara and Madhupur Sadar.
3. Durgapur: Chondigor, Kakoirgora Durgapur Sadar and Durgapur Municipality (Birisiri).

1.4 Research Objectives

The purpose of this study is to assess a sustainable water harvesting solution for communities of the study area of Mymensingh, Madhupur and Durgapur. It also seeks to give the overview about technologies of water harvesting in Bangladesh. The main objective of the research is to find out the appropriate water harvesting system for the disadvantaged communities who do not have the enough excess to safe drinking water. Therefore the basic objectives are:

- Indentify water related problem in the study area.
- Identify and analyze the water harvesting methods in Bangladesh.
- Find out existing water harvesting system in the study area.
- Develop a solution for water harvesting system for the community in the project area.
- Utilize programming and visualization to assess the efficacy of the solution and its details.

1.5 Assumptions

The research aims to find appropriate, affordable and environment friendly approaches for the water harvesting system. Considering the above criterion the basic assumptions has been predefined. The assumptions area

- No environmental or other contamination other than those from the catchment area will be present in the harvested water.
- The rainwater harvesting method is socially accepted in the study area.
- Per household drinking water consumption is assumed to be above 5 liter/day.
- Rainfall in the area supports the RWHS.

Chapter II: Methodology

2.1 Methodology

The purpose of this study is to evaluate opportunities and options of water harvesting systems which is safe, affordable and socially acceptable. Therefore qualitative and quantitative data are used for this research. The methodology of this study confined to field observation, in depth interviews, sample collection, laboratory test, data presentation and analysis. For the better understanding of the site situation both primary and secondary data sources are used. In order to assess the appropriate water harvesting system, various formal and informal approaches are adopted in the field survey and data analysis. The location variation is analyzed by considering the physiography, climate, social structure and availability of materials for water harvesting systems. Community's idea and culture related to water harvesting system is analyzed carefully. The study is conducted during the period from September 2010 to April 2011.

2.2 Research methodology

Guided by the research objectives, the methodology of this research is divided into three major parts, namely

- Data Collection from the field and form secondary sources.
- Data Analysis for appropriate system (Both quantitative and qualitative)
- Formulating findings.

The whole methodology of the research is described below.

2.3 Data collection methods

The study area is big and it is difficult to assess the appropriate water harvesting system for different areas. For the convenience of work some secondary data has been used to support the primary information. Mainly two types of data have been collected for the research purpose. These are:

1) Primary data
2) Secondary data

2.4 Sources of primary data

To find out the proper water solution beyond the traditional tubewell water, a study has been conducted for water harvesting system at household and community level. Primary data has been used to identify the knowledge about the water harvesting system. Other subordinate data has been gathered from the field by a base line survey which has been done at the initial stage of the project. To justify the data and find out the causes of the problems FGD and physical observation has been made directly in the field.

The methodology of this study confined to

- **Base line survey data (Structured questionnaire):** The base line survey data is the base for identification of problem. Water, sanitation and hygiene related basic problems of the community have been assessed from the base line survey. It gives the overview about the dimension of problem and causes of the problem. So the FGD has been conducted to justify the problem and to learn details about the dimension of the problem. Some solution also found from the base line survey. The most important data has been used for assessing the socio economic condition of the community. It gives the answer how much water a family required for their daily acidities and for consumption and about the construction materials of the roof.

- **Focus Group Discussion (FGD):** The norms of FGD have been maintained properly during the study. Total 15 FGD has been conducted to understand and find out appropriate water harvesting systems.FGD has been carried out among the major groups of the community. It incorporates male, female, and adolescent girls. Further the FGD is conducted among the community leaders, community members and PNGOs. The final findings have been unified in the report.

- **Lab analysis of water quality:** Laboratory analysis of water quality is done in three different study areas of Mymensingh, Madhupur and Durgapur. Sample of water is collected form Dhapunia union of Mymensingh, Chandigar Union of Durgapur and Goshaibar of Madhupur union. Water is tested from BUET using different methods of analysis as per the standard protocol.

- **Field observation:** Physical observation considering the physiography, environment, and associated geographic features has been assessed and proper documentation has been made during the field observation.

- **Photograph taking:** Photograph taking is another one important source of data collection.

2.5 Secondary data

Literature review and context analysis has gave the major strength for justifying the problems and find out the appropriate solutions for the community. Further the approach which has been taken by the different organizations for the water harvesting system is taken into consideration. In the working area, Different NGOs supported facilities like awareness program and training also taken into consideration.

2.6 Data Analysis

Data analysis has been maintained by a process. According to baseline survey information sever water problem is found some areas and the specified areas has given priority to get the whole picture of the project area. The whole study has three main parts of analysis.

First one is Analysis of water related problem: To know problem and its dimension water related problems and causes has been identified of the project area. Then it has been documented.

Second one is analysis water harvesting options: Analysis of water harvesting options and possibilities has been assessed in this part. This part assessed different options for water harvesting e.g., motor jar, RCC ring tank for RWHS. On the other hand underground RWHS and tubewell system has been assessed properly. Finally communities view, preference, its association with social culture of the community has been taken into consideration carefully.

Spatial analysis (Using GIS): To interpret appropriate options for the appropriate community and area, GIS has been used to produce map for visualization. Arsenic concentration map is represented by the graduated color according to BCA Data base .Geostatistical analysis tool of ArcGIS 9.2 has been used for the preparation of raster map from point data using kriging interpolation method. The overall methodology of the study is described below by a flow diagram.

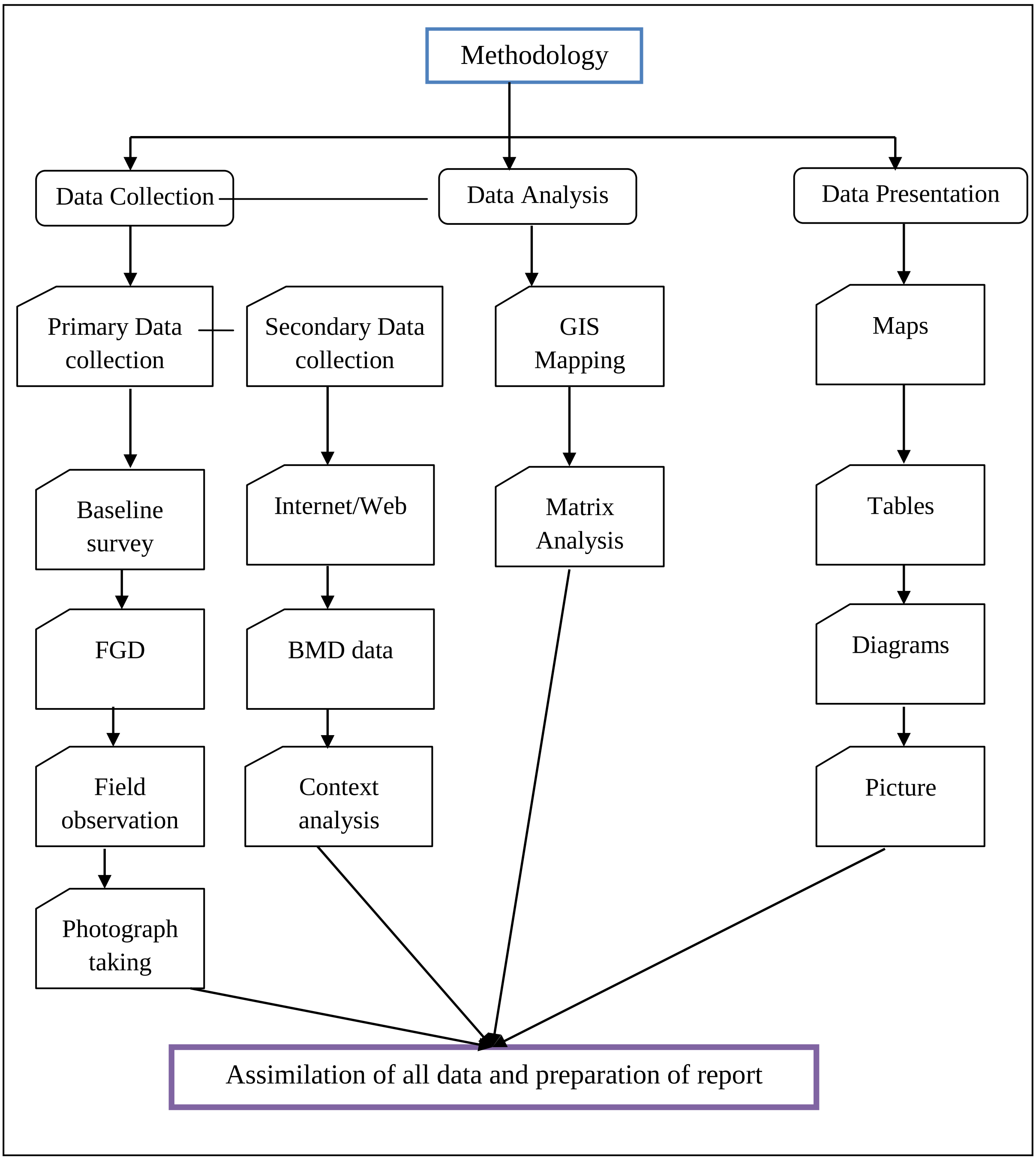


Figure 1: Diagrammatic presentation of research work

The above described (Figure 1) method is used in the field. The analysis of all data has been done by acquiring sufficient knowledge about the culture, physiography and social structure of the community. During the field visit, close observation and documentation is done properly. All the field experience is used for assessing the appropriate options for the community. Conceptualization of physiographic condition and environment has helped to decide area wise water options.

Chapter III: Literature review

3.1 Literature review

It is affirmed that Water forms the lifeline of a society. Safe water is essential for the environment, disease reduction as well as for sustainable development. Availability of drinking water and provision of sanitation facilities are the basic minimum requirements for healthy living. Water supply and sanitation, being the two most important urban and rural services, have wide ranging impact on human health, quality of life, environment and productivity. Despite the technological advancements, the global scenario still remains grim, as all the inhabitants of the world do not have access to safe water and adequate sanitation.

3.2 Urgency of Sustainable and environment friendly water technology

Human development of a country and use of water is interlinked with one another. For agriculture, industrial use, water is essential whereas it goes without saying that the need of water for drinking, daily activities for the growing population is a must. Huge amount of water is pumping each year for irrigation and industry it is creating the situation of ground water depilation. On the other hand people of rural area that do not have the municipal water supply facilities, mostly relay on hand pumps/drawing from tube wells. It is predicted that by the year 2025, two third of the world population may be subjected to water scarcity (Figure:2).The situation can be observed in the rural part of Bangladesh where hand pump is only source of drinking water but it is not safe in some parts due to the excessive limit of iron and arsenic. On the other hand scarcity of ground water during dry season is a common phenomenon. In this situation the urgency of alternative source for drinking water need to be considered. The alternative source mostly

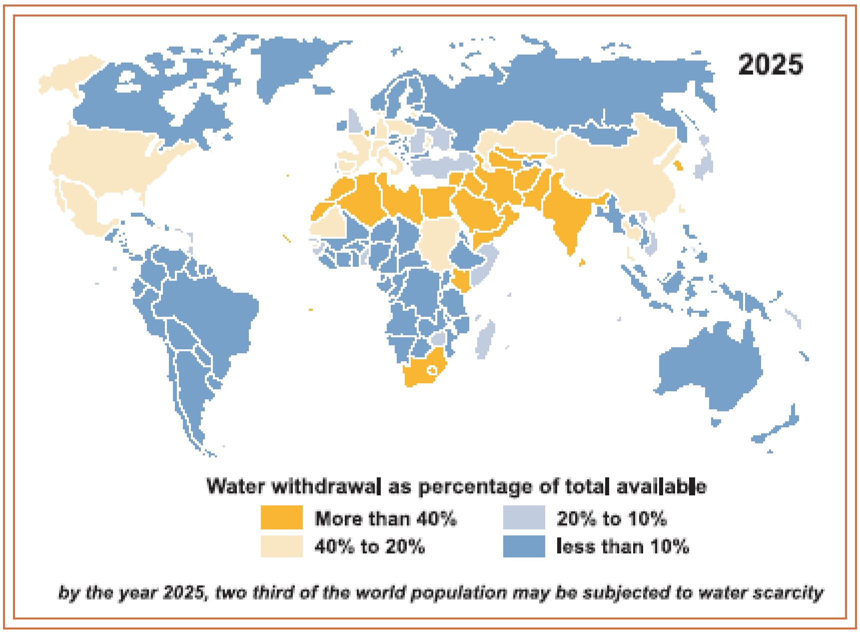


Figure 2: Prediction about water scarcity, Source: UN-HABITAT, 2005

relies on RWHS, and creating a process of ground water recharge and harvesting system. RWHS provides the long-term answers to the problem of water scarcity. Rainwater harvesting offers an ideal solution in areas where there is sufficient rain but inadequate ground water supply and surface water resources are either lacking or are insufficient. RWHS is particularly useful in remote and difficult terrain as it has the ability to operate independently. The whole process is environment friendly. There are a number of ways in which water harvesting can benefit community water harvesting enables efficient collection and storage of rainwater, makes it accessible and substitutes for poor quality water (UN-HABITAT, 2005)

A water harvesting system helps various ways to the community by providing water. The benefits can be described as

- The system collects and stores water within accessible distance of its place of use as traditional sources are located away. So it enhances the accessibility and convenience of water supplies.
- Underground RWHS can store water and recharge into the ground water to improve the quality of ground water and raise the water levels in wells and bore wells that dry up in dry season. It is also effective in drought proofing.
- Water harvesting system provides safe water in areas where surface and ground water is contaminated (especially RWHS) and harmful chemicals or pathogenic bacteria or arsenic or iron is found.
- A water harvesting system can provide supplementary, back-up or emergency water supply which is important in view of increased climate variability in drought and flood affected area. The system is also effective in areas where increasing pressure is put on existing water resources.
- Rainwater harvesting technologies are flexible and can be built to meet almost any requirements. Construction, operation, and maintenance are not labor intensive.

So it is clear from the discussion that in urban areas where scarcity and accelerating demand of water is a major problem, rainwater harvesting system can provide options of using existing structures like rooftops, parking lots, playgrounds, parks, ponds, flood plains.

3.4 Assessing the voice of international community for the alternative water source

The conventional water supply system in all around the world in under threat and sometimes fails to provide the required support for the people as water sources area most often contaminated and went out of favor. So the option which has come under consideration is rain water which is potable, safe. It is also cost effective for poor communities. RWHS got the priority as The Millennium Development Goal (7) calls for the environment sustainability. The goal set out the target of reducing the proportion of people without sustainable access to safe drinking water to half by 2015. The importance of RWHS can be identified as several International Conferences on Rainwater Harvesting has been conducted form 1982- 2001. Since around 1980, things have changed and there have been numerous grassroots initiatives supported by enlightened government and donor agencies promoting and implementing rainwater harvesting technologies. After 1986 UNICEF, several bi-lateral donor agencies including DANIDA and CIDA, and many NGOs has promoted the use of household roof catchment tanks in East Africa and working on developing various low cost designs in different countries. The system directly incorporated the community groups. After the success of the system nine conferences took place in different place U.S. Virgin Islands (1984), Thailand (1987), The Philippines (1989), Taiwan (1991), Kenya (1993), China (1995), Iran (1997), Brazil (1999), Germany (2001). The Vision 21 initiative also placed the use of appropriate technologies such as rainwater harvesting at the centre of its proposed strategies for providing clean water, adequate sanitation, and hygiene education for 95% of the population by 2025. So the global voice is also gives priority to promote the use of alternative water source especially RWHS.

3.5 History of water harvesting system and concept of rain water harvest

Water harvesting refers to collection and storage of rainwater and other activities aimed at harvesting surface and ground water. So water harvesting is the activity of direct collection of rainwater. The rain water harvesting technology also incorporates above the ground and underground water harvesting systems. Rain water is the first form of hydrological cycle and major portion of fresh water comes from rain. From the ancient time RWHS has been using in different format in different places around the world. Evidence of roof catchments systems date back to early Roman times represents the truth. Roman villas and even whole cities were designed to take advantage of rainwater as the principal water source for drinking and domestic purposes since at least 2000 B.C. The earliest known evidence of the use of the technology in Africa comes from northern Egypt, where tanks ranging from 200 to 2000 m3 have been used for at least 2000 years, many are still operational today. In many remote rural areas, this is still the method used today. The world's largest rainwater tank is probably the Yerebatan Sarayi in Istanbul, Turkey. This was constructed during the rule of Caesar Justinian (A.D. 527-565). It measures 140m by 70m and has a capacity of 80,000 cubic meters. Rainwater harvesting is practiced on a large scale in Bangladesh, many Indian cities like Chennai, Bangalore and Delhi where rainwater harvesting is a part of the state policy. Elsewhere, countries like Germany, Japan, United States, and Singapore are also adopting rainwater harvesting (UN-HABITAT, 2005).

3.6 Types of Rainwater Harvesting Systems

There are different types of RWHS in all around the world. The technology and design varies according to physiography, climate, culture etc. the system is mainly found in remote part of the developing countries where access to safe water is a problem. The RWHS comprises of three basic elements. They area;

1. The collection system
2. The conveyance system
3. The storage system.

All the three system varies according to the rainfall, catchment area and reservoir types.

3.7 Existing RWHS in Bangladesh

Major two types of RWHS present in Bangladesh they are

1. Water harvesting system above Ground
2. Underground water harvesting system

3.7.1 Water harvesting system above Ground

The most implemented RWHS which has been found in Bangladesh area made of different materials and technologies which are used in rural areas of Bangladesh for rain water. The system can be divided into major four types on the basis of construction materials and size. They area

- **Cement/ Mortar Jar:** Cement/Mortar Jar system can provide 2000 to 4000 liters of water and cost ranges from 5000 to 15000 taka. Family members containing 4 to 8 person, can be served easily by these types of water harvesting system.

- **Ferro - Cement Tank:** Storage capacity of Ferro-Cement tank can vary from 2500 to 4600 liters. Depending on size, the cost also varies and it ranges from 10,000-20,000 taka.
- **RCC Ring Tank:** RCC ring tank can store 1000 to 2500 liters of water which are mainly install for household level. The cost also varies according to the capacity of storage tank. It ranges from 6000 to 10,000 taka and can supply drinking water for 3 to 7 members of a family.
- **Do-it-yourself model (Motka):** For rain water harvesting, Motka is used especially in rural and remote areas. It is the easiest and cheapest system of rain water harvesting. Motka can carry 100 to 500 liters of water (WaterAID-Bangladesh, 2006).

3.7.2 Underground RWHS (Community Based and Household Based)

From the ancient time underground RWHS is popular. Underground RWHS mainly developed for the community base use and it can serve a small community population. It is also usable for the micro level agricultural purpose. This type of RWH is suitable where a group of families live in a congested area and face scarcity of safe drinking water. It can supply 10,000 to 25,000 liters of water.

Further there is popular water harvesting system all over the country that is tube well system. The tube well system varies according to technology. Some of them are deep and some of them are shallow. The systems are described below;

3.7.3 Tube well water system

Under the tube well water system different technology is used which is integrated with underground rain water tank. They are mainly used for the supply of drinking water as well as other domestic purpose.

3.8 Limitations of RWHS

Rainwater harvesting system is site specific and depends on local rainfall hence it is difficult to give a generalized idea and make it successful. Household base RWHS is used to harvest drinking and cooking water. But other daily activates are not possible by the harvesting system. Big and community base RWHS can provide chance to use water for other purpose like bathing, washing, irrigation but the maintenance of this types of RWHS is difficult. Incorrect prediction of rainfall can make the system unusable.

The Action Research project executed by NGO Forum in the context of the WPP program, has shown that a rainwater harvesting system was favored by the consumers over dug well and several arsenic removal techniques, but that an arsenic free tubewell still had first preference. Further In public supply situations it is often not easy to put adequate management systems in place and so RWHS fall in disrepair due to conflict, or they become the user right of some specific households.

Chapter IV: Assessment

4.1 Introduction

This chapter will give an insight of proper water harvesting system for the study area. There are different types of water harvesting system in Bangladesh. As the rain water is available and can provide safe water this option provides an alternative source for good quality water seasonally or evens the year round. Water harvesting technologies are flexible and can be built to meet almost any requirements. But this depends on the social acceptability, available technology and materials and favorable climatic condition. As the traditional water systems have various problems like iron, arsenic and seasonal scarcity alternative water harvesting system can provide safe water all over the year.

4.2 Problem found in the study area

The study area comprises three different areas where the social, culture, occupation and physiography vary. There is difference in income, types of occupation. Average household income is low in Madhupur and Durgapur relative to Mymensingh, but savings of the household family is relatively low in Madhupur and Mymensingh than Durgapur. In Durgapur the household have very few service related expenses because of the absence of gas, electricity, water etc. The absence of water related services make the people use of pond, canal and river water where still 58 households in Madhupur and 44 households in Durgapur use the unprotected sources. Although this situation has made them use the dug well in some parts of Durgapur. Many household do not have their own tube well. In Durgapur the soil permeability is relatively low and after boring 20-30 feet the hard rock hinders the path. So the installation of tube well cost is high which gets out of reach for the household those whom are impacted by poverty. On the other hand scarcity of water has been found all over the area during the dry season. Form the January the water becomes scarce and it stretches to May. In this time household have to collect water from neighbors tube well and for daily activates, pond is only one source for survive. Area wise problems are stated below (Table 1):

Table 1: Problems of the study area (Community knowledge)

Area	Problems related to water	Physiographic condition	Seasonality/ Scarcity of water	Social-economic Conditions	Knowledge on Water harvesting technologies	Support from NGO and Govt.
Mymensingh	•Iron, Bad smell	•The area is relatively plain area. •The area inundates after every one or two years.	•During the months of Falgun, Chaitra, Baishak, Jaistha (November - March) water level goes down and shallow tube well does not work. •Women's and girls' have to walk long distance to fetch water during the mentioned months.	•Day labor is major occupation. •Low income •Poverty	•Limited excess to information is a problem to them. Most of the household do not have any training on water harvesting system. •Some household knows about the water harvesting system but never applied it.	•Most of the household do not get support from NGO's for the water harvesting system.
Madhupur	•Iron •Many families do not have their own tube well. .	•Higher part of the Madhupur area.	•During the month of Chaitra, Baishak, (December-March) water becomes scarce in shallow tube well.	•Some household has the capability to install tube well, but they do not give priority of install it.	•No knowledge on water harvesting technology. •Do not get any training on water harvesting system.	•Govt. is giving support by some NGO's to install tube well, but it is not sufficient.
Durgapur	Iron, arsenic, Bad smell, Insufficient tub well.	•Flash flood and inundate frequently. •Hard rock found just below 10-20 feet which hinder boring tube well.	•Whole the year they have the scarcity of pure drinking water.	•Lack of money. •	•House hold has knowledge about water harvesting but not willing to practice it.	•Limited support form NGOs and Government regarding financial as well as training purpose.

Source: Field survey, 2011

So the major problems which has been found related to water in the study area are

- Shortage of safe drinking during the months of November to March.
- Arsenic and iron contamination and no alternative water supply. Water test result found excessive iron and arsenic concentration in Mymensingh and Durgapur. In Durgapur iron is found 5.5 mg/l. on the other hand arsenic is found at the level of

0.374 mg/l which is dangerous for health. Further concentration of coliform in tubewell water is found in Durgapur and Madhupur at the dangerous level of 2-10 CFU/100ml.

- Many families do not have their own tubewell or not enable to install by their own.
- Limited training or awareness program on water harvesting system and technology.

There are some under lying causes of the problems. The problems more or less associated with social structure, physiography as well as hydrological components. The under lying causes are described below:

4.3 Impact of Socio economic condition

Drinking water as well as water required for daily activities, is scarce in some parts of Mymensingh, Madhupur and Durgapur. Huge withdrawal of ground water from underground aquifers during the dry season is the major cause of this crisis. In Durgapur the scenario is little bit different than other areas. In Durgapur, physiography and environment problems are the source of difficulties for collecting drinking water. Arsenic and iron is Causing severe environmental problems in the area and inadequate recharge of ground water is also accelerant the scarcity of water. On the other hand lack of safe water, concentration of iron and arsenic in water above the acceptance level in making the condition more critical in areas of Durgapur Madhupur and Mymensingh. Further, many people in Mymensingh live in under poverty level. All over the area average 75.09% people have the income less than 10000 taka per months and cannot afford sound technology especially deep tube well for the safe drinking water. Lack of knowledge on water harvesting system is also found in the areas.

4.4 Geology

The study area is affected by iron and arsenic contamination in ground water. Most of the wells within the depth of 50-100 meters area contaminated with higher than permissible limit of arsenic. The arsenic contamination in ground water has connection with the geology of the area. The plain land especially the Holocene sediments area severely affected. The old Brahmaputra delta complex is build during the time of Holocene time. Unconsolidated sediments of Holocene time are fund in Madhupur clay, which is older than 75,000 years. But the Holocene sediments of Brahmaputra delta complex are important for ground water withdraw. On the other hand the aquifers system is the biggest consideration to find out the water problem in the study area.

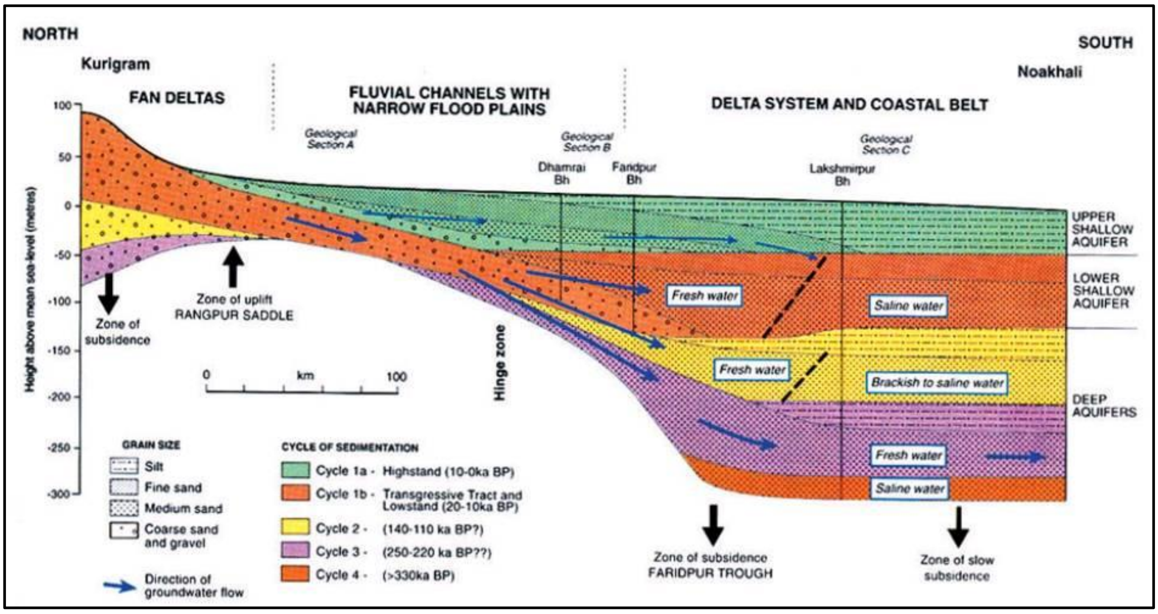


Figure 3: Geological structure of Bangladesh, Source: Nehal, Abdullah, 2005

Historically the late Pleistocene-Holocene aquifers of the country are divided into three types considering the depth. (Nehal, Abdullah,2005) Three parts of the aquifers are

1. The upper Aquifer which ranges from 10 to 100 m depth.
2. Main Aquifer which ranges from 100 to 200 m depth.

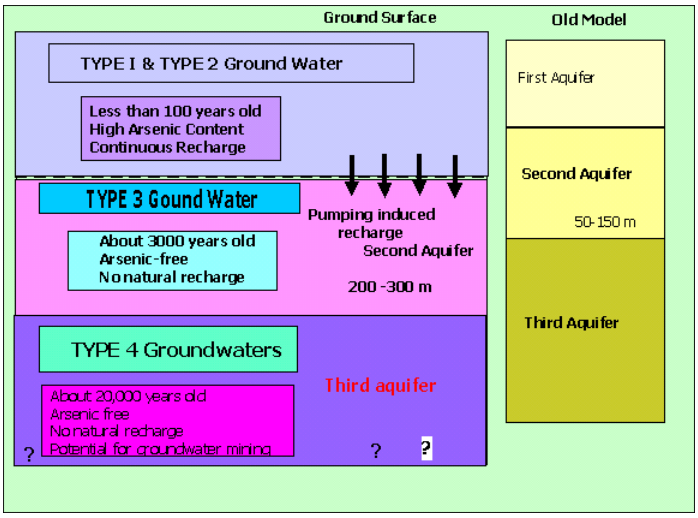


Figure 4: Parts of aquifers Source: Nehal, Abdullah, 2005

3. Deep Aquifer which underlies below 200 m depth.

Figure 5: Concentration arsenic in Ground water in Mymensingh District, Source: BCA Database, compiled by author, 2011

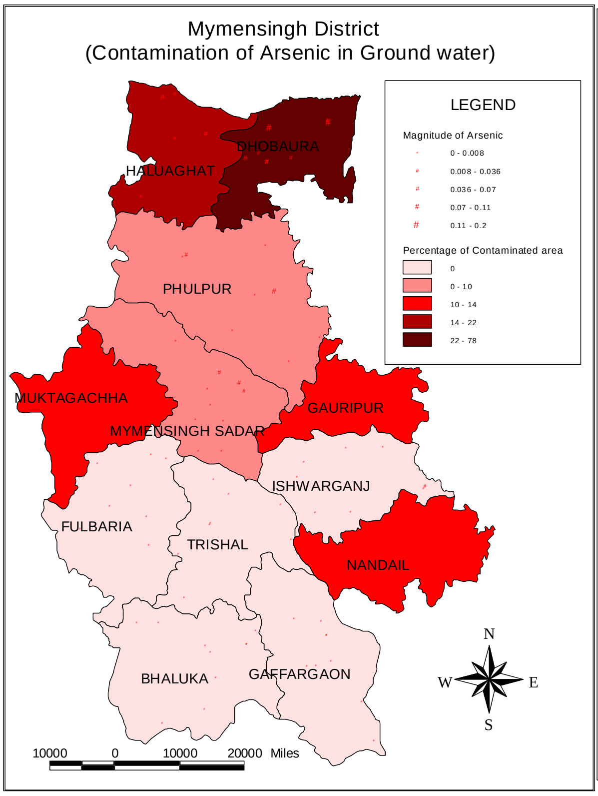
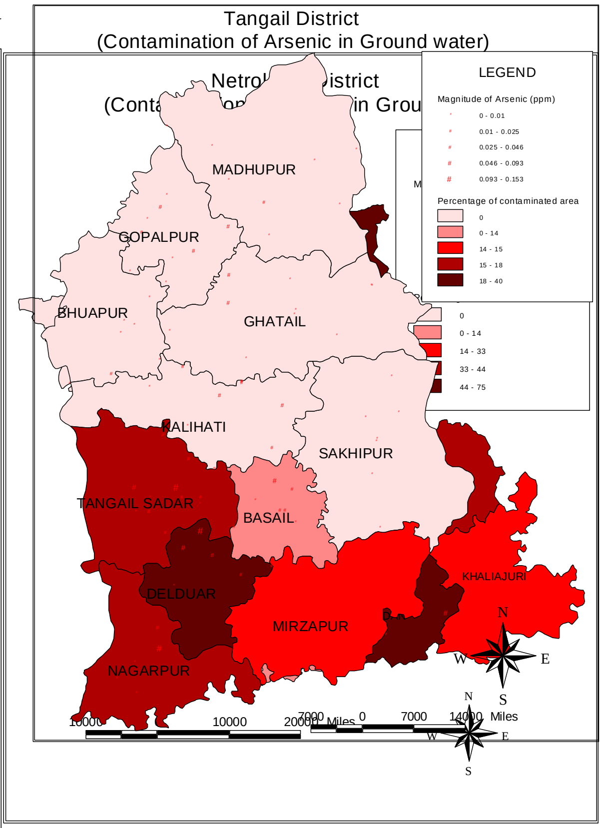


Figure 6: Concentration arsenic in Ground water in Tangail District, Source: BCA Database, compiled by author, 2011



The upper and main aquifers are hydraulically connected and major portion of drinking water is withdrawn from the main aquifer. But the main problem of water especially arsenic is found in the upper and main aquifer which consists in between 10-200 m depth (Figure-5, 6, 7). But water from the deep aquifer is not much affected by arsenic. In the map it is clear that most vulnerable area of arsenic in found in the working areas of Mymensingh Sadar of Mymensingh, Tangail Sadar of Tangail and Durgapur Upazila of Netrokona District. It is clear that the geological structure and depth of tube well is the main phenomena of contamination of arsenic.**4.5 Lack of proper knowledge and awareness**

In Mymensingh, Madhupur and Durgapur, the water harvesting system and its benefit is not widely spread. Average 3.47% family knows about the water harvesting system especially about rain water. The main problem is community do not have specific information about the benefits and constructing mechanism of Rainwater Harvesting System. Besides this, as RWHS is not popular in the area, they do not have skilled masons to do so. Thus HFHI-B is trying to make it familiar and creating awareness to adopt the system. In advance HFHI-B has completed small scale project of latrine with RWHS.

Figure 7: Concentration arsenic in Ground water in Netrokona District, Source: BCA Database, compiled by author, 2011

4.6 Assessing the solution based on problems

In the study area, scarcity of water is common but the dimension is different. . Scarcity of water is common in the months of November to March and people use different technique to cope with the situation. For example in Mymensingh household goes to neighbors' house or goes to the deep tubewell which is installed for the irrigation purpose. Women and girls fetch water for drinking and cooking. Even they take their bath beside the road side drains of deep tubewell. Sometimes they are harassed by the passerby. On the other hand some families use the cement jars to collect water. They collect water from the nearby or distant channels and pond and store in such a manner that all the dust can subside. After few hours the dust subsides and they use it for washing or for other hygiene purpose.


Figure 8: Community practice in Mymensingh

The problem is more severe in Durgapur as lots of people do not have tubewell. On the other hand the existing tubewell contains arsenic and iron. More ever seasonally impact during the dry season. People are forced to use unsafe and unprotected water of dug well.


Figure 9: Community practice in Durgapur (Unprotected Dug well)

Table 2: Research matrix; Problem of the study area and solution regarding the problem (community knowledge and practice)

Area	Problem found related to water harvesting and water purification system	Indigenous Options used by the household found to cope with the adverse situation	Local peoples idea and preference	Option mostly preferred by the community	Cause of rejecting other options	Options can be considered
Mymensingh	•Iron	•Carry the water and fix it in a place for long time and keep in a quiet place so that iron can subsides into the bottom of the water pot or jar.	•In Mymensingh community like to have tubewell at household level. They also prefer the deep tube well technology for the assurance of water all over the year.	•Tube well (Deep more than 200 feet)	•Not familiar with RWHS and they think that maintenance and operation of RWHS is complex.	•Ring well with hand pump (options of ground water recharging system from rain water) •Deep tube well (Deep more than 300 feet)
	•Water scarcity during dry season. •Many household don't have own tube well	• Families go to neighbor's house those whom do not have deep tubewell as well as do not have own tubewell. On the other hand tube wells that area functional can be found at the depth of 200-300 feet. •Families go the deep tube well which is use for irrigation. But they have to maintain specific time when the deep tube well starts (Specifically two times a day). •Use pond water for daily activates like bathing, washing.	**Options said to them:** •Rain water harvesting •Use of tubewell			
			Level of service 1.Community based 2.Individual/ Household level 	•Household/ Individual level	•In community level one family must have to give his land to install the system. They think no one will sacrifice for the system.	•Community base WHS can be considered if it is possible to install the system in "Khash"land/ Government owned land.

Area	Problem found related to water harvesting and water purification system	Indigenous technology used by the household found to cope with the adverse situation	Local peoples idea and preference	Option mostly preferred by the community	Cause of rejecting other options	Options can be considered
Madhupur	•Iron, Arsenic	•Household use indigenous system like jug, pot to harvest water. They tie the jug with a rope. The jug is mechanized with sand and stone at the bottom and has a small whole at the bottom to seep the water to a safe water jar/jug.	•In Madhupur community like to have tube well at household level. They also prefer the deep tube well technology for the assurance of water all over the year.	•Tubewell in plain land and Tara pump locally called "Tanan Pump" in hilly area.	• Tubewell is best to them because water is available at the depth of 200-300 feet. They also think that RWHS will not be able to supply sufficient water all over the year.	•Deep tube well (Deep more than 300 feet) •Water harvesting system in iron affected area and RWHS in hilly area.
	•Water scarcity during dry season, • Many household don't have own tube well	•Household goes to neighbor's tubewell that is installed at the depth of 200-300 feet. Because tube well at the depth of 200-300 feet always functioning effectively. •Use pond water for daily activities.	**Options said to them:** •Rain water harvesting •Water purification system •Use of ground water/ tube well	•Tube well (Deep more than 200 feet) •Water purification system	•Not familiar with RWHS system.	
			Level of service 1. Community based 2. Individual/ Household level	•Household/ Individual level	•They think that Community based approach will create conflict with each other.	

Area	Problem found related to water harvesting and water purification system	Indigenous technology used by the household found to cope with the adverse situation	Local peoples idea and preference	Option mostly preferred by the community	Cause of rejecting other options	Options can be considered
Durgapur	•Iron • Arsenic •scarcity of water during dry season •Many household don't have own tube well 	 	•RWHS or Deep tube well with water harvesting system both can be effective. According to the convenience of the household tube well is best if it is possible to install as deep as 300 feet deep.		•All the approaches have advantage and disadvantage to them. •If choose the tube well then it is difficult to install as Stone is found after digging 10-20 feet. Iron in tube well is common. If it be dug well then it is difficult to maintain. •If it be the RWHS they are scared that will not be able to fulfill there all need.	•Ring well and with RWHS can be effective in hilly area and in plain land deep tubewell will be accepted by the community.
			•Options said to them: •Rain water harvesting •Use of ground water/ tube well	•RWHS •Tube well •Ring well •		
			•Level of service •Community based •Individual/ Household level	•Most of the respondent preferred the service at household level		

Source: Field survey, 2011

Table 3: Matrix analysis for choosing options of RWHS

S. No.	Durgapur	Mymensingh	Madhupur
	RWHS & Tubewell in some parts (Household level)	**Ground Water harvesting system or Tube well (Household level)**	**RWHS &Tube well in some parts/ (Household level)**
Stakeholder's involvement			
1	•Can essentially run as a people's self initiated program with support of NGOs or community groups. •Women can easily get excess to water as it is near to house and do not need to carry water form long distance.	•Usually people have information and technology help from various sources so community people do not agree to install RWHS or community based approach for water. They prefer Tube well for individual family. •Tubewell can reduce the water howling form long distance by women and can create easy excess to drinking water source as well as for bathing, cooking, washing.	•Usually people have information and technology help from various sources. In relatively plain land Community people do not agree to install RWHS or community based approach for water. They prefer Tube well for individual family. But in hilly parts the RWHS has the potentiality.
Technical issues			
2	•RWHS will help to reduce their water crisis. Lowest cost (Physical, mental, financial) of supply as compared to other cases. It is also easy to maintain. •Maintenance is predominantly household oriented/basic level maintenance of tank/ roof	•Tube well will provide water all around the year. •Maintenance is predominantly household oriented/basic level maintenance of tube well.	•RWHS have the potentiality but Tube well will provide water all around the year. •Maintenance is predominantly household oriented.
Economic considerations			
4	•Main spending involves with construction of tanks •Maintenance cost is relatively low, but need more involvement of household members.	•Main expense concerned with installation of tube well and labor cost.	•Main expense concerned with installation of tube well and labor cost.

Analysis			
6	In areas of seasonal rainfall, and relatively hilly areas a standalone domestic RWHS caters to demand for only a little more than the rainfall months. Works better in conjunction with RWHS.	This system is beneficial both for individual households/reduces water crisis for all over the year. But overall benefits are related to widespread usage.	This system is beneficial both for individual households/reduces demand in overall water supply system. But overall benefits are related to widespread usage.
7	Useful for households/building owners and reduces dependence or ground water extraction.	Directly mitigates scarcity of water and make excess to safe water for whole season. But ground water recharge system can be included with the system to increase ground water recharge from rain water.	RWHS is useful for households and it reduces dependence or ground water extraction. But with the tubewell ground water recharge system can be included with the system to increase ground water recharge from rain water.
8	Extremely beneficial for individual householders/building owners. Shows immediate results.	Most effective system and as a starting pilot for a community level initiative. Could be combined for high efficacy for a second phase DRWH system.	Works out to be best system if integrated with GWR & DRWH system. In conjunction, it could take care of the complete demands of the project area.
9	Not as effective overall as compared to the ground water system. Difficult to make people accept behavioral changes	Does not work to recharge ground water.	Difficult to make people accept behavioral changes on the other hand Tubewell Does not work to recharge ground water.

Source: Field survey, 2011

From the above discussion it is found that two options we have to consider for the study area. One is RWHS and another one is Tubewell system. Tubwell is familiar to the community and people have sufficient knowledge about the system. But RWHS is relatively new to the community. Familiarity and cost effectiveness can make the system popular, and then an alternative source can be developed which is environment friendly. So the assessment of RWHS is described below.

4.7 Benefit of water harvesting system

A functional RWHS can meet different deeds of a society where cost, technology, degree of affordability is basic requirement. A RWHS can provide multiple facilities. The facilities area:

a) Can afford required water for dry season.
b) Could able to store adequate quantity of water having acceptable quality for certain period of time.
c) All necessary parts are in place.
d) Good, clean and effective catchment, gutter, down pipes, first flush system, platform, tank with lid are available.
e) Sanitary condition of RWHS and surrounding is satisfactory.
f) Help to reduce the physical stress for water collection from long distance.
g) Use of local but available materials for construction.

4.8 Construction of Rainwater Harvesting System and Design aspects

Construction of RWHS requires the appropriate technologies and resources that are available and relevant to the local area. So the analysis of design and system is needed to be analyzed properly considering the opinion of the local community. Rainfall, existing water sources, availability of materials, housing and roof types and the people's means of livelihood are the criteria to be analyzed prior to the design of tanks and the entire system. The design consideration often compromised by site conditions, or negated by the purposes for which people actually use rainwater. It is also important to analyze the capacity of storage tank, its safety, hazard aspects such as contamination of water, cleanliness of water. Overall the cost of construction should be defined according to family's resources. Construction is not end of the system regular use and usability by all age sex group of a community is a big consideration of the RWHS.

4.9 Components of RWHS and its Functions

The major component of a RWHS comprises of Catchment, Gutter, flushing system, storage tank and water collection points. All the components are must to develop and construct a RWHS. Without any of the components the RWHS cannot function. The components and its pre required condition is described below in a table format.

Table 4: Components and function of RWHS

Component	Function of the components	Construction materials	Required condition
Catchments	In RWHS clean rooftop is used as catchment.	CGI sheet roof, tile roof, concrete roof.	Clean rooftop is required as catchment.
Gutter	Gutter is the water passage from catchments to storage reservoir.	Gutter may be made with different type of materials such as GI sheet, PVC pipe, split bamboo.	Need cleaning regularly.
Flushing System	Discharge first foul rainwater outside the tank easily.	Can be made with PVC pipe, GI pipe or bamboo.	To maintain the quality of harvested water easy flushing system is very essential.
Storage Tank	In the storage tank, collected rainwater is stored for subsequent use.	Can be made with concrete, Ferro cement, brick, plastic sheet, fiberglass, earthen Motka	Required clean condition so that water cannot be contaminated. Regular cleaning is required
Water Collection Point	From where the water is collected for daily activates	It is mainly constructed by brick concrete	Safety of water collection point insures the hygienic use of stored water

Source: WaterAID-Bangladesh, 2006, (Compiled by author, 2011)

4.10 Assessment of information and condition required for designing Rainwater Harvesting System

Assessment and information required for designing RWHS can be classified according to some phenomena. They area:

1. Climatic and Environmental phenomena.

2. Social aspects like Social structure, family structure and family size, daily consumption rate.
3. Structural component of RWHS.
4. Economic aspects.

Climatic and Environmental Phenomena

4.10.1 Rainfall Quantities

The most important considerations to designing the RWHS are rainfall quantities and pattern. Rainfall has close association with physiography, climate and associated features. The pattern of rainfall and quantity is most important consideration for providing the system. Rainfall in each area is not equal especially in Bangladesh (Figure: 11). availability of ground water also depends on rain water as it requires recharge. The total amount of water available to the consumer is a product of the total available rainfall and the collection surface area. The climatic conditions vary widely throughout the country. Being the tropical country, The average annual rainfall varies from a maximum of 5,690 mm in the northeast of the country to minimum of 1,110 mm in the west. Bangladesh receives heavy rainfall during the rainy season with an average annual rainfall of 95 inches (BBS, 2009).

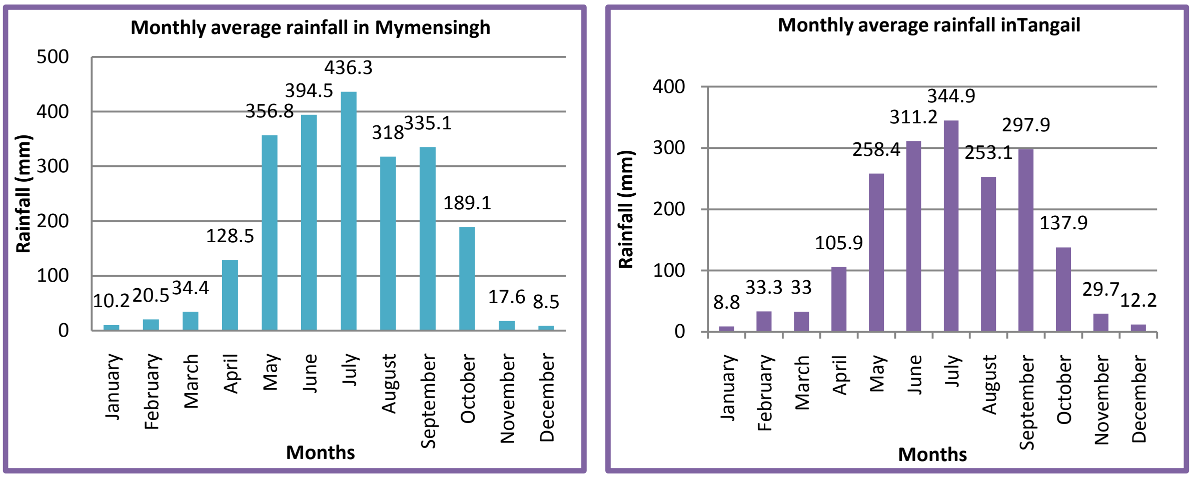


Figure 10: Ten years monthly average rainfall in Mymensingh & Tangail, Source: BMD (Compiled by author, 2011)

In the study area of Mymensingh, Madhupur and Durgapur the average monthly rainfall is 187.46 mm (Figure 10). Although the rainfall is relatively low in Madhupur which is 152.19 mm. spatial analyses (Figure 11) of the study area remarks that this area receives mean annual rainfall ranging from 2101mm to 3300 mm. The average annual rainfall amount and pattern shows, the amount of rainfall mainly occurred from April to October has the potentiality for rainwater harvesting. The heavy monsoon rain makes rainwater harvesting a viable option among the other technologies. The amount of rainfall in the Northeast region is highest (about 5,500 mm/year) and gradually decreases towards Southwest direction. So the annual monsoon rainfall that occurs in the study area could be utilized as a seasonal supply for safe drinking water means of reducing water crisis at the household level in areas having scarcity of drinking water. This amount makes rain water harvesting an obvious solution for the arsenic and iron contamination when it is found that major portion of Durgapur and Madhupur community is suffering from arsenic contamination. On the other hand problems with iron are found in wider area of Mymensingh, Madhupur and Durgapur, which can be partially solved by the alternative source of water.

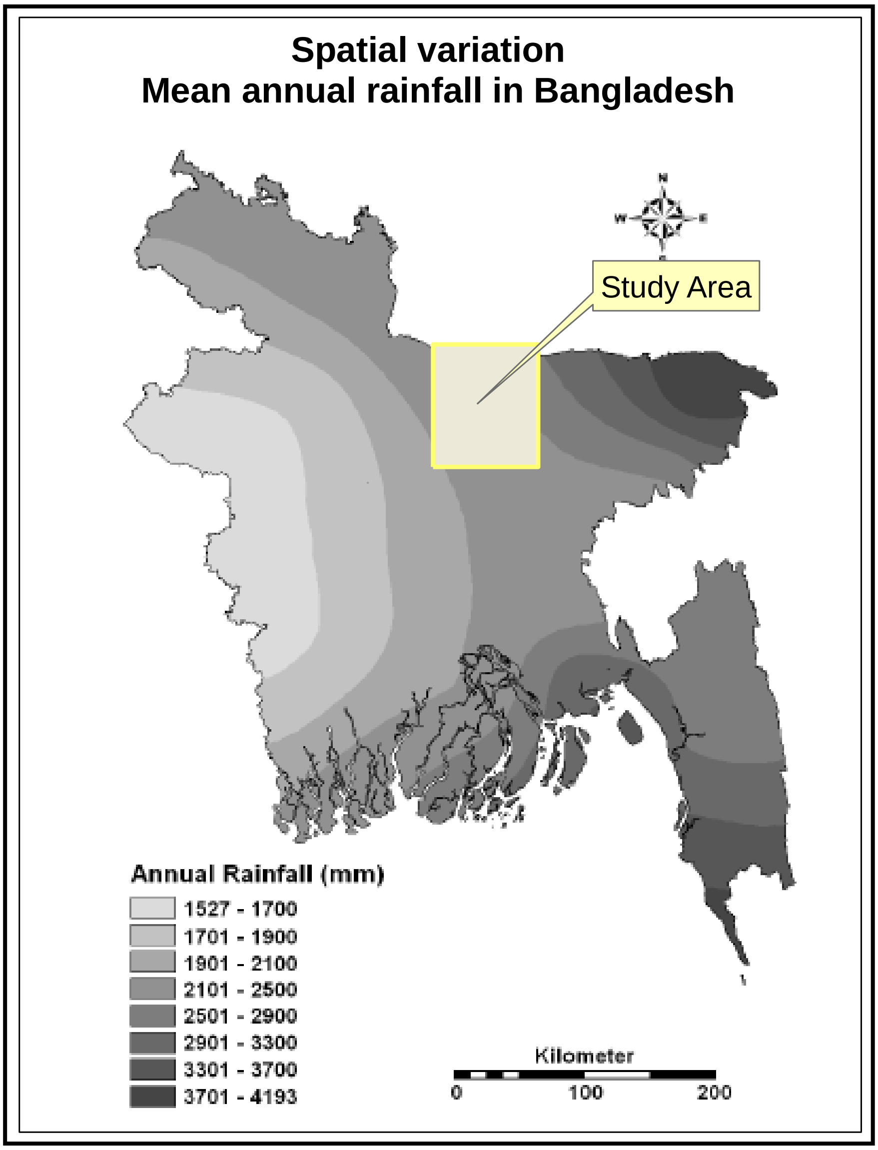


Figure 11: Twenty years rainfall pattern in Bangladesh (1988-2007),
Source: BMD (Compiled by author, 2011)

4.10.2 Rainfall Pattern

The pattern of rain fall is important criteria for assessing the conditions. The number of days rainfall occurs in a particular region is a big consideration for assessing RWHS. Rainfall all around the year in all parts of the country is not same. In north eastern parts receive relatively high rainfall than other parts of the country. In the table the rainy days has been identified where May to September months receive average 16 days rainfall. It signifies that there is potentiality of using rainwater for water harvesting in the project area as the rainy sufficient rainy day prevails in all over Mymensingh and Tangail (Mymensingh covers the Durgapur area).

Table 5: Monthly Normal Rainy Day

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mymensingh	2	3	4	8	16	16	18	16	14	6	2	1
Tangail	2	4	4	8	13	14	16	14	13	6	2	2

Source: BMD (Compiled by Author, 2011)

4.10.3 BMD station and data validation

The map above described the validation of data which is analyzed for rain water harvesting. Mainly the data provided by the BMD is gathered from the selected stations. The study area have only one station in Mymensingh but used for forecasting the whole region of Mymensingh, Madhupur and Durgapur. From the map it is significant that major part of Durgapur and Madhupur is unnerved and the prediction of this unnerved area is difficult. But overall the data provided is accurate and can give the insight of the rainfall situation in the study area.

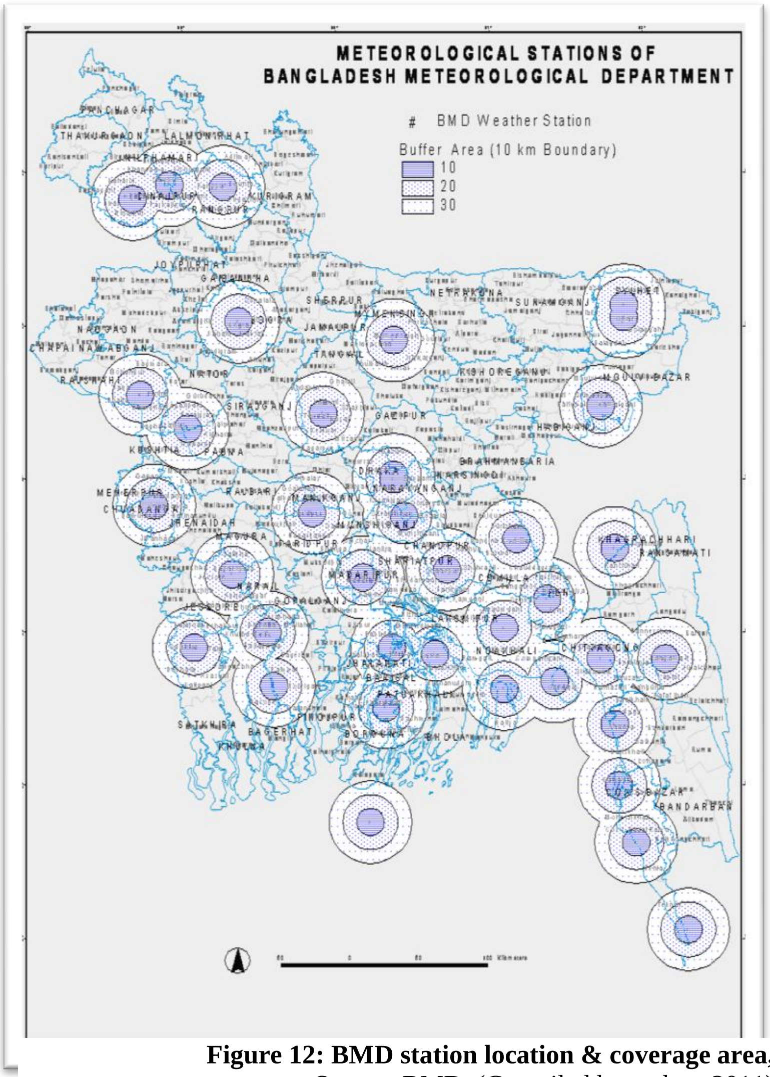


Figure 12: BMD station location & coverage area,
Source: BMD, (Compiled by author, 2011)

4.10.4 Environmental problems

It is mentioned earlier that scarcity of water, Iron and arsenic is common water related problem in the study area. But the alternative source of water especially RWHS provides the alternative sources of arsenic and iron free water. It also provides a suitable, safer, socially acceptable, locally affordable and environmentally sustainable alternative source of water for drinking and cooking.

4.11 Social aspects

4.11.1 Estimating the consumption rate by a family or household

Consumption per family varies with the number of family members and also their water use pattern. From the FGD discussion it has been identified that; average daily water requirement (for drinking & cooking) for a nuclear family may be taken 5 liter per day (2 liters for drinking & 3 liters for cooking). Although the overall water needed for a family for daily activities is more than 25 liters per day.

4.11.2 Number of Consumer

In Mymensingh, Madhupur, Durgapur Upazila the nuclear family has average member of 4.14 although some families has more than 6 members too. But for the design aspect of RWHS 5 members per household has been taken into count. The family size of the study area is given in the list below:

Table 6: Table average family size and male female ratio

Demographic Information	Mymensingh		Madhupur		Durgapur	
Particulars	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)
Sex Ratio	49.77	50.23	51.50	48.50	51.66	48.34
Average family Size	4.02		3.89		4.51	

Source: Baseline survey, 2010

4.11.3 Social acceptability

Social acceptability of RWHS is important criteria. Social acceptability for RWHS depends on some components. They are:

- ⇒ Use and management of stored water
- ⇒ Women involvement.
- ⇒ Security (in wet and dry season), in comparison to other sources

In the management approach most of the family prefers to have family based options. Community people think that if the system becomes the community base, it may create the some problem, like once the RWHS is installed in a households own land, he/she will claim the land is his/her own and he want not to give access other household to collect water. The situation most often create social problem and out breaks as a quarrel with each other. . The research matrix (table: 2 and 3) has described the acceptability options.

4.12 Economic aspects

4.12.1 Cost

The main aim is to build an appropriate water harvesting system required the cost effectiveness for households. The construction and maintenance cost is most important information that should be kept in mind when making a decision in designing aspects of water harvesting system. The affordability of the family is most important criteria to make it acceptable and popular. The Graph gives us idea about the household's average income per months. Average 75% household earn in between 5,000 to 10,000 per month. On the other hand table can give us a brief idea about the savings of the household. It signifies that most of the household have average 600 taka per month though the savings is relatively high in Durgapur.

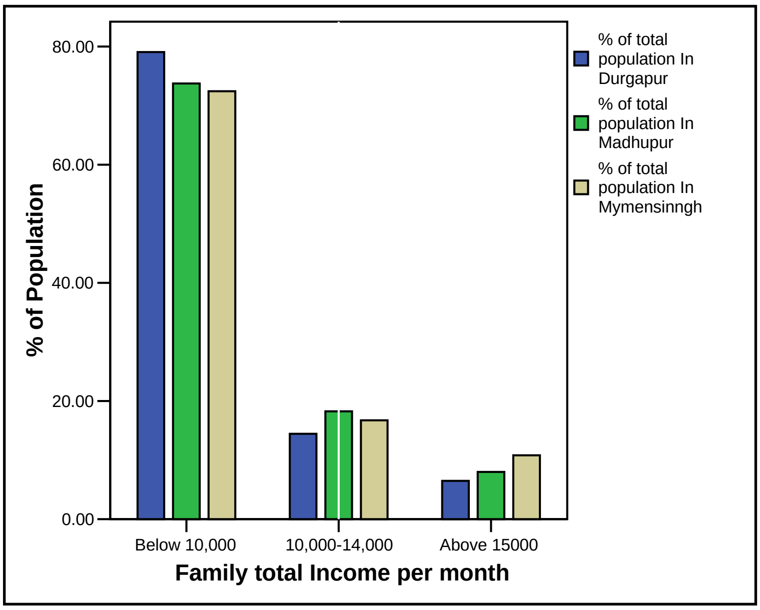


Figure 13: Average income of household,
Source: WaSH Baseline survey, 2011

Table 7: Average household income and savings per month

Particulars	**Mymensingh**	**Madhupur**	**Durgapur**
Average house hold Income	8222	7653	7688
Savings Per month	506	439	855

Source: WaSH Baseline survey, 2010

From the above discussion it is assumed that the water harvesting system can be given to the household having income of 10,000 taka per month.

4.13 Structural components

Structural components comprises of different features. They mainly requires to identify the storage capacity, stage construction, operation, Maintenance, construction materials etc. Proper calculation and assimilation of all the components can show the form of appropriate structural options for RWHS.

4.14 Designing different Components of RWHS

Rainwater Harvesting is used in many ways. In the study area especially in some parts of Durgapur, households have to suffer for safe drinking water because of arsenic, iron and safe water is not available during the months of November to March. They use old dug well during this month's although the dug well is not protected (Figure 9). On the other hand during the months of rainy season they collect rain water on few small pots to store enough water for a day or half a day. There are many variables that mentioned earlier to determine components of Rainwater harvesting systems. The design of major components of a RWHS is briefly described below for the project area.

- Storage Tank
- Catchments
- Gutter
- Flushing System
- Water Collection Point

4.15 Design of Storage Tank

Usually, the main calculation for designing a Rainwater Harvesting System will be to define the size of the water tank correctly to give adequate storage capacity. The storage requirement may be determined by a number of interrelated factors. They include:

- Local rainfall data and weather pattern
- Roof (or other) collection area
- Runoff coefficient (this varies between 0.5 and 0.8 depending on roof material and slope)
- User numbers and consumption rate.

There are a number of methods for calculating the size of the tank of a Rainwater Harvesting System. Here the demand and supply side approach is considered for calculation. The demand and supply approach will find out the storage tank and capacity of collection of rain water.

4.15.1 Demand Side Approach

A very simple method is used to calculate the largest storage requirement based on the consumption rates occupancy of the household. This simple method assumes sufficient rainfall and catchments area which is adequate, and is therefore only applicable in areas here this is the situation. It is a method for acquiring rough estimates of tank size. A simple calculation has been shown to quantify the size of the tank on the basis of set considerations such as consumption per capita per day, number of people per household and longest average dry period, And this will acquiring rough estimates of tank size.

Assumption

- Consumption per capita per day (C) = 5 liters
- Number of people per household (n)=5
- Longest average dry period (T) = 5 months or 150 days
- Annual consumption, Q = C x n x 365 = 5×5×365= 9125 liters
- Storage requirement, q = 9125×150÷365=3750 liters in 365 days

4.15.2 Supply Side Approach

In low rainfall areas or areas where the rainfall is unevenly distribution, more care has to be taken in determining the size the storage properly. In some months of the year there may be an excess of water, while at other times there will be a deficit. If there is sufficient water throughout the year to meet the demand, then sufficient storage will be required to bridge the periods of scarcity. As storage is expensive, this should be done carefully to avoid unnecessary expense.

Assumption

- Consumption per capita per day (C) = 5 liters
- Number of people per household (n) =5
- Longest average dry period (T) = 5 months or 150 days
- Demand of water per month for a nuclear family = 25×30=750 liters

4.15.3 Reconsideration

- Roof area: 10 m^2
- Runoff coefficient (for corrugated GI roof) : 0.8

- Average monthly rainfall (April to October): 308 mm/Month
- Monthly available water which can be collected from the mentioned roof = 10×308×0.8=2464 liters

So, if we want to supply water all the year to meet the needs of a nuclear family, the demand cannot exceed 2464 liters per month. But the actual demand is 3750 liters for the whole year. So deficit remains 1286 liters) the available harvested water cannot meet the expected demand. Careful water management will, therefore, be required. Following table (Table 8) shows the comparison of water harvested and the amount of water required for a nuclear family.

Table 8: Water and storage of tank required for the whole year for RWHS in Mymensingh, Madhupur and Durgapur

Month	Rainfall (mm)	Catchment Area (Sq. M)	Runoff Coefficient	Supply of Water (Liter)	Cumulative Supply (Liter)	Monthly Demand (Liter)	Cumulative Demand (Liter)	Surplus /Deficit (Liter)
Apr	128.5	10	0.8	514	514	750	750	-236
May	356.8	10	0.8	1427.2	1941.2	750	1500	441.2
Jun	394.5	10	0.8	1578	3519.2	750	2250	1269.2
Jul	536.3	10	0.8	2145.2	5664.4	750	3000	2664.4
Aug	318	10	0.8	1272	6936.4	750	3750	3186.4
Sep	335.1	10	0.8	1340.4	8276.8	750	4500	3776.8
Oct	189.1	10	0.8	756.4	9033.2	750	5250	3783.2
Nov	17.6	10	0.8	70.4	9103.6	750	6000	3103.6
Dec	8.5	10	0.8	34	9137.6	750	6750	2387.6
Jan	10.2	10	0.8	40.8	9178.4	750	7500	1678.4
Feb	20.5	10	0.8	82	9260.4	750	8250	1010.4
Mar	34.5	10	0.8	138	9398.4	750	9000	398.4

Source: BMD, Compiled by Author, 2011

Above tables shows the calculation for fixing the size of storage tank for different project area. While calculating the greatest excess of water over and above consumption, the accumulated inflow (supply of water) and out flow from the tank and the capacity of the tank are taken under consideration. This occurs in October with a storage requirement of 3783.2 liters in Mymensingh and 1787 liters in Madhupur. All this water will have to be stored to cover the shortfall during the dry period.

4.16 Estimating the Design of Catchment

Catchment size and materials of construction is very important measurement which requires careful estimation. In rural Bangladesh Catchments is made of different materials like CI sheet, Tiles, concrete, Polyethylene sheet over thatched roof, polythene sheet, clean clothes etc.

Table 9: construction materials of Roof in the study area

Construction materials	Mymensingh	Madhupur	Durgapur
Concrete/ cement	18.71	4.85	1.33
Metal (zinc, aluminum, etc.)	75.29	69.04	83.72
Wood	0.29	12.70	
Straw or thatch	2.29	0.14	5.98
Others	0.86	12.13	8.31
Did not answer	2.57	1.14	0.66

Source: WaSH Baseline Survey, 2010

In the study area most of the house roof is made metal or CI sheet. Average 76% house roof is made of CI sheet. But the percentage is relatively high in Durgapur which is 83.72% in total. So main design may be made considering CI sheet roof. The roof runoff coefficient (f) varies significantly on the basis of roof material, slope of the roof etc. This parameter varies in the range of 0.75 - 0.85. For calculating the required area of catchments made with CI sheet, the value of 'f' assumes 0.80.

Assumption:

- Consumption per capita per day per nuclear family (C) = 5 L/capita/day
- Number of member per household (n) = 5
- Run-off coefficient (f) = 0.80
- Average monthly rainfall (R) = 187.46 mm (Mymensingh and Durgapur)
- Catchments area (A) =?
- Demand of water per month for a family = 5 × 5 × 30 = 750 liters.

$$\text{Total Demand} = R \times A \times f$$

$$A = \frac{750}{0.80 \times 187.46}$$

$$A = 5.0013 \text{ m}^2$$

$$\text{Say, } A = 5.0 \text{ m}^2$$

In Mymensingh, Madhupur and Durgapur most of the house roof is made of CI iron sheet therefore the catchment area for appropriate harvesting system is required more than $5m^2$. As there is no exact data of roof size, we took relatively bigger size to avoid the error of calculation.

4.17 Guttering

Size shape and forms guttering vary as it can be homemade or in factory made PVC. Gutter is usually fixed to the house just below the edge of roof, so that water falling from the roof into channel. Factory made gutters are usually expensive and beyond the reach of the poor. 'V' shaped gutters from galvanized steel sheet can be simply made by cutting and folding flat galvanized steel sheet. Such sheet is readily available in most of the local market. Fitting a down pipe to V-shaped gutter is very easy. The gutter can easily be hung along the edge of the roof with hanger. The hanger can be made easily with MS rod of 6mm diameter or MS flat bar. The roof area and slope determine the size of gutter. An appropriate gutter width is corresponding to the roof areas. The cross sectional area (width and depth) of a guttering system can be calculated using the following formula and assumptions

Assumptions

- Highest rainfall intensity (r) = 10 mm/min
- Slope of the roof (S1) = 25º - 30º
- Slope of the Gutter (S2) = 400:1

Considering a strip of one meter width of the catchments and length is 2.50 meters

Therefore, area of the strip (A) = 1×2.50 = 2.50 m^2

r = 10mm/min

Inflow (Q) = Area of the Strip (A) × Highest intensity of rainfall (r)

= 2.50 ×10

= 25 liter/min

= 0.00042 m^3/sec

We know, Velocity (V) = $10.8(R)^{2/3}S^{1/3}$

Here,

R = Mean hydraulic radius of gutter, 3 inch

S = 1/400

$V = 10.8\,(3)^{2/3}\,(1/400)^{1/3}$

= 0.26 m/s

$$\text{Area required, } A_q = \frac{0.00042}{0.26}$$

= 0.017 ft^2

Actual area provided, $A_c = 0.195\ ft^2 >> 0.017\ ft^2$

Note that the actual cross sectional area of the gutter should be twice than the calculated area and the depth of the gutter is one half of the gutter width

4.18 Water Collection Point

Different types of water collection device may be constructed. These are brick made small chamber with lid, burnt clay pot with cover etc. The tap has been designed considering the optimum use of water, ease of collection, hygienic purpose, cost and reducing risks of accidental water loss etc.

The diameter of the outlet drain is proportional to the roof area i.e. the volume of rainwater collected in the gutter and also proportional to the width of the gutter. The rainwater would overflow if the outlet drain were too small. The calculation for determining the size of the gutter is shown below:

Diameter of the down pipe, d = 1½ inch

Inflow, Q = 0.00042 m^3/sec

Velocity of flow at inlet v = 0.26 m/s

Cross sectional Area of the down pipe, A = 0.0045 m^2

Volume of Water could flow through the pipe = A × V

= 0.0045 × 0.26

= 0.0012 m^3/sec >> 0.00042 m^3/sec

4.20 Assessment of appropriate water tank and cost

Construction cost for installation of tank can vary according to size and Storage capacity. It also varies according to types of water harvesting system. Average cost varies form 6000-20000 taka. Cement/Mortar Jar costs from 10,000 to 12,000 taka on the other hand Ferro Cement Tank costs from 12,000 to 20,000 taka. The table represents that RCC ring tank requires low cost than any other options. It varies from 6000 taka to 10,000 taka only. The table is given below to get a brief about the storage capacity, cost, and required materials of RWHS.

Table 10: Capacity and cost of different RWHS

	Storage capacity (Liters)	Minimum Catchment area (Sq. m)	Construction materials of Catchment	Nos. of family members can be served	Average total Construction Cost (Tk.)
R.C.C Ring Tank (Household RWHS)	1000	4.0 – 5.0	CI sheet, Concrete, Tiles, Polythene	3-4	6000
	2000	4.50 – 5.50	CI sheet, Concrete, Tiles, Polythene	4 -5	8000
	2500	5.50 – 6.50	CI sheet, Concrete, Tiles, Polythene	6-7	10000
Cement/ Mortar Jar (Household RWHS)	1000	4.0 – 5.0	CI sheet, Concrete, Tiles, Polythene	3 – 4	5000
	2000	4.50 – 5.50	CI sheet, Concrete, Tiles, Polythene	4 – 5	7000
	2500	5.50 – 6.50	CI sheet, Concrete, Tiles, Polythene	6 – 7	10000
	3000	7.0 – 8.50	CI sheet, Concrete, Tiles, Polythene	7 – 8	12000
Ferro – Cement Tank (Household RWHS)	2500	5.50 – 6.50	CI sheet, Concrete, Tiles	6 -7	12000
	3200	8.00 – 9.50	CI sheet, Concrete, Tiles	9 -10	14000
	3800	9.50 – 11.50	CI sheet, Concrete, Tiles	11 - 12	18000
	4600	11.50 – 13.50	CI sheet, Concrete, Tiles	13 - 14	20000
Motka system	It is an indigenous process of RWHS, which has been practicing in different part of Bangladesh from the ancient. During rainy days rainwater could be collected in clean pot from the gutter where rain water falls. Or a piece of split bamboo/wooden channel/ can be hanged along the ridge of clean roof and clean rainwater can be harvested into pitcher. This could serve the crisis of water for the rainy season (about six-months).				

4.21 Construction of above ground RWHS (Household)

During literature review different model of household RWHS has been identified which are being practiced by different organization in Bangladesh and also in the abroad countries. Construction material of these types of RWHSs is locally available and trained up local mason & private producer can easily construct the system. Some of the photography of RWHS is given below

1. Cement/Mortar Jar
2. Ferro - Cement Tank
3. R.C.C Ring Tank
4. Motka system
5. Poly system
6. Corrugated metal cistern system

Figure 14: Some photograph of different WRH tanks, Source: www.wateraid.org

Depending on space availability and shape the tanks can be installed above the ground. It is easy to identify that the cylindrical shape is most common and preferable to the community because it will save space.

4.22 Underground RWHS

In Bangladesh underground water harvesting is used in urban areas where supply water is required. The underground RWHS is implemented for the community purpose in different

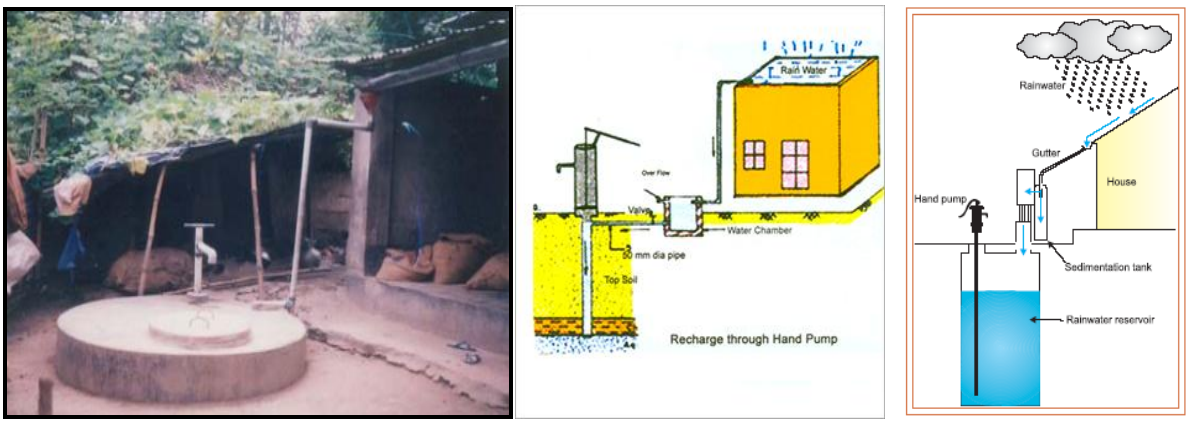


Figure 15: Underground RWHS, Source: www.wateraid.org & UN-HABITAT, 2005

remote parts of Bangladesh where water is scarce. The world largest community based RWHS constructed in Istanbul. This type of RWH is suitable where a grouped of family lives in a compacted area and faced the scarcity of safe drinking water.

There is another kind of underground RWHS and it is known as underground recharge through hand pump. For environmental sustainability the system is incorporated with the tube well pipe to recharge form the storage tank.

4.23 Tube well water system

4.23.1 Improved Deep Tube well

The deep aquifers in Bangladesh have been found to be relatively free from arsenic contamination as well as iron. So Deep tube wells installed in those protected deeper aquifers can produce arsenic and iron safe water. To reach into the protected aquifer 300-400 feet depth is required. Considering the depth and situation some criteria need to be maintained. They area described below:

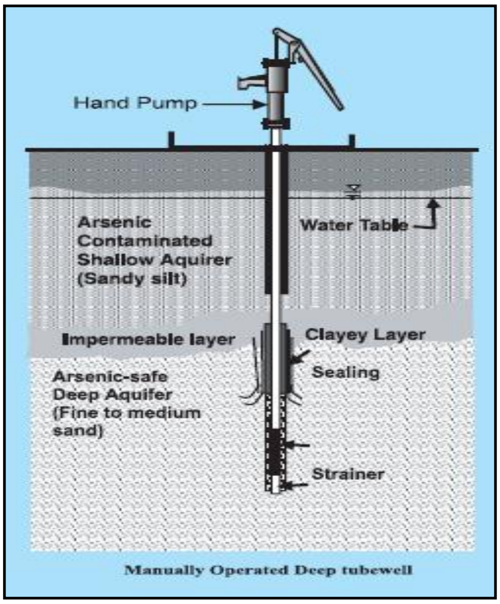


Figure 16: Improved tubewell,
Source: DPHE, 2008

4.23.2 Pre-requisite criteria

- It can be installed where shallow aquifer is separated from deeper aquifer by substantially thick impervious layer.
- Minimum 200-300 feet depth can insure the water all over the year.
- The entire tube well should be installed straight and vertically deep bore hole is required therefore.

4.24 Low Water Table Technology

Lowering of water table is big issue for the tube well in the study area. In view of low cost, affordable by the community lever action tar pump in required. It can pump water up to 80-90 ft depth of water table. The component of direct action & Tara pumps are shown as below:

Figure 17: Low water table technology (Locally called Tana pump), Source: Field survey, 2011

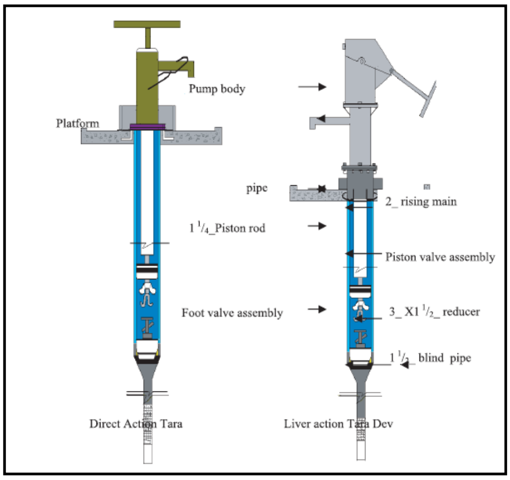


Figure 18: Low water table technology, Source: DPHE, 2008

Table 11: Cost estimate of tubewell system

Types of tubewell technology	Components/Materials required	Cost	Total cost
Improved Deep Tube well with direct lever system	Hand Pump	3000	12000
	PVC/GI pipe (Depends on depth)	3000	
	Rod joint with Direct lever	1000	
	Labor	4000	
	Platform (Brick, Cement, Sand)	1000	
Low Water Table Technology/Tara pump	Pump body	4000	16000
	PVC/GI pipe (depends on depth)	5000	
	Lever action tara	2000	
	Labor	4000	
	Platform (Brick, Cement, Sand)	1000	

Source: Field survey, 2011

4.25 Cost

Cost varies depending on the depth of the tubewell to be installed. The tubewell which is installed at the depth of 150-400 feet requires 12,000-15,000 taka including the labor cost. Sometimes cost vary region to region. For example the labor cost is relatively high in Durgapur as the soil is not easily permeable and it is more labor and energy and time intensive. Therefore the labor cost is also high. Moreover depending on the technology the labor cost varies. Low water table/tara pump technology requires skilled labor so the installation cost is also high.

Successful assessment requires judging the technology, cost and social acceptability. In this assessment all the assessment has been done carefully. The demonstration of the system in the field can assess the success from beginning to end. The popularity and advantages and disadvantages will be assessed form the field.

According to the community perception, first growth of population and urbanization followed by rise in demand for water in irrigation and other activities is the main cause of ground water depilation and scarcity during dry season. Therefore it has created a chance to relook the alternative water sources like RWHS. The stories of water harvesting in developing and developed country serve as examples for the people facing and living in water scarce areas or flood prone places, places encroached by water salinity or affected with the problem of arsenic or the areas needing recharge of aquifers. Therefore the successful implementation of the system can reduce the dependency on ground water in the studied area. The RWHS has potentiality in areas of flood, salinity, arsenic and iron affected area but tubewell system cannot be avoided as it is the easiest system in most parts of the study area.

4.26 Analysis for the appropriate water harvesting system for three different areas

The study area is spatially located in three different areas of Dhaka division. So there is difference in physiography as well as culture and religion. Considering the entire thing, a uniform system for water harvesting system is difficult. Garo people inhabitants in Durgapur and some part of Madhupur Upazila therefore they have different culture. The physiography of the area is also different. In Durgapur Lots of channels flowing from the hilly area the area is located in relatively in distant part of Bangladesh. The channels cause flash food in the area. Further due to geological structure arsenic and iron in water is common problem in drinking water. In this context RWHS can be implemented in this area. But in relatively plain area of Mymensingh and Madhupur tubewell system is appropriate for the families. To solve the problem the matrix analysis can give the area wise water solution. The matrix is represented below:

Table 12: Decision making matrix for identifying appropriate technology

Parameters / Types of WHS	Material costs	Labor costs	Total cost of construction	Process of construction	Skills required	Space requirement	Community Preference	Women involvement
RCC Ring tank	☼	☼	☼	○	☼	☼	☺	☺
Cement/Motar Jar	☼	☼	☼	●	☺	☼	×	☺
Ferro-cement tank	☺	☺	☺	●	☺	☼	×	☺
Corrugated metal cistern	☺	☺	☺	○	☼	☼	×	☺
Poly system	☺	☼	☺	○	☼	☼	×	☺
Motka system	◊	◊	◊	○	☼	☼	×	☼
Underground RWHS	☺	☺	☺	●	☺	☺	×	☺
Improved Deep Tube well	☺	☺	☺	○	☼	☼	☺	☺
Low Water Table Technology	☺	☺	☺	●	☺	☼	×	☺

Legend	☺ = Good/ High	☼ =Medium ◊= Cheap	×= Not good	○= Easy, ●= Difficult

Source: Field survey, 2011

4.27 Household based RWHS: RCC Ring Tank

Considering the types of water harvesting system the cost, benefit, and community involvement, it is clear that RCC ring tank is most appropriate for RWHS. In this system the material cost is relatively low and available to the community (See "Appendix B" for design and cost estimate). Labor cost is also low because the construction does not require skilled labor as well as community prefers the system because women involvement is easy. In all over the study area it is found, in water howling activities women are mostly engaged. As RWHS is installed in court yard connecting the roof by gutter, it creates the opportunity not to howl water from distant part. It reduces their physical stress. Water pumping is a difficult task for women. RWHS also reduce laborious work of pumping tubewell as the system do not requires pumping of water.

4.28 Household based improved deep tube well

In the study area water scarcity is identified during the months of November to March. Moreover many poverty impacted families do not have their own tubewell. In most of the areas of Mymensingh, Madhupur and Durgapur household prefer to have their own tubewell. In the field it has been established that tubewell having the depth of 150-400 feet is functioning all over the area. If individual family can have a tubewell, it would serve their need all over the year. So household prefer to have tubewell. Cost of Improved tubewell is relatively high but community prefer this system as this system is able to serve all the need of a family including cooking, bathing, washing etc.

4.29 Spatial analysis (System preferred by the community)

The map presents area wise preference of tubewell and RWHS in the study area. During the FGD most of people prefer to have tubewell in Mymensingh, Modhupur and Durgapur who do not have their tubewell. Most significant response is found about RWHS in relatively hilly part where the iron and arsenic contamination is found. With respect to the feasibility of using rainwater harvesting systems it is important to realize that rainwater harvesting can be the only option in areas where there is no other source of water supply. Also, rainwater can be used as a sole source of water supply or in conjunction with other water sources such as surface water or groundwater. The system is valued in areas where short term drought or scarcity of water if found.

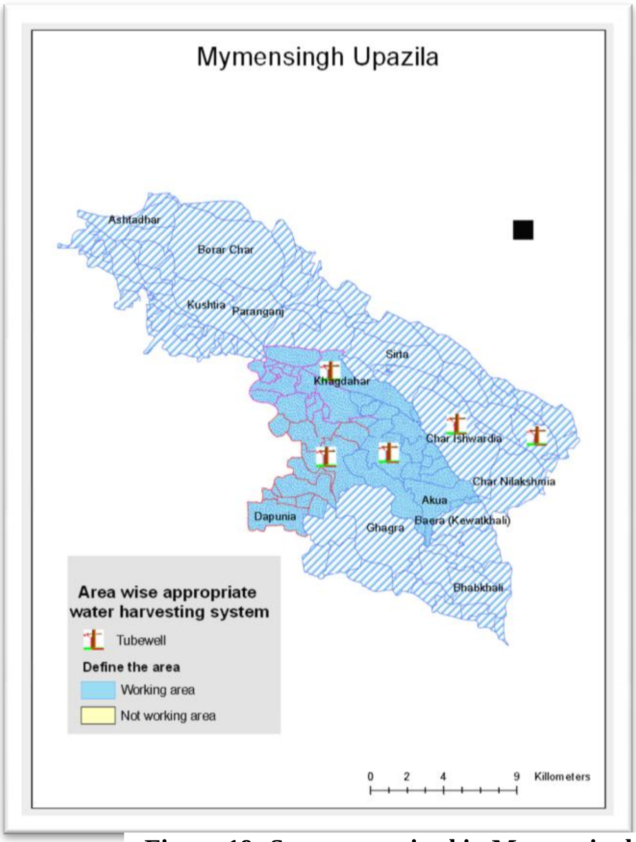


Figure 19: System required in Mymensingh,
Source: BCA database, Compiled by Author, 2011

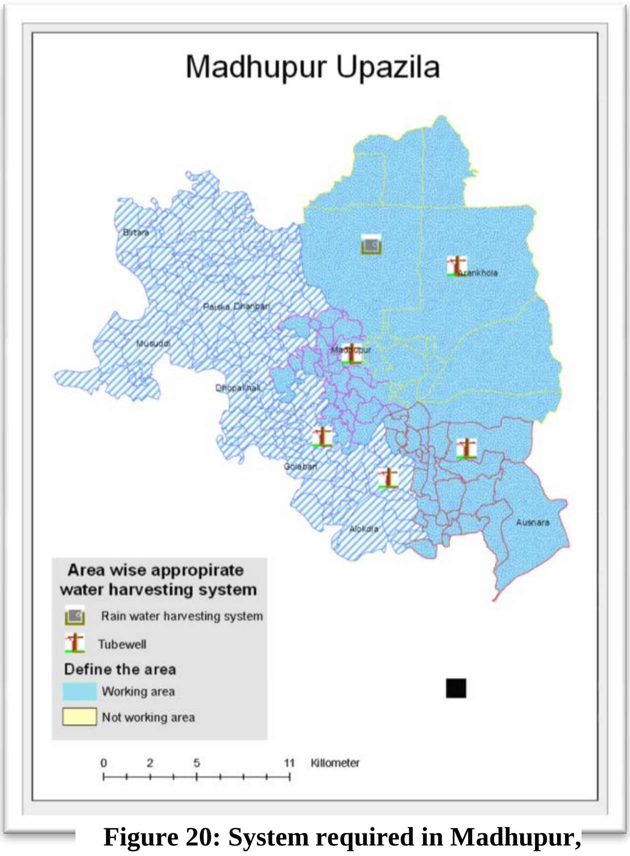


Figure 20: System required in Madhupur,
Source: BCA database, Compiled by Author, 2011

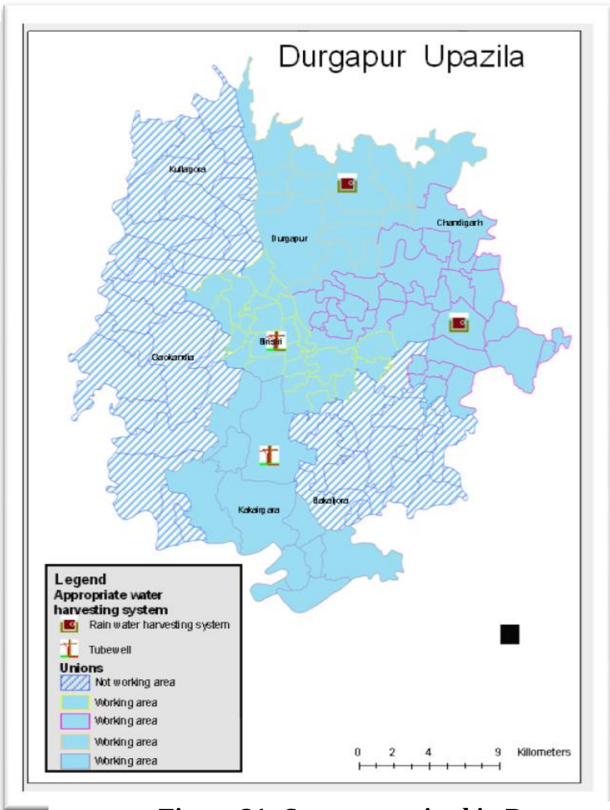


Figure 21: System required in Durgapur,
Source: BCA database, Compiled by Author, 2011

From the map (Map: 7, 8 and 9) it has been identified that two specified Upazila of the study area consist the potentiality of RWHS. Two unions of Netrokona and one unions of Madhupur have the options to implement RWHS although scarcity of drinking water prevails all over the study area. Household of other unions of Mymensingh, Madhupur and Durgapur prefers to have improved deep tubewell. The areas which have the potentiality of RWHS are relatively hilly part and dominated by different ethnic groups. Further rainfall in the study area varies slightly which is not significant in amount. So if the system is properly designed, it can provide adequate water supplies in most regions of the areas even during the dry season. It is, however, necessary to practice water conservation to ensure the success of rainwater harvesting, especially when it is the sole source of water supply.

4.30 Conclusion

Traditionally rainwater has been harvested in Bangladesh using earthenware pot, jar or motka. The introduction of hand pumps in the 1970s and the widespread installation of shallow well hand pumps through the private sector in the 80s and 90s, brought water close to the home in most part of Bangladesh but the fact remain as lowered ground water table, arsenic and iron becomes a inevitable part of water related issues in Bangladesh as well as in the study area. Even there is seasonality of rain water and some critical issues like social acceptability, quantity, and quality of water, maintenance and physiography. Considering all the realities, opportunity is still found during the analysis of demand and supply approach of RWHS. The proper management of rainwater can be used for drinking and cooking and can very well act as a safe substitute for the consumption of contaminated groundwater. An adequate collection surface with sufficient periodic rainfall will give sufficient water during the rainy period and some time beyond. The size (and cost) of storage and the capability to capture rain also provide the opportunity for alternative source of drinking water. In general rainwater in the study area is of good bacteriological and chemical quality as most of the roof of the household is build of corrugated iron sheet that is prerequisite for installation of RWHS. Construction of RWHS in household level by giving awareness training and raising awareness on the potential of rain water as an option for arsenic avoidance (source substitution), and explaining advantages, will create the opportunity of proper implementation and promotion of such types of services.

Safe water and sanitation are essential for the development of public health as well as other health issues. So the successful implementation of the system preferred by the community can made the provision of basic water supply services to the studied area. It will also increase the services and accessibility to all within the shortest possible time at a price affordable to all. It will also make behavioral changes regarding use of water and sanitation.

Chapter V: Conclusions and Recommendation

5.1 Concluding remarks

A set of technologies has been recommended for each union depends on the available hydro-geological information and according to the views of field personnel. However, these technologies have to be implemented systematically ensuring the participation of communities. According to the findings and recommendation the action research followed by ensuring the active participation of community can make the system successful. So proper knowledge and information have to gather from the action research and shall have to be provided to the community so that the option can meet the basic criteria of the water supply such as safe, adequate and reliable round the year. It is to be mentioned that if a technology is new for the particular area, utmost care should be taken for its implementation and replication. Some important options have to take care and monitor regularly. They are described below.

5.2 Quality control during construction

Quality of the construction works is very important for the sustainability of the water harvesting system. It should be ensured properly. Success also depends on follow up of the construction steps of the different components of the harvesting system like; construction of main reservoir, or tubewell, construction of cover, joining of wall, placing of wire mesh, plastering, fitting fixing drainage & delivery pipes, setting of gutter and flushing pipes, fixing the net in place etc. for the tubewell the proper assessment of place to install the tubewell and quality of construction materials is very important. After the completion of the construction work of the water harvesting system, proper monitoring and data collection is important to assess the sustainability.

5.3 Operation & Maintenance

Proper operation and maintenance is an important for the longevity of water harvesting system. Construction is not the last step. Regular operation and maintenance can make the system useful to the family. They process operates through following ways:

Table 13: Required maintenance for RWHS

RWHS	Tubewell
Clean the flushing system once in a week and keep clean the surrounding of the tank every day.	For tubewell the cleanliness of surrounding area is important.
Gutter and catchment should clean regularly (at least once a week)	Water collection points should clean regularly.
Flush the fist foul water 5-10 minutes depending on the intensity of rain. The first rain normally washes away the debris and dirt from the roof.	After two or three months the leaver and washer should clean so that the dust and other materials cannot dump inside the tubewell.
The tank cover should be kept closed so that flies & mosquitoes cannot enter into the tank. Sun light should be protected fully from entering the tank, as this would cause algae to grow inside the tank.	
Users should always follow up the RWHS so that children do not waste the stored water or damaged the parts of RWHS.	

Source: Compiled by author, 2011

5.4 Water Quality Monitoring

After the construction and operation water quality monitoring is important. During this time the water should be tested regularly. Water quality should be tested on seasonal basis to maintain the standard set by WHO. For the tubewell water iron and arsenic test is important for each tubewell.

5.5 Management of Stored Water

Proper management of stored water is very important to satisfy the requirement for the purpose it has been constructed. Because rainwater has a limitation and it can only be collected in the rainy days when it rains.

The experience regarding implementation of the technologies in the field will be helpful for upgrading the technological mapping and for proper application of the technologies.

5.6 Recommendation

The action research will give a proper insight about the whole system. So the research activities on water harvesting system need to improve according to the community feedback. Some models of RWHS need to apply in the community so that it can be popular among them. As tubewell system is popular in the community people show less interest to take the option by spending money. To make the rainwater harvesting system popular, subsidy should be given to install the system to the beneficiaries so that they can use it. Further research can put some modification and as well as develop the system more efficient.

On the other hand there are three un-served unions in Durgapur, four unions in Madhupur and six unions in Mymensingh where the research is much required. If it is possible to implement all over the areas, the community will be benefited as well as improve the access to the basic need of sanitation and hygiene components. It will also improve the wash activates and will be able to reduce the pressure on ground water.

In broader tern the options that need to be improved according to the community feedback. So the research and supports need area described below.

- Action research is a must for RWHS. The implementation of Rain water harvesting system in the area by action research, it is possible to bring out the community form the traditional practice of using tubewell. This will also help to recharge the ground water as well as reduce the dependence on tubewell and hygiene behavior.
- For implementing rain water harvesting system community need financial support. To make popularity of rainwater harvesting system subsidy is much more required so that community can easily take it and become inspired seeing others.

5.7 Conclusion

In most Unions of the study area rainfall is sufficient to make rainwater harvesting a reliable and economical source of water even during short-term droughts. Because rainfall is generally copious in the location where it will be used and the complex and costly distribution systems will be eliminated. But Successful and widespread integration of rainwater harvesting systems requires education, training to the community regarding its purity or quality, economic value and environmental benefits.

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Useful websites

1. Rainwater harvesting in pdf format- vedeo, courtesy of the city of Austin http://www.twdh.state.tx.us/assistance/%20conversation/conversation/rain.htm.
2. Rainwater harvesting in honduras - technical description the harvesting of water from the surface of roofs for domestic or agricultural uses is a technology. http://www.oas.org/sp/prog/chap5-1.htm
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4. Central ground water authority - the official web site of the central ground water authority of india provides a primer on rainwater. http://www.cgwaindia.com/
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Summary of Problem and need of verification (Tool pack for FGD)

Problems	Probability of Correlation with (Questions)	Verification need
Diarrhoea	• Water (Surface sources) • Contamination of ground water source may cause disease • Latrine condition and defecation practice • Hygiene practice • Seasonality of diseases • How long a person have to spend for illness	Analysis of Water Quality Parameters both Surface and Ground water (Physical, Chemical, Biological)
Skin diseases	• Water (Surface sources) • Latrine condition • defecation practice • Hygiene practice • Seasonality of diseases • How long a person have to spend for illness	Analysis of Water Quality, hygiene practice, defecation practice, latrine condition is needed.
Many household don't have own tube well and latrine and don't have access to safe water and latrine.	• From where they collect water. • Where the members of household defecate	From where they collect safe water or are this types of people use unsafe water and latrine.
Distance of water source	• Causes that make them use other source of water (Pond, lake, canal, river) • Time of water collection • Amount of water have to carry in each day • Does it impact on the health of the women or female members? • Is there any sexual harassment during water hauling	Physical verification and FGD is will bring the answer.
Use of unsafe water and unsafe water carrying elements (e.g. pots, jars, buckets).	• What types of jars, buckets, pots, and containers are used for water carrying? • Regularity of cleanliness. • Distance of tube well related to latrine and other susceptible sources of water like (Congested pond, canal)	Do the household use unsafe and unclean water hauling containers?
Seasonality of water	• Water Dry season. • During flood or rainy season. • Which source use?	Find the Seasonality of water, what source of water use in dry season.
Lack of Water, Sanitation and hygiene knowledge	• Types of latrine used by the family member. • Physical fitness of latrine.	Disease may cause form the damaged latrine. So verification is need to identify is people using the

	• Children defecation Practice • When child gets diarrhoea care givers only give ORS. Why don't they go for health service?	damaged latrine?
Lacking of Hand washing behavior	• hand washing behavior (After child defecation, before eating, before preparing food,) • what types of washing materials used (Soap, ash)	Need to verify the hand washing behavior.
Latrine condition and cleanliness	• Damaged or unsafe latrine may pollute the environment and people may affect. • Diarrhoea and skin disease may cause due to use of unclean latrine.	Area wise physical verification and analysis is needed. Need to understand the sharing facilities. Diarrhoea and other diseases may found in these particular households.
Gender discrimination	• In the case of water carrying and latrine cleaning about 80% female member of household is responsible where male has negligible participation. • Does it hamper the education of child especially female children.	Need to identify the causes.
Problem of waste management	• Household waste pollutes the environment and cause diseases.	Physical verification to identify the intensity of problem.
Lack of knowledge about water harvesting system	• Is the community familiar with any water harvesting system or process (if yes what types). • If no then why • What source and system of water is safe and affordable for them.	

Appendix A (FGD Tools Pack)

Water, Sanitation and Hygiene promotion in Banglades

Habitat for Humanity International-Bangladesh

Dhaka HRC (North)

Basic question for FGD

FGD with	Community people		Male	Female	Date:	
	Leader		Male	Female	Time:	
	Adolescent girls		Female		Place:	
	PNGO, Govt. representatives		Mix (Male& Female)			
Main objectives	**Objectives of the FGD**	**Informatio n we have already got**	**Causes**	**Does it have any negative effect on health or other sectors**	**What initiatives household take as alternatives to cope with the situation**	**According to them what is the best solution of the problem**
Main objectives of the FGD	What types of problems related to water prevails in the area					

Main objectives	**Objectives of the FGD**	**Information we have already got**	**Causes**	**Does it have any negative effect on health or other sectors**	**What initiatives household take as alternatives to cope with the situation**	**According to them what is the best solution of the problem**
Main objectives of the FGD	Find out the causes of Water born diseases (Diarrhoea, Skin diseases etc)	Diarrhoea and Skin Disease prevails in the study area				
		Lack of Water, Sanitation and hygiene knowledge				
		Some house hold use pond, lake and sometimes household have to travel more than 150 feet				

Main objectives	**Objectives of the FGD**	**Information we have already got**	**Causes**	**Does it have any negative effect on health or other sectors**	**What initiatives household take as alternatives to cope with the situation**	**According to them what is the best solution of the problem**
Main objectives of the FGD	Find out appropriate water harvesting system	Seasonality of water. Ask the question to find out is there any scarcity of water (Summer, winter) if yes then learn details				
		About 95% people use tube well water and no other water sources				

Main objectives	Objectives of the FGD	Information we have already got	Causes	Does it have any negative effect on health or other sectors	What initiatives household take as alternatives to cope with the situation	According to them what is the best solution of the problem
Main objectives of the FGD	Find out appropriate water purification system	No water purification system				
Cross cutting issues and objectives	Gender issues	81% female members are involve for house hold water carrying and for cleaning latrine				
	Latrine cleanliness	43% in Mymensingh and 32% in Durgapur clean their latrine once in a week and 21% in Mymensingh, 14% in Madhupur and 11% in Durgapur clean their latrine in a month				

Main objectives	Objectives of the FGD	Information we have already got	Causes	Does it have any negative effect on health or other sectors	What initiatives household take as alternatives to cope with the situation	According to them what is the best solution of the problem
Cross cutting issues and objectives	Health service	Only 5.11% house hold go for health services				
	Latrine conditions	In Madhupur and Durgapur 41.83% household use off set (Joint water seal) and 24.97% use off set (without water seal) latrine. Many people use pit and hanging latrine.				
		In Mymensingh 2.60%, in Madhupur 4.18% and in Durgapur 3.65% household don't have latrine				

Appendix B (Design & Costing)

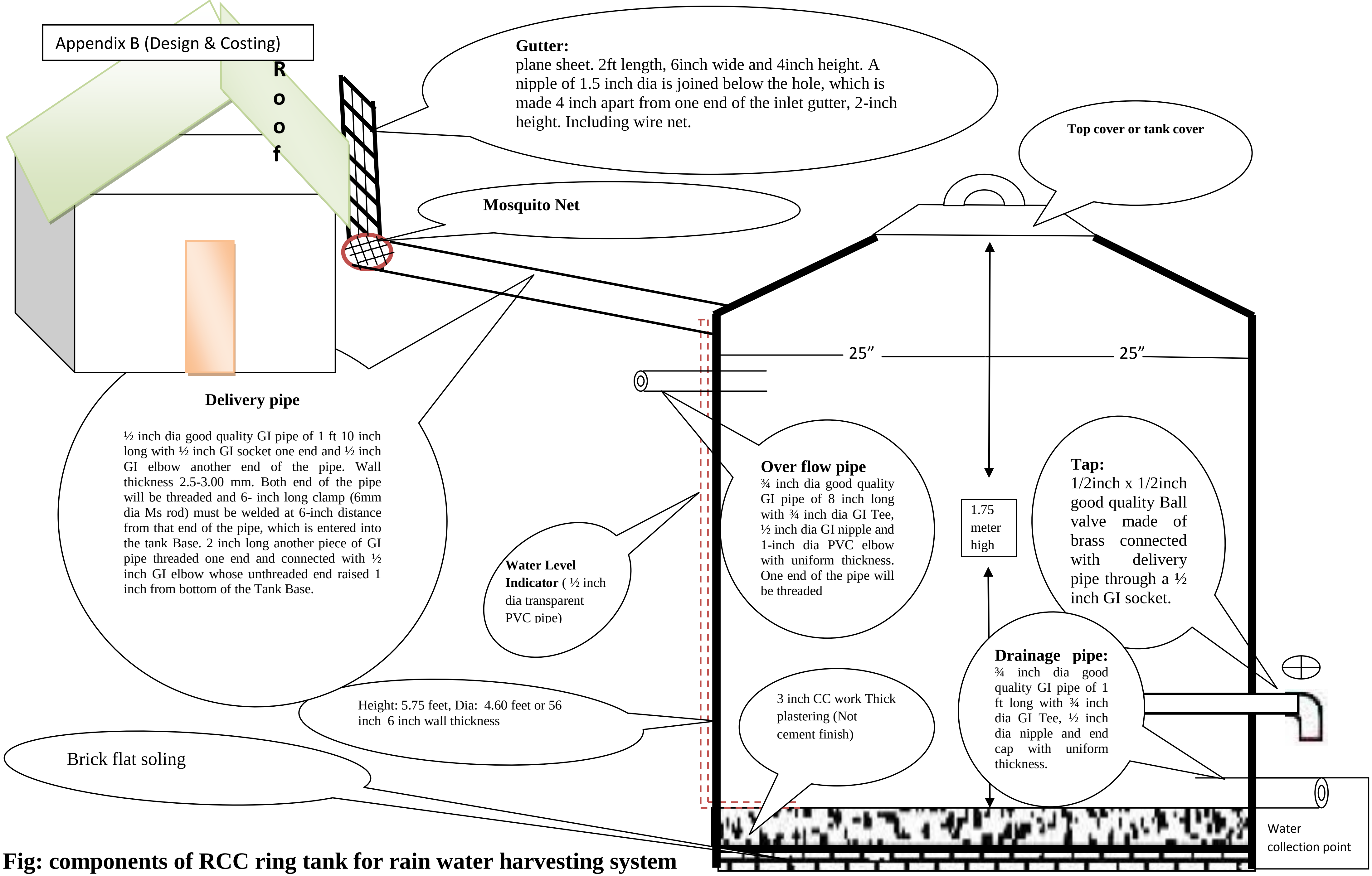

Fig: components of RCC ring tank for rain water harvesting system

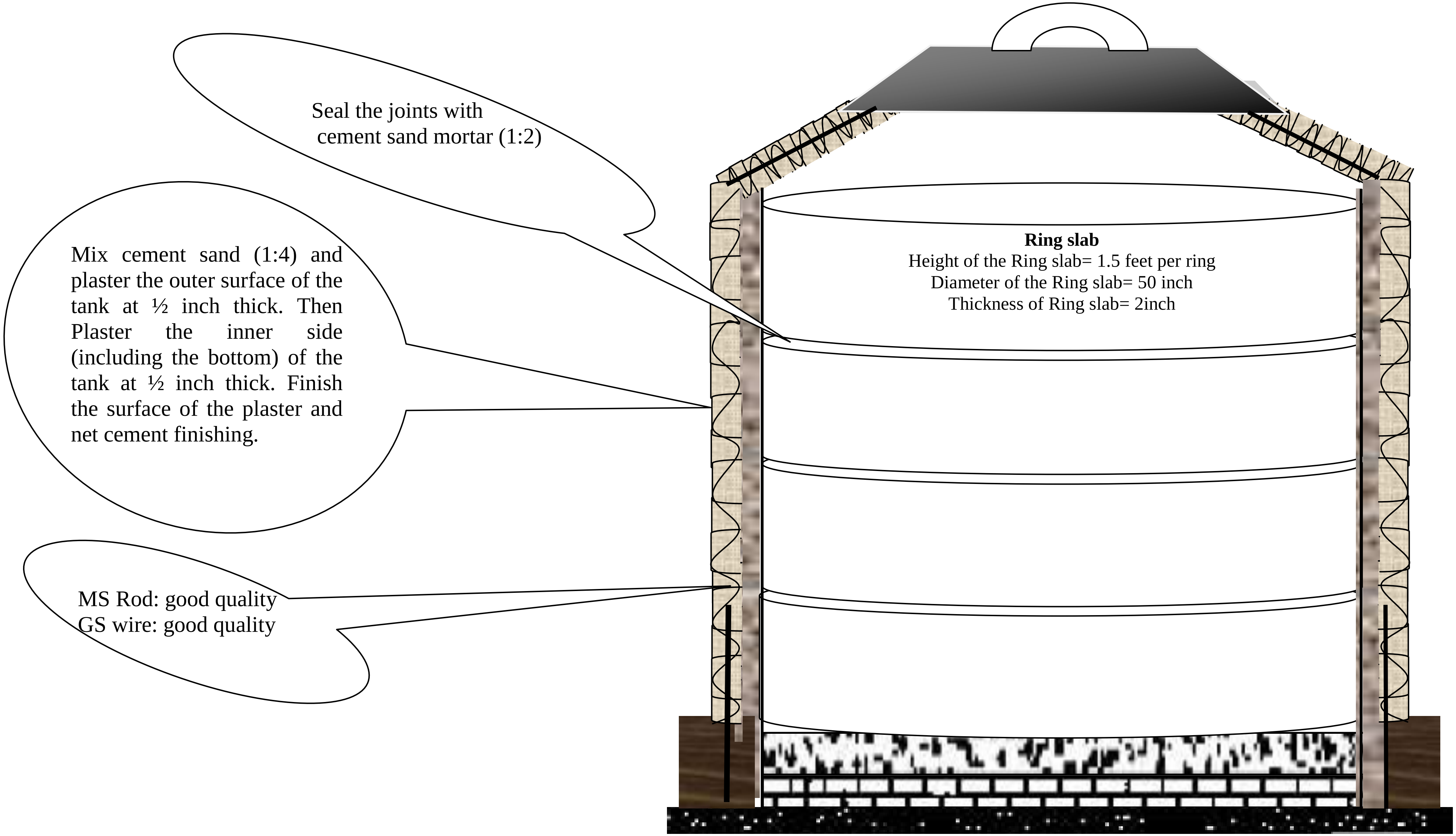

Fig: components of RCC ring tank for rain water harvesting system

Note: During the calculation for designing the RCC ring tank it is found that we need 50" diameter ring slab which is difficult to find in present market or from any other contractor. Local contractor normally build 36" diameter Ring slab for the latrine well/pit or (WaSH) activities. Two options is open for us

1. Collect RCC Ring form the contractor who builds the RCC Ring form the Roads and High ways department. They have the dice to build such Big (50") dia.
2. Or order to build a Forma/Dice for our research activates. It will cost 4000-6000 taka. If order such Forma/Dice, it will take 3-5 days to delivery.

Total cost of construction for rain water harvesting system

A Construction Materials

Item No.	Description of the material	Quantity	Rate (Tk.)	Amount (Tk.)
1.	**Cement:** Normal cement, 50 kg per bag, initial setting time 40-50 minutes and final setting time 8-12 hours	8 bags	400 /bag	3200.00
2.	**Sand:** Good quality local coarse sand. Free from clay, silt, organic matter and shells.	50 cft	15/cft	750.00
3.	**Brick:**First class Brick free from any defects. Cracking strength 5000-8000 psi.	150 nos.	9/no.	1350.00
4.	**Khoa:** Broken Brick of 1st class or picked, size from ¾ inch to ¼ inch of angular shape	5 cft	50/cft	250.00
5.	**Indicator:** ½ inch dia transparent PVC pipe, good quality.	6 ft.	30/ft	180.00
6	**R.C.C. Ring:** 4.16 ft inner dia, 1.5 ft height, 1.5 inch thick good quality R.C.C. Ring.	6 nos.	500/no.	3000.00
7.	**MS Wire:** No. 24# (3mm dia) good quality.	3 kg	100/kg	300.00
8.	**18 no. GI wire:** 18 no. good quality	2 kg	100/kg	200.00
9.	**Polythene:** Polythene with good quality.	6 yard	20/ yard	120.00
10.	**Gutter:** Made of Good quality plane sheet of ½ mm thick, length 6ft.	3 nos.	200/no.	600.00
11.	**Inlet gutter:** Made of good quality plane sheet. 2ft length, 6inch wide and 4inch height. A nipple of 1.5-inch dia is joined below the hole, which is made 4 inch apart from one end of the inlet gutter, 2-inch height.	1 no.	200/no.	200.00
12.	**Delivery pipe:** Best quality PVC pipe (as required)	1no.	200/L.S.	200.00

13.	**Tap:** Best quality Ball valve made of brass connected with delivery pipe through a ½ inch GI socket.	1no.	250/no.	250.00
14.	**Drainage pipe:** Best quality PVC pipe of 1 ft long with ¾ inch dia GI Tee, ½ inch dia nipple and end cap with uniform thickness. One end of the pipe will be threaded and 6-inch long clamp (6mm dia Ms rod) must be welded at 5-inch distance from the unthreaded end of the pipe.	1 no.	250/L.S.	250.00
15.	**PVC pipe:** 1.5 inch dia PVC pipe, wall thickness 2.5 –3.0 mm.	15 ft	15/ft	225.00
16.	**PVC elbow:** 1.5 inch dia PVC elbow, wall thickness 3.0-3.5 mm.	3no.s	50/no.	150.00
17.	**PVC Tee:** 1.5 inch dia good quality PVC Tee, wall. thickness 3.0-3.5 mm	1 no.	30/no.	30.00
18.	**Over flow pipe:** ¾ inch dia good quality GI pipe of 8 inch long with ¾ inch dia GI Tee, ½ inch dia GI nipple and 1-inch dia PVC elbow with uniform thickness. One end of the pipe will be threaded.	1 no.	120/L.S.	120.00
19.	**GI elbow and cap:** 1.5 inch dia good qualities GI elbow and cap in flushing system for water control.	1 no.	200/L.S.	200.00
20.	**Hanger for gutter:** Made of 6mm dia MS rod for gutter and used along the corner of the catchment. Average length of each 3 ft.	5 nos	200/L.S.	200.00
21.	**Mosquito Net:** Made of nylon good quality. with 2.5-f long and 8 inch wide.	As required	100/L.S.	100.00
22.	**Solvent cement:** Good quality solvent cement	L/S	200/L.S.	200.00
23.	**Others:** 26gauge GI wire, 12 feet MS Rod (9 mm.)Newspaper, thread tape etc.	As required	1000/L.S.	1000.00
Total				**13100.00**

B. Labor charges

Labor	**Day**	**Charge/day**	**Total (Tk.)**
Mason	5days	350	1750.00
Helper	5days	250	1250.00
Total			**3000.00**
Grand Total	**(A+B)**		**16100.00**

Construction process of RCC Ring Tank

Step –1: Preparing and construction of base

- Select a relatively high and hard palace of a house. Draw a circle with the dia of the tank base at the selected place and compact soil.
- Construct brick wall of 5" wide and 9" height. When the brick wall will become hard, fill home-sand (local) inner side of the wall in such a way that 5.5" remains empty from the top surface of the Brick wall. Pack layers to layer carefully during sand filling and damp with water.
- Level the upper surfaces of sand filling and lay flat brick soling. Mix cement concrete (Cement: Sand: Khoa = 1:2:4) and cast mixed cement concrete on Brick flat soling at 3 inch thick. Compact the concrete before setting with hammering by wooden patent.
- Install drainage and delivery pipe accordingly.

Step – 2: Construction of main body of tank

- Draw a circle with respect to the centre of base measuring the dia of the tank after setting concrete. Place cement mortar (1:2) along the line and place pre-cast or locally purchased R.C.C. Ring. Set 5 to 6 nos of khoa ½ "size on first Ring before placing second Ring on it according to figure.
- Seal the joints with cement sand mortar (1:2). In this way place the required number of Rings.

Step – 3: Plastering the surface of tank

- Mix cement sand (1:4) and plaster the outer surface of the tank at ½ inch thick. Then Plaster the inner side (including the bottom) of the tank at ½ inch thick. Finish the surface of the plaster and net cement finishing.

Step – 4: Construction of outer cover

- Penetrate a 9 mm dia MS rod into the soil of roughly plane and hard soil surface as if 375 mm remains the top of the soil. Mark at the height of 225 mm of the rod above the soil surface. Draw a circle of as per the measured dia with respect to the centre. Place lower dice of the outer cover along the line of circle. Pile sand inside the dice up to the mark of the rod.
- Place inner dice of the outer cover with respect to the rod and plane sand from the bottom of dice to the rod mark.
- Remove sand from the inside of outer dice about 1.5 inch width along the circumference and maintain sand sloping up to the bottom of inner dice according to figure.
- Compact sand carefully. Cutting & binding 3 mm dia MS wire and make frame. Cut wire mesh and bind on frame. During binding MS wire and wire mesh it should be kept in mind that MS wire and Net fall equally on the prepared sloping pile sand.

- Mount wires mesh and MS wire and again level sand. Lay newspaper sheets on sand and again check the placement of two dices with respect to the centre.
- Mix cements sand (1:3) and laid one layer of ½ inch thick on newspaper. Place the frame of MS wire and wire mesh on laid cement sand layer. Place MS wire and wire mesh on one layer of ½ inch thick mixed cement sand. And lay another layer of cement sand mixture.
- Place the middle dice to make collar of manhole in such a way so that equal distance remain within the inner dice. Pour cement sand mixture between the two dices. After ½ an hour leave inner dice at first, then the middle dice. Finishing the top surface with net cement finishing.
- After 2 days mount the cover and remove paper from the bottom of cover. Curing should be done regularly after 12 hours of casting.

Step – 5: Construction of top cover tank cover

- Fill the rest part of the central rod with sand of like a cone. The cone must start from the outer rim of the collar of lower cover. Cut and bind 3mm dia MS wire and make a cone. A layer of wire mesh should be cut and bind with GI wire on the cone. It should be kept in mind that the cone should fall equally on the prepared conical pile sand.
- Mount the Frame and level the piled sand. Cover the sand with wet papers. Before laying newspaper, cut and bind bark of banana tree or ½ inch thick newspaper sheet. Place the outer dice of upper cover in such a way that equal distance maintained in all sides from the collar of lower cover manhole. Lay cement sand (1:3) mixture on newspaper at ½ inch thick.
- Place MS wire and wires mesh conical frame on cement sand layer and place another layer of cement sand at ½ inch thick. Force in mixed cement sand into the frame with Trowel very carefully. Put another layer of cement sand mixture at ½ inches thick and then use finishing and net cement finishing.
- After 2 days mount lower and upper cover, remove newspaper and clean thoroughly. After 12 hours of moulding, arrange curing with fine.

Step –6: Setting of inlet and overflow pipe

- Place inlet and overflow pipe with 1½" dia at same level and one inch below the top of the main tank.

Step – 7: Cover placing of the tank

- Place the pre-cast cover on Tank, which was constructed elsewhere and seal the joint between cover and tank with cement mixture (1:2) well from both side.
- Place the cover after a day of plastering of both side of the tank.

Step – 8: Plastering of tank Base

- Clean gently of Brick wall of tank Base. Mix cements sand (1:4). Place a layer of cement sand mixture (1:4) with ½ inch thick and give net cement finishing.

Step – 10: Placing water collection point

- Construct water collection point with 75 mm thick brick wall. The inner dia of the collection point should be at least 1'-6", so that users easily collect water. 2" thick brick chips must be placed at the bottom of the point and cover with GI/ Ferro cement lid.

Source: (www.wateraid.org), Modified by Mahfuz