COST-BENEFIT ANALYSIS OF SUSTAINABLE RAIN WATER HARVESTING SYSTEM OF A RESIDENTIAL BUILDING OF DHANMONDI AREA AT DHAKA-1205

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A thesis submitted to the Department of Civil Engineering in partial fulfillment
for the degree of Bachelor of Science in Civil Engineering

Department of Civil Engineering
Sonargaon University
147/I, Green Road, Dhaka-1215, Bangladesh
Semester: Spring-2023
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BOARD OF EXAMINERS

The thesis titled "Cost-Benefit Analysis of Sustainable Rain Water Harvesting system of a Residential Building of Dhanmondi Area Dhaka-1205" submitted by Md. Noor Hossain Chowdhury (BCE1903018150), Md. Suman Ahamed (BCE1903018040), Shamima Akter (BCE1903018123), Sagorika Biswas Setu (BCE1903018087), Anamul Kabir (BCE1903018036) has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Civil Engineering on Date-of-Defense.

1. Md Lutfor Rahman — Chairman
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Dedicated

To

Our all lovely friends.

DECLARATION

This is to declare that, except where specific references are made to other investigators, the work embodied in this thesis paper is the result of investigation carried out only by the author under the supervision of Associate Prof. Md. Lutfor Rahman, Head of the Department, Department of Civil Engineering, Sonargaon University Bangladesh (SU). Neither the thesis nor any part of it has been submitted to any other university or other educational institution for a degree, diploma or other qualification.

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ABSTRACT

The study was conducted to develop and analysis cost benefit analysis of rainwater harvesting system of a residential building project from different types of system. Also find the optimal quality of the rain water.

Firstly we selected three rainwater harvesting system existing project in Dhaka city. After detailed analysis rainwater harvesting system (RHS) project at Dhanmondi, Dhaka a B+9 is seemed to be sustainable RHS. Water quality test of rain water and mixed ration of rainwater and tape water of pH value, Total dissolve solid, Conductivity and Chloride shows all values except chloride meet WHO guideline. Rain water thus needs to treat drinking purpose but it can be used for other purposes like toilet flushing, car washing etc.

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LIST OF ABREVIATIONS OF TECHNICAL SYMBOLS AND TERMS

SU	Sonogram University Bangladesh.
RHS	Rainwater Harvesting System.
RWH	Rain Water Harvesting.
MLD	Million Liters per Day.
HRWH	History of Rainwater Harvesting.
USGS	United State of Geological Survey.
B.C	Before Christ.
FF	First Flush.
UNEP	United Nations Environment Program.
DWASA	Dhaka Water and Sewerage Authority.
GWT	Ground Water Table.
INARS	Institute of National Analytical Research and Service.
BCSIR	Bangladesh Council of Scientific and Industrial Research.
BMD	Bangladesh Meteorological Department.
L/p/d	Littre per Day.
CSE	Center for Science & Environment.
WHO	World Health Organization.
BSTI	Bangladesh Standards and Testing Institution.
TW	Tape Water.
RW	Rain Water

Chapter 1 :INTRODUCTION

1.1Background

Dhaka, the capital of Bangladesh is the 19th mega city in the world with a population of over 17 million. With the rapid growth of the urban population the city is unable to cope with changing situations due to their internal resource constraints and management limitations. Water crisis has become an acute problem faced by the inhabitants of Dhaka city. It is found that the total water demand in Dhaka city is 2450 million liters water per day (MLD). Whereas supply is 2500 (MLD). About 87 percent of this supply comes from groundwater resources and the remaining 13 percent from surface water. For the huge extraction from the underground water source, the ground water table is declining day by day. It has been found that the current groundwater depletion rate is 3.52 m/y [1].Bangladesh has an emerging problem with water supplies not adequate to meet even the minimum requirements for potable water. Surface water is being continuously contaminated by both industrial and human pollutions; rapidly increasing demands due to population explosion results in withdrawal of ground water at a faster rate than it is replenished by recharge.

Rainwater harvesting, the long traditional wisdom, might be a solution to the problem. Rainwater harvesting means proper use of rainwater by storing for domestic uses & recharging groundwater table. Over the years, water crisis has become a severe problem of Dhaka city and the crisis twofold. One is acute water storage during summer with ground water depletion and other is, urban flooding in monsoon due to water logging. The scarcity of water has forced people to use contaminated sources of water, triggering a massive diarrhea outbreak in every summer, mostly affecting children. Ground water resources of the Dhaka mainly depends on the number of groundwater storage and the volume of annual recharge.

1.2 History of rainwater harvesting (HRWH)

Water, food, and shelter are a continuous struggle to provide, especially in dry climates where water is scarce. But to get rid of this scarcity of water from ancient time people think to invent methods. [2]

1.2.1 Ancient Rome

The Romans excelled in many technological advancements, including rainwater harvesting and aqueducts. They would build entire cities with the infrastructure to divert rainwater into large cisterns. The Romans would use this collected water for drinking, bathing, washing, irrigation, and for livestock.

They were master engineers. In fact, there is a rainwater collection cistern built to capture rainwater from the streets above in the Sunken Palace, Istanbul that remains to this day, and it is so large that you can sail in it. The age of rainwater harvesting has not reached its peak. Many farms continued to use rainwater cisterns for feeding livestock. And as technology developed in water treatment abilities, people started to use rainwater in their homes as the primary source of water yet again.

For the most part, development brings advantages, but there has been a side effect of increasing development that is depleting our natural underground water supply. In the water cycle, there is a critical step that must occur for the process to be effective-groundwater recharge.

Through the construction of roadways, cities, and increasing population in metro areas, water is being used, but no water is being replenished. Storm water is collected and sent into rivers and out to the ocean. Large amounts of water needs to reach the earth and be absorbed in the ground to replenish the natural underground aqueducts. And because this is not happening, water sources are drying up. According to the U.S. Geological Survey (USGS), groundwater depletion in the Chicago metro area has lowered the water level 900 feet.

Countries like Australia are taking steps to combat this by installing rainwater harvesting systems in homes. These systems use the rainwater captured from the roof, and overflow can be sent to groundwater recharge

In Israel, they are beginning to install rainwater harvesting devices in schools as a way of teaching kids the value of water conservation and in South Africa research is well under way to find new ways of employing catchment technology. [2]

1.2.2 Middle East

The Middle East has a rich history in the rainwater harvesting timeline. Dating back to 2000 B.C., people in the Negev Desert, which is modern-day Israel, survived by capturing water from the hillside and storing it in Cisterns.

Back then, water availability was truly a life or death situation. According to Heather Kinkade-Levario in Design for Water Rainwater Harvesting, Storm water Catchment, and Alternate Water Reuse, in tales of a war for the land east of Jordan, King Mesha of Moab used reservoirs to capture rain and gave his warriors the ability to survive in the dry heat.

In the civilizations, rainwater harvesting cisterns were common on a home by home basis, based on a historical document of that time in the Middle East. These cisterns would range from 10,000 gallons to 50,000 gallons, and would often be stored underground. Community cisterns were also common. They used technologies such as sediment traps prior to entering the large cistern, which could hold as much as 1,000,000 gallons of water. And even larger reservoirs would hold 11,000,000 gallons of water such as one in Madaba, Jordan. [2]

Bangladesh is a rain prone zone. During rainy seasons rain drops cats and dogs. Sometimes day long and continuous consecutive day rain occurs.

A study named **“Cost-Benefit Analysis of Sustainable Rain Water Harvesting system of a Residential Building of Dhanmondi Area Dhaka-1205”** was conducted by undergraduate students of Department of civil Engineering, **Sonargoan University of Bangladesh**. They estimated considering the building’s roof as catchment and found that the amount of water met the drinking purpose, the domestic and other uses. But they did not study the parameters of the rain water to use as drinking purposes.

1.3 Objectives

- ❖ To develop awareness about rainfall harvesting system.
- ❖ To develop sustainable rainfall harvesting system.
- ❖ To analyze cost benefit analysis of rainfall harvesting system.
- ❖ To determine optimal quality of rainwater harvesting.

1.4 Activity

The research is planned the cost-benefit analysis of sustainable rainwater harvesting residential building of dhanmondi, Dhaka city. Almost 3 building projects data were collected and considered these 3 building data for the study. Data store in MS word sheet, Excel sheet and notebook for the study. The software Auto CAD 2020 and MS Excel 2013 were used as the tools for this research. In the proposed study primary data were collected from different building holder in dhanmondi area. Also others data were collected different rainwater harvesting projects in Dhaka city for a pilot project. Initially a pilot project was carried out to identify the issue and finally a full survey was conducted. At first prepare a design for the pilot project. Then all probable cost element were identified by the pilot project. All materials collected from the market and construct the project within a short time.

1.5 Scope of the study

The specific study are:

- Conduct a preliminary survey in dhanmondi area building holder.
- Conduct meeting with these area building holder.
- Survey different RWH system project in Dhaka city.
- Analyzed these project data for the pilot project.
- Designed the rainwater harvesting pilot project for residential building.
- Estimation and costing of the study with recent rate for the pilot project.

1.6 Origination of the thesis

The thesis was presented in Six (6) chapter as follows:

Chapter 1: Gives the introduction which also includes background of the research, outlines the aims and objectives. It also states scope and method of their search briefly.

Chapter 2: Gives on overview of literature related with this work.

Chapter 3: This chapter describes the methodology adopted to carry out the research. This chapter also shows the research data collection and analysis process, discussion and finding.

Chapter 4: Gives the general overview of the principle of regression analysis.

Chapter 5: This chapter shows project result calculation.

Chapter 6: Contains the conclusions drawn from the research, the researcher's contribution to knowledge and recommendation for further research.

Chapter 2 :LITERATURE REVIEW

2.1 Introduction

Rainwater harvesting is a common practice in the countries and areas where the annual precipitation is high and pure drinking and usable water is scarce. All over the world, economical condition has prompted the low-income groups to harvest the rainwater for household and essential uses. Several countries of the world in different regions have showed the popularity of this method. Originated almost 5000 years ago in Iraq, rainwater harvesting is practiced throughout the Middle East, the Indian subcontinent, Mexico, Africa, as well as in Australia and United States. Demand of water both from surface and underground sources continually increases with the increase in world population, leading to a consequence of crisis of water supply in different regions. Among other available alternative sources for water supply, rainwater harvesting has become the most economical solution for the water crisis. [3]

Studies and experiments have been done to establish the portability of rainwater 2, 3, 4. Composed in a comprehensive system, rainwater harvesting yields several benefits. Krishna indicates that the most important benefit of rainwater harvesting is that it is totally free; the only substantial cost involves storage.

Increased awareness on water crisis has led rainwater harvesting to be proposed as a community facility. For example, small and medium residential and commercial constructions in the United States have shown increasing interest in rainwater harvesting since 1996. Cities and states around the world are adopting rules related rainwater harvesting, especially in United States.

Kenya has successfully adopted rainwater harvesting systems [3]. Kenya Rainwater Association uses low cost technical options to build the systems through community based organizations. A combination of improved health awareness and benefits from clean and safe water and resulting income from sale of surplus farm produce gives rise to an increased willingness of people to pay for improved housing and water supply. A study by Mutekwa and Kusangaya indicates a successful adoption of RHS technologies in Zimbabwe that has contributed to alleviate problems faced by resource poor subsistence farmers. Benefits of RWH technologies include an increase in agricultural productivity, enhancing household food security and raising of incomes. The technologies also have assisted in improving environmental management through water conservation, reduction of soil erosion and resuscitation of wetlands in the study area. The study concludes that RWH technologies are suitable for smallholder farmers in semi-arid areas provided they are properly tailored the conditions of the region where they are promoted. Other benefits of adopting RWH include improvement of people's standard of living and reduction in environmental degradation. [3]

2.1.1Practice in Bangladesh

Bangladesh used the surface water as the principal source for drinking water up to the recent past. But nowadays, withdrawal of groundwater has become norm. One of the major problems with groundwater is arsenic contamination. Almost 50 percent of the country suffers prom this contamination. Figure-1 shows the alarming scale of the problem in Bangladesh.

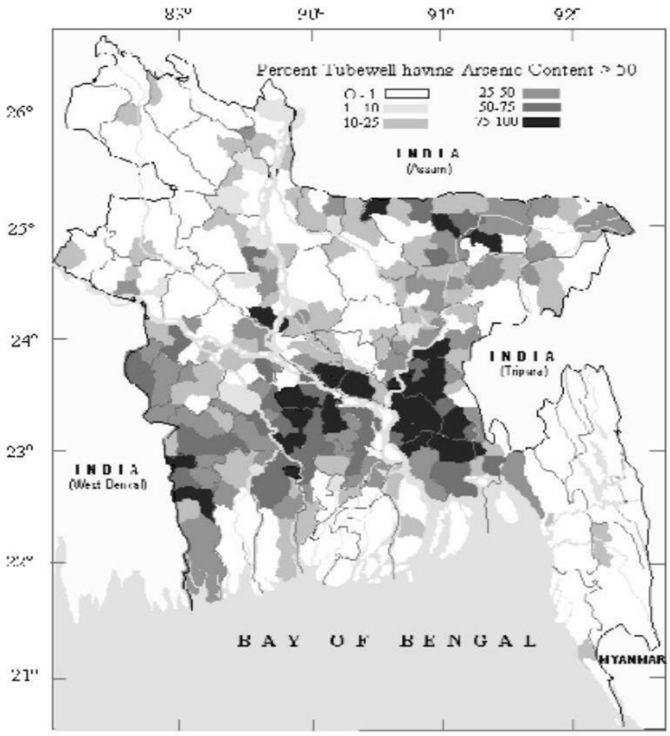

Figure 2-1: Arsenic Contamination of Groundwater in Bangladesh

Rainwater is almost a free source of pure water and RWH inferred to collection and storage of rainwater aimed at harvesting surface and groundwater. It also includes the prevention of losses through and seepage all other hydrological and engineering intervention. In general water harvesting is the activity of direct collection of rainwater. The collected rainwater can be stored for direct use or can be recharged for developing the GWT. As rain is the first form of water in the hydrologic cycle, it's also become the primary source of water for us.

Rivers, lakes and ground water are all secondary sources of water. Now we enormously depend on such secondary sources of water. The process is generally involve with the forgotten that rain is the ultimate source that recharged all secondary sources. Water harvesting means creating the optimum use of rainwater at the place where it falls so as to attain the self-sufficiency in water supply without being depends on to the remote water sources. Cities get lot of rain, but yet cities are facing water deficit. The only reason behind that is people are not reflected enough to the value of raindrop. At present the global average rainfall is estimated as 800 mm. However this rainfall occurs in very short spells of time with a probably high intensity. These short time period and high intensity rain falling on the surface flow away rapidly, leaving a little amount to recharge groundwater table. It has noticed at cherrapunji, India that an average rainfall of 11000 mm per year still creating the shortage of drinking water. That is why it does not matter that how much rain falling in the place, if it's not captured. RWH may be a solution to solve this problem by capturing the run-off.

Being a tropical country, Bangladesh receives heavy rainfall during the rainy season with an average annual rainfall of 2450mm. This amount makes rainwater harvesting an obvious solution for the country.

The ever-increasing population in Dhaka, the capital of Bangladesh, is putting increased load on underground aquifers. Dhaka receives an annual rainfall of about 100 inches which can easily be an answer to the vertical recharge for the aquifers. Rainwater harvesting has also the promise of facilitating the consumers with some additional benefits such as reduction in the scale of seasonal flooding and water logging.Rooftops in buildings may be designed to collect rainwater solving the challenging issues of minimizing the storage cost and management. If the system is incorporated in the design and construction process of buildings, cost of such a system could be very minimal.

2.2 Rainwater Harvesting Technology

2.2.1 Catchment Surfaces

Unlike conventional water supply system, which is either dependent on groundwater or on stream flow, rainwater harvesting is totally based on the availability of water from precipitation. It has to be intercepted first in order to make it available for consumption. The quantity of water that can be harvested depends on the

- Amount of rainfall and the size of the catchment area.

- Types of area (if its making by RCC water storage rate more, if its making by dew tin water storage rate is poor, if its making by Husk (Dry grass) water storage rate is very poor

2.2.2 Separation of Sediments

When rainwater is collected from roof, the first consignment of water contains dust, debris, bird droppings, or other sediments. This should be separated from the supply before it is stored. Simple, automatic systems are available for diverting this water (called first flush (FF) diverter) that can be easily installed with a rainwater catchment system (see Figure 2).

It consists of a ball float and a pipe chamber. When the rain starts to fall, it drains through a screen and accumulates together with any debris in the pipe chamber. As the chamber fills, the ball floats on the surface of collected water. Eventually the ball becomes stuck at the intersection between the first flush device and the pipe that leads to the storage tank. Thus water is redirected subsequent toward the storage tank.

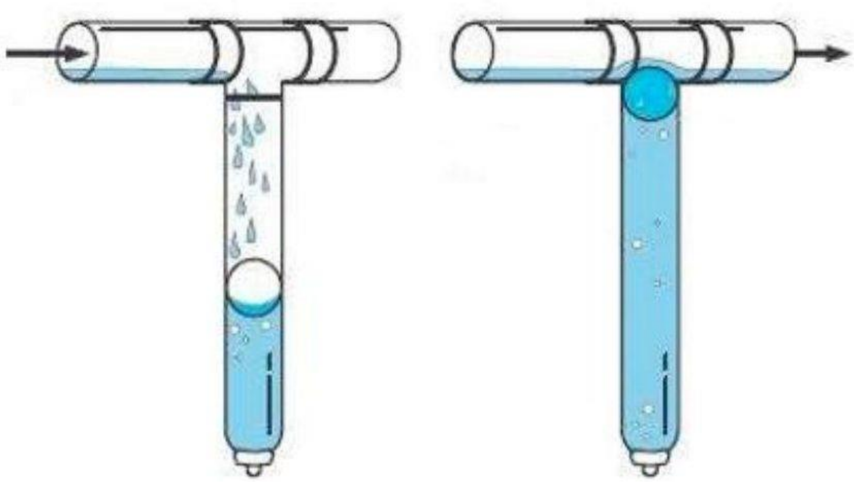

Figure 2-2: First flush (FF) device

2.2.3 Storage of Rainwater

Quantity runoff from a catchment area is dependent upon the amount of precipitation. Since it is intermittent in nature, storage must be an integral part of a rainwater harvesting system. Storage facilities can either be below or above ground depending on site conditions and other factors. The cistern or tank selected should be completely covered in order to prevent health hazards and loss of water due to evaporation.

2.3 Concept of Rainwater harvesting in city areas

However, Rainwater harvesting is a technique used for collecting, storing, and using rainwater for potable and various non-potable uses and the rainwater is collected from various hard surfaces such as rooftops and/ or other types of man-made above ground hard surfaces (Rainwater Harvesting, Dublin city council). There are generally three components in any rainwater harvesting system include catchment, conveyance, filters, and storage.

In urban or city areas, rainwater harvesting can be done mainly in two ways: one is surface runoff harvesting, and another is rooftop rainwater harvesting.

2.3.1 Surface runoff harvesting system

landscapes, open fields, parks, gardens, roads and pavements, driveways and other available open areas of the environment is used to harvest the rainwater.

2.3.2 Rooftop rainwater harvesting system

Rainwater is captured from roof catchments, and stored in reservoirs, and it is can be harvested in city's household buildings, offices, factories; particularly, where adequate land spaces are not available. And in this regard, according to the United Nations Environment Program (UNEP), some cities around the world have already best examples of rainwater harvesting and its utilization including Singapore, Tokyo, Berlin.

2.4 Rainwater harvesting in Dhaka city: the need of the hour

Dhaka is the 11thlargest megacity in the world which is the home to more than 18 million people, and its population size is estimated to have reached more than 27 million in 2030. [4] Since the independence of the country, the population of Dhaka city has increased more than 10 folds due to the rapid urbanization, growth of informal settlements, and industrialization in and around the city. Like many other utilities and services crisis, and problems (i.e. electricity, gas, traffic congestion, municipal solid waste collection, and management etc.) in the city, water scarcity is the ones that the dwellers in several parts of the city are severely facing this problem almost round the year over the decades. And each year, the situation is going from worse to worse.

Though Dhaka Water and Sewerage Authority (DWASA) continues to make several efforts and initiatives to bring the situation under control, it is not being much able to deal with the ever-rising water demand resulting in rapid growth of population in the city.

And most shockingly, the city exclusively depends on the groundwater for meeting the water demand need for its dwellers as the most of the existing surface water sources (i.e. ponds, rivers, lakes, etc.) in the city have lost its natural state in terms of physical, chemical, and microbiological composition because of indiscriminate discharge of industrial effluents, household wastages into them, and finally they have turned in to large drains. In the city, groundwater extraction is solely responsible for meeting over 80% of the water demand whereas, the remaining demand is trying to fill up by treating the surface water. But, this extensive dependency and over-pumping of groundwater for meeting the water need of city dwellers, factories, and commercial establishments have caused severe groundwater level depletion, and which in turn causes the water severe. Water scarcity in the city particularly, in the dry seasons.

As per the DWASA's annual report 2014-15, the groundwater level is declining by 2-3 meters per year because of continuous over-extraction of water. Against this backdrop, rainwater harvesting can be a sustainable solution to mitigate both severe groundwater depletion problem and water demand crisis in the city.

Like many areas in Bangladesh, Dhaka city is also blessed with rain, receiving a plenty amount of rain water annually which is from May month through until the end of September month, while particularly the months of April, June, July, and August bring the highest amount of rainfall, having about 20-25 rainy days with average monthly rainwater of 300mm-340mm (World weather & climate, Bangladesh information, 2017). In these months, rainwater can be harvested in the city, and harvested rainwater can be stored properly (for 4-5 months) for later use. It is also stunning to note that this year in the month of April; Dhaka city has experienced a record amount of rainfall (i.e. around 9,000 mm in the first three weeks of the month) in 35 years.

Therefore, in Dhaka city, considering the natural blessing of rainfall, and the inadequate availability of land spaces, rooftop rainwater harvesting can be the best and sustainable water supply option for its households, offices, commercial and industrial establishments, particularly in the time of an emergency situation (i.e.in the event of the breakdown of supply water) or drought times. And, from this perspective, it is now the need of the hour.

2.5 RWH Practice in different countries

2.5.1 RWH in Bangladesh

In recent years, Bangladesh used surface water as the main source of the potable drinking water. As a developing country, Bangladesh is quite familiar with the term of RWH but yet the practice is a little bit obsolete through the country. At present, around 36% of the households especially in coastal belt of the country use this technique. Bangladesh receives a heavy amount of rainfall tentatively 95" in depth, which is very helpful to generate RWH. Further due to increasing pressure on the underground aquifer as a result of vastly growing population, RWH would be a good way to solve this increasing demand. Reception of an annual rainfall of 71"-80" in Dhaka city become a key to solve the present decreasing of GWT of Dhaka city. In last decade, the GWT in Dhaka city lowered almost 65'. RWH also releases the people from some water related problems such as flood problem, water logging etc. For above reasons, RWH is considered as an alternative option for the water supply. But one of the disadvantages of this method is that it's sometimes burdensome for low income people hence rooftops of the building can be designed to collect rainwater solving the challenging issues of minimizing the storage cost. During initial stage, the budget allocated for the RHS system should be minimize. [5]

2.5.2 RWH in Bangalore

Bangalore, a city of over 270 lakes and tanks, is now down to 80 or thereabouts. The city is located at 920 meters above sea level. The decline in ground water levels as well as the effects of pollution with nitrates poses a threat. The Bangalore Water Supply and Sewerage Board manages water supply to the city. Two major sources are the River Arkavathy and the River Cauvery. The latter is now the predominant source but is located 95 kilometers away and about 500 meters below the city necessitating huge pumping costs and energy usage. As loss of water is high, there is a large section of the population dependent on ground water through bore wells. Nearly 3000 million liters per day of rainwater is incident on the city of Bangalore with area of 1279 square kilometers. This is in contrast to approximately 1500million liters per day which will be pumped in after the completion of two augmentation projects under implementation. The study points out that about 20 per cent of the city's water requirement can be met through rainwater harvesting provided a strategy is put in place to persuade owners to go in for rooftop rainwater harvesting and also if surface storage structures like lakes and ponds are maintained well. [5]

2.5.3 RWH in Brazil

In Brazil, over the past decade, many NGOs and grassroots organizations have focused their work on the supply of drinking water using rainwater harvesting, and the irrigation of small-scale agriculture using sub-surface impoundments. In the semi-arid tropics of the north-eastern part of Brazil, annual rainfall varies widely from 200 to 1,000 mm, with an uneven regional and seasonal rainfall pattern. People have traditionally utilized rainwater collected in hand-dug rock catchments and river bedrock catchments [5]

2.5.4 RWH in Germany

In October 1998, rainwater utilization systems were introduced in Berlin as part of a large scale urban redevelopment, the DaimlerChrysler PotsdamerPlatz, to control urban flooding, save city water and create a better micro climate. Rainwater falling on the rooftops (32,000 ㎡) of 19 buildings is collected and stored in a 3500m3 rainwater basement tank. It is then used for toilet flushing, watering of green areas (including roofs with vegetative cover) and the replenishment of an artificial pond. In another project at Belss-Luedecke-Strasse building estate in Berlin, rainwater from all roof areas (with an approximate area of 7,000 ㎡) is discharged into a separate public rainwater sewer and transferred into a cistern with a capacity of 160 m3, together with the runoff from streets, parking spaces and pathways (representing an area of 4,200 ㎡). The water is treated in several stages and used for toilet flushing as well as for garden watering. The system design ensures that the majority of the pollutants in the initial flow are flushed out of the rainwater sewer into the sanitary sewer for proper treatment in a sewage plant. [5]

2.5.5 RWH in Hawaii, USA

At the UJ.S. National Volcano Park, on the Island of Hawaii, rainwater utilization systems have been built to supply water for 1,000 workers and residents of the park and 10,000 visitors per day. The Park's rainwater utilization system includes the rooftop of a building with an area of 0.4 hectares, a ground catchment area of more than two hectares, storage tanks with two reinforced concrete water tanks with 3,800m3 capacities each, and 18 redwood water tanks with 95m3 capacities each. Several smaller buildings have their own rainwater utilization systems as well. A water treatment and pumping plant was built to provide users with good quality water. [5]

2.5.6 RWH in Africa

Although in some parts of Africa rapid expansion of rainwater catchment systems has occurred in recent years, progress has been slower than Southeast Asia. This is due in part to the lower rainfall and its seasonal nature, the smaller number and size of impervious roofs and the higher costs of constructing catchment systems in relation to typical household incomes. The lack of availability of cement and clean graded river sand in some parts of Africa and a lack of sufficient water for construction in others, add to overall cost. Nevertheless, rainwater collection is becoming more widespread in Africa with projects currently in Botswana, Togo, Mali, Malawi, South Africa, Namibia, Zimbabwe, Mozambique, Sierra Leone and Tanzania among others. Kenya is leading the way. Since the late 1970s, many projects have emerged in different parts of Kenya, each with their own designs and implementation strategies. These projects, in combination with the efforts of local builders called "fundis" operating privately and using their own indigenous designs, have been responsible for the construction of many tens of thousands of rainwater tanks throughout the country; where cheap, abundant, locally available building materials and appropriate construction skills and experience are absent; Ferro-cement tanks have been used for both surface and subsurface catchment. [5]

2.6 Advantages of Rainwater Harvesting

- Easy to Maintain:
- Reducing Water Bills:
- Suitable for Irrigation:
- Reduces Demand on Ground Water:
- Reduces Floods and Soil Erosion:
- Can be used for Several Non-drinking Purposes:
- Rainwater for drinking purpose:

2.7 Disadvantages of Rainwater Harvesting

- Unpredictable Rainfall
- Initial Cost is more
- Regular Maintenance is required
- Certain Roof Types may Seep Chemicals.
- Full rainwater cannot possible to harvest.

2.8 Potential of RWH

All the water falling over an area cannot be effectively harvested due to the various losses like evaporation, spillage etc. The amount of water received in the form of rainfall over an area is called rainwater endowment of that area. The amount that can be effectively harvested is called rainwater potentiality. The quantity of rainwater which can be effectively harvested is always less than the amount of rainwater endowment.

The efficiency is mainly depends on to the run-off coefficient and first flush wastage. The most important terminologies of rainwater harvesting potentiality are generally-

2.8.1 Rainfall

Rainfall is most unpredictable variable in the calculation of RWH. It is better to use rainfall data from nearest station with comparable condition. The number of annual rainy days also influence the need and design for rainwater harvesting. If the dry season is too long big storage tanks would be needed to store rainwater. As a result, it's more feasible to use rainwater to recharge aquifers than storage.

2.8.2 Catchment Area

The characteristics of the catchment area determine the storage condition. All calculations regarding the RWH of a catchment directly involve the run-off coefficient. To account the losses, consider reducing the amount of run-off.

A general relation between water harvesting potential, amount of rainfall, catchment area and run-off coefficient is:

Water harvesting potential=rainfall (mm) X area of catchment X run-off coefficient or Water
Harvesting potential=rainfall (mm) X collection efficiency.

2.9 Storage of RWH

The storage container (cistern, tank) is often the most visible or recognizable component of a RWH system. It is where the captured rainwater is diverted to and stored for later use. The main goal of the storage tank is safety. It should store water that is safe to use, and it should be secure so that children or animals cannot access the tank. There are several topics related to storage containers and you should go through each before making a decision on purchasing one. Please see each topic below.

2.9.1 Storage Container

Safety for the User

The main goal of safety for the user is good water quality. For a storage tank to maintain good quality water, it must not allow for any light penetration. Sunlight entering the tank causes algae growth. Also, the tank must be properly screened and secured so that no insects or animals can enter. For detailed treatment information, see the Treatment section.

Tank Material

There are several materials available for a storage container.

(i) Corrugated Steel and Enclosed Metal

Corrugated steel tanks are often used because of their availability, price, and aesthetic value. They can range in sizes from a few hundred gallons to tens of thousands of gallons.

The large corrugated steel tanks are usually the support structure for a vinyl bladder on the inside which actually stores the water. The roof of these tanks, often conical, is usually not made strong enough to be walked on, so avoid getting on top of the tank. Because of their size, these tanks are usually assembled on-site.

An enclosed metal tank is typically prefabricated and assembled off-site. The tank is sealed on the inside with a potable water approved liner or sealant. They are often more expensive than the corrugated tanks because they need to be shipped as a whole unit. The example on the left is galvanized steel.

Figure 2-3: Storage container (Steel) [6]

(ii) Concrete

Concrete tanks are durable, strong, and heavy. They can be installed above ground or below ground. There are two common types of concrete storage containers: Ferro-concrete and monolithic-pour concrete. Ferro-concrete is a relatively new approach where a special concrete mixture is sprayed on directly applied on a metal frame. This type of approach is common in developing nations. Monolithic-pour concrete tanks are either poured in place or prefabricated and assembled on site. An advantage to concrete is that they can raise the pH of the stored water. (Rainwater is naturally acidic, so it actually neutralizes it)

Figure 2-4: Storage container (Concrete) [6]

(iii)Polyethylene and Polypropylene (Plastic)

Plastic tanks are the most common material used for residential RWH systems in Texas. This is because they are lightweight, come in many sizes and colors, and can are affordable. Polyethylene is flexible plastic and polypropylene is a rigid plastic. Both can be translucent or opaque. An opaque, solid color is better for reducing the chances of algae growth.

Figure 2-5: Storage container (Plastic) [6]

2.9.2 Inlets, Outlets, and other Openings

The storage container of every RWH system must have an inlet, outlet, overflow, vent, and inspection or service port. If multiple tanks are connected, there can be modifications to these requirements

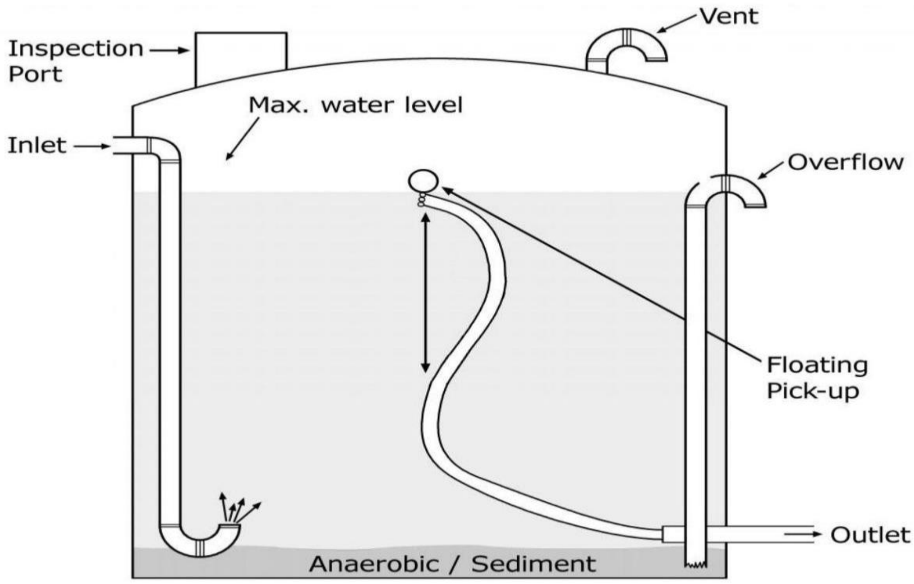

Figure 2-6: Storage container [6]

(i)Inlet

The inlet is where the water goes into the tank from the conveyance system. It can go into the tank through the large opening on the very top of the tank or can be directed in from the side of the tank near the top (as shown in this image). An important characteristic to this component is having a calming inlet (as seen at the bottom of the image). This prevents incoming water from disrupting any potential sediment at the bottom of the tank.

(ii) Outlet

The outlet is where the water leaves the storage container to go to the point-of-use. In most RWH systems, the water will be drained from the bottom. This is acceptable as long as it is at least 4 inches from the bottom (to avoid draining sediment). An alternative to the bottom outlet is a floating tank pickup which drains water from the top 4 inches of the water level by using a float ball and mesh screen. These devices are commercially available or can be easily homemade.

(iii) Overflow

Regardless of how big your storage container is, you need to plan for overflow. This is any excess water that may occur during heavy rain events. The overflow usually drains directly from the top of the tank. However, as show in this image above, the overflow can be drawn from the bottom (remember there must be a hole in the top of the gooseneck to prevent a siphoning effect). The overflow must be slightly below the level of the inlet.

(iv)Vent

Vents are necessary so that a vacuum situation does not occur during a rain event. Vent and overflows need to be equipped with a screen or other device to prevent entry of mosquitoes and small animals.

(v) Inspection Port

The inspection port is the large opening at the top of most storage containers. It allows the user or maintenance provider access to the inside of the tank (remember Safety regarding tanks). In many RWH systems, this inspection port is used as the inlet of the tank, and there are basket screens which fit perfectly into these openings.

2.9.3 Storage tank design

The principles of the storage tank design depends on several factors such as-

- Number of persons in the household
- Per capita requirements
- Average annual rainfall
- Rainfall pattern
- Type and size of catchment
- The design of the storage tank, can be done using following three approaches: Matching the capacity of the tank to the area of the roof.
- Matching the capacity of the tank to the quantity of water required by its user.
- Choosing a tank size that is appropriate in terms of costs, resources and construction methods.

2.9.4 Filter

When the collected rainwater is generally used for drinking purpose, a water filter should provide before the construction of storage tank. The filter is used to eradicate the harmful pollutants from the collected rainwater from roof. It's a chamber generally consists of a chamber filled with filtering media such as fiber, coarse sand and gravel. Before entering the storage tank, these mediums remove the majority of impurities and debris. There are various types of filters which have been developed all over the country. The type and selection of the filters are generally depends upon the usage of harvested water. Depending upon the filtering media various types of filters are named below-

- Sand filter.
- Charcoal water filter.
- Slow sand filter.

2.10 Aquifer recharge

Artificial recharge of the ground water is a technique by which ground water reservoir is augmented at a rate exceeding the obtaining under natural condition. Any type of man-made facilities that connected to an aquifer can be considered to be artificial recharge system. To make it sure that rainwater percolating the subsurface rather than to flow away from the surface, various types of recharge structures are available. Trenches and permeable pavement encourage the percolation of water through soil strata at a quite lower depth. Recharge well, another type of recharge structure can carry water to a greater depth from where it join to the ground water. In some cases it's more appropriate to modify al the existing recharged structure rather than creating some new structures. In a country like Bangladesh it's not possible to spent huge amount of money for this purpose, so it's more appropriate for us to develop the current recharge system. Rainwater may percolate to the ground water aquifers through dug wells, bore wells, recharge trench etc. The main techniques of artificial aquifer recharge are:

Figure 2-7: Gutters and Down take pipe [7]

Figure 2-8: Main elements of a guttering system [7]

Chapter 3 :METHODOLOGY

3.1 Introduction

Rainwater harvesting is one of the feasible options of fresh water sources in the coastal areas of Bangladesh and recently a lot of initiatives and programmer were undertaken to promote and install rainwater harvesting systems both in the coastal and arsenic affected areas in Bangladesh. Moreover, every year the country is also blessed with ample rain. The average annual rainfall in Bangladesh is about 2200 mm, seventy-five percent of it occurs between May and September.

Dhaka Water Supply and Sewerage Authority (DWASA) have shown that rainwater is free from arsenic contamination and the physical, chemical and bacteriological characteristics of harvested rainwater represent a suitable and acceptable means of potable water. In urban areas, at a household level, rainwater can be used for flushing toilets, watering gardens and washing floor and these uses are known as non-potable. While in rural areas, it becomes the main source of water for potable uses which include drinking, bathing, and cooking.

In order to provide a rationale for adopting rainwater harvesting systems for Bangladesh, it is necessary to find out (1) the extent of treatment required to make the water potable, (2) overall savings and (3) Sustainable if any, to the consumers when they switch either partially or completely to supply from this source.

Sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." Simply put, sustainability is the ability to retain or maintain something at a certain rate or level. This could be applicable to absolutely anything, from weight loss diet to the environment and Planet Earth. Sustainability can be perceived in different ways. It used in many sectors worldwide to successfully improve social & environmental performance.

3.2 Different method RWH Project in Bangladesh

3.2.1 First Flush automatic sensor based harvesting system project at INARS & BCSIR

Development of a fabricated first-flush rainwater harvested technology to meet up the freshwater scarcity in a South Asian megacity, Dhaka, Bangladesh.

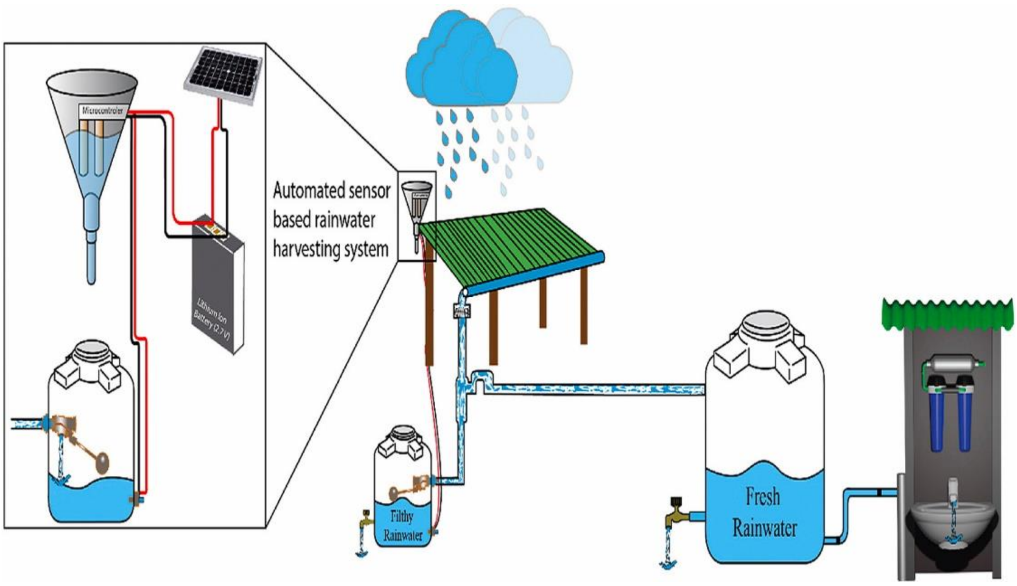

Figure 3-1: Process diagram of harvesting system project at INARS & BCSIR [8]

Figure 3-2: Fabrication of this rainwater harvesting system project (RHS) [8]

Table 3-1: Cost of this rainwater harvesting system project (RHS) for 1000 sft. Catchment area [8]

Sl·No.	Item	Material and Quantity	Unit Cost ($)	Total Cost ($)
1	Rooftop/Shed	PVC (3mm), (1000 sq. ft)	0.32	320.00
2	Collecting Pipe	PVC (110mm), (10m)	0.70	7.00
3	Solar Panel	12V, 20W, (1 pcs)	13.42	13.45
4	Sensor	Custom made (1 pcs)	20.00	20.00
5	Debris Filter	Polypropylene (1 pcs)	5.00	5.00
6	Diverter Pipe	PVC (1 pcs)	3.00	3.00
7	Floating Valve	Plastic and Steel (1 pcs)	5.00	5.00
8	Water Tap	PVC (3 pcs)	3.00	9.00
9	Solenoid Valve	Copper (1 pcs)	16.00	16.00
10	Storage Tank 1	PVC (200L) (1 pcs)	20.40	20.40
11	Storage Tank 2	PVC (1000L) (1 pcs)	75.15	75.15
12	Submersible Pump	24V DC (1 pcs)	5.00	5.00
13	UV-C Filter	24V DC (1pcs)	20.00	20.00
14	Sediment Filter	Polypropylene Fiber (1 pcs)	10.00	10.00
15	Carbon Filter	Activated Carbon (1 pcs)	10.00	10.00
Total				539.00

3.2.2 First Flush manual based harvesting system project at Adabor Dhaka

Project location

Prof. Dr. Md Abdul Jalil

House #28, Road #3, Block #C, Monsurabad residential area, Adabor Dhaka

Description

6- Storied rooftop harvesting system with RCC catchment area. From roof to underground water tank connect by 100mm UPVC pipe for harvest rainwater.

Used one manual operating valve for first flush. Also used an extra water tank for storage rain water.

Total cost of this project BDT 79800.00 (Seventy Nine Thousand Eight Hundred) only. [9]

Figure 3-3: Project view at Adabor

Figure 3-4: Roof top catchment area of this project

Figure 3-5: Roof top catchment area of this project

3.2.3. Aquifers recharge rainwater harvesting system at Shyamoli, Dhaka

Project location:

Polli Kormo-sohaok Foundation

House #23/5, Block #B, Khilji road, Mohammadpur, Dhaka-1207

Description:

13- Storied with 4 basement floor building Aquifers recharge rooftop rainwater harvesting system with RCC catchment area. Rainwater going to direct underground aquifers from roof by 100mm UPVC pipe. Aquifers made by deep well. After harvesting, rainwater collect from aquifer by pumping. When rainwater going to underground aquifer it's naturally purified.

Total cost of this project BDT 926460.00 (Nine Lac Twenty Six Thousand Four Hundred Sixty only. [10]

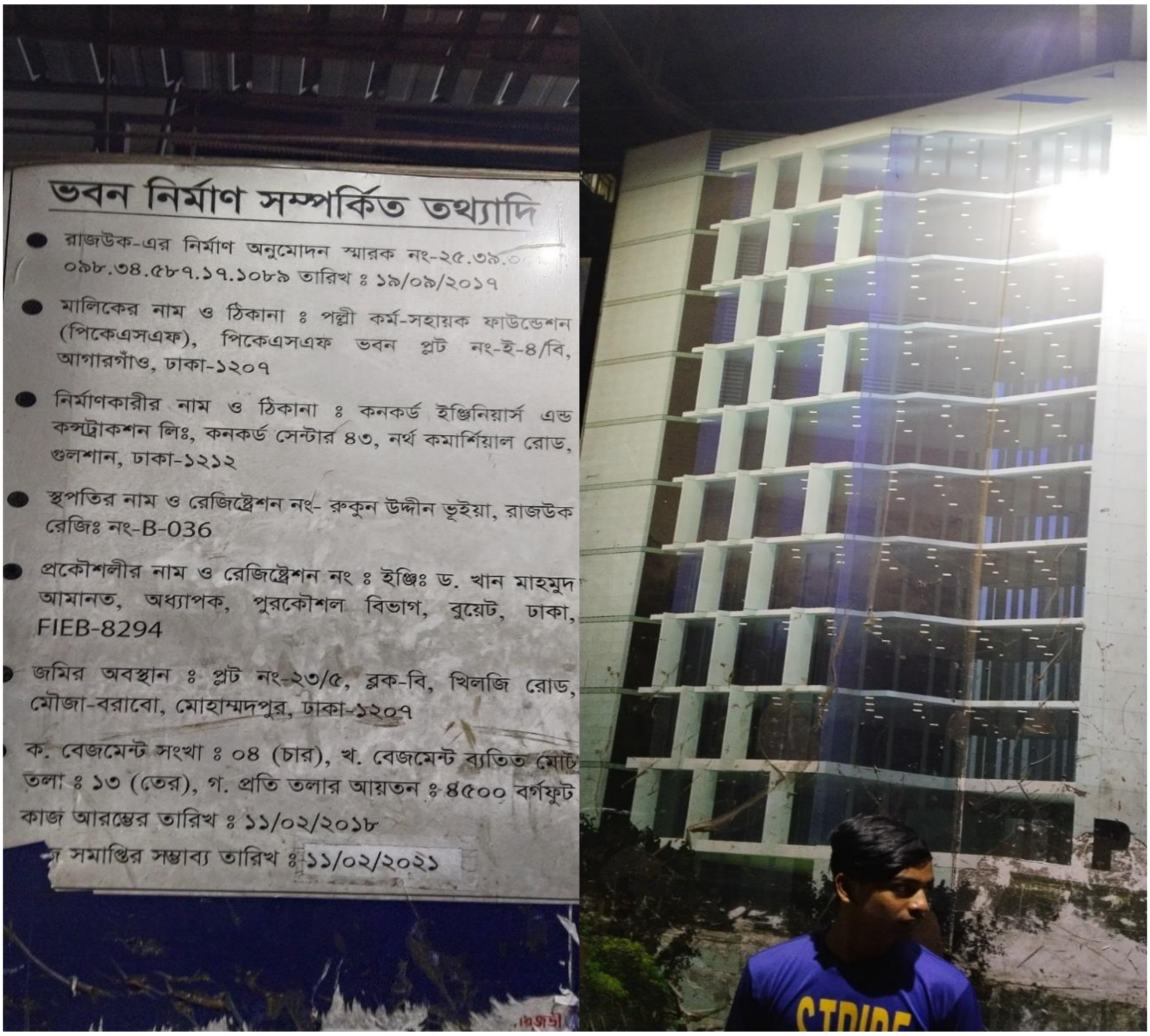

Figure 3-6: Project view at Shyamoli

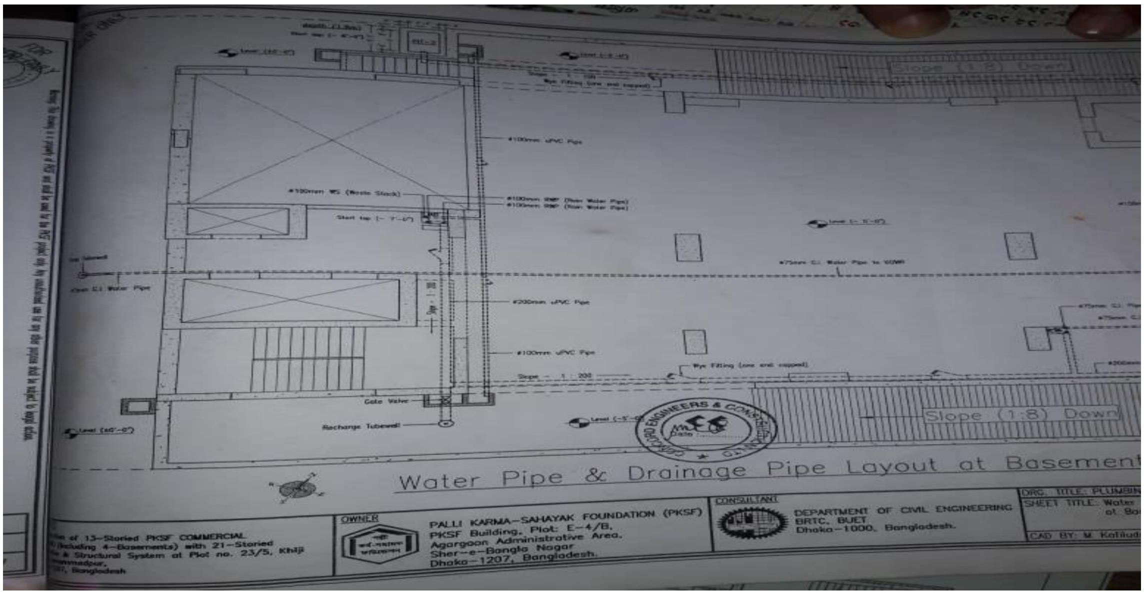

Figure 3-7: Details design of Project (Shyamoli) [10]

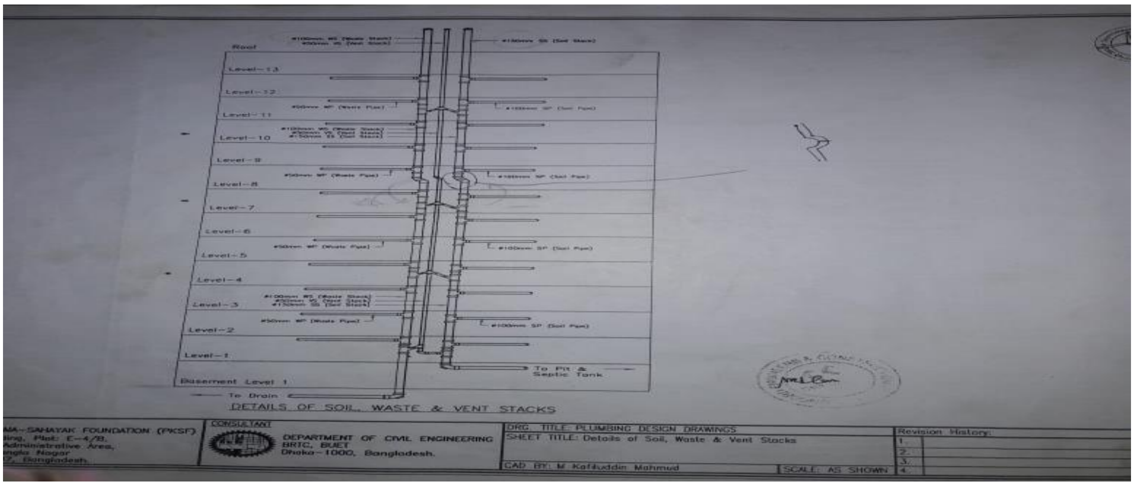

Figure 3-8: Details design of Project (Shyamoli) [10]

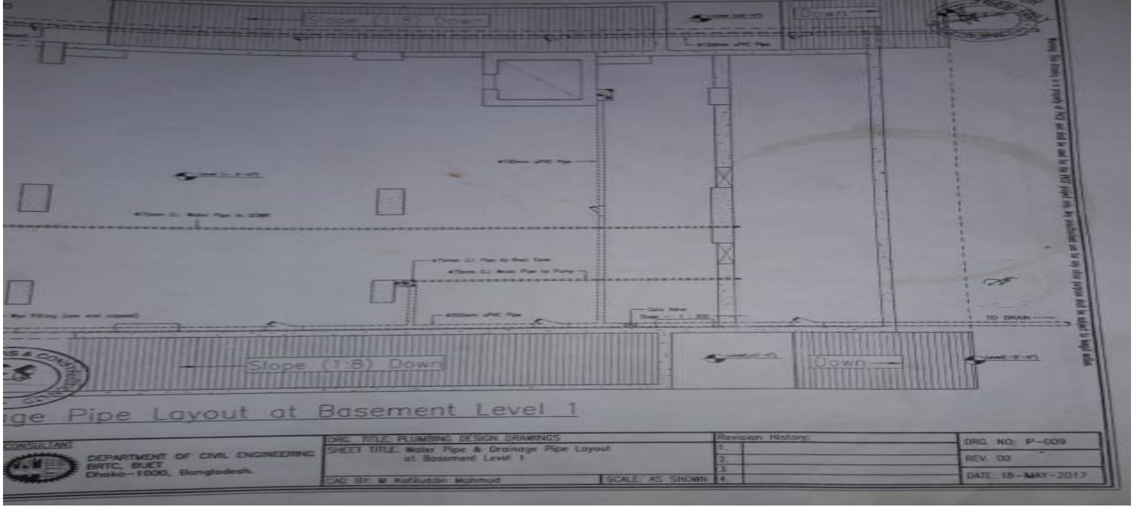

Figure 3-9: Details design of Project (Shyamoli) [10]

3.3 Potentiality of RWH

Rainfall is an unpredictable variable to calculate the potential of rainwater harvesting of an area. In this study, average monthly rainfall of 10 years (2010-2018) from Bangladesh Meteorological Department (BMD) was used. The rooftop of the buildings were considered as catchment area. The rain that falls on those rooftops were considered for calculating the rainfall potential. Rainwater harvesting potential was measured by using the formula, Runoff (Potential for Harvesting) = AxRxC

Where,
A=Area in sq. m
R=Annual Rainfall in mm
C=Runoff Coefficient

3.4 Water Quality Analysis

Water samples were collected from the building of Dhanmondi, Dhaka-1207 area. The water samples were collected in the month of April 2023. Sample water was collected separately in two 1000milimeter plastic bottle and filled the total volume of the container and cap was locked sufficiently so that no air space can be remained inside to minimize the chemical changes.

In this study, a roof top rainwater harvesting system is considered only. It is necessary to calculate the area of rooftop in order to identify the potential of rainwater harvesting in each building.

The parameters checked of the samples collected from selected area are pH value, Total Dissolved Solids (TDS), Conductivity and Chloride. All tests were performed in the "Water Test Laboratory" of Dhaka Water and Sewerage Authority (DAWSA) & Analytical service sell of the Bangladesh Council of Scientific and Industrial Research, (BCSIR, Dhaka).

3.5 Implementation of First Flash (FF) manual based operation rainwater harvesting Project at Dhanmondhi

Location:
House# 308/A, Road# 8/A, Dhanmondhi, Dhaka-1205
Building storied# B+9, Unit# 18 units, Dwellers# 80

Figure 3-10: Rooftop of study project building at Dhanmondi

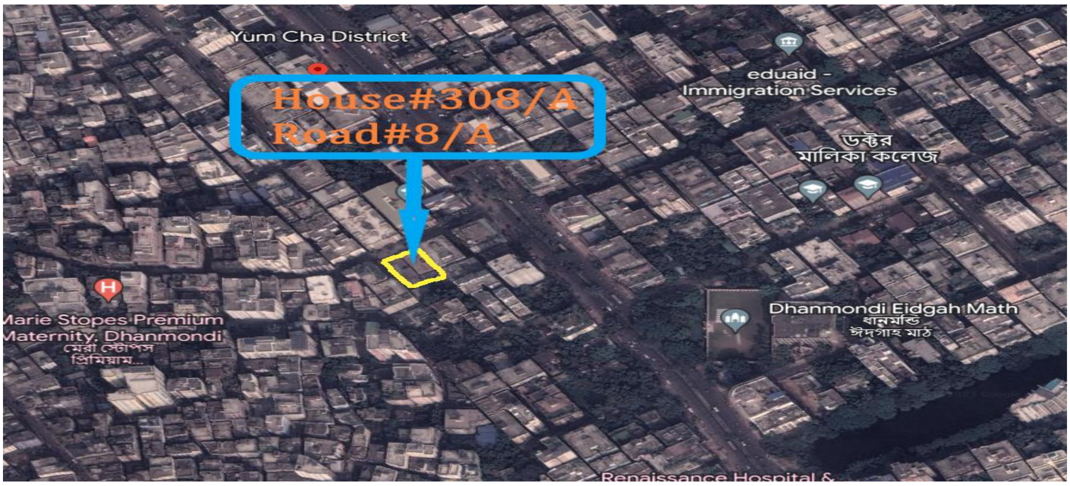

Figure 3-11: Google Location Plan of study project building

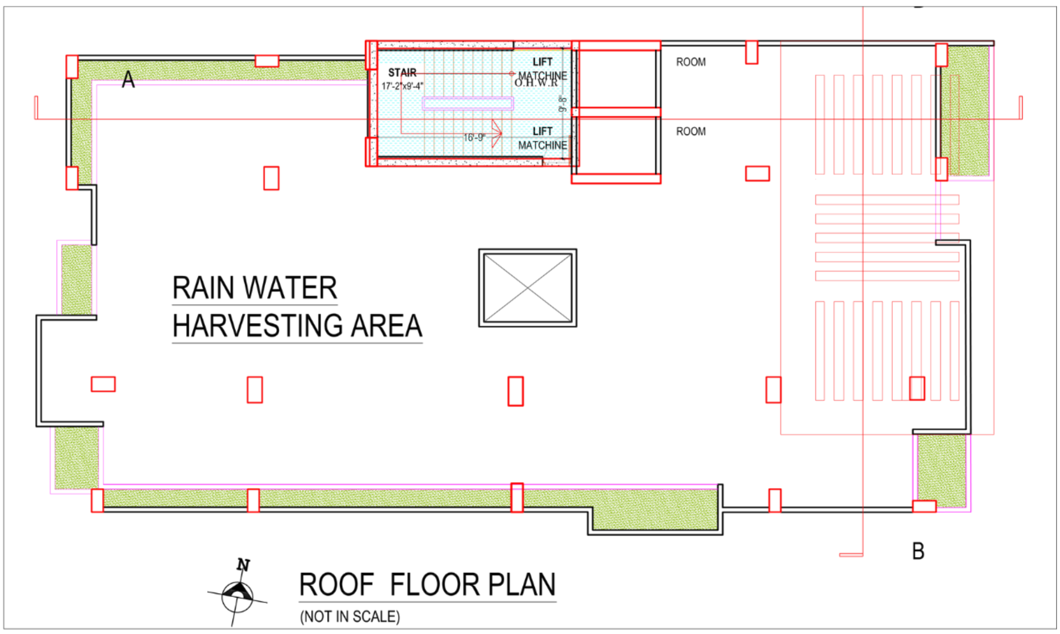

Figure 3-12: Rooftop Plan of study project building

Figure 3-13: Ground floor Plan of study project building

Figure 3-14: 3D view of study project building

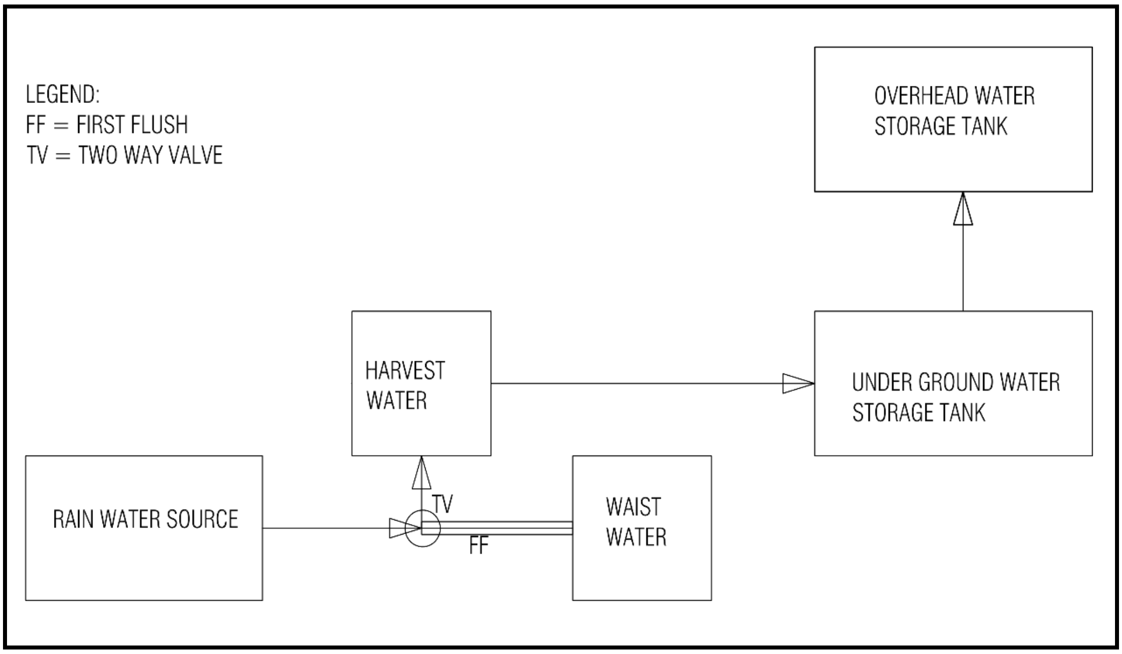

Figure 3-15: Process diagram of RHS of study project building

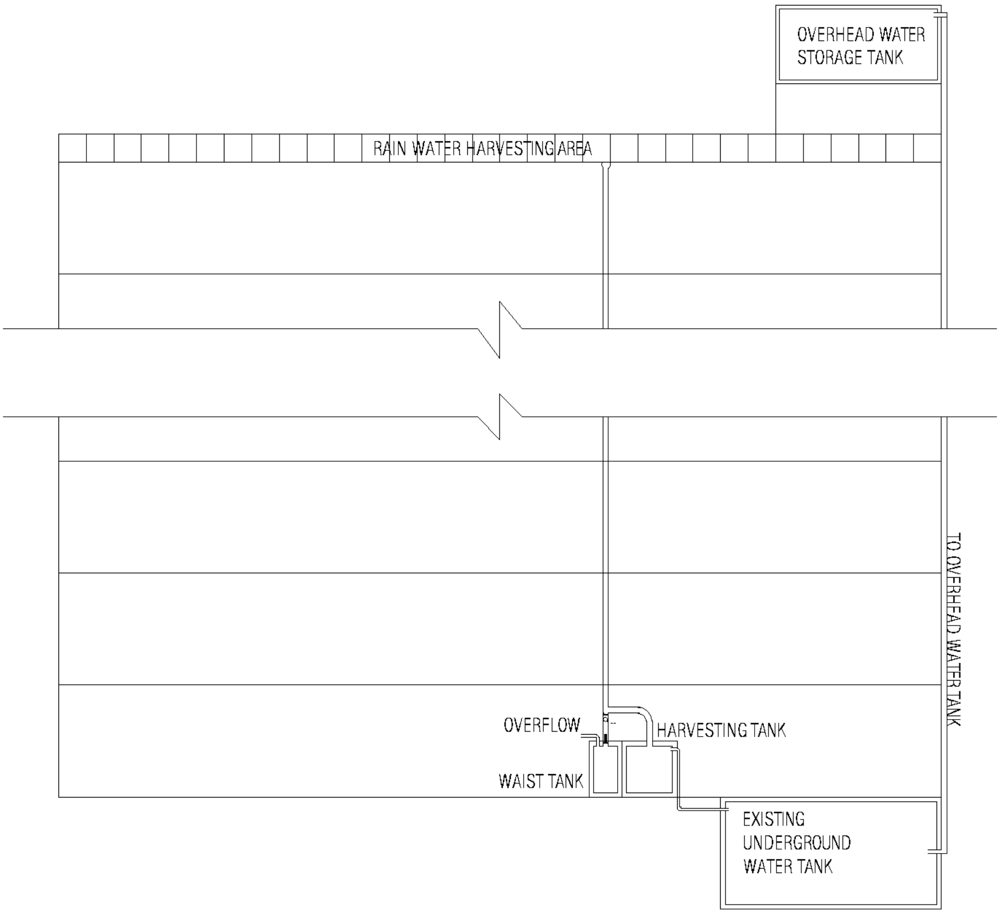

Figure 3-16: Sectional elevation of RHS of study project building

3.6 Data Collection

Data collected are as follows:

- Rainfall data for the last 10 years and monthly.
- Basic Water Requirements for Human Activities.
- Catchment area data.
- Daily water demand and supply by Dhaka WASA.
- Determination of rainwater quality for drinking water purpose according to BSTI & WHO Standards.

3.6.1 Rainfall data

To find out the total available rainwater, rainfall amount is necessary. The rainfall data of the Dhaka city for the year 2010-2018 was collected from BMD. In our study area, there is no particular rain gauge station. So rainfall data from a representative location (recommended by BMD) was collected to estimate the rainwater volume. The collected rainfall data for the year 2010-2018 is given in Table 3.1

For the last ten years (2010-2018)

Station name: Dhaka

Table 3-2: Monthly and annual total rainfall in millimeter [11]

Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Annual
2010	0	48	22	37	177	308	167	340	169	174	0	81	1523
2011	0	0	20	123	235	314	356	409	207	112	0	0	1776
2012	10	1	37	269	137	175	226	282	81	38	68	5	1329
2013	0	8	26	32	378	325	302	212	172	131	0	4	1590
2014	0	12	10	80	147	342	212	391	156	49	0	0	1399
2015	3	17	4	166	185	375	623	395	346	51	0	1	2166
2016	1	15	46	213	679	136	216	162	210	76	44	0	1798
2017	8	29	66	156	339	340	373	317	300	172	34	13	2147
2018	0	3	34	324	690	358	356	473	145	33	12	52	2480

Table 3.1 and figure 3.1 and 3.2 illustrate the monthly and annual rainfall in the Dhaka city. The figure 3.1 shows the annual rainfall from 2010 to 2018. Where the maximum annual rainfall occurred in 2018 which was 2480mm. **The average annual rainfall is**

1800mm.The annual minimum rainfall in the 9 years is 1329mm on the 2012. However from the figure 3.2 which shows year wise monthly rainfall. The graph indicates that maximum rainfalls in the month of April-May. This graph also shows that the rainfall starts from March and continue to October. In the Dhaka city's inhabitants can get rainwater for more or less 8 months.

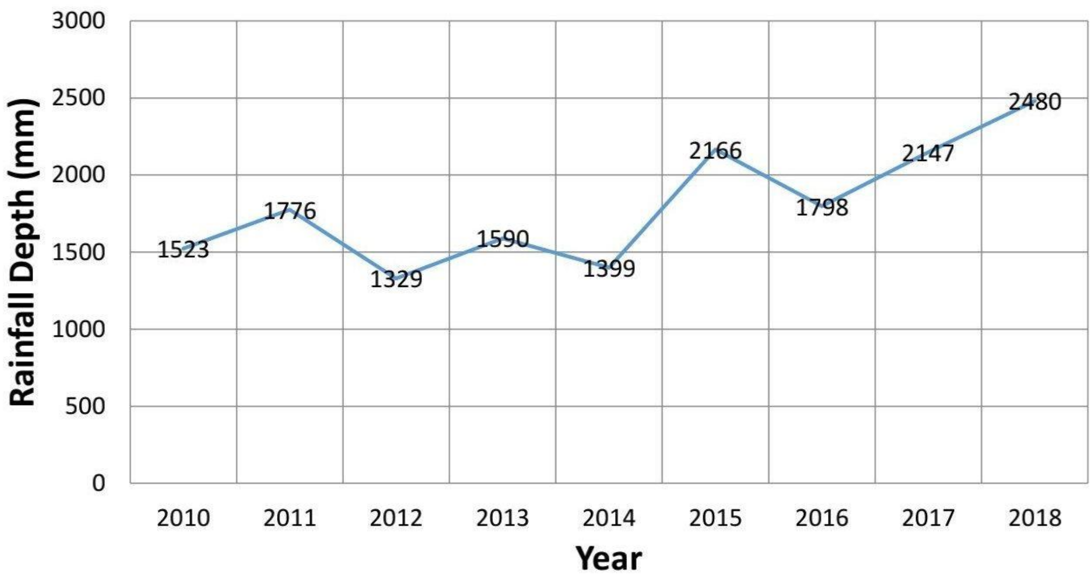

Figure 3-17: Yearly rainfall hydrograph (2010-2018) [11]

Figure 3.17 [11]

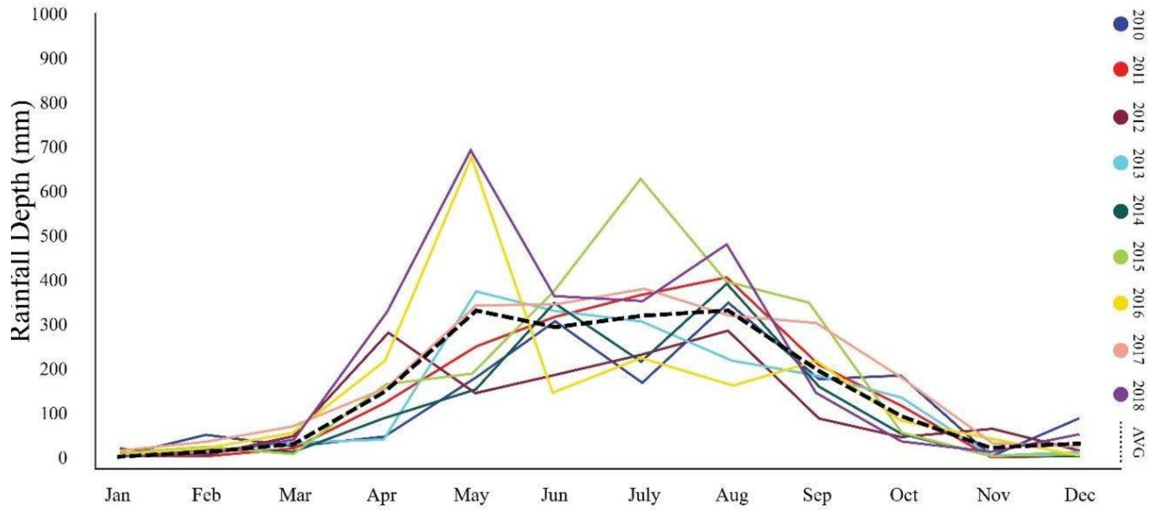

Figure 3-18: Monthly rainfall hydrograph (2010-2018) [11]

3.6.2 Domestic Water requirement in Dhaka city

Daily water consumption depends on different variables such as

- Total number of resident's in an apartment.
- Daily per capita use of plumbing fixtures such as lavatories, showers, water closets, etc.

One of the fastest growing cities of the world, Dhaka has a high daily water consumption rate. Water is used for various purposes. From drinking purpose to toilet flushing, water is required. There are several studies focusing on daily demand of Dhaka city. According to a research paper of "Unnayan Onneshan" titled: "DWASA has projected water demand as 150 liters per person per day (l/p/d). Empirical evidence shows that one-third of the city dwellers receive only 40 1/p/d and they have to manage their daily activities with this little amount of water. Only 5.1 percent of total population of Dhaka city receives more than 60 1/p/d. On an average, 42.8 percent of the respondents can receive basic requirement of 50 1/p/d and the rest (57.8 percent) are suffering from water scarcity despite piped connection. According to another research of "Center for Science & Environment," the daily water consumption rate has estimated 135 l/p/d. it is shown below in Table 3.2.

Table 3-3: Water Consumption Rate [12]

Sl.no	Use	Consumption(l/p/d)
1	Drinking	5
2	Cooking	5
3	Washing clothes	20
4	Bathing(including ablution)	55
5	Washing utensils	10
6	Cleaning house	10
7	Toilet flushing	30
	Total	135

3.6.3. Catchment area

In this study, one B+9 storied buildings were taken into consideration of 18 units. The main catchment is the roof top of the building. Building catchment area were calculated. **The catchment areas are 334.57 m^2.**

3.7 Rainwater Parameters

Rainwater is a mixed with electrolyte that contains varying amounts of-

- Major and Minor ions
- Sodium
- Potassium
- Magnesium
- Calcium
- Chloride
- Bicarbonate
- Sulfate ions are major constituents together with ammonia
- Nitrogen and
- Other nitrogenous compounds

(Reference: Hutchinson, 1957)

Rainwater quality tests were performed as the Dhaka Water and Sewerage Authority concern lab and Bangladesh Council of Scientific and Industrial Research (BCSIR) Dhaka.

The following Table-3.4, 3.5, 3.6 provides below contains the data of water quality parameters of rainwater samples were collected from Dhanmondhi-1207 residential area where water samples were collected from building rooftop. The values are then compared with the Bangladesh Standards and the standards of World Health Organization (WHO). [13]

Table 3-4: Chemical Characterization of Rain water

SI.NO.	Test Parameters	Results	Acceptable Limit		Remarks
			BSTI BDS1240:2001 ECR (1997)	WHO(1993, 1997,1998, 2011)	
01	pH value	7.12	6.4-7.4	6.5-9.2	Value is within BDS Standard & WHO Guideline value 1998.
02	Total dissolved solids, mg/l	175.6	500.0(Max.)	500	Value is within BDS Standard & WHO Guideline value 1997.
03	Conductivity, µS/cm	399	6.0(Max.) (ECR-1997)	4-6	Values are within BDS Standard & WHO Guideline value 1998.
04	Chloride, mg/l	12	400.0(Max.) (ECR-1997)	250	Value is less than BDS Standard & WHO Guideline value 1993.

Table 3-5: Chemical Characterization of Tap Water

SI.NO.	Test Parameters	Results	Acceptable Limit		Remarks
			BSTI BDS1240:2001 ECR (1997)	WHO(1993, 1997,1998, 2011)	
01	pH value	7.10	6.4-7.4	6.5-9.2	Value is within BDS Standard & WHO Guideline value 1998.
02	Total dissolved solids, mg/l	176.2	500.0(Max.)	500	Value is within BDS Standard & WHO Guideline value 1998.
03	Conductivity, µS/cm	371	6.0(Max.) (ECR-1997)	4-6	Value is within BDS Standard & WHO Guideline value 1998.
04	Chloride, mg/l	13	400.0(Max.) (ECR-1997)	250	Value is within BDS Standard & WHO Guideline value 1998.

Table 3-6: Chemical Characterization of Mix water (Rain water & Tap Water)

SI.NO.	Mix Ratio Tap water : Rainwater (TW:RW) (ml)	Test Parameters				Remarks
		pH value	Total dissolved solids, mg/l	Conductivity, µS/cm	Chloride, mg/l	
01	70:30	8.44	231	480	41	Value is within BDS Standard & WHO Guideline value 1998.
02	50:50	8.27	222	466	36	Value is within BDS Standard & WHO Guideline value 1998.
03	30:70	8.81	263	551	61	Value is within BDS Standard & WHO Guideline value 1998.
Acceptable Limit	**BSTI BDS1240:2001ECR (1997**	6.4-7.4	500.0(Max.)	6.0(Max.) (ECR-1997)	400.0(Max.) (ECR-1997)	
	WHO(1993, 1997,1998, 2011)	6.5-9.2	500	4-6	250	

Figure 3-19: Collected rainwater samples

Figure 3-20: During laboratory test in SU Environment lab

Chapter 4 :ANALYSIS AND CALCULATION

4.1 Calculation of potential of rainwater harvesting

Each building roof top area has been calculated and accordingly surface runoff has been calculated using the equation as follows. Then catchment areas are multiplied by the average annual rainfall and runoff co-efficient, potential of rainwater harvesting would be

Potential of rainwater harvesting in each building=A x R x C

Where,

A=Area of rooftop in sq. m

R=Average annual rainfall

C=Coefficient of runoff (Which value is 0.90)

(Source: Center of science and Environment, 2010)

Water demand, D=n x q x d

Where,

n= No. of occupants

q= per capita water demand daily in m/day; and

d=No. of days

Evaporation loss is negligible.

4.2 Potential of rainwater harvesting in building per year

Total Rainwater harvesting per year = 334.57 x 1.8 x .9 = 542 m^3/y

Table 4-1: Water demand in whole building per year

Sl No	Description	Total Person	Demand ltr/P/d	Day	Demand ltr/year	Remarks
1	Drinking	80	5	365	146000	
2	Cocking	80	5	365	146000	
3	Clothes washing	80	20	365	584000	
4	Bathing	80	55	365	1606000	
5	Washing utensils	80	10	365	292000	
6	House cleaning	80	10	365	292000	
7	Toilet flushing	80	30	365	876000	
			Total Demand		**3942000**	**ltr/y**
					3942	**m^3/y**

Table 4-2: Project implementation cost

Item No	Item Name	Unit	Quantity	Rate	Cost Amount Tk.
1	4" Pvc pipe	rft	130	68	8840
2	4" pvc Band	pcs	4	150	600
3	2" Pvc Band	pcs	40	34	1360
4	4" Tee	pcs	1	280	280
5	4" Gi short pcs	pcs	1	2000	2000
6	4" Gi Band	pcs	1	2000	2000
7	Fluid Valbe	pcs	1	5200	5200
8	4" Class D Pipe	rft	10	350	3500
9	4" Class D Band	pcs	2	400	800
10	Labour Cost	person	6	800	4800
			Total		**29380**

Chapter 5 :RESULTS AND DISCUSSION

5.1 Introduction

Study main aim is analysis the cost benefit of the Rainwater harvesting System (RHS) project. After analyzed others three project we select manual based system and considered one residential building project for study with in Dhanmondhi area. Where Total 18 unit and total people 80 person.

See from this project.
Total Rainwater harvesting **542** m^3/y
Total demand in building **3942** m^3/y
Project implementation cost only **Tk.29380.00** only

5.2 Result and Discussion

At this moment this project building
Water comes from rainwater harvesting 542 m^3/y where Demand 3942 m^3/y.
Water comes from rainwater harvesting 13.75% against the demand
Which is amount = 542 m^3/y x 13.5 tk/m^3 = 7317 Tk. Save per year.
Need time for recover the project cost Tk. 27680/Tk. 7317 = 4.0y

So now can say this project is very profitable for building holder. Return period is short. Implementation cost is very low. Easy to operation & maintenance. Existing manpower as like guard or caretaker of building handle this system easily. No need any maintenance cost in future. **So that now can say that, this project is Sustainable.**

Chapter 6 :CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The harvesting of rainwater simply involves the collection of water from surfaces on which rain falls, and subsequently storing this water for later use. One method of rainwater harvesting is "Rooftop rainwater harvesting manual based operation"
At this stage we visit and analyzed three (03) different project in Dhaka. As like

- First Flash automatic based system
- First Flash manual based system
- Automatic base with aquifers recharge system.

After analyzed we only First Flash manual based system is more reliable, acceptable. It also easier to implementation, operation and maintenance. It is most cost effective to others method. That's why we implement a manual based system at Dhanmondi, Dhaka.

In construction stage we see with minimum materials and labor project completed by 1 week. It is very short time for this project.

In this research water purification was considered with laboratory test for water quality parameters such as chemical characteristics. Laboratory experiments on water quality had been done. In all the experiments showed that the results are safe with respect to Bangladesh and WHO standard respectively. The people of Bangladesh especially those who are living in countryside are not eager to use rainwater as drinking as well [13] as household uses.

Awareness may be developed through motivation in developed rain water harvesting system in house also using rainwater.

6.2 Recommendation

From the study, the following recommendations may be made:

- Rainwater may be used potable as well as domestic (household) purpose.
- Awareness through motivation may be developed to the people for using rainwater and rainwater harvesting system.
- A 3D model may be developed for the solution of RWH system to make it easily comprehensive to the users.
- The model proposed in recommendation-3 along with the computer programs, from the guideline for the design and installation of the rainwater harvesting system.
- DWASA can involve themselves in developing rainwater harvesting and it connect to national water supply grid.
- Here shown cost-benefit analysis are preliminary. But recommendations to details cost-benefit analysis for further study.

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APENDIX-1

Test Result of Rain Water

Dhaka Water Supply and Sewerage Authority

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"শেখ হাসিনার মূলনীতি
গ্রাম শহরের উন্নতি"

Memo No:46.113.519/520.00.00.001.2023.549 MCD Date 17-05-2023

মোঃ সুমন আহম্মেদ
বাড়ী নং-৩০৮/এ, রোড নং-৮/এ (নতুন)
ধানমন্ডি, ঢাকা।

Subject: Testing Report of Supplied Rain Water Sample from House No-308/A, Dhanmondi, Dhaka.
Ref: Nil , Date:16-05-2023

Date of Sample Received: 16-05-2023
Date of Testing: 16-05-2023 - 16-05-2023

Water Quality Analysis Report

SN	Parameters	Units	Drinking Water Standards		Obtained Results	Analysis Methods
			Bangladesh ECR 2023	WHO-2011		
1	pH	--	6.5-8.5	6.5-8.5	7.12	Electrometric
2	Conductivity	µS/cm	--	--	399	Electrometric
3	Total Dissolved Solids	mg/L	1000	1000	175.6	Electrometric
4	Chloride	mg/L	250	250	12	Argentometric

NB: Results are applicable for the above mentioned sample.

17-05-2023 10:16 AM	17-05-2023 10:26 AM	17-05-2023 10:27 AM	17-05-2023 11:12 AM
Md. Abdur Rahman	Md. Ruhul Amin	Hasna Hena Rahman	Dr. Md. Alamgir Hossain
Lab. Assistant	Assistant Chemist	Assistant Microbiologist	Deputy Chief Microbiologist

NB: 1. Samples supplied to the laboratory by client.
2. This report is valid only for particular sample tested and can not be used for publicity.
3. Reports are not allowed to be used or reproduced for any commercial purpose.

APENDIX-2

Test Result of Tap water and mix water

Dhaka Water Supply and Sewerage Authority

Office of the Deputy Chief Microbiologist
Microbiology & chemical Division
(Dhaka WASA Central Laboratory)
Asad gate, Mohammadpur
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"শেখ হাসিনার মূলনীতি
গ্রাম শহরের উন্নতি"

Memo No:46.113.519/520.00.00.001.2023.551 MCD Date 18-05-2023

মোঃ সুমন আহম্মেদ
বাড়ী নং-৩০৮/এ, রোড নং-৮/এ (নতুন)
ধানমন্ডি, ঢাকা।

Subject: Testing Report of Supplied Rain & Tap Water Sample from House No-308/A, Dhanmondi, Dhaka.
Ref: Nil , Date:18-05-2023

Date of Sample Received: 18-05-2023
Date of Testing: 18-05-2023 - 18-05-2023

Water Quality Analysis Report

SN	Parameters	Units	Drinking Water Standards		Sample N0-1, Tap Water	Sample No-2, Rain Water- 50 %, Tap Water- 50 %,	Sample N0-3, Rain Water-70 %, Tap Water-30 %,	Sample N0-4, Rain Water-30 %, Tap Water-70 %	Analysis Methods
			Bangladesh ECR 2023	WHO-2011					
1	pH	--	6.5-8.5	6.5-8.5	7.10	8.27	8.81	8.44	Electrometric
2	Conductivity	µS/cm	--	--	371	466	551	480	Electrometric
3	Total Dissolved Solids	mg/L	1000	1000	176.2	222	263	231	Electrometric
4	Chloride	mg/L	250	250	13	36	61	41	Argentometric

NB: Results are applicable for the above mentioned sample.

18-05-2023 12:16 PM	18-05-2023 12:23 PM	18-05-2023 12:20 PM	18-05-2023 12:38 PM
Md. Abdur Rahman	Md. Ruhul Amin	Hasna Hena Rahman	Dr. Md. Alamgir Hossain
Lab. Assistant	Assistant Chemist	Assistant Microbiologist	Deputy Chief Microbiologist

NB: 1. Samples supplied to the laboratory by client.
2. This report is valid only for particular sample tested and can not be used for publicity.
3. Reports are not allowed to be used or reproduced for any commercial purpose.

APENDIX-3

Cost Analysis BCSIR project

Table 5-1: Cost of BCSIR Project

Sl·No.	Item	Material and Quantity	Unit Cost ($)	Total Cost ($)
1	Rooftop/Shed	PVC (3mm), (1000 sq. ft)	0.32	320.00
2	Collecting Pipe	PVC (110mm), (10m)	0.70	7.00
3	Solar Panel	12V, 20W, (1 pcs)	13.42	13.45
4	Sensor	Custom made (1 pcs)	20.00	20.00
5	Debris Filter	Polypropylene (1 pcs)	5.00	5.00
6	Diverter Pipe	PVC (1 pcs)	3.00	3.00
7	Floating Valve	Plastic and Steel (1 pcs)	5.00	5.00
8	Water Tap	PVC (3 pcs)	3.00	9.00
9	Solenoid Valve	Copper (1 pcs)	16.00	16.00
10	Storage Tank 1	PVC (200L) (1 pcs)	20.40	20.40
11	Storage Tank 2	PVC (1000L) (1 pcs)	75.15	75.15
12	Submersible Pump	24V DC (1 pcs)	5.00	5.00
13	UV-C Filter	24V DC (1pcs)	20.00	20.00
14	Sediment Filter	Polypropylene Fiber (1 pcs)	10.00	10.00
15	Carbon Filter	Activated Carbon (1 pcs)	10.00	10.00
Total				539.00

This project per 1000sft cost BDT. 539.00 (Five Hundred Thirty Nine) only.

APENDIX-4

Cost Analysis Adabor project

Table 5-2: Cost of Adabor project

Item No	Item Name	Unit	Quantity	Rate	Cost Amount TK.
1	4" Pvc pipe	rft	100	68	6800
2	4" pvc Band	pcs	2	150	300
3	2" Pvc Band	pcs	30	34	1020
4	4" Tee	pcs	1	280	280
5	4" GI short pcs	pcs	1	2000	2000
6	4" GI Band	pcs	1	2000	2000
7	Fluid Valve	pcs	1	5200	5200
8	4" Class D Pipe	rft	10	180	1800
9	4" Class D Band	pcs	2	400	800
10	Labor Cost	person	12	800	9600
11	RCC Tank	pcs	1	50000	50000
			Total		**79800**

Total cost this project BDT. 79800.00 (Seventy Nine Thousand Eight Hundred) only.

APENDIX-5

Cost Analysis Shyamoli project

Table 5-3: Cost of Shyamoli project

Item No	Item Name	Unit	Quantity	Rate	Cost Amount TK.
1	4" Pvc pipe	rft	300	68	20400
2	4" pvc Band	pcs	20	150	3000
3	4" Tee	pcs	5	280	1400
4	4" upvc pipe class-D	rft	650	350	227500
5	4" upvc strainer	rft	30	400	12000
6	2" upvc pipe	rft	250	82	20500
7	2" upvc bend	pcs	40	120	4800
8	2" upvc socket	pcs	30	110	3300
9	2" Union	pcs	4	140	560
10	2" GI Get valve	pcs	4	1000	4000
11	Submersible Pump	pcs	1	87000	87000
12	Electrical Cost (Weir, Circuit Brecker, Switch etc.)	lot	1	60000	60000
13	Deepwell boaring cost	lot	1	400000	400000
14	Labour Cost	person	40	800	32000
15	RCC Tank	pcs	1	50000	50000
			Total		**926460**

Total cost this project BDT. 928460.00 (Nine Lac Twenty Six Thousand and Forty) only.