This thesis is submitted to the Department of Mechanical Engineering of Military Institute of Science and Technology (MIST) in partial fulfilment of the requirement for the B. Sc. in Mechanical Engineering Degree.

RAINWATER HARVESTING AND UTILIZATION

Submitted by:

Md. Arif Hannan	Student no: 2008180 05
Ashek Ahmed	Student no: 2008180 12
Md. Saiful Islam	Student no: 2007180 54
Md. Hafizur Rahman Khan	Student no: 2009180 59

Submitted to

Lt Col Md.Lutfor Rahman
Instructor Class A
Department of Mechanical Engineering
Military Institute of Science and Technology (MIST)
Dhaka.

Date
10 December, 2012

03 March, 2012

Lt Col Md.Lutfor Rahman
Instructor Class A
Department of Mechanical Engineering
Military Institute of Science and Technology (MIST)
Dhaka.

Subject: Submission of the Project Report.

Sir,

We would like to inform you that, it is an immense gratification for our to put forward the Project Report on "**RAINWATER HARVESTING AND UTILIZATION**", as a requisite for B. Sc. in Mechanical Engineering Degree.

Sincerely Yours,

MD. ARIF HANNAN
Student no: 2008180 05

ASHEK AHMED
Student no: 2008180 12

MD. SAIFUL ISLAM
Student no: 2007180 54

MD. HAFIZUR RAHMAN KHAN
Student no: 2009180 59

SUPERVISOR CERTIFICATION

This is to certify that, Md. Arif Hannan, Student No: 200818005, Ashek Ahmed, Student No: 200818012, Md. Saiful Islam student No: 200718054 and Md Hafizur Rahman Khan, Student No: 200918059 have completed their undergraduate project and thesis in title **"RAINWATER HARVESTING AND UTILIZATION".** This thesis embodies original work done under my supervision.

Supervisor

____

Lt Col Md.Lutfor Rahman
Instructor Class A
Department of Mechanical Engineering
Military Institute of Science and Technology (MIST)
Dhaka.

ACKNOWLEDGEMENT

First and most earnest gratitude goes to the Almighty Allah; most gracious and most merciful who has bequeathed us with aptitude, the vigour and the perseverance unless which it would have not been possible for us to complete this project.

We would like to express our heartiest gratitude to Lt Col Md. Lutfor Rahman, Department of Mechanical Engineering, MIST for his support, patience, and encouragement throughout our project. His technical and editorial advice was essential to the completion of this dissertation and has taught us innumerable lessons and insights on the workings of academic research in general. Throughout the project, he has been an advisor, and a mentor who helped us realizing this project in a convenient way. Without his help and proper directions, it would have been nearly impossible to make it a success.

We would like to express our sincere gratitude to Capt. M. Munir Hasan (E) ,BN, Head of the Mechanical Engineering Department ,MIST for his valuable guidance, encouragement, suggestions and support. The direction he has given us during our project work was invaluable.

Gracious appreciation is extended to the Department of Mechanical Engineering and MIST authority for providing us with different facilities for experimental work.

We acknowledge the support and the friendly environment extended by the fellow students and other instructors towards us. We are ever grateful for it and their precious memory will forever be cherished.

The Authors
December, 2012

ABSTRACT

Water is a vital element in human life. Requirement of pure and clean fresh water is undeniable in daily life. All over the world this water is extracted from underground and surface sources. Continuous extraction of underground water with inadequate renewal leads to fall of water level. For meeting the needs WASA extracts underground water to a large scale (87%) in comparison to surface water (13%). Thus the groundwater level in the capital has dropped by six meters in the last seven years. The capital's groundwater level had now dropped to 52 meters below mean sea level (MSL). Last year the level has dropped by one meter. If this situation continues in this manner in near future water level will drop to such a level that prompts to natural disasters like: landfall, earthquake, emerging of salty sea water into the underground etc.

In our rural and urban areas scarcity of drinkable water and arsenic free water has reached its peak situations. In rural areas people has to depend on deep tube-wells and on pond, river, canals etc. In most cases the underground water is affected by arsenic and the surface water is dirty and unhygienic. On the other hand, rainwater throughout the year causes many municipal and others problems. For example flooding and damaging roads and constructions etc. If we could collect this abundant water and use them in our daily life we surely can reduce these problems, besides relief the underground water level from going down.

This project will hopefully be a partial solution to these problems and contribute to the greater interest of the nation. This is a mini project; from this project we will have an overall idea of the contribution of harvesting rain water.

NOMENCLATURE

GPPD- Gallon per Persons per Day

DC- Daily Consumption

MC- Monthly Consumption

ROF- Runoff Factor

CRF - Critical Rainfall

ARF- Mean Annual Rainfall

MFI - Monthly Factor of Insufficiency

YFI - Yearly Factor of Insufficiency

TS - Total Storage

LF - Leakage Factor

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1. Introduction and Background.

Fresh water, a renewable but limited resource, is scarce in many areas of the developing world because of unplanned withdrawal of waters from rivers and underground aquifers causing severe environmental problems like arsenic contamination. In many countries, the amount of water being consumed has exceeded the annual amount of renewal creating a no sustainable situation.

In addition to that, rainwater run-off during rainfall from roofs and other sealed surfaces during heavy rain is leading to accumulated flooding in the urban areas of many countries like Bangladesh where the drainage system was not designed including the volume of rainwater runoff. As ancient as the early days of civilization, rainwater harvesting, the system of collecting and using the precipitation from a catchment area is considered as an alternative option for water supply in Bangladesh. Unless it comes into contact with a surface or collection system, the quality of rainwater meets Environmental Protection Agency standards and the independent characteristic of its harvesting system has made it suitable for scattered settlement and individual operation. This thesis follows the style and format of Journal of Construction Education and Research.

1.1 Purpose.

The purpose of this study is to assess a sustainable rainwater harvesting solution for Bangladesh using interactive tools like monitoring, calculating and visualization etc.

1.2 Research Objectives.

a. To identify and analyze the rainwater harvesting methods of Bangladesh.

b. Analyze the significance of rainwater harvesting in the urban residential areas of Bangladesh.

c. Develop a solution for rainwater harvesting solution for a typical multi storied residential apartment in Dhaka, Bangladesh.

d. To monitor the quality of harvested rainwater and to suggest a guideline for long term use.

e. To assess the present water use rate and acceptability of rainwater use for domestic purposes.

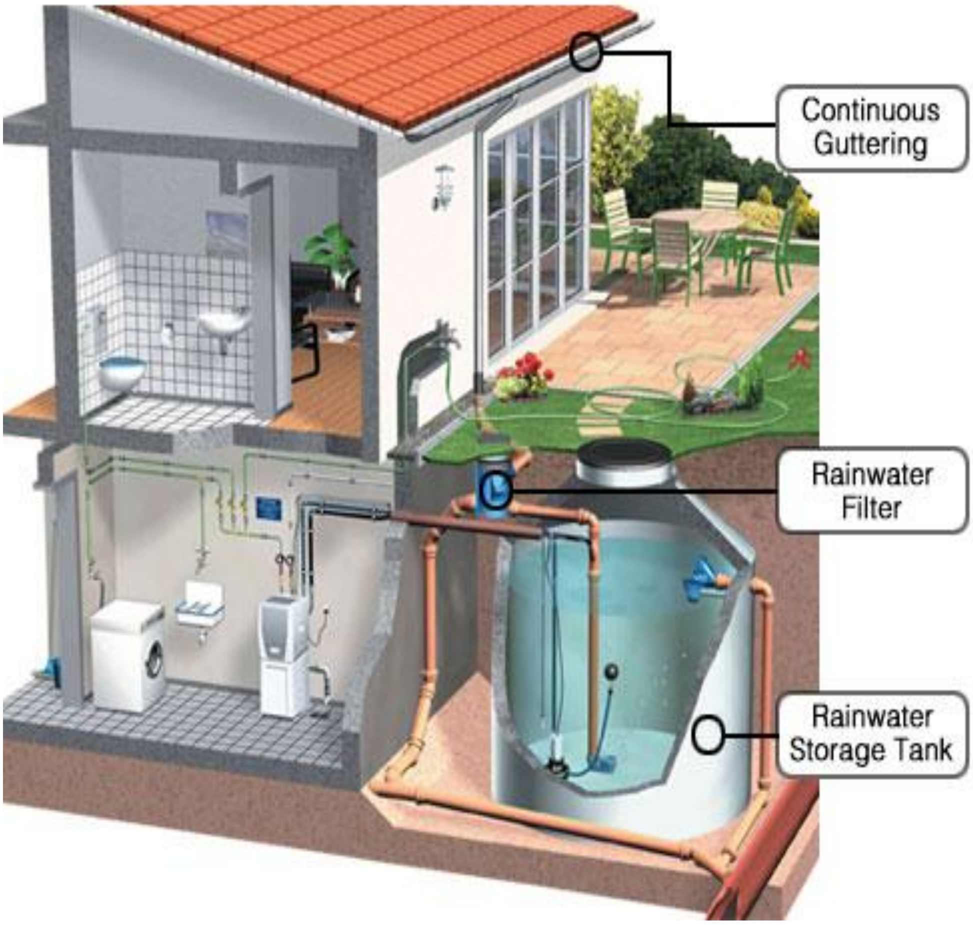


Figure1.2.1: Typical rainwater harvesting.

1.3 **Limitations.**

a. The research will be confined only to the urban area of Dhaka, Bangladesh.

f. The study will be confined to residential apartments of Dhaka, Bangladesh.

1.4 **Assumptions.**

a. No environmental or other contamination other than those from the catchment area will be present in the harvested rainwater.

b. The rainwater harvesting method is socially accepted in the study area.

g. The per capita water consumption is assumed to be 25 gal/day or 94.75 lpcd.

i. 1.5 gal/flush; frequency of use/day=4, total 6 gal
ii. 2.5 gal/ shower, duration per shower= 5 minutes, total=12.5 gal
iii. Cooking and drinking: 1.5 gal
iv. Cleaning and miscellaneous: 5gal. Grand Total: 25 gal/ person /day.

2. **Why Harvest the Rain?**

RWH is most suitable where...

a. Groundwater is scarce.

b. Groundwater is contaminated.

c. Terrain is rugged or mountainous.

d. Seismic & flooding events are common.

e. The aquifer is at risk of saltwater intrusion.

f. population density is low.

g. Electricity & water prices are rising.

h. Water is too hard or mineral laden.

j. Consumers must restrict salt/chlorine intake.

k. Where utility service is unreliable.

l. Conservation is an objective.

2.1 <u>Practical Advantages of RWH</u>.

a. Availability not subject to outside utility control.

b. Not subject to pipelines interruption (seismic).

c. Quality is controlled by the consumer.

d. Available even when power is interrupted.

e. Reduces run-off and erosion.

f. Available even when storms & disaster strike.

g. Available immediately for fire suppression.

h. Reduces mosquito breeding grounds (Dengue Fever).

j. Thermal mass can naturally cool buildings.

k. Ideal for people on low sodium diets or with health concerns (weakened immunity systems).

2.2 <u>Qualitative Advantage of RWH</u>.

a. naturally pure.

b. naturally soft (no dissolved minerals).

c. free for those who collect it.

d. sustainable.

e. free of chlorine and its by-products.

f. free of pesticides and other man-made contaminants.

2.3 <u>**How to Harvest the Rain**</u>.

The six basic components of a Rain Water Harvesting system include:

a. Catchment: roof surface to collect the rain.

b. Conveyance: channels or pipes from roof or catchment area to storage.

c. Roof washing: ‘first flush’ diverter system to filter and remove contaminants.

d. Storage: cisterns or tanks where collected rainwater is securely stored – i.e. insect proof.

e. Purification: includes filtration, ozone or UV light to purify the collected rainwater for potable use.

f. Distribution: system that delivers the rainwater, usually including a small pump and pressure tank

3. <u>**Definitions**</u>.

3.1 <u>**Catchment Area**</u>.

Catchment area is the net roof surface, in square feet/square meters, from which rainwater is, collected.

3.2 <u>**Cistern/Storage Tank**</u>.

A cistern or a storage tank is a receptacle built to catch and store rainwater. They range in capacity from a few litres to thousands of cubic meters. Cisterns are usually built underground.

3.3 <u>**Potable Water**</u>.

The water of sufficient quality which is fit for human consumption is called potable water.

3.4 Aquifer.

An aquifer is an underground layer of water-bearing permeable rock, or unconsolidated materials (gravel, sand, silt, or clay) from which groundwater can be usefully extracted using water well.

3.5 Ground Water.

Groundwater is the water located beneath the ground surface in soil pore spaces and in the fractures of geologic formations.

3.6 Alternative Technology.

Alternative technology refers to technologies that are more environmentally friendly than the functionally equivalent technologies dominant in current practice, aims to utilize resources sparingly, with minimum damage to the environment, at affordable cost and with a possible degree of control over the processes.

3.7 Filtration.

Filtration is the method of separating solid and suspended contaminants in rainwater achieved by the interaction between the rainwater and a porous interface i.e. the filter.

3.8 First Flush.

First flush is the first part of the rainwater runoff after a dry period, which contains higher concentration of contaminants than a subsequent flush.

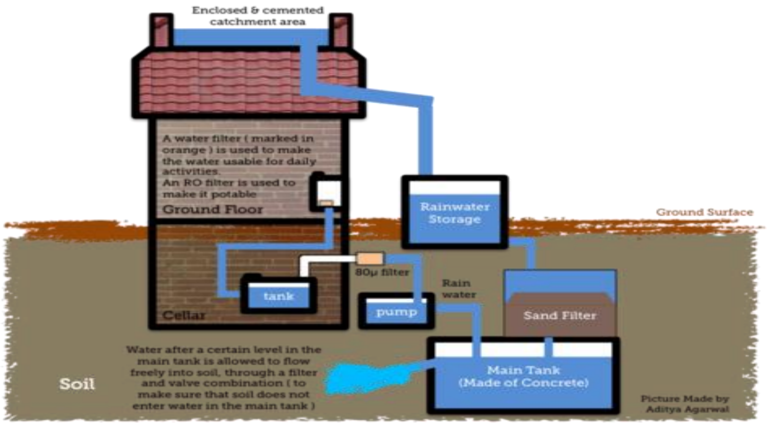


Figure 3.1.1: Rainwater harvesting layout with components.

4. **Review of Related Literature.**

4.1 **Historical Background.**

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. As the population of the world increased, irrigation, the most water consuming human activity, as well as domestic water usage increased, leading to a consequence of crisis of water supply in different region. Among other available alternative sources for water supply, rainwater harvesting has become the most economic solution for the water crisis.

4.2 **Rainwater and Community.**

Domestic Rainwater Harvesting (DRWH) is a sub set of rainwater harvesting whereas policies and legislation mostly refer to the generality. The popular means of water harvesting is surface run-off providing water in large quantity, of low quality mainly for agriculture. In water policies of the African countries, such as Kenya, RWH as a means of poverty alleviation refers to harnessing water by constructing appropriate dams and pans for collection of water for small-scale agriculture and livestock. In Kenya, DRWH can mean both surface run off and roof water harvesting while in Sri Lanka and Thailand it means only roof water harvesting.

Due to recent rapid development of roof water harvesting in some countries, some policy documents now distinguish between roof water harvesting and rainwater harvesting. Although the one of the largest development of roof water harvesting took place in Thailand in the 1980's, neither rainwater harvesting nor roof water harvesting are mentioned in the local Water Act. Bangladeshi water policy clearly identifies the problems associated with over-use of surface and ground water, which has been causing depletion and pollution of ground water resulting in salt-water intrusions and arsenic threats. While the policy recognizes sustainable development of surface, ground and rainwater as a possible solution, it does not refer to roof water harvesting.

4.3 Table 1: Status on Different Countries.

Country	Status	Description
Sri Lanka	Public Ownership	No restriction on development of DRWH
India	Not specified	Water is a state object. No potential threat to development of DRWH
Bangladesh	State ownership	No constraints on development of DRWH
Thailand	State ownership including atmospheric water	Storage of water requires a license as decided by the river basin committees
Kenya	State ownership	Requires a permit to construct water works. Not clear whether this includes DRWH. No restriction on water for domestic use.
Uganda	State ownership	Requires a permit to construct water works. Not clear whether this includes DRWH. No restriction on water for domestic use.
Ethiopia	Public Ownership	No permit is required. But large scale water development is practiced without permission. Status of DRWH is not clear. No restriction on water for domestic use.

As shown in table 1, most countries of the world, state owns the water resources, while the current debate in the water sector reforms is the Community Verses State Ownership in Water Resources Development. Although the presumption of most activists is that water resources development should be transferred to community ownership for it to serve the communities and attain sustainable development, all water policies (contributing to this view) are still engrossed in the conventional state ownership of water resources.

4.4 Table 2: Strengths and weakness in recycling, rainwater and conservation.

Strategic option	Strength	Weakness
Recycling	Continuous supply available. Variety of reuse option available.	Frequent maintenance of system often required. Can be expensive to purchase and install (Particularly if dual reticulation is required). Health impacts uncertain.
Rainwater	Lower Treatment Requirements. Cost effective Technology.	Storage tank space requirements. Intermittent and unpredictable supply.
Conservation	Low cost. No technology Dependent.	Sustained Impact often dependent on long term behavioural change. Incorrect installation of devices is a problem

In Bangladesh, in 1989, the Ministry of Environment and Forest was established to address the emerging environment related issues. In the consecutive years, the National Environment Policy, 1992 was adopted; a new law called the Bangladesh Environment Conservation Act, 1995 was enacted repealing the earlier law of 1977 and restructuring the Department of Environment. The national environment management action plan (NEMAP) has also been finalized and is being implemented. Eventually, other laws were framed including the followings:

a. The Environment Court Act, 2000.
b. The Environment Conservation Rules, 1997.
c. The Environment Pollution Control Ordinance, 1977.
d. The Water Pollution Control Ordinance, 1970.

And so on. Although all these acts and rules are specific about water pollution and wetland conservation, little has been done from the part of the government for water conservation specially relating rainwater groundwater and groundwater recharge. The Ministry of Housing and Public Works Department, Government of Bangladesh, had published a rainwater-harvesting manual applicable for the rural and urban areas in 2002. The guidelines were applied in the installation of rain water harvesting system in one governments housing (Member of Parliament Hostel) as a study.

However, after the change of Government the study was left incomplete as well as the publication of the manual. To make the rain water harvesting a practice for any target area, examples should be the first step. With that, Government should frame appropriate policies regarding tax incentive to individual households for the rain water harvesting practice, which will encourage the citizens to adopt it. All the existing public buildings and new building constructions can be a good place to start installing and study the output of rainwater harvesting. Promotional and educational activities from local government will also be necessary to realize the following issues that could be solved or improved by rainwater harvesting:

a. Water shortage, i.e. of safe drinking water
b. Seasonal flooding
c. Ground water recharge i.e. water management
d. Health and sanitation
e. Alternative water supply

Bangladesh Water Development Board (BWDB), Water Resources Planning Organization (WARPO) are institutions under the Ministry of Water Resources, the Government of the People's Republic of Bangladesh. They are among the key Organizations dealing with nation - wide macro level water resources planning and management. At present, they are helping the government with tasks such as monitoring implementation of the National Water Management Plan (NWMP) and its impact, upkeep of water resource assessments, maintenance and updating of the National Water Resources Database (NWRD) and MIS etc.

But these organizations can help the government in planning large scale rain water harvesting project through local government and monitor the application and outcome. The Bangladesh Environmental Lawyers Association (BELA), Participatory Review International Network, BRAC are some private organization and NGO’s that are working hand in hand with the government with the energy conservation issues.

In the implementation phase of the government plans, these NGO's can work directly work with communities under local government to educate and involve them in water conservation practices. Including female citizens will definitely improve the outcome which was successful in similar projects in several parts of India.

In Tanzania, the vast majority of farmers depend on rain-fed agriculture. Therefore, future food security depends upon developing improved dry land cropping systems. An important step towards tapping the potential of these systems is be to use the available rainfall, known as 'green water', more efficiently. The challenge is to select and apply appropriate RWH interventions that capture the unproductive green water flows. *In-situ*, micro catchment and macro catchment rainwater harvesting systems were tested against the local practice of flat cultivation as control. All were managed according to local extension recommendations, and the benefits were measured in terms of grain yield. *Inset* rainwater harvesting provided no benefit. Micro catchment rainwater harvesting resulted in increased yield per unit area cultivated. On a total system area basis including the outcropped catchment), however, production decreases were observed. A cost-benefit analysis does show a benefit in the short rainy season. Macro catchment rainwater harvesting provided increases in grain yield in both the short and the long rainy seasons.

Along with economic justification, the promotion of rainwater harvesting projects requires an analysis of the eco-hydrogeology and human dynamics. Based on the case from Tanzania, rainwater harvesting for crop production showed the potential for poverty reduction which is evident in the results from two-seasons (2002 to 2003) yield monitoring for maize and lablab. According to the results obtained from the yield monitoring exercise, Rainwater harvesting for crop production has a great potential of poverty reduction given impressive returns to land and labour even during b-average seasons. Interventions to improve productivity of rainwater (more crop out-put per drop) while maintaining the integrity of the eco-hydrology and other natural systems in the watershed would result in tremendous economic benefits.

This would result into tremendous financial earnings too. Such efforts could be in empirical knowledge of which best agronomical and runoff management practices could optimize physical yields for the intercrop also presents an analysis of economics of rainwater harvesting by poor farmers in Tanzania. Results show that rainwater harvesting for production of paddy rice paid most with returns to labour of more than 12 US$ per person-day invested. These benefits are very high due to the fact that without rainwater harvesting it is not possible to produce paddy in the study area. The results also show that contrary to expectations, improving rainwater harvesting systems by adding a storage pond may not lead to increased productivity. Another finding that goes against the widely held belief is that rainwater harvesting results in more benefits during the above-average seasons compared to below-average seasons. It is therefore, concluded that there is a potential for combining rainwater harvesting with improved drainage of roads. The construction of rural roads in semi-arid areas can beneficially be integrated with efforts to increase water availability for agricultural needs.

He et al. (2007) evaluates the determinants of farmers' decisions, using a binary logistic regression model, to adopt rainwater harvesting and supplementary irrigation technology (RHSIT) and its elasticity of adoption in the rain-fed farming systems, based on a survey of 218 farmers in the semiarid areas of Loess Plateau in 2005.
The result shows 12 variables to be significant in explaining farmers' adoption decisions Farmers. educational background, active labour force size, contact with extension, participation in the Grain-for-Green project, and positive attitudes towards RHSIT are some of the variables having significantly positive effects on adoption of RHSIT, while farmer's age and distance from water storage tanks to farmers' dwellings have significantly negative correlation with adoption of the technology. Variables such as family size, off-farm activity, level of family income, risk preference, and land tenure do not significantly influence adoption.

In Gansu and other provinces in northwest China, the preliminary implementation of Rainwater Harvesting Agriculture (RHA) suggests that RHA has the potential to improve performance in rain fed farming systems and to address environmental problems; example: soil erosion. The small-scale, low cost RHA systems make application by household farmers simple. Successful RHA needs to be integrated in a comprehensive agricultural-management system; i.e. with other agricultural technologies and management practices. Also, the spread of RHA over large areas entails consideration of a range of technological, agro-hydrological, ecological, social, cultural, economic, and political factors.

In particular, training and extension services to farmers is required to develop and disseminate more effective and affordable types of RHA technologies as alternatives and to design and develop alternative policy instruments and social institutions that facilitate adoption of RHA practices. Also in a time period of 2002 to 2004, the influence of different in situ rainwater harvesting and moisture conservation methods on soil moisture storage and growth of Tamarix ramosissima was studied in the semiarid loess region of China. Rainwater harvesting and moisture conservation treatments increased growth of T. ramosissima, tree height was significantly higher for the rainwater harvesting and moisture conservation treatments than the controls.

5. Benefits of Poverty Alleviation and Socio Economic Development.

Composed in a comprehensive system, the basic three components of rainwater harvesting a collection surface, guttering and a water store, yields several benefits. According to Krishna (2003), the most important benefit of rainwater harvesting is that the water is totally free; the only cost is for collection and use. Also, the end use of harvested water is located close to the source, which eliminates the need for complex and costly distribution systems. When groundwater is unacceptable or unavailable, rainwater provides a water source, or it can supplement limited groundwater supplies. A superior solution for landscape irrigation, rainwater harvesting reduces flow to storm water drains and also reduces non-point source pollution while reducing the consumers' utility bills. Having lower hardness than groundwater, rainwater helps prevent scale on appliances and extends their use (Li et al., 2005). Studies carried out on a global basis indicate that in the past fifty years, the world's population has doubled, as did the per capita water consumption rate (from about 400 m3/year to about 800 m3/year) having only a small percentage of the available water is of good enough quality for human use. The countries of Africa have been experiencing an ever-growing pressure on their available water resources, with increasing demand and costs for agricultural, domestic and industrial consumption. These pressures have caused both environmental deterioration like pollution of freshwater systems and overexploitation of important water catchments, resulting in lowered groundwater levels. Water stress has several consequences including Social, Economical, and Environmental etc.

A large proportion of Africa's population is affected by water shortages for domestic use. As a response to the 1971–74 droughts with the introduction of food-for-work (FFW) programmes, government-initiated soil and water conservation programmes promoted the application of rainwater-harvesting techniques as alternative interventions to address water scarcity in Ethiopia. These also intended to generate employment opportunities to the people affected by the drought. Issues like poverty, drought, sanitation etc strongly support the need to focus on development and promotion of rainwater-harvesting technologies as one of the alternatives to enhance water availability for different uses including domestic water supply, sanitation and food production. Kenya, having a population of about 25 million people, has current water supply coverage of 42% meaning millions of Kenyans with no access to an adequate and safe water supply, facing, severe social and economic consequences.

The Kenya Rainwater Association (KRA), founded to bring together individuals and institutions wanting to face the challenge of low water coverage by utilizing rainwater, used low cost technical options and built local capacity through community based organizations (CBOs). This also built the village organization and management capacities. A combination of improved health awareness and benefits from clean and safe water and income from sale of surplus farm produce resulted in an increase in willingness to pay for improved housing and water supply. The lessons learnt in this study includes compulsory community involvement in RWH, use of motivation, mobilization and participation for achieving desired goal, observation at commencement, control of Quantity and quality of the output.

The conclusions from the study of He et al. (2007) indicate that the rainwater harvesting and supplementary irrigation technology (RHSIT) extension project should incorporate consideration of farmer age, farmer educational attainment, and active labour force members. The benefits of RHSIT must be clearly perceived by the users looking at their own socioeconomic conditions. The results also suggest the need for greater political and institutional input into RHSIT projects. There is a need to design and develop alternative policy instruments and institutions for extension, technical assistance, training, credit services that will facilitate adoption of the farmer participatory practices to better fit the needs of farmers in particular.

Also in Zimbabwe, the successful adoption of RWH technologies has the potential 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 assisted in improving environmental management through water conservation, reduction of soil erosion and resuscitation of wetlands in the study area. The major constraints facing technology adopters were water distribution problems, labour shortage, and water-logging during periods of high rainfall and risk of injury to people and livestock as a result of some of the technologies. However, the farmers who have adopted RWH have devised ways of dealing with some of the cited problems, for instance, formation of labour groups to militate against labour shortage. It was concluded that RWH technologies are suitable for smallholder farmers in semi-arid areas provided they properly tailored the conditions of the locality where they are promoted. Other benefits of adopting RWH include improvement of people’s standard of living (break out of the cycle of poverty) and reduction in environmental degradation.

The impacts of rooftop rainwater are greatest where it is implemented as part of wider strategies that considers people’s overall livelihood strategies. Water should be seen as a key productive as well as domestic resource, with different uses being made of it by men and women. By taking such an approach, and widening the role of potential benefits to include economic and health related issues, the overall benefit to households and communities of rainwater harvesting will be doubled. The most important impact in terms of women and the poor is the reduction in time spent collecting water, a vital issue which can be as much as several hours per day. This time then becomes available for other purposes, productive and ‘social’; more time to spend on education, with children and friends etc. Research on appropriate technologies and infrastructures to support water reuse has progressed rapidly over recent decades presenting a wide range of source – treatment –reuse options for planners to choose from.

Although the economics of water reuse schemes supports application to new developments than retrofit projects (table 2), there are few studies which seeking to address strategic option selection issues for large developments. The potential advantages of using treatment and reuse systems in new developments require an understanding of the relationships between a wide variety of factors, namely social, environmental, technological, and operational. Using a commercially available software package, reports the design and implementation of a low resolution simulation tool to explore sustainable water management options for a live case study site in the south of England (a per-urban development of 4,500 new homes) with particular reference to opportunities for rainwater harvesting, and water reuse.

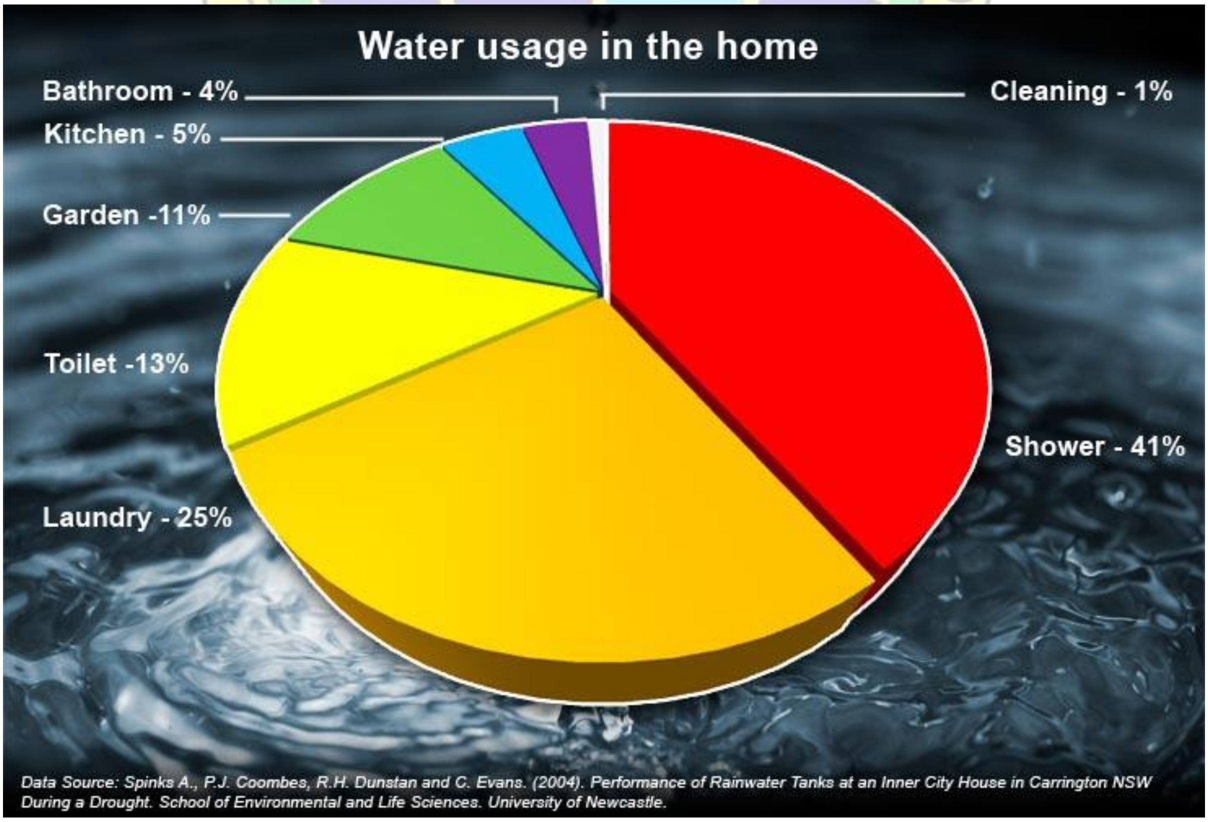


Figure 5.1: Water usage in the home.

6. **Present Situation**.

Studies and experiments have been done not only to establish the portability of rainwater but also to design buildings installed with rainwater catchment facilities with optimum treatment facilities. Materials like ceramic tile and galvanized metal roofs has been recommended by Woods and Choudhury (1992) for quick transportation of precipitation and minimization of loss through evaporation. Studies on management and treatment of vegetation, surfaces and chemicals have been done to achieve economic solution for specific region. Additional attention is given to storage capacity according to duration of dry periods, affordability, robustness and durability of materials, safety and maintenance of the filtration system. Increased awareness on water crisis has led rainwater harvesting to be proposed as a community facility. As for example, the small and medium residential and commercial construction of United States has shown increasing interest in rainwater harvesting since 1996. Cities and states around the world are adopting rules related rainwater harvesting, especially in United States (TWDB, 2005). The most universal and critical services to a building, water supply reaches building through one of the following three ways: piped supply, rivers and other water bodies and rainwater. It is almost the only way to upgrade ones household water supply without waiting for the development of community system. The acceptance of rainwater harvesting will expand rapidly if this method is treated like other building services and if designed into the structure instead of being retro-fitted.

Rainwater Collection in Multistoried Roofs

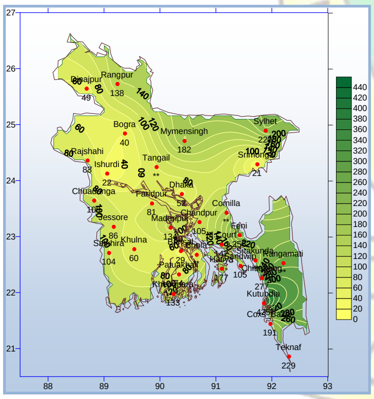
7. Government Statistical Report.

Government of the Peoples' Republic of Bangladesh
Bangladesh Meteorological Department
(Agro-meteorology Division)
Meteorological Complex, Agargaon, Dhaka-1207.

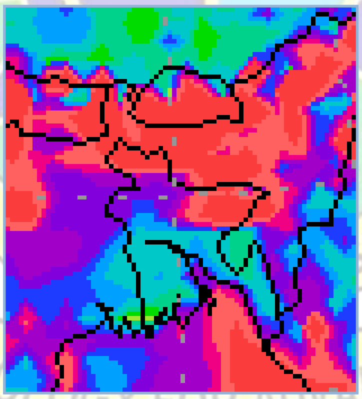
Agm-3 (2)/2012/ **27** **Issue date:** 15-07-2012

7.1 Forecast for the period: 15.07.12 to 21.07.2012.

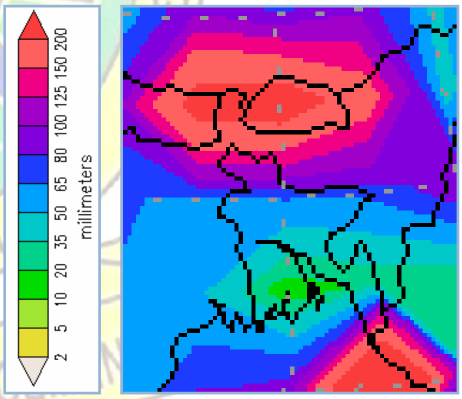
Spatial distribution of Rainfall



Accumulative Rainfall forecast



Extended Outlook for accumulative rain



7.2 Highlights.

Free water loss during the previous week was averaged 3.24 mm per day. Sunshine hour during the previous was averaged 3.14 hours per day.

7.3 Weather Forecast and Advisory for the Period of 15.07.2012 to 21.07.2012.

Free water loss during the next week is expected to be between 3.0 mm to 4.0 mm per day. Bright sunshine hour during the next week is expected to be between 3.0 to 4.0 hrs per day.

a. Trough of monsoon axis runs through Rajasthan, Uttar Pradesh Bihar, and West Bengal to Assam across northern part of Bangladesh. One of its associated troughs extends to Northwest Bay. Monsoon is fairly active over Bangladesh and moderate elsewhere over North Bay.

b. Under the influence of fairly active Southwest monsoon, Light (4mm-10 mm) to moderate (10mm-22 mm) rain/thunder showers accompanied by temporary gusty or squally wind may occur at most places over North and North-eastern part of the country with a chance of moderately heavy (22mm-44mm) to heavy (44mm-88mm) falls at places over Rangpur, Sylhet and Rajshahi divisions, coastal regions along with catchment area of Assam & Meghalaya regions during this period.

c. Farmers are requested to prepare T. Amon seedbed at chigh land/flood free area.

d. Farmers and concerned authorities are requested to preserve late variety T. Amon seed to use for post flood plantation.

e. Mean surface temperature of this week may remain nearly unchanged and near normal (climatologically 25-30° C) over the country except Khulna region where it may be above normal by 2-3° C during this period.

(Md. Shameem Hassan Bhuiyan)

Meteorologist

For Director

8. Short Weather Description. (From 08.07.2012 to14.07.2012).

Light to heavy rainfall was recorded over the country during the period. Maximum rainfall 425 mm was recorded at Kutubdia in Chittagong division which was 150% above normal. Minimum rainfall 21 mm was recorded at Sylhet in Sylhet division, which was 73% below normal.

Highest maximum temperature was recorded in Dhaka Division 29.2-35.0^{0}C Chittagong Division 26.7-34.7^{0}C, Sylhet Division 27.8-35.4^{0}C, Rajshahi Division 31.0-35.7^{0}C, Rangpur Division 31.2-33.5^{0}C Khulna Division 30.6-35.8^{0}C and Barisal Division 28.6-34.2^{0}C.

Extreme maximum temperature was recorded at Madaripur in Dhaka Division 35.0^{0}C, at Chandpur in Chittagong Division 34.7^{0}C, at Sylhet in Sylhet Division 35.4^{0}C, at Ishurdi in Rajshahi Division 35.7^{0}C, at Rangpur and Dinajpur in Rangpur Division 33.5^{0}C, at Jessore in Khulna 35.8 ^{0}C and at Barisal in Barisal Division 34.2 ^{0}C. Lowest minimum temperature was recorded in Dhaka Division 25.6-27.7^{0}C, Chittagong Division 23.5-27.6^{0}C, Sylhet Division 24.8-26.9^{0}C, Rajshahi Division 24.9-27.2^{0}C, Rangpur Division 25.0-27.8^{0}C, Khulna Division 26.0-28.0^{0}C and Barisal Division 25.6-28.0^{0}CExtreme minimum temperature was recorded at Tangail in Dhaka Division 25.6^{0}C, at Rangamati in Chittagong Division 23.5^{0}C, at Sylhet and Srimongal in Sylhet Division 24.8^{0}C, at Bogra in Rajshahi Division 24.9^{0}C, at Rangpur in Rangpur division 25.0^{0}C, at Chuadanga in Khulna Division 26.0 ^{0}C and at Khepupara in Barisal Division 25.6^{0}C.

Statistical Analysis

9. <u>Rainfall Analysis and Average Temperature</u>.

Name of the Divisions	Name of the Stations	Total Rainfall in (mm)	Normal Rainfall in (mm)	Deviation in %	Total Rainy days	Average Max Humidity in %	Average Min Humidity in %	Average Max. temp in ℃	Average Normal Max. temp in ℃	Average Min. temp in ° C
Dhaka	Dhaka	52	102	-49	07	093	067	32.3	31.6	27.0
	Mymensingh	182	107	70	07	089	081	31.2	30.7	25.4
	Faridpur	81	83	-2	06	098	069	32.8	31.5	26.5
	Madaripur	134	96	40	07	097	068	33.0	31.9	26.3
	Tangail	**	80	***	**	**	**	**	31.6	**
Chittagong	Chittagong	277	174	59	06	100	069	31.2	31.1	26.2
	Sitakunda	**	179	***		**	**	**	30.5	**
	Rangamati	**	144	***		**	**	**	31.1	**
	Cox'sBazar	191	242	-21	07	097	079	30.9	30.6	25.2
	Teknaf	229	236	-3	006	099	080	29.7	30.0	25.7
	Hatiya	177	189	-6	007	098	084	30.5	29.9	25.8
	Sandwip	105	238	-56	07	098	082	30.6	30.2	25.3
	Kutubdia	425	170	150	07	094	082	30.2	30.2	25.3
	Feni	256	161	59	07	099	080	30.2	30.4	25.0
	M.Court	142	158	-10	07	098	063	30.6	30.8	26.0
	Chandpur	105	102	3	06	087	073	32.8	31.5	26.0
	Comilla	**	117	***		**	**	**	31.0	**
Sylhet	Sylhet	220	167	32	07	097	075	32.4	31.3	26.1
	Srimongal	21	78	-73	05	094	060	32.7	32.1	25.4
Rajshahi	Rajshahi	83	78	6	06	100	063	33.6	32.3	26.1
	Bogra	40	95	-58	06	096	058	33.2	31.9	26.5
	Ishurdi	22	76	-71	05	098	062	33.8	32.1	26.5
Rangpur	Rangpur	138	130	6	06	**	**	**	31.3	**
	Dinajpur	49	125	-61	06	**	**	**	31.6	**
Khulna	Khulna	60	91	-34	06	100	076	33.2	32.0	26.8
	Jessore	86	77	12	06			**	32.5	**
	Chuadanga	109	89	22	07			**	32.8	**
	Satkhira	104	76	37	07	098	064	33.4	32.3	26.6
Barisal	Barisal	29	96	-70	07	098	076	32.5	31.2	26.8
	Bhola	**	102	***		**	**	**	30.8	
	Patuakhali	74	105	-30	05	099	080	32.4	31.1	26.7
	Khepupara	133	138	-4	07	098	069	31.5	30.7	26.1

10. Rainwater Collection Data.

JUNE, 2012

DATE	AMOUNT OF WATER COLLECTED in Litter	READING IN mm
01-06-2012	09	03
02-06-2012	00	00
03-06-2012	04	01
04-06-2012	00	00
05-06-2012	21	08
06-06-2012	148	56
07-06-2012	00	00
08-06-2012	11	05
09-06-2012	00	00
10-06-2012	00	00
11-06-2012	00	00
12-06-2012	00	00
13-06-2012	00	00
14-06-2012	00	00
15-06-2012	00	00
16-06-2012	00	00
17-06-2012	27	09
18-06-2012	46	17
19-06-2012	106	42
20-06-2012	11	02
21-06-2012	19	06
22-06-2012	00	00
23-06-2012	00	00
24-06-2012	29	08
25-06-2012	27	07
26-06-2012	35	10
27-06-2012	00	00
28-06-2012	00	00
29-06-2012	00	00
30-06-2012	14	04

10.1 Rainwater Collection Data.

JULY, 2012

DATE	AMOUNT OF WATER COLLECTED in Litter	READING IN mm
01-07-2012	53	17
02-07-2012	21	07
03-07-2012	06	02
04-07-2012	54	18
05-07-2012	68	29
06-07-2012	05	02
07-07-2012	14	04
08-07-2012	00	00
09-07-2012	2.5	01
10-07-2012	27	10
11-07-2012	2.5	01
12-07-2012	13	04
13-07-2012	46	16
14-07-2012	22	06
15-07-2012	57	14
16-07-2012	00	00
17-07-2012	00	00
18-07-2012	166	51
19-07-2012	04	02
20-07-2012	04	02
21-07-2012	02	01
22-07-2012	17	05
23-07-2012	18.5	05
24-07-2012	00	00
25-07-2012	00	00
26-07-2012	00	00
27-07-2012	22.5	09
28-07-2012	02	01
29-07-2012	40	18
30-07-2012	02	01
31-07-2012	00	00

10.2 Rainwater Collection Data.

AUGUST, 2012

DATE	AMOUNT OF WATER COLLECTED in Litter	READING IN mm
01-08-2012	00	00
02-08-2012	02	01
03-08-2012	00	00
04-08-2012	12	05
05-08-2012	00	00
06-08-2012	28	09
07-08-2012	12	05
08-08-2012	3.5	02
09-08-2012	00	00
10-08-2012	00	00
11-08-2012	00	00
12-08-2012	177	68
13-08-2012	97	32
14-08-2012	00	00
15-08-2012	00	00
16-08-2012	00	00
17-08-2012	00	00
18-08-2012	00	00
19-08-2012	48	20
20-08-2012	98	42
21-08-2012	12	05
22-08-2012	00	00
23-08-2012	00	00
24-08-2012	00	00
25-08-2012	03	02
26-08-2012	02	01
27-08-2012	108	39
28-08-2012	00	00
29-08-2012	00	00
30-08-2012	00	00
31-08-2012	00	00

11. <u>Data Analysis</u>.

Total accumulated collected water in **90** days=1779 litres

Surface area of the project=24 square-ft

Assuming roof area in single DOHS building=2300 square-ft.

Probable water collection for a single DOHS building= (2300*1779)/24

=170487.5 litres

Per person water consumption per day=110 litres

Assume, each family having 4 members and each building contains 10 families;

Therefore,

Total number of living members in the building=4*10=40

According to the previous stated data:

Collected rain water can be used for=170487.5/(110*40)=38.82 days

= **39** days (approximately)

12. <u>Findings</u>.

a. Dependency on regular supplied water from WASA can be reduced to a great extent.

b. Dependency on extraction of underground water by WASA can be minimized.

c. Water treatment cost can be reduced.

d. Rain water harvesting can reduce the proximity of flooding in urban areas to an encourage able extent.

e. Allow rising of underground water level to some extent during rainy season.

f. It contributes in safeguarding urban areas from natural disasters like land-fall, earthquake etc.

g. It reduces power consumption of WASA to some extent.

h. Arsenic free water can be used for cooking and drinking purpose.

j. Simple to design and less initial and maintenance cost.

k. Above all, if it is implemented nationwide, it could contribute to our national economy to a great extent.

13. **Construction**.

The construction of the project consist of three main sections, those are:

13.1 **Rainwater Collecting Tray**.

This made of mild steel sheets of 0.9 mm thickness. Its length being 6 feet and width 4 feet. The tray has a surface area of 24 sq-ft.

The tray is supported by a stand made of angle bars. One side being 3.5 feet another is 3.0 feet. So the tray is inclined at a small angle. Angle of inclination is

$\tan\Theta=(.5/6)$

Or, $\Theta=\tan^{-1}(.5/6)= 4.763\,°$

13.2 **Filtration Unit**.

To clean the rainwater a filtration unit is installed in between tray and reservoir. The unit is made of glass and for filtration purpose a collection of layers of sand, stone and coal has been used. These layers are placed at midway of the filter unit so that water pass through them and get cleaned.

13.3 **Reservoirs**.

Rainwater is preserved in two drums. One being at the tray outlet and the other at the filter outlet. First drum is used to preserve the primary water from the tray and when reaches a level high enough water is passed to the filter for filtration. Clean water from the filter is then guided to the larger reservoir for preserving. Both the drums are calibrated with litters to measure water collected.

13.4 **Project Layout**.

14. Summary and Conclusion.

From the above research it was clear that for the water scarce areas and the arsenic contaminated areas, the rainwater harvesting was a very useful and acceptable as low cost rainwater harvesting techniques. In the arsenic contaminated areas, this source might be an alternate option of water source. Also in the scarce safe drinking water areas like Dhaka, it might be very useful. The water quality was acceptable as safe drinking water in Dhaka areas up to four months and it was applicable only for this area, because the other cities, the air quality might not be the same, so the rainwater quality might differ.

For the further development of the study the more care should be taken when the water was stored in the storage tank and the inlet of the tank may close carefully, so that the total coli form bacteria cannot enter and grow in the tank up to whole year or the water can use up to whole year as safe drinking water.

The solution developed and expressed can be a comprehensive and effective tool for learning and designing rainwater harvesting solution both for the user and for the professionals in the building industry of Bangladesh. Under the guidelines, using the local water demand and rainfall, a rainwater water harvesting method can be designed even for a different location. The water conservation calculation in monetary terms as well as the estimate of the installation cost will provide the owners, builders as well as the users with the freedom to choose the option reviewing their own buildings to save more. This will serve more for the Industrial Projects where the buildings are associated with large tilted roof, which will harvests the rain water in huge amount. Along with that, the City Government can use this research as a guideline to calculate the possible amount of supply water conserved by the rainwater harvesting as well as the decrease in load on the ground water to advocate this method to be included in housing policy. The results can be an effective teaching tool for the fields like Sustainable Architecture, Water Conservation, Green building etc where alternative technologies like rainwater harvesting are getting more and more importance.

15. Recommendations.

a. Further Research: Although data from secondary sources were used for this study to assess the portability of rainwater, physical experiments should be executed for the rainwater collected from the study area to have the respective chemical composition, which will feed into the decision making stage. Also, no research was done on the volume of First Flush with respect to intensity of rainfall, location and time. Determination of an effective First Flush volume will definitely increase the credibility of rainwater to be chosen as an alternative technology.

b. Promotion and Education: providing the cost benefit scenario of rainwater harvesting system comparing the social, economic and environmental gains.

c. Formulation of Government policies such as Tax incentive for energy conservation (water, electricity etc.) in individual household, etc.

d. Pilot study through community involvement: execution through the local government and NGO participation. At national scale, rainwater conservation plans and policies can be formulated to handle water crisis and flood issues of the nation. Feedback from different region and communities of the country is essential to make these plans comprehensive and need based. For an example, making the existing water bodies deeper to increase the storage capacity during the monsoon will not be suitable to areas where the existing water table is very high or all the water bodies are highly arsenic contaminated. Also application of local technology and material will be different depending on the regional production. To implement these policies, water management projects can be formulated (and awarded as professional assignment) at organizational level including rain water harvesting system. For implementation, private organizations can be engaged with projects to promote, educate, and involve communities for rainwater harvesting practice (this will also relieve the government from taking risk with public funds). Then with the help of these organizations, local government can develop cooperative system to maintain, monitor and ensure the aimed benefit of rain water harvesting. However, the achievement of sustainability starts forms individual household practice that adds up to the national level contributing the water consumption demand, alternatives to arsenic contamination, flood control and ground water recharge.

Rainwater harvesting at a household (be in the rural or urban area) improves the affordability of water consumption, irrigation and drainage facility of the site and structure. At the community level this practice contributes to the local/regional geography and water resources developing the socioeconomic condition of the area (through new job opportunities associated with rainwater harvesting technology, female citizen involvement etc). At national level, the output is much more visible in poverty alleviation (rain water harvesting for mass irrigation resulting in better agricultural production and thus national economy, development of public health and hygiene). The outcome of the policies framed at national level can be compared to similar international cases for correction, up gradation and development. Also similar cases in different nation can be collaborated in a combined project where the socioeconomic development aims at a global perspective; individual economic development of each nation (through rain water harvesting) contributes to global water crisis, independence from foreign donations.

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